MAB

THE ECOLOGY AND CONSERVATION OF THE TROPICAL HUMID FORESTS OF THE INDOMALAYAN REALM

Proceedings

REGIONAL TRAINING WORKSHOP

South and South East Asia

COLOMBO, SRI LANKA

17 FEBRUARY – 7 MARCH 1987

RESEARCH IS THE FOUNDATION OF KNOWLEDGE

UNESCO

Organized by the Natural Resources, Energy & Science Authority of Sri Lanka (NARESA) and the MAB National Committee for Sri Lanka with financial and technical support from UNESCO and financial support from World Heritage Committee and USAID.

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CONTENTS

SUMMARY OF PROCEEDINGS

1. Introduction

The Indomalayan realm is one of the three biogeographic realms of the world that still supports considerable extents of tropical humid forests which consists of a variety of genetic resources of potential benefit to mankind. Conservation of tropical humid forests is thus being assigned high priority by countries within the realm. Increasing numbers of scientists representing several disciplines are also focussing their research efforts on aspects related to tropical humid forests and are thus contributing to the knowledge that could be used in conserving this ecosystem. The Man and the Biosphere Programme of UNESCO has been concerned since its inception with the conservation of this ecosystem as it is one of the more fragile ecosystems.

2. Rationale

Development of feasible strategies to conserve tropical humid forests demands active collaboration between ecologists, forest managers and administrators to identify realizable objectives and prescribe necessary actions. The internationally adopted Action Plan for Biosphere Reserves of the MAB Programme is an example of an interdisciplinary strategy which needs to be adapted to suit local needs. The World Heritage Convention provides incentives for the conservation of national natural heritage values by rendering them international acclaim and much needed technical and financial support. It is necessary that resource personnel within the Indomalayan realm regularly meet (the last regional meeting on a topic related to conservation of nature within the Indomalayan realm was held in February 1985 under the sponsorship of the IUCN/CNPPA) to update their knowledge on the scientific basis of conservation, review and discuss national experiences in tropical humid forest conservation and management and develop optimal modes of participation in international conventions and programmes so as to consolidate local conservation efforts.

3. Objectives

(a) To provide an updated overview of the scientific basis of conservation with an emphasis on the ecology of tropical humid forests of Indomalayan and discuss the relevance of recent advances in ecological research to the conservation of the ecosystem.

(b) To provide a thorough outline of the conceptual framework and scope of the Biosphere Reserve Action Plan and the World Heritage Convention.

(c) To review the current diversity of national systems of tropical humid forest conservation and management in the light of current scientific knowledge and the resources accessible through participation in international programmes and conventions, in order to identify and recommend essential steps needed to consolidate national efforts.

(d) To encourage participants to present case studies related to successful efforts in tropical humid forest conservation within their own countries.

(e) to encourage free exchange of ideas and information among participants through discussion and group activities in the field.

4. Participants

Thirty two participants attended the workshop from countries in the South and South East Asian region including, Bangladesh, China, India, Indonesia, Malaysia, Nepal, Pakistan, Philippines, Sri Lanka Thailand and Vietnam. The participants were mainly researchers, managers of protected areas and park wardens. In addition there were 20 observers who were mainly research students.

5. Opening Session

Dr R.P. Jayewardene, Director General of NARESA made a welcome address to the chief guest, participants,resource persons,representatives from UNESCO and other organizations and special invitees. He described the importance of the proper managmeent of the Biosphere if man is to servive in this planet. He invited the chief guest the Hon. Minister of Justice Dr Nissanka Wijeyaratne to inaugurate the workshop.

The chief guest the Hon. Minister of Justice, Dr Nissanka Wijeyaratne inaugurated the workshop by lighting the traditional oil lamp and addressed those present.After thanking the organisors for inviting him to inaugurate this important workshop he said that the workshop was related to a subject area that was of paramount importance to the countries in the region and that was the clash between development and conservation. He recapitulated the strategies adopted by the ancient kings of Sri Lanka regarding the conservation of the forests where some forests were held sacred and protected by deities. However in the recent past forests have been dissappearing at an accalerated pace, so much so that some species of plants and animals have become extinct while some others were facing extinction. Some of these species are endemic to this Island and as such their loss will be a loss to the whole world.

Efforts should be made by the world community to protect them. He said that interest in conservation of resources and protection of the environment are unfortunately restricted to researchers interested in these areas and to a few laymen who have spent sometime in it. He also described the apathy exhibited by officials towards conservation and emphasised that their attitudes should change. He suggested that politicians should be made aware of the problem and they should bring in the necessary legislation regarding conservation. He wished the seminar success and called upon the foreign participants to carry the message across to their countries so that the tropical forests in the region could be conserved for posterity.

Dr von Droste, Director of the Division of Ecological Sciences of UNESCO in his address conveyed the greeting of the Director General of UNESCO for the success of the Training Workshop. He also conveyed the greetings of the Chairman of the International Coordinating Council of MAB and the President of the World Heritage Committee for the success of the Workshop.

He highlighted some of Sri Lankas contribution to the UNESCO, specifically mentioning the cultural triangle project and the publication of the new journal through the National Commission of UNESCO. He also said that for the first time that Sri Lanka has nominated a natural property to be included in the world heritage list, and this property is the Sinharaja Forest which due to its scientific interest is already a part of the national network of biosphere reserves established under the MAB programme. He said that he was happy to note that field work during this workshop will be undertaken in the Sinharaja Biosphere Reserve. The conservation plan recently developed for the Sinharaja Biosphere Reserve would be the model for the implementation of the multi-faceted Biosphere Reserve Concept. Dr von Droste said that the motivation for the MAB focus in the humid tropics comes from both a social environmental and a scientific interest. He said that statistics from the UN compendium from social statistics clearly show that compared with the temperate nations tropical countries have lower supplies of essentials and services and therefore enjoy a lower quality of life, thus the social motivation for identifying the tropics as a major topic of MAB activities. There is also interest in the tropics for scientific reasons. Of the 4.5 million species in existence today 3 million are located in the tropical region, suggesting that the tropics are a centre of biological evolution. And thus the study of life must begin with the tropics. He concluded by saying that weak tropical science inevitably results in weak world science and that the MAB is attempting to redress this imbalance. He wished the participants a fruitful three week workshop period.

6. Workshop Programme

The programme consisted of lectures, discussion periods, poster displays, field exercises at a Tropical Rain Forest MAB reserve, visit to the Botanical Gardens and a visit to a World Heritage site.

The topics covered in the programme include:-

1. Scientific basis of conservation.
2. Tropical Humid Forest Ecology in the Indomalayan Realm
3. Diversity and Endemism in Tropical Humid Forests
4. Reproductive Ecology in Humid Forests
5. Techniques and Methodologies in Tropical Humid Forest Research
6. Tropical Humid Forest Management
7. Tropical Humid Forests as a Resource for Local People and as Conservation Areas.
8. International Mechanism for consolidating Local Conservation.
9. Case Study Presentations by Participants.
10. Field exercises at the Sinharaja (International) MAB reserve.

Each presentation was followed by a discussion at which participants narrated experiences and problems in their countires. Case study presentation highlighted the conservation activities in the participants own countries and the discussions that followed allowed participants to compare similar activities in their countries.

7. Field exercises at the "Sinharaja MAB reserve"

Participants took part in field exercises over a 3 day period at the MAB reserve. During these field exercises demonstrations on the capture and ringing of birds, capture of rodents and other animals that inhabit the forests for study and enumeration were provided. The participants were also made familiar with techniques of mapping and survey of tropical rain forests to estimate animal populations and the roles that they play in the ecosystem. The participants were divided into 3 groups and led through 2 forest trails to familiarise them with the different plant species inhabiting rainforests, their associations, forest structure and tree architecture. They were also given demonstrations in polination and demographic studies that are being conducted at the reserve. During their field work the participants visited local communities living in the vicinity of the reserve and obtaining most of their daily needs from the forest. Here they saw the tapping of the Caryota palm by the local people for the palm sap which is converted into treacle or juggery for sale. Apart from the few crops that were cultivated by these local residents the money derived from the sale of treacle and juggery provided their main source of income.

The participants also had the benefit of acquainting themselves with the large number of endemic species found at the Sinharaja MAB reserve where approximately 10% of the approximately 3000 species found there are endemic. The three field programmes that were arranged are given in the text.

8. Visit to a World Heritage Site and the Botanical Gardens at Peradeniya

Participants visited the World Heritage site of the Rock Fortress at Sigiriya situated within a tropical dry zone forest. The fortress and palace complex built on a rock with ponds and gardens round the rock dates back to the reign of King Kassapa an ancient ruler of Sri Lanka dating back to the 5th Century AD. On the way to the Rock fortress the participants were acquainted with the florestic composition of dry zone forests of Sri Lanka and were also shown some plantation forests in the semi dry areas.

The Botanical Gardens at Peradeniya in the hill capital Kandy is one of the richest gardens in Asia.The participants were shown round by the Director of the Garden who said that there were well over 1000 species of plants in the gardens.

9. Recommendations

On the final day of the workshop the participants were divided into two groups-the South Asian group and the South East Asian group. The two groups went into syndicate sessions and discussed the state of Tropical rain forests in their region and the steps that should be taken to conserve them. At the plenary sessions that followed a chairperson appointed by each group gave an account of the group discussion and recommendations. The recommendations of the two groups were discussed by the entire group along with the resource personnel and a common set of recommendations were approved to be submitted to UNESCO for its consideration. This final session ended with a vote of thanks to all those who were involved with the workshop by the Chairman of the Sri Lanka MAB National Committee. The recommendations are as follows:

1. Encourage greater participation of the countries within the Indomalayan realm in the implementation of international conservation programmes and conventions. In this connection countries within the realm that are yet to ratify/accept or accede to the World Heritage convention are encouraged to take the necessary steps to this effect. Nations within the Indomalayan realm are also urged to actively participate in the implementation of the Action Plan for Biosphere Reserves.

2. Explore all possible ways to conduct regional training workshops, at least once a year, separately for south and southeast Asia. The venue of such workshops could be changed according to a rotational basis among the countries of the given geographical region of Asia. The subject matter on which these workshops would focus upon should be related to ecology and conservation of ecosystem types and defined broadly. Individual workshops could deal with selected themes under the defined subject matter. A workshop for the whole realm, bringing together specialists from south and southeast Asia be held at a regular interval of about 4-6 years.

3. Training and collaborative research between institutions, protected areas such as biosphere reserves and other relevant agencies be encouraged within the realm. It is also essential that ecological terminologies are standardised and the meaning of protected area categories internationally recognised by UNESCO be given wider publicity.

4. The selection of particiapnts for the workshops be done in consultation with as many government agencies, research and training institutes as possible. The number of participants be restricted to 2 trainees from each country with the host country being given the advantage of including 4-6 participants.

5. In realising the recommendations all possible assistance and expertise available with international agencies such as UNESCO, IUCN, UNEP and FAO be sought.

NA-91-7

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REGIONAL TRAINING WORKSHOP ON THE ECOLOGY AND CONSERVATION OF TROPICAL HUMID FORESTS OF THE INDOMALAYAN REALM

17 FEBRUARY - 7 MARCH 1987

PROGRAMME

OPENING SESSION

February 17th 1987

9.00 - 9.30 a.m.	- Registration of Participants
9.30 - 9.45 a.m.	- Welcome Address by Dr R.P. Jayewardene, Director General, NARESA
9.45 - 10.15 a.m.	- Address by the Chief Guest - Hon. Dr Nissanka Wijeyeratne, Minister of Justice
10.15 - 10.30 a.m.	- Address by UNESCO representative - Dr Bernd von Droste, Director, Division of Ecological Sciences, UNESCO, Paris
10.30 - 11.00 a.m.	- T e a
11.00 - 12.00 noon	- Rationale and objectives of the Workshop - Prof. R.N. de Fonseka, Chairman, Sri Lanka MAB Committee

TECHNICAL SESSIONS

Session 1 — Scientific Basis of Conservation

Chairman : Prof. B.A. Abeywickrema

1.15 - 2.45 p.m.	- The Scientific basis of conservation and its multidisciplinary character - Dr Bernd von Droste, UNESCO,Paris
2.45 - 3.00 p.m.	- T e a
3.00 - 4.45 p.m.	- The status of tropical humid forest conservation in the Indomalayan Realm - Dr N. Ishwaran, UNESCO, Paris

18th

Session II — Tropical Humid Forest Ecology in the Indomalayan Realm

(a) Nutrient Cycling

Chairman: Prof. S. Balasubramaniam

8.30 - 12.00 noon - Shifting agriculture (Jhum) and rain forest management in North-Eastern India
- Prof. P.S. Ramakrishnan, Jawaharlal Nehru University, India

12.00 - 1.15 p.m. - L u n c h

1.15 - 2.45 p.m. - Litter production and decomposition and mycorrhizal associations in tropical humid forests - Dr N. Gunatilleke/Peradeniya University and Dr(Mrs.) K. Abeynayake/ Colombo University

2.45 - 3.00 p.m. - T e a

(b) Diversity and Endemism in Tropical Humid Forests

Chairman: Dr Francis NG

3.00 - 4.45 p.m. - Role of animals in dispersal and regeneration of plants in humid tropical forests
- Dr S.W. Kotagama, Miss N.D. de Zoysa and Mr W. Lyn E. de Alwis

19th

8.30 - 10.15 a.m. - Diversity and endemism and the need for conserving representative areas within national boundaries
- Prof. B.A. Abeywickrema, Colombo University

10.15 - 10.30 a.m. - T e a

10.30 - 12.15 noon - Animal diversity in tropical forests
- Dr S.W. Kotagama, Open University

12.15 - 1.15 p.m. - L u n c h

Chairman: Dr N. Ishwaran

1.15 - 2.45 p.m. - Vegetation types of peninsular India in relation to environmental conditions

- Dr Meher Homji/French InstItute

2.45 - 3.00 p.m. - T e a

(c) Useful Techniques and Methodologies

Chairman: Dr Meher Homji

3.00 - 4.30 p.m. - Quantitative Methods in Ecology

- Dr R.O.J. Thattil, Peradeniya University

20th

Chairman: Prof. S. Balasubramaniam

8.30 - 12.00 noon - Forest Maps of South India

- Dr J.P. Pascal, French Institute

12.00 - 1.15 p.m. - L u n c h

1.15 - 2.45 p.m. - Remote sensing applications for vegetation mapping

- Mr S.D.F.C. Nanayakkara, Survey Department

2.45 - 3.00 p.m. - T e a

3.00 - 4.30 p.m. - Vegetation Maps of Peninsular India and Sri Lanka at 1:1,000,000 scale

- Dr V.M. Meher Homji, French Institute

21st

(d) Energy Flow

Chairman: Prof. P.S. Ramakrishnan

8.30 - 10.00 a.m. - Tree Architecture
Dr Francis NG, Forest Research Inst., Malaysia

10.00 - 10.15 a.m. - T e a

10.15 - 12.15 p.m. - Mineral nutrition of tropical trees: Patterns of foliar nutrient contents in major forest formations of Sri Lanka

- Prof. S. Balasubramaniam & Prof. G. Glatzel

12.15 - 1.15 p.m. - L u n c h

22nd Sunday - Visit to Botanical Gardens, Peradeniya

23rd

(e) Reproductive Ecology

Chairman: Prof. B.A. Abeywickrema

8.30 - 10.00 a.m. - Phenology of tropical forest species

- Dr Francis NG, Forest Research Inst., Malaysia

10.00 - 10.15 a.m. - T e a

10.15 - 12.00 noon - Reproductive Biology of tropical humid forest plants (Sinharaja Project)

- Dr(Mrs.) C.V.S. Gunatilleke, Peradeniya University

12.00 - 1.15 p.m. - L u n c h

Session III Forest Management

(a) Humid Forest as a Timber Resource

Chairman: Mr V.R. Nanayakkara

1.15 - 3.00 p.m. - Tropical humid forests as timber resources and its implications on conservation with particualr reference to Sri Lanka

- Mr M. Pushparajah, Forest Department

3.00 - 3.15 p.m. - T e a

3.15 - 4.30 p.m. - Significance of seed technology in relation to the natural growth and development of forests and in reforestation programmes

- Dr A.K. Kandya, India

24th

(b) Tropical Humid Forests as a Resource for Local People and as Conservation Areas

Chairperson: Dr(Mrs.) S. Gunatilleke

8.30 - 10.00 a.m.	-	Protected areas in the tropics, An overview - Dr Jim Thorsell, IUCN, Paris
10.00 - 10.15 a.m.	-	T e a
10.15 - 12.00 noon	-	Tropical humid forests as a resource for local people for shifting cultivation, timber, fuelwood & non-timber resources - Dr I.A.U.N. Gunatilleke, Peradeniya University
12.00 - 1.15 p.m.	-	L u n c h
1.15 - 4.30 p.m.	-	Agro-forestry and social forestry concepts and their role in serving the needs of local people - Mr V.R. Nanayakkara, Forest Department

25th

8.30 - 10.15 a.m.	-	Integrating local people and protected areas in the humid tropics - Dr Jim Thorsell, IUCN, Paris
10.15 - 10.30 a.m.	-	T e a

Session IV

International Mechanisms for Consolidating Local Conservation

Chairman: Prof. R.N. de Fonseka

10.30 - 12.15 p.m.	-	Research and training under the international man and the biosphere programme - Dr N. Ishwaran, UNESCO, Paris
12.15 - 1.15 p.m.	-	L u n c h
1.15 - 4.30 p.m.	-	International mechanisms for consolidating national efforts in nature conservation - Dr N. Ishwaran, UNESCO, Paris

26th and 27th	-	Case study presentation by the trainee participants Co-ordinator: Prof. R.N. de Fonseka
28th	-	Visit to World Heritage site
1st March	-	Leave for Sinharaja
2nd, 3rd and 4th	-	Field exercises at Sinharaja
5th	-	Return to Colombo
6th	-	Plenary sessions and recommendations
7th	-	Departure

* * *

ACKNOWLEDGEMENTS

The Regional Training Workshop on the Ecology and Conservation of the Tropical Humid Forests of the Indo-Malayan Realm was organized by the Sri Lanka MAB National Committee and the Natural Resources, Energy and Science Authority of Sri Lanka at the invitation of the Division of Ecological Sciences of UNESCO.

The organizing Committee gratefully acknowledges the assistance and cooperation extended to it by the resource persons in conducting the training programme, sometimes under difficult conditions in the field. The guidance and assistance provided by Dr von Droste, Head of the Ecological Sciences Divsion of UNESCO in the preparation of the agenda for the training programme and the assistance of Dr N. Ishwaran of UNESCO in the preparatory stages and in the implementation of the programme are thankfully acknowledged.

Financial assistance for the Workshop were provided by

(1) UNESCO Paris under the World Heritage Convention Project.

(2) UNESCO Regional Office, New Delhi.

(3) USAID under its Reforestation and Watershed Management Project of the Forest Department.

Their contributions are gratefully acknowledged.

The assistance provided by the Conservator of Forests Mr V.R. Nanayakkara and his staff in allowing the facilities at the Kudawa camp of the Sinharaja MAB reserve to be used during the field exercises is acknowledged with thanks. The Committee wishes to acknowledge the assistance provided by "March For Conservation" in arranging the poster display, and also expresses its gratitude to all those who assisted in conducting the training programme to a successful completion.

D.E.F. Ferdinandez

on behalf of the Organizing Committee

NARESA, 47/5, Maitland Place
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Opening Session

Chairman : Dr R.P. Jayewardene

1. Welcome address by Dr R.P. Jayewardene
2. Address by the Chief Guest Dr N. Wijeyeratne
3. Address by Dr Bernd von Droste

ADDRESS BY DR R.P. JAYEWARDENE

Honourable Minister of Justice Dr Nissanka Wijeyeratne, Dr Bernd von Droste from UNESCO in Paris, Prof. Fonseka, distinguished delegates from UNESCO and distinguished delegates from many countries represented here. It is my pleasant duty to welcome all of you to this workshop which has been organized by the Natural Resources, Energy and Science Authority with the help of UNESCO, USAID and World Heritage Foundation. I must first express my thanks to the Honourable Minister for coming here this morning to be our Chief Guest. A Minister of the Government has many things to do and he can hardly spare the time to come for a meeting of this nature which is a very scientific one, although the subjects are of general interest to all the people in Sri Lanka. We thank, Dr von Droste for coming from Paris to be with us and for all the assistance that he and UNESCO have given, and USAID - the World Heritage Foundation and many others who have helped. I welcome all of you, especially the delegates who have come from long distances, and those from Sri Lanka who have helped to make this workshop a success. This workshop is dealing with the tropical humid forests which exist only in the tropical part of the world, and extends from the Far East to Latin America. The tropical forests have been exploited by man and depleted over the ages. It exists in a thin layer of atmosphere called the biosphere, in which plants and animals have to survive. If this biosphere is destroyed or changed in anyway, its life supporting properties will be altered so that it cannot support life anymore. You have heard of the things that man in his efforts for development have produced: acid rain, nuclear explosions, and the after effects, which according to the newspaper, has caused 75,000 deaths. Medical Science will have to determine in the years to come the serious sequelae that will follow. Together with the biosphere there is what we call the ecosystem. A very delicate system which nature in its bountry has developed for the sustenance of the tropical forests. The ecosystem is the system in which plants, animals, rainfall, light and the atmosphere interact together to enable life to go on. Life consists of the conversion of what ever is available into energy and ultimately energy comes from the sun. Biosphere is not a modern concept. It was first suggested by Lamarck. After Lamarck, it was taken up by the Russian scientist Verdansky and the French gave the name "la biosphere". So the concepts that we discuss today and for many days to come are not very new. They have been thought of, worked upon, and written about 50-60 years. Even before that we have heard the Prince of teachers, Prince Siddhartha Gauthama who said "it affords protection to all beings, offering shade even to the axeman who destroys it". Hon. Minister of Justice we are very happy that you are here today and I now invite you to inaugurate this Workshop and speak a few words to us this morning.

Thank you.

ADDRESS BY HON. DR NISSANKA WIJEYERATNE

Mr President, distinguished visitors, I consider it a privilege to have been invited to make the inaugural address as guest speaker at a workshop that is held here relating to a subject that has become today a paramount concern of Governments in our region.

Quite recently in India there was a very acute contraversy in the State of Kerala with regard to the needs of maintaining and continuing a heritage when challenged by man's needs and irrigation development. It ultimately ended up with various commissions. Finally, an uneasy truce was declared between conservationists and those interested in development. Conservation has, in India as elsewhere, many valuable dedicated supporters, those who are interested in maintaining the forests, the eco-systems, those interested in bird life and also those who look far into the future and want to maintain their resources, knowing how much unintelligent expansion has created problems for the Community.

In Sri Lanka, we have had our problems too. 'Sinharaja Adaviya' features large in our programme. I remember in the year 1952 when I was a young government officer, I was posted to a Camp for Land Settlement work on the pheriphery of Sinharaja Adaviya. I remembered discussing in the course of my walks in the villages, of how the villages had expanded from the valley right up the hills, how illicit gemmers were working their way up the streams and how the needs of the villagers for cultivation had led to encroachment upon that valuable treasure we had. But what surprised me most was that a herd of elephants which had long lived in that area, which due to the terrain had developed marked characteristics quite distinct from the marsh elephant of the north central and north eastern forests of our country, were rapidly becoming extinct.

I remember how years later, a very distinguished scientist in Sri Lanka, Dr Deraniyagala,telling me of how the Rhinozirus went extinct in Sri Lanka, and how within historical times a speciman of Bison quite common in India, the gaur, which existed in Sri Lanka and is borne out by various village names, had within the last 150 years completely gone extinct.

This applies equally to trees. There are various varieties of commercial value, vast groves of the famous varieties known in Sri Lanka as the "Dambulla Halmilla" which is hardly available today.

There is also a fear that special systems that have developed; for instance in the Ritigala Massive - an isolated area in the north central plains of Sri Lanka,which had evolved a special type of plants discussed by a scientist Dr Trimen may now run the risk of going completely extinct. Similarly, a number of plants which might have survived in the out crops of the Moneragala District of Sri Lanka have been completely destroyed with the opening up of tea estates on the summits of those hills.

The approach is not purely exotic.One of course laments the fact that one hardly sees today the famous foxtail orchid that was so common in the jungles of Bintannepattu and Wawgampattuwa of Sri Lanka. The Vanda Tesselleta, the beautiful grey orchid is hardly seen today. There are many varieties of ground orchids that were in the jungles of Sri Lanka, that one does not see because needs have compelled man to expand.

In 1833, Elephant Kraals were held within 20 miles of Colombo, Elephant Kraals were held in Kandy, where elephants were driven into the city for their capture to be witnessed by royalty. By the inexorable march of civilization we have pushed back the jungle and lost the animals. But we do not realise the danger that we are bringing upon ourselves by losing a large amount of valuable species of fauna and flora which would have been valuable to Sri Lanka, and which even for purposes of science will not be available for those who are interested in research. Quite recently, there was a seminar about the mangrove swamps in Sri Lanka which are being rapidly destroyed. Quite often it is not merely the axe but the effluvia of industries that destroy completely the fish and other acquatic life.

The government is seriously concerned about it, because we are finding all over a vast amount of encroachments and illicit felling going on. Infact, yesterday or day before, the Media reported that I said that the death penalty would be imposed by me for illicit felling. I did not say it, but I wish that such a cry came from the nation. I do not think I would be permitted to make such a recommendation and get away with it as we governments are so responsive to public opinion and there is a danger that the illicit feller may ultimately see us out of office. But the dangers are there and the need is there.

An unintelligent extraction of timber, a proper pattern of forestry, and the growth of trees for commercial use, is absent here. Trees are substituted with crops, sometimes permanent like rubber, sometimes semipermanent cash crops and there is no proper plan for the growth of trees in our country. I must say that a few years ago, a very enterprising businessman - I do not know whether his talent came from the fact that his family were recent emmigrants to Ceylon and whether he brought a special knowledge and skill which is lacking in our people and an old friend of mine told me that he was interested in building up a timber reserve near his estate. I said I was not able to get involved because the principles the Government followed restricted us from getting involved in commercial enterprises. However, a son of mine did get involved with him becuase they were family friends, and after three years they derived from thinnings alone much more than my friend derived from one acre of tea, on an acre to acre to basis.

It therefore, shows that an intelligent analysis of timber potential is lacking. As I mention this there came into this hall a lady who has dedicated quite a lot of her time to the preservation of trees, though she has not been very successful at it. This preservation of trees is sometimes sentimental. We have in Sri Lanka an emotional attachment to one particular tree out of a variety of species. Of them one particular tree, perhaps the oldest recorded tree in the history of the world. That is the secred Bo-tree in Anuradhapura sent to Sri Lanka as a gift by the Emporer Ashoka. Over centuries and the visitudes of History and the long tale of Sri Lanka, records show how it was protected. Unfortunately this protection has not been extended to other species. Large number of species are no longer available, or if they are available they are so rare. A particular example is the Madara tree of which there are only three known specimens in Sri Lanka. There may be more in the jungles. One identified tree is in the garden of the Government Agent of Ratnapura. The other is in the Peradeniya Gardens and the other I believe is in the Mahawelathanne collection in Balangoda.

We are not interested, or if we are interested, the interest is only with a few people interested in research, and a few laymen who have spent sometime on it. One clear example, (and I would be very happy if you do meet him), is at Dambulla and quite close to Sigiriya. He is an old Englishman called Pophem who has lived much of his life in Sri Lanka as a Planter and now lives on about 30 acres of land, near Dambulla, growing a mango grove looking after it with care, plucking every fruit singly so that the tree would not be damaged, and during the course of his life there, he has produced a wonderful manuscript, where he has described and drawn with his own hand, beautiful pictures of different varieties of trees, with notes on them and given the history and some aspects of their commercial value. He told me how when he was a young planter, stationed in Haputale, he put stones at his own cost around every tree that was in his garden and marked the names. And he said his greatest sorrow was to find that years later an unintelligent planter, unfortunately a Sri Lankan, had thrown the stones all about the garden, may be to decorate the garden or present the stones in a better form, but in the process he helped to lose their identification. This is a tragedy.

Man from his earliest stages of growth was essentially a tree worshiper. Elements of it remained. We, in the East converted the trees into objects of worship. We have in our minds, homes in the trees to dieties. The same pattern remained in Europe. The Druids followed it. The worship of nature was ingrained in early man whether it was the sun or whether it was Ushas the dawn or whether it was Vayu the wind or the trees or the streams. There was a tendency to deify them, to worship them and to look after them. But one of the most sadest aspects of civilisation is a corruption of ancient faiths, beliefs and traditions and an unending process of pollution and destruction.

In the Northern part of the African continent, the arid areas in Rajasthan, the denudation of forests in Nepal, and what we have done in Sri Lanka should be recorded, so that history, if mankind servives, will know that in this era of human civilization, the greatest enemies of man lived and pretended to be civilized. It is of no purpose, there is no value in having conferences if you cannot get the message across. If you feel that as a scientist, your study and work ends with the particular area of research you are doing, in many ways you have betrayed the science to which you belong, for all human knowledge is of no value if it cannot be applied and therefore you have to be the torch bearers of knowledge for the benefit of man so that man will be awakened from his stupor and be made to realize the inherent tragedy that will beset him, if he does not live in relation to nature. To relate to nature does not mean to completely avoid the needs of man but there has to be an intelligent interface. Nature can be very kind, it can be very cruel, and where man unintelligently loses and destroys the resources nature had guarded over centuries and sometimes millenia, and which man loses not in a year or two, not in a month, but in a few weeks, should be always presented to the unintelligent people around you, so that their eyes will open and they will see what has to be done.

Tree planting has been enjoined upon man from the earliest time when responsible and effective governments were established in our region. In the edicts of Asoka Policies in regard to forests are sometimes reflected as in the Artha Sastras of India and the various edicts among our kings to protect royal forests and ultimately meant conserving the resources available to human beings. The regulation of even the hunters who lived in the forests are the evolution of general principles, were basically conservationist and are indicative of the application of a valuable thought.

In Europe the last 2-3 thousand years the people have lost valuable forests. The great groves where the Druids worshipped, the beech forests and the oak forests, are no more. The forests that were in England in the Southern areas are no more. But there has been an attempt to develop a love for trees realizing their necessities, and the evolution thereby of an intelligent forestry programme for that country.

Animals have been lost and it is with great difficulty then the European Bear is being presently preserved and other animals that were once very common, are being looked after by conservationists. There are many animals that have gone extinct, the Dodo has gone extinct, and probably at the rate we are going, we will render homo sapians too extinct. That is a price we should pay. Therefore, the policies must start from the schools, for you cannot have an adult nation in whom the ideas have not been engrained in their youth. But in unfortunately schools curricula, devoted to cramming in knowledge, for the purpose of exams and not for the purpose of living, that ultimately it needs sometimes a rare example of an enthusiastic person to raise the issue. Here I am very proud of Dr B.A. Abeywickreme from Sri Lanka who took up this aspect with regard to our humid forests, which was one of our treasures, at one of the UNESCO Conferences. But one or two individuals, even great individual like Dr Khan in India, and various other people who have thoughts for animals, thoughts for plants are inadequate and their fight is of no value, if they do not get wider support, and it is only with wider public support that the polititian would be made to be aware of the problem and to bring in the necessary remedial legislation.

There is of course a very peculiar problem I must mention, which sometimes strikes me as being rather unusual, I remember discussing with some scientists about bringing certain extinct animals like the gaur and breeding them in Sri Lanka, and they said that that is not generally done. There are so many plants that have come from outside, the rubber plant was unknown to Sri Lanka, the tea plant was unknown to Sri Lanka, the coffee plant may have been known, the Lantana plant now growing wild in Sri Lanka was introduced during the British period and a large number of other plants, grasses like Brachiaria brizantha, various other plants have been brought in and they spread throughout our country. I do not know why we cannot bring in some of the older extinct animals and even breed them in captivity. But anyway it is not for a layman to offer this advice before a scientific gathering. It is you who must educate the public and encourage it to be aware of the problem and force the politicians to open his eyes. All of you, especially those from abroad, I expect you, when you go through Sri Lanka to look at all the public buildings and the gardens around them, and you will see what lovely little deserts we have round them, denuded of trees; Principals of schools too lazy to plant trees, to teach students to do so; government officers in government buildings without the intelligence and capacity to plant trees. And you will find that sometimes the barest land is around government buildings, reflecting the bareness of the minds of those who have by accident been called upon to hold public office. It is something that is necessary to be exposed, and ruthlessly exposed. For the scientist who does not have the courage to tell society what ought to be done, is ultimately the betrayer of the knowledge to which he claims inheritance.

May that capacity develop and grow with you. May we, whom accident has thrust into politics, ultimately benefit from the knowledge that you through the people, whom you encourage to think and look anew, will be able to do somethings so that ultimately jointly we could claim credit and all of us when we draw to the finish of our little lives, be able to remember that we have done our bit for future generation so that they would not be born into deserts, where no birds sing and not animals walk, and no plants exist no flowers bloom, and man made deserts and arid lands become the inheritance of mankind. Thank you.

ADDRESS BY DR BERND VON DROSTE

Honourable Minister of Justice, Dr Nissanka Wijeyeratne, Distinguished Director-General of NARESA, Dr R.P. Jayewardene, Distinguished members of the UNESCO National Commission and the MAB National Committee of Sri Lanka, ladies and gentlemen, let me first convey to all of you greetings on behalf of the Director General of UNESCO, Mr Amadou Mahtar M'Bow, who wishes success for your regional training workshop on the "Ecology and Conservation of the Tropical Humid Forests of the Indomalayan Realm". As secretary of UNESCO's intergovernmental Man and Biosphere Programme, in short called MAB, I have the pleasure to convey to you, warmest greetings on behalf of the Chairman of the International Coordinating Council of MAB, Professor Dr Li Wen Hua and of the worldwide scientific community working within MAB, through the MAB National Committees,so far established in more than 10 countries. Furthermore this workshop has been sponsored under UNESCO,s World Heritage Convention. The President of the World Heritage Committee, Assistant Deputy Minister for Environment in Canada, Mr J.D. Collinson, has also asked me to greet you on his behalf. I am also pleased to note that this workshop has been supported by the USAID.

I am impressed by the manner in which this inaugural session has been organised by NARESA, which augurs well for our joint work during the next three weeks. Indeed, the hospitality rendered to us by the local organisers, namely the Natural Resources, Energy and Science Authority (NARESA) headed by Dr Jayewardene, and the MAB National Committee of Sri Lanka, chaired by Prof. R.N. de Fonseka, has been marked by the warmth and tradition characteristic of our hosts. I take this opportunity to thank the workshop participants for their attendance coming from 10 south and south-east Asian countries, namely Bangladesh, China, India, Indonesia, Malaysia, Nepal, Pakistan, Philippines, Thailad and the People's Republic of Vietnam, giving a truly international character to our meeting.

UNESCO was created 40 years ago as part of the UN system to provide specialised services in the fields of Education, Science, Culture and Communication. From the early stages, Sri Lanka, has been a strong supporter of UNESCO, and provided leadership in these contexts. Here, I wish to mention the pioneering work of His Excellency the Ambassador to UNESCO, Professor Dr Ananda Guruge, who in UNESCO leads the group of the 77 in the work of UNESCO's Executive Board.

Let me briefly highlight some of Sri Lanka's contributions to UNESCO. As one of the few countries in the region recording a literacy rate as high as 87.0%, educational opportunities are within the reach of nearly every citizen of Sri Lanka. The availability of free education, the distribution of free text books to pupils of primary and junior secondary grades in government and private schools and the high quality of secondary and university education are worthy of mention.

There are over 130 UNESCO clubs in Sri Lanka engaged in adult education activities which supplement the formal educational programmes. We were greatly encouraged and pleased to see the new journal "DUTA" that has been started by the Sri Lanka National Commission for UNESCO since 1986. This local adoption of UNESCO's Courier idea is most welcome and most effective in disseminating information pertaining to UNESCO programmes and activities.

Another outstanding example for the excellent cooperation between Sri Lanka and UNESCO is the safeguarding of the Cultural Triangle of Sri Lanka. Let me quote from the appeal made by Mr Amadou Mahtar M'Bow, Director General of UNESCO: "The Cultural Triangle has to be preserved for the sake of Sri Lanka since it forms part of the country's historical core and gives supreme expression to its religious values. It must be preserved for the sake of Asia as a whole for it is a centre of Buddhist tradition and has heightened the sense of Asian solidarity. It must be preserved for the sake of the world at large since it forms an integral part of its indivisible heritage".

With the help from UNDP, UNESCO's World Heritage Convention and others the Government of Sri Lanka has already taken major steps to preserve and restore most of the age-old monuments situated in the ancient cities of Anuradhapura, Sigiriya, Polonnaruwa and Kandy. The first three of these sites are protected under UNESCO's World Heritage Convention, to which Sri Lanka adhered in 1980. As of today it is the most successful convention in the field of the conservation of natural and cultural heritage and counts 92 states parties which have 247 sites inscribed on the World Heritage List, so far. The World Heritage Committee will decide this year, whether or not two other cultural properties from Sri Lanka, namely the sacred city in Kandy and the Dutch Fort in Galle, should also be inscribed on the World Heritage List.

For the first time, this year Sri Lanka has also nominated a natural property for the World Heritage List: the Sinharaja Forest which due to its scientific interest is already part of the international network of Biosphere Reserves established under the Man and Biosphere Programme. I have not yet mentioned in any detail Sri Lanka's contribution to UNESCO's Man and Biosphere Programme. Among the 14 MAB Project Areas, those dealing with tropical forest ecosystems research and genetic resources conservation in biosphere reserves have attracted most active participation in Sri Lanka. In Sri Lanka there are two Biosphere Reserves: namely the Sinharaja and the Hurulu Forest Reserves. Field work during this workshop will be undertaken in the Sinharaja Biosphere Reserve. In fact the "Conservation Plan" recently developed by the Sri Lankan authorities will help to develop the Sinharaja Biosphere Reserve as a model for the implementation of the multi-faceted Biosphere Reserve Concept.

UNESCO's World Heritage Convention and the intergovernmental programme on Man and Biosphere are among the most important international mechanisms for the conservation of tropical humid forests.

The motivation for the MAB focus in the humid tropics comes from both a social-environmental and a scientific interest. Statistics from the UN compendium of Social Statistics clearly show that compared with the temperate (western) nations tropical countries have lower supplies of essentials and services and therefore enjoy a lower quality of modern life. Thus the social motivation for identifying the tropics as a major topic of MAB activity can be appreciated. There is also interest in the tropics for scientific reasons. At present, it is established that there are 4.5 million species in existence, with 3 million species of the total occurring in the tropics. These topics suggest that the tropics are a centre of biological evolution. Therefore the study of life must begin with the tropics. Weak tropical science inevitably results in weak world science and MAB attempts to redress the imbalance. Perhaps it is now clear why MAB so enthusiastically supports this workshop. Let me conclude by wishing all the participants a fruitful three-week period during this workshop.

Thank you.

Technical Sessions

Session I

Scientific Basis of Conservation

Chairman : Prof. B.A. Abeywickrema

The Scientific Basis of Conservation and its Multidisciplinary Character	Bernd von Droste
The Status of Tropical Humid Forest Conservation in the Indomalayan Realm	N. Ishwaran

THE SCIENTIFIC BASIS OF CONSERVATION AND ITS MULTIDISCIPLINARY CHARACTER

BERND VON DROSTE

Abstract

Modern concepts of conservation, such as the Biosphere Reserve Concept of UNESCO'S Man and Biosphere Programme, stress the need for participation of specialists representing a variety of disciplines. The organizational basis of the MAB programme and the International Network of Biosphere Reserves is discussed in relation to three different continua. The main features of the Biosphere Reserve Concept are highlighted and the manner in which it had avoided the biases of traditional conservation efforts emphasised. The need to combine genetic resources conservation with scientific research to produce socio-economic benefits to local people is considered to be the major challenge facing conservationists in the future.

Introduction

The scientific basis of conservation, though it has been the subject of much discussion and research, remains unclear. Conservation science, e.g. conservation biology, is still relatively a new subject, considered by many as the cinderella of the sciences. Moreover, conservation, as we shall see, is a complex task which, in the sense of the World Conservation Strategy of the IUCN, is not limited to protected areas alone. It deals with the maintenance of essential ecological processes and the sustainable utilisation of natural resources. Today, in fact, many of the genetic resources are found outside of protected areas. Conservation therefore concerns all land use systems and their rational management. Conservation is defined as the management of human use of the biosphere so that it may yield the greatest sustainable benefit to present generations while maintaining its potential to meet needs of the future generations (IUCN, 1981).

Conservation is for the benefit of, and depends upon, the human race. Conservation is a management option which is a future oriented undertaking of each generation on behalf of coming generations. In this sense those involved in the management of natural resources have to fulfill an evolutionary responsibility to perpetuate, to the extent possible, a legacy from the past. In order to best fulfill this evolutionary responsibility, a scientific approach has to be chosen, and knowledge already available in respect of the management of natural resources, has to be used and applied by all actors.

What sort of research can provide the scientific knowledge needed for the conservation and rational use of natural resources of the biosphere? How can different scientific disciplines be brought to bear on the multiple dimensions of complex land-use systems? How can decision makers and local people be sensitised to apply research findings? Since its inception in 1971, UNESCO's Man and Biosphere Programme has been wrestling with such questions in attempting to foster ecological research which responds to conservation/ development needs.

UNESCO-MAB Multi-disciplinary Research Needs

The aim of the MAB programme is to promote applied research on the interaction between man and his environment and to provide the scientific knowledge and trained personnel necessary to manage natural resources in a rational and a sustained manner. The programme emphasises field research, at the local level, and within the general framework of scientific cooperation at the international level.

One of the most successful parts of MAB has been the launching of the International Network of Biosphere Reserves, marked by the innovative approach to harmonise conservation/development needs. Many difficulties encountered in tackling conservation/development problems of today arise out of our tendency to compartmentalise knowledge and action. The Biosphere Reserve (BR) Concept tries to overcome this. Conservation, according to the BR concept, is a task of the society as a whole, and therefore requires concerted efforts to resolve conflicting demands on land and natural resources. This task has many actors at several levels whose responsibilities are interlinked. Within MAB an attempt has been made to provide a comprehensive framework for placing conservation activities. Three types of continuum can be recognised within this framework (Di Castri & Hadley, 1984).

The first continuum is a geographic one. The programme is concerned with the whole range of terrestrial, freshwater and aquatic ecosystems from equator to polar regions and from littoral to high mountain systems. By combining the contributions of different countries, it is possible to include in the research and conservation effort a gradient of the ecosystem and biogeographical conditions found in a particular region. MAB is therefore, characterised by regional and global networks of research on ecosystem types and for conservation of genetic resources, within the overall framework of the international network of BRs.

The second continuum concern's man's efforts in different parts of the biosphere. MAB encompasses the full range of situations from sparsely to densely populated zones, of biosphere reserves with human settlements. In each situation, the focus is on the impact that different types and intensities of human actions have on ecosystems and on the repercussions of environmental change for the social, economic, cultural and biological characteristics of human populations.

The third continuum comprises activities carried out within the programme. They include basic and applied research, demonstration and training, popularisation and education. The BR Action Plan is an example for this holistic approach and its nine objectives for individual BRs including in situ conservation of genetic resources, ecological research and monitoring, training and education and most importantly demonstration of rational land use models are illustrative of this continuum (UNESCO, 1984).

Justifications for Conserving Nature

The justifications for conserving nature, while they are self-evident to some, are frequently questioned by others. Three broad reasons are normally given (Di Castri & Robertson, 1982). The 'knowledge justification' for conservation refers to our present ignorance of the amount of information irrevocably lost due to extinction of species. This information may be useful to solving a variety of problems related to natural resources management. The actual and potential useful products that living organisms can provide humanity, e.g. drugs, timber, food, perfumes etc., are increasingly being used to justify conservation efforts. Other intangible benefits such as environemntal monitoring may also be considered as 'useful products' of conservation. Measuring ~~man-made~~ natural changes in conservation areas helps to improve our understanding of ecosystem functioning. Monitoring is increasingly becoming a key function of biosphere reserves mainly due to the increasing scale of environmental changes, both at the local and the global levels, affecting the life support systems of the earth. The last but not the least is the 'enjoyment justification', which refer to the aesthetic, artistic and moral reasons that direct conservation action.

In order to understand the evolving new concept of biosphere reserves some biases of traditional approaches to conservation must be recognised (Di Castri & Robertson, 1982). For a long time, reaction to unprecedented levels of destruction of the natural environment focused on the protection of certain spectacular species (e.g. tigers) whose scarcity was easier to perceive than less significant organisms. Similarly, beautiful and unique landscapes were protected while man-modified ecosystems were considered less worthy of conservation. The 'western' tendency to systematically keep man out of conservation areas, an idea which has its roots in the setting up of early national parks in wilderness areas uninhabited by man, has not been easy to apply in countries where indigenous grazing, hunting and agriculture have prevailed since the earliest times of human history. Influence of 'western' economic thoughts sometimes have led to excessive exploitation of the recreational value of conservation turning national parks or similar reserves into tourist centres. In general traditional conservationists were strictly protectionists with little scientific basis. The biosphere reserve network constitutes an international effort to counterbalance this effect.

The biosphere reserve concept, increasingly applied to different types of protected areas, provides a fundamental link between conservation, scientific research and sustainable use of natural resources. The concept, based on the recognition that apart from protecting unique and beautiful landscapes there was also a need to conserve a representative sample of the world's major ecosystems and the genetic diversity they contain, places greater emphasis on ecological research, long-term protective measures and environmental education.

The future success of conservation efforts would strongly rely upon their relevance to people who will be affected by them. As the resource-rich conservation areas increasingly become islands in a sea of incompatible land-use, their survival would rely upon the appreciation local people have for the values they contain. This appreciation must be favourably influenced through environmental education programmes. Furthermore it is also necessary that local people accrue tangible benefits due to the presence of the conservation area in the form of priority consideration for employment opportunities, benefits of tourism and accessibility to some of the resources of the conservation area of traditional importance to them. The biosphere resserve concept therefore stresses the need to integrate the conservation area into its region so that it constitutes a positive element in the local economy.

In biosphere reserves research provides the link between conservation of genetic resources and the sustainable development of surrounding areas. Research designed to advance conservation theory, such as the theory of island biogeography, need not essentially have practical implications. It may be more common sense than scientific fact that the larger the protected area the better the chances for reducing the number of extinctions. However, several smaller reserves totalling large aggregate areas covering a wide range of soil and vegetation types could be extremely valuable in conserving biological diversity.

The number of new protected areas that could be set up are likely to be limited by political and socio-economic considerations than purely biological or scientific ones. Hence, the use of basic and applied research to promote development of areas surrounding biosphere reserves is a strategy to minimise conflicts between conservation and development needs. In the Mapimi and La Michilia biosphere reserves of Mexico modernisation of traditional agricultural and husbandry practices combined with the introduction of new crops have demonstrated the contribution of genetic resources conservation towards improving living standards of people (Halfter, 1981). Although such examples are few the potential for demonstrating similar relationships between conservation and development is high in developing countries and the biosphere reserves would continue to be the centres where such experiments could be attempted.

Conclusions and Summary

The real challenge in conservation today lies in the vital issue of combining conservation of genetic resources with measures for the socio-economic development of local people. Cooperation of people at various national and international levels needs to be enlisted in meeting this challenge. While many people are forced to destroy the environment to eke out a living it is encouraging to note that the general level of conciousness of the needs of conservation seems to be expanding. Since the need for linking conservation and development is being increasingly felt, the biosphere reserve concept, which emphasises such a link and in some instances had formed the basis for demonstrating it, merits widespread application in protected area management.

No longer can we claim evolutionary innocence. We are still subject to evolutionary processes, but today we are also capable, to a great extent, to influence the direction of those processes. While we have acquired a new evolutionary responsibility we are also being increasingly compelled to use our abilities to predict, control and redevelop on ecosystems and communities, particularly in those parts of the world where they harbour the highest biological diversity, to conserve and utilise them in accordance with the principles of sustainable development. Whether we can succeed in this endeavour or not appears to be the key question for the future.

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Summary of discussion following presentation:

Philippines - Mr Jose O. Sargento: Conservation is multi-disciplinary in character. Could you provide any guidelines for an administrative framework within which such multidisciplinary activities could be encouraged?

Dr Bernd von Droste: It would be nearly impossible to provide guidelines that would cater to the different administrative structures of all countries. But, in general, stressing the need for managers to have an open mind to consult any kind of specialist they feel could be useful is helpful.

Indonesia - Mr Achmad Abdullah: I am in general agreement with all what you have said but to convince policy makers of taking the necessary steps is not an easy task.

Bangladesh - Mr M. Kalimuddin Bhuiyan: Could you cite any specific examples where management of a biosphere reserve had improved socio-economic conditions of local people.

Dr Bernd von Droste: There are a few. But the case of Mapimi in Mexico is perhaps most relevant to the situation in this realm. Here the application of the biosphere reserve concept has helped raise productivity for grazing in the buffer zone to levels higher than that in outside of the reserve. The value of conservation is so well recognised by people that there are local songs praising the virtues of conservation.

Prof. P.S. Ramakirshnan: Certainly, one success story in Asia will definitely help understanding as well as application of the concept to a very great extent.

THE STATUS OF TROPICAL HUMID FOREST CONSERVATION IN THE INDOMALAYAN REALM

N. ISHWARAN

Abstract

A brief introduction to Udvardy's (1975) system of classification of biogeographical provinces of the world is given. Data from MackKinnon & MacKinnon (1986) is used for comparing percentage of natural forest cover remaining and the extent of lowland rain-forests (one forest-type categorised under the tropical humid forest biome) protected in selected countries of the realm. In most countries it is likely that small reserves will come to lie adjacent to a variety of incompatible land-use. Concepts such as the Biosphere Reserve Concept which emphasise the role of protected areas in the development of local people as well as that of the region would therefore become increasingly relevant to nature conservation within the realm.

Introduction

The excessive depletion of a natural resource, is an "ecological problem"; i.e., it is a special kind of a social problem, like alcoholism, crime or road accidents, without which we believe that society would be better off (Passmore, 1974). Conservation, hailed widely as a remedial measure for most problems of natural resources depletion, thus can no longer avoid the social, economic and the human or moral dimensions of natural resources management. This is becoming increasingly evident in respect of the management of the tropical humid forest in the Indomalayan Realm. The Indomalayan Realm is home to two of the largest human populations of the world in the People's Republic of China and India, respectively. The tropical humid forest is well documented as a biome with a wide variety of timber and non-timber resources of potential and realized value. The opportunity costs of protecting even small areas of tropical humid forests could therefore be substantial.

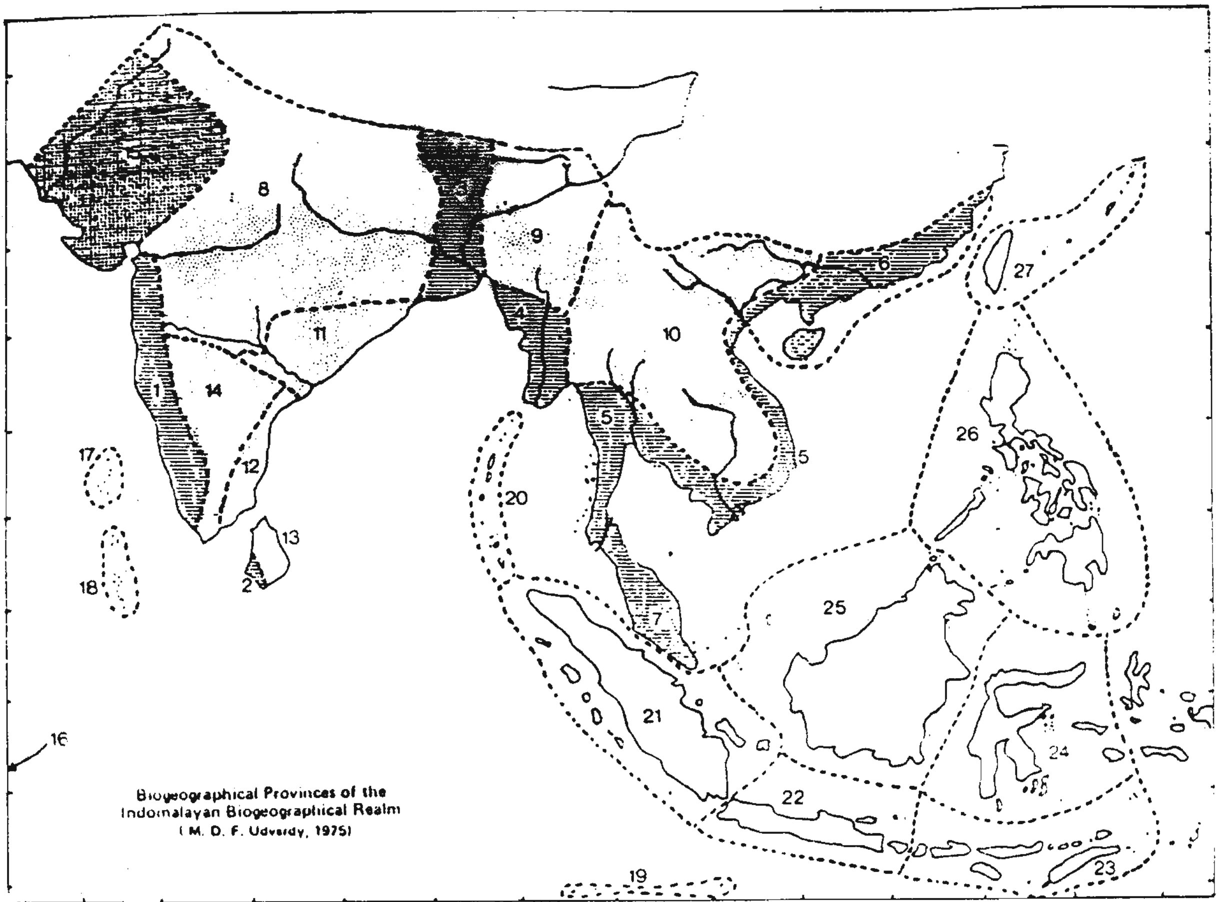
Providing a comprehensive review of the status of tropical humid forest conservation for the realm under consideration is not an easy task given the large area and the multidisciplinary nature of the required conservation effort. Hence, this paper attempts to provide only a partial assessment of tropical humid forest conservation in the realm. In discusisng data presented in relation to remaining extents of natural forests and one of the forest-types classified under tropical humid forests, the prospects for conservation are reviewed in relation to the overall socio-economic content of the countries under consideration.

Classification of Ecosystems

Early efforts in the conservation of natural resources were marked by the selection of protected areas which were either home ranges of unique animal species threatened with extinction or sites of exceptional scenic value. In connection with the implementation of the Man and Biosphere Programme, which was initiated in 1971, a more objective basis for selection of areas that could be protected together with the genetic resources they contained therein, was desired. A classification of the biogeographical provinces of the world (Udvardy, 1975) was prepared to fulfill this need which was of particular relevance to the implementation of Man and Biosphere Programme's Project No. 8-conservation of natural areas and of the genetic material they contain.

The classification of ecosystems proposed by Udvardy (1975) built upon and expanded upon the earlier schemes of Dasmann (1973a; 1973b) and UNESCO (1973). Udvardy's classification scheme, though by no means a perfect one, has provided the basis for a variety of international actions which identified important natural areas for conservation; e.g. selection of sites for inclusion in the International Network of Biosphere Reserves under the Man and Biosphere Programme's Project No. 8, (UNESCO, 1984); identification by the Commission of National Parks and Protected Areas of the IUCN, of 'The World's Greatest Natural Areas' (1982) some of which are inscribed on the World Heritage List maintained by UNESCO as part of its activities related to the implementation of the World Heritage Convention.

Udvardy (1975) categorised eight biogeogrpahic realms and for each major biome-type within a realm recognized several biogeographic provinces. For the tropical humid forest biome, within the Indo-malayan realm, Udvardy (1975) indentified seven biogeographic provinces (Fig. 1). Each of these seven provinces e.g. Burman Rainforest (Fig. 1) referred to a well defined geographic area (Burma) and an ecosystem-type (rainforest). The term rainforest was used by Udvardy (1975) only to the mainland-patches of the tropical humid forest biome. The fauna and flora in the islands of the southeastern parts of the Indomalayan realm were considered unique since they comprise a mixture of elements from Indomalayan and the Australian realms with a strong endemic component; hence, these islands, individually or in clusters (Fig. 1), were considered as biogeographic provinces of the biome referred to as mixed island systems (Udvardy, 1975). However, several of the islands such as Sumatra, Java and Phillipines, comprise vegetation types e.g. lowland rainforest, tropical moist deciduous forests etc., found in mainland and the island of Sri Lanka (Fig. 1). Comparisons of remaining extents of a vegetation (forest) type among countries of the realm were thus possible.



The Indomalayan Realm (4)

No.	Biogeographic Province
4.1.1	Malabar Rainforest
4.2.1	Ceylonese Rainforest
4.3.1	Bengalian Rainforest
4.4.1	Burman Rainforest
4.5.1	Indochinese Rainforest
4.6.1	South Chinese Rainforest
4.7.1	Malayan Rainforest
4.8.4	Indus-Ganges Monsoon Forest
4.9.4	Burma Monsoon Forest
4.10.4	Thailandian Monsoon Forest
4.11.4	Mahanadian
4.12.4	Coromandel
4.13.4	Ceylonese Monsoon Forest
4.14.4	Deccan Thorn Forest
4.15.7	Thar Desert
4.16.13	Seychelles & Amirantes Islands
4.17.13	Laccadives Islands
4.18.13	Maldives & Chagos Islands
4.19.13	Cocos-Keeling & Christmas Islands
4.20.13	Andaman & Nicobar Islands
4.21.13	Sumatra
4.22.13	Java
4.23.13	Lesser Sunda Islands
4.24.13	Celebes
4.25.13	Borneo
4.26.13	Philippines
4.27.13	Taiwan

Biome Types

[hatched]	1	Tropical humid forests
[ ]	4	Tropical dry or deciduous forests (incl. monsoon forests) or woodlands
[stippled]	7	Warm deserts and semideserts
[ ]	13	Mixed island systems

Fig. 1. Biogeographical Provinces of the Indomalayan Realm (Udvardy, 1975)

Assessing the Status of Tropical Humid Forest Conservation in the Indomalayan Realm

Data used in this paper for illustrating the present status of the tropical humid forest conservation in the Indomalayan realm were obtained from MacKinnon & MacKinnon (1986). Their data has been presented in two different tables. In table 1 some basic information on the different countries of the Indomalayan realm, such as total land area and population density, are provided along with the percentage of the land area known to be under natural forest cover. Table 2 provides some statistics, for countries where data were available, on the remaining extents of lowland rainforests which is one of the vegetation (forest) types classified under the humid forest biome.

Table 1

Total land area, population density and percentage forest cover for some countries of the Indomalayan realm

a) Mainland and the island of Sri Lanka

Country	Total land area (km2)	Population density (/km2)	% Forest cover
Bangladesh	142,776	593	9
Bhutan	46,600	26.4	64
Burma	676,528	48	47
India	3,387,593	188	15
Kampuchea	181,000	47	41
Laos	236,725	15	35
Peninsular Malaysia	131,235	87	57
Nepal	141,414	106	13
Pakistan	803,491	94	2.7
Sri Lanka	65,610	226	21
Thailand	513,517	90	18
Vietnam	329,566	164	23

(separate figures for southern China were not available)

b) Islands of the south and southeast Asian regions of the Indomalayan realm

Country	Total land area (km2)	Population density (/km2)	% Forest cover
Brunei	5765	23.6	70
Indonesia	2,027,083	74 (Java 700)	59 (Java 8 Borneo 65)

Country	Total land area (km2)	Population density (/km2)	% Forest cover
Sabah and Sarawak Provinces of Malaysia in northern Borneo:			
a) Sabah	76,115	13.3	65
b) Sarawak	124,235	10.5	67
Philippines	299,756	155	31
Taiwan	36,960	455	10

(population density estimates of countries given here were based on census data for the following periods: Brunei-1971; Bhutan, Pakistan and Taiwan-1977; Bangladesh, Burma, India and Philippines-1978; Laos-1979; Penninsular Malaysia and the provinces of Sabah and Sarawak-1980; Indonesia, Kampuchea, Nepal and Sri Lanka-1981; Vietnam-1982; Thailand-time period not known)

Source: MacKinnon & MacKinnon (1986)

It is perhaps worth noting that there were a few differences between the Indomalayan realm recognised by MacKinnon & MacKinnon (1986) and Udvardy (1975); e.g. the easternmost islands of the Indonesian archipelago, namely those of the Moluccas and New Guinea (Irian Jaya) were considered as part of the Australian realm by MacKinnon & MacKinnon (1986) while Udvardy (1975) included them in the Indomalayan and Oceanic realms, respectively. Despite these anomalies, for the purposes of this paper the data of MacKinnon & MacKinnon (1986) provided a useful basis for undertaking an overview of the status of conservation of the tropical humid forest.

Other issues related to classification arise again when types of forests that could be included in the tropical humid forest biome are con sidered. If one considered the Udvardy scheme as applied to Sri Lanka, only two biogeographic provinces, namely the Ceylonese rainforest and the Ceylonese monsoon forest, were recognised. All forest-types of the Sri Lankan wet zone, both of the lowlands as well as those of the higher elevations, have been included in the biogeographic province Ceylonese rainforest which represented the tropical humid forest biome in this country (Fig. 1). While ideally one needs to consider the status of all wet or evergreen forest-types in the realm (MacKinnon & MacKinnon, 1986) only the status of lowland rainforest is discussed in this paper.

Table 2

Remaining patches of lowland rain forests and their status as protected areas in selected countries of the Indo-malayan realm

Country	Estimated original area (km2) of LR	% remain-ing	% prote-cted	% proposed for protection
Bangladesh	2,000	15	-	5.0
Brunei	3,843	74	43.7	-
Burma				
a) Indian sub-region	6,000	16	-	-
b) Indo-Chinese sub-region	104,285	13	0.2	3.3
c) Sundaic sub-region	4,112	-	-	-
India				
a) Indian sub-region	70,000	50	3.0	0.2
b) Indo-Chinese sub-region (Andamans)	3,000	70	3.6	-
c) Sundaic sub-region	530	73	-	-
Indonesia	682,294	52	2.9	8.8
Kampuchea	15,307	79	8.4	1.3 9
Penninsular Malaysia	267,884	55	4.2	1.5
Philippines	101,903	23	0.6	-
Sri Lanka	14,500	0.3	0.3	-
Thailand	12,027	16	5.7	-
Vietnam	3,065	20	-	5.7

(Source: MacKinnon & MacKinnon, 1986)

(percentage of remaining lowland rainforest in Sri Lanka calculated on the basis of 6,650 ha remaining in the Sinharaja Biosphere Reserve)

In countries such as Pakistan climatic and historic factors contribute to the low percentage of natural forest cover. Percentage natural forest cover of most countries (Table 1) were higher than 10%. Of the 12 countries from the mainland and Sri Lanka (Table 1a) four (Bhutan, Burma, Kampuchea and Penninsular Malaysia) still had greater than 25% of their natural forest cover remaining relatively undisturbed. In the mixed island systems of south and southeast Asia (Fig. 1) four of the five countries considered had more than 25% of their natural forest cover intact. Of the 10 countries considered as the world's principal tropical forest countries (including broad leaved humid and dry forests with closed canopy) three (Indonesia, India and Burma) are within the Indomalayan realm (Guppy, 1984).

A cursory review of Table 1 might tempt someone into complacency regarding the situation of natural forest cover remaining intact in the Indomalayan realm. However, looking at Table 2 one could realize that efforts to conserve sufficient acreages of natural forests, in this case lowland rainforests in particular, do not meet with high degrees of success. With the exception of Brunei, only Indonesia and Kampuchea seem to protect about 10% of the lowland rainforest areas which existed there originally. Figures provided in Table 2 might have been biased by the author's consideration only of protected areas recognised by IUCN (1978) to the exclusion of other reserves of national importance. Nevertheless, substantial increases in the area of lowland rainforests protected would be desired so that in most countries about 10% of the original extent of this ecosystem could be conserved for the future. The commendable situation in Brunei, which has nearly 34% of the land in protected areas, was attributed to the oil revenues which seem to ease the situation for exploitation of natural resources (MacKinnon & MacKinnon, 1986).

Despite the fact relatively high percentages of natural forest cover still remains intact in several countries of the Indomalayan realm, the prospects for protecting substantial extents of those forests are grim. The growing populations characteristic of these countries render setting aside of large conservation areas extremely difficult. Smaller conservation units may thus become the rule; the Indomalayan realm has a higher number (572) of conservation units than the Afrotropical (426), Neotropical (296), Australian (75) and Oceanian (51) realms. However, the total land area covered by conservation units of the Indomalayan realm extends over 27,568,406 ha, a figure lower than that of the Afrotropical (88,166,096 ha) and the Neotropical (43,503,474 ha) realms. Protected area coverage of the tropical humid forest biome showed a similar trend; the Indomalayan realm had 122 conservation units (IUCN management categories I-V) as compared to 44, 53 and 61 for the Afrotropical, Australian and Neotropical realms, respectively. Total area of these conservation units were, however, highest in the Neotropical realm (17,277,197 ha) followed by the Afrotropical (8,905,733), Australian (7,776,347) and the Indomalayan (5,092,774) realms (IUCN, 1985).

The large populations of several countries of the Indomalayan realm and their governments will continue to give priority to socio-economic development over other alternative strategies. A situation where a number of relatively small conservation units are surrounded by other forms of land-use is thus imminent. The need for conservation units to become part of regional and national development efforts and contribute towards the socio-economic upliftment of local people will be increasingly stressed by planners. Concepts which emphasise such aspects of conservation areas, e.g. UNESCO's Biosphere Reserve Concept, are likely to become increasingly relevant for management of protected areas in the Indomalayan realm. This concept places emphasis on allowing for a wide variety of interests such as conservation, scientific research, monitoring of indices of environmental quality, environmental education and socio-economic development of local people influencing the management objectives of specially designated protected areas referred to as Biosphere Reserves. The total number of protected areas of the Indomalayan realm which have become part of the International Biosphere Reserve Network remains small compared to that of other realms. Increased participation by countries of the Indomalayan realm in the implementation of the Biosphere Reserve Action Plan therefore needs to be encouraged.

Summary

Depletion of natural resources, such as tropical humid forests, are special kinds of social problems and hence recommended solutions cannot avoid the socio-economic and moral dimensions of the problem. Since the inception of the Man and Biosphere Programme in 1971, selection of conservation units to be included as part of an international network of Biosphere Reserves, has relied upon a system of ecosystem classification formulated by Udvardy (1975). Recent data of MacKinnon & MacKinnon (1986) indicated that though some countries of the Indomalayan realm still had substantial extents of natural forest cover, protecting forest-types considered to be part of the tropical humid forest biome, e.g. lowland rainforests, were not easy. In spite of the fact the Indomalayan realm had the largest numbers of conservation units for the tropical humid forest biome their total area was smaller than in the Afrotropical, Neotropical and Australian realms. It is likely that in the Indomalayan realm several reserves which are set aside to conserve tropical humid forests might come to lie adjacent to areas of incompatible land-use. Adoption of concepts such as UNESCO's Biosphere Reserve concept, which emphasise the role of conservation areas in the socio-economic development of local people and the region, would therefore become increasingly applicable in the future.

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Summary of discussion following presentation:

Dr Bernd von Droste: The present classification of biogeographical provinces in the world is not the most satisfactory one. It perhaps needs to be revised to include present understanding among ecologists of a greater variety of ecosystem types.

Dr N. Gunatillake: Your consideration of only the extents of lowland rainforests in countries of the realm is not sufficient to clearly illustrate the overall trends in tropical humid forest conservation.

(Prof. S. Balasubramaniam, Dr T. Jayasingham, Dr Bernd von Droste and several others considered that the status of other forest types, which could be considered part of the tropical humid forest biome, should be included as well)

(Participants from Indonesia, Bangladesh, Pakistan and Sri Lanka thought that the figures provided for percentages of natural forest cover remaining or lowland forests protected were not accurate)

Dr N. Ishwaran: There could be differences in the figures due to differences in areas considered as being part of the realm; the figures given here are based upon one accepted delimitation of the realm, irrespective of the fact whether that needs to be revised or not. Furthermore, it is not intended to be an extensive survey of the status of tropical humid forest conservation but was presented as a basis for initiating discussion on possible constraints facing conservationists.

NA-91-57

Session II (a)

Tropical Humid Forest Ecology in the Indomalayan Realm

(a) Nutrient Cycling

Chairman: Dr Bernd von Droste

Shifting Agriculture (Jhum) and Rain Forest Management in North-Eastern India	P.S. Ramakrishnan
Mycorrhizal Association in Tropical Humid Forests	K. Abeynayake
Mineral Nutrition of Tropical Trees: Patterns of Foliar Nutrient Contents in Major Forest formations of Sri Lanka	S. Balasubramaniam & G. Glatzel

SHIFTING AGRICULTURE (JHUM) AND RAIN FOREST MANAGEMENT IN NORTH-EASTERN INDIA[1]

P.S. RAMAKRISHNAN

Abstract

The paper is a summarized account of a multidisciplinary study on shifting agriculture (Jhum) system of the north-east India. The paper deals with agroecosystem function of Jhum, terrace and valley cultivation, weed demography, population dynamics and their eco-physiological attributes, secondary successional patterns and processes, hydrology and soil fertility through varied successional stages starting with agricultural operations and tribal village ecosystem function. The growth strategies and architectural patterns of trees over a successional gradient have been considered for designing social forestry, agroforestry and condensed succession for damaged sites. Such a whole system approach is important not only in an academic sense but has strong implications for designing strategies for ecosystem management and development of the region. The developmental strategies are by implication location specific.

Introduction

Shifting agriculture (referred to as slash and burn agriculture, rotational bush fallow agriculture and popularly known in India as 'Jhum') is the important land use in north-eastern hill areas. This along with valley agriculture, a sedentary form of cropping of rice, meets the food needs of the varied tribal communities in the hill areas. In recent times, however, the local governmental agencies have introduced terrace cultivation as an alternative to jhum but with little acceptance by the tribals. Jhum itself often has a shortened jhum cycle (intervening fallow phase period in between successive croppings on the same site is one cycle period) of 4 to 5 years. A longer cycle of 10 years or more is rather uncommon. Rarely, in more remote areas, one does come across a long jhum cycle of 30 years. The present study therefore compares a short 5-year cycle with longer cycles of upto 30 years. For the present discussion the study sites at a low elevation (90 m) at Burnihat (90 km north of Shillong at 26^{o}N and 91^{o}E) and at a high elevation (1500m) at Shillong are considered.

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1 Summarized version of a series of six lectures delivered during the workshop.

AGROECOSYSTEM

Low elevation jhum

The low elevation jhum is the typical version of the jhum done throughout the region (Toky and Ramakrishnan, 1981a). The Garo tribe which was studied had an average family size of two adults and three to four children. Jhum plots are on steep slopes of 20 to 40^{o} with a jhum plot of 1 to 2.5 ha. The practice essentially consists of slashing the vegetation during the winter months, allowing the slash to dry up to early April when it is burnt in situ. During the slashing phase, the larger logs of wood and bamboo are removed as fuel wood or as timber for hut building. The short stumps of trees are left in tact and the underground organs are often not disturbed. This helps in rapid regeneration of bamboo and trees during the fallow phase after cropping. The slash is burnt after a fire line is cleared around the plot.

Soon after the first rain, a number of crops are sown together on the soil enriched with the ash. Cereals form the major component under longer cycles of 10 years or more whereas perennials and tuber crops are emphasized under a short 5-year cycle (Table 1). Fallows after clearing and burning are used for one year only, except when a garden of banana or pineapple is maintained in the subsequent years. For the first year of mixed cropping, rice and maize seeds are dibbled into the soil using a long stick; some such as Setaria italica are broadcast while perennial crops such as many tuber crops are randomly sown. Weeds pose a problem, more so under shorter cycles and hand-hoeing is done, usually twice under longer cycles and upto four times under short cycles. Some such as Imperata cylindric and Eupatorium odoratum are slashed.

High elevation jhum

The jhum at higher elevation practised by the Khasi tribe (Mishra and Ramakrishnan, 1981) is a modified version, in that the slash and burn is only partial. While the shrubs and herbs are totally slashed, only the lower branches of the sparsely distributed pine trees (Pinus kesiya) are lopped. The slash is arranged in parallel rows running down the slope so as to form ridges. It is topped over with a thin layer of soil before a controlled burn. Mixed crops are sown on these ridges while the furrows in between are compacted for drainage.

Table 1: Sequential harvesting of crops on jhum plots under 30-year cycle at lower elevation of Meghalaya (after Ramakrishnan et al. 1981a)

Species	Harvesting time
Setaria italica	Mid-July
zea mays	Mid-July
Oryza sativa	Early September
Lagenaria spp.	"
Cucumis sativa	"
Zingiber officianalis	Early October
Sesamum indicum	"
Phaseolus mungo	"
Cucurbita spp.	Early November
Manihot esculenta	"
Colocasia antiquorum	"
Hibiscus sabdariffa	Early December
Ricinus communis	(Perennial crop)

Note: All the seeds were sown in April.

The crop mixture also differs in that potato is a major component. Besides, Ipomoea batatas and Colocasia antiquorum are planted on the ridges soon after the first few showers. Zea mays is mixed with potato. Cucurbits are sown at random while Phaseolus vulgaris, a legume, is sown around pine trees. Colocasia antiquorum is generally placed on the top and bottom portions of the ridges. After the harvest of the monsoon crop species, a winter crop of potato is sown on these ridges. Unless a second year of cropping is done on the same site, the land is fallowed for natural regeneration of vegetation. While a long jhum cycle of 15 years may not receive any fertilizer application, pig and vegetable manure may be applied under a 10-year cycle. Under a 5-year cycle some inorganic fertilizer may also be applied (Mishra and Ramakrishnan, 1981). Weeds such as Eupatorium adenophorum, Imperata cylindrica and Pteridium aquilinum on the ridges are removed 2-3 times during the cropping season by hand hoeing.

Valley cultivation

This is a monoculture of rice and is a sedentary form of agriculture. Wet cultivation of rice is done. The soil is fertile due to the wash out of nutrients from hill slopes.

Terrace cultivation

This land use has been introduced from time to time as an alternative to jhum by governmental agencies. The cropping here is either a monoculture of rice or maize or other crop species. Often this is a mixed cropping as under jhum. Terracing has not found any acceptance from the tribals as an alternative to jhum.

CROPPING AND YIELD PATTERNS

Low elevation jhum

In one of the detailed studies done at lower elevations of Meghalaya at Burnihat the crop mixture had eight species under a short cycle of 5 years and 13 species under a 30-year cycle. All the species are sown together after slash and burn but harvesting is sequential as crops mature, starting from July to December (Table 1). This has the advantage of creating more space for the others which may be at their peak growth. Besides, the non-edible biomass of crops ploughed back into the plots (Ramakrishnan, 1984) or cycled through the manure pit (Mishra and Ramakrishnan, 1982) improve soil fertility.

The crop placement often follows a definite pattern with cereals being emphasized along the lower half of the slope and perennial and tuber crops along the top. This pattern is related to nutrient uptake and use efficiencies of the species; those which have low efficiencies are placed below and those having high efficiencies above on nutrient poorer sites on the same plot (Ramakrishnan, 1984). Mixed cropping also provides the farmer all his varied needs of cereals, protein through legumes, and vegetables. Mixed cropping has the advantage of providing a good crop cover on the soil thus checking losses of nutrients through hydrology once the crop cover is established (Toky and Ramakrishnan, 1981b)because of a high leaf area index and dense root cover upto a depth of 40 cm. High leaf area index also improves photosynthetic efficiency.

Under longer jhum cycles the grain and seed crops contribute to the economic return while under shorter cycles high returns come from tuber and rhizomatous crop species along with vegetable crops (Table 2). The economic returns from the different jhum cycles become obvious when one considers the monetary input/ output pattern (Table 3), calculated on the basis of prevailing market rates. Though the returns are highest under a 30-year cycle, a 10-year cycle seems to be reasonable from an economic view point as well as on ecologic consideration of fallow regrowth (Tokyo and Ramakrishnan, 1983a) and fertility recovery (Ramakrishnan and Toky, 1981). Terrace cropping had a return comparable to a 10-year jhum cycle but is at a high cost for inorganic fertilizer input. Valley cultivation gives good returns and at the same time has the additional advantage of sustained yield year after year without any external application of fertilizers.

High elevation jhum

With the introduction of potato into this region a few decades ago, potato forms an important component of jhum along with a variety of vegetables, legumes such as <u>Phaseolus vulgaris</u>

Table 2: Crops grown and yield in the jhum plots at lower elevations in Meghalaya (after Toky and Ramakrishnan, 1981a)

	Total economic yield kg ha^{-1} yr^{-1}		
	30-yr	10-yr	5-yr
Grain and seed			
Oryza sativa	1161	378	66
Sesamum indicum	446	541	25
Zea mays	770	397	30
Setaria italica	193	23	9
Phaseolus mungo	10	-	-
Ricinus communis	5	-	-
	(21046)	(6318)	(753)
Leaf and fruit vegetables			
Hibicus sablariffa	44	139	96
Hibiscus esculentus	-	50	-
Capsicum frutescence	-	1	-
Lagenaria lencantha	140	81	-
Cucurbita maxima	62	-	-
Cucumis sativa	16	-	-
Momordica charantia	-	5	-
Musa sapientum	-	105	-
	(657)	(5679)	(16182)
Tuber and rhizomes			
Manihat esculenta	338	1352	690
Colocasia antiquorum	260	294	180
Zingiber officianalis	10	-	-
	(1043)	(2712)	(1556)
Silk worm			
Cocoon (silk)	4	-	-
Pupae (without cocoon)	0.2	-	-

Note: In parenthesis is given total plant biomass (kg ha^{-1} yr^{-1})

Table 3: Monetary budget (Rs. ha^{-1} yr^{-1}) under low elevation jhum terrace and valley agro-ecosystems (after Toky and Ramakrishnan 1981a)

	Jhum			Terrace	Valley
	30-yr.	10-yr.	5-yr.		
Input	2616	1830	896	2542	4843
Output	8586	3354	1690	3658	5565
Net gain/loss	2970	1524	794	1116	722
Output/Input	2.13	1.83	1.88	1.43	1.14

and Ipomoea batatas (Mishra and Ramakrishnan, 1981). Potato has a high yield inspite of low fertility and acid soils of the sub-temperate high elevation zones as reflected from a comparison of Tables 3 and 4 which consider the monetary input/output analysis of jhum at lower and higher elevations, respectively. Under terraces with potato, maize and Brassica oleracea in the mixture, studied by us, the economic efficiency was very low and was not commensurate with the input of fertilizers. Though valley cultivation gave poorer returns, it was a self-sustaining sedentary agricultural system.

Table 4: Monetary budget (Rs. $ha^{-1} yr^{-1}$) under high elevation jhum, terrace and valley agro-ecosystems (after Mishra and Ramakrishnan 1981)

	Jhum			Terrace	Valley
	15-year	10-year	5-year		
Input	3281	3430	3154	6004	1671
Output	19790	14171	8188	12561	3161
Net gain/loss	16509	10741	5034	6557	1490
Output/Input	6.03	4.13	2.60	2.09	1.89

ENERGY RELATIONS

Modern agriculture based on the models of the west depend upon heavy energy subsidies derived from fossil fuel. Increased cost of petro-based fertilizers and the non-renewable nature of this resource have led to a renewed interest in more energy efficient agricultural systems such as jhum. Unlike modern agricultural systems which require 5 to 10 units of fossil fuel energy to produce one unit of food energy (Steinhart and Steinhart, 1974), for every unit of energy input the jhum system could produce upto 50 units of food energy (Table 5). Besides, the energy input for jhum is qualitatively different in that it is chiefly human labour (Mishra and Ramakrishnan, 1981; Toky and Ramakrishnan, 1982). In fact, apart from the relatively inefficient system of terracing where the output/input ratio is low, heavy demand for energy through inorganic fertilizer input are two of the major deterrents to its acceptance by the tribals as an alternative to jhum. If the jhum cycle is long enough and land is not a limiting factor, solar energy capture by vegetation could offset imported fossil fuel energy and would ensure harmony of the system with the environment. Even after applying a correction factor of 1/30, 1/10 or 1/5 to calculate energy output from a 30,10 or 5 year jhum cycle, respectively, a 10-year cycle would still prove to be efficient. It should be possible to increase food production to a reasonable extent , keeping the energy efficiency high and without departing too much from the traditional jhum system (Gleissman et al.1981), a system which is considered to be highly evolved for the forested areas of the humid tropics (Conklin, 1957; Nye and Greenland, 1960; Watters, 1971).
In the wider context of Indian agriculture which has an energy efficiency of about 7 per unit input (Mitchell, 1979), it should be possible to further improve on this and to replace the scarce chemical fertilizers by more efficient recycling of renewable plant resources as bio-fertilizers.

Table 5 : Energy efficiencies of agricultural systems at lower elevations (after Toky and Ramakrishanan, 1983)

Agricultural systems	Energy(MJ $ha^{-1}yr^{-1}$)		Output/Input ratio
	Input	Output	
Jhum			
30 year cycle	1665	56766	34.1
10 year cycle	1181	56601	47.9
5 year cycle	510	23858	46.7
Terrace	6509 (8003)	43602	6.7 (5.4)
Valley (two crops)	2843	50596	17.8

SECONDARY SUCCESSION AND ECOSYSTEM FUNCTION

Low elevation

When a forest is converted to cultivable land for jhum its original vegetation is destroyed due to perturbations caused by clear-cutting and fire. Agricultural operations such as weeding and crop harvesting results in a progressive reduction in the pool of species originally present. Thus the species diversity is low to start with and dominance high and these are reversed as succession progresses at lower elevations of Meghalaya (Fig. 1) starting from a herbaceous weedy community in the first 5 to 6 years of fallow regrowth, the vegetation passes on to a bamboo forest of Dendrocalamus hamiltonii which soon is replaced by mixed broad-leaved forest communities at later stages as fallows develop (Toky and Ramakrishnan,1983a):

Imperata cylindrica - Eupatorium odoratum and other weeds (upto 5 years)

↓

Dendrocalamus hamiltonii - Dicot trees and shrubs (light demanders)

↓

Shade intolerant Dicot trees and shrubs - Schima wallichii, Vitex peduncularis, Terminalin bellarica, Banhinia alba and others

↓

Shade tolerant trees - Dillenia indica, Artocarpus chaplasha and others

A remarkably linear relationship was observed in various functional attributes of the ecosystem during secondary succession upto 20 years of regrowth. These pertain to litter production, biomass and net primary productivity (Table 6). This may be attributable to drastic change in community structure from herbaceous weeds to shrubs and bamboos and subsequently to shade intolerant mixed broad-leaved trees. While secondary succession would follow this pattern under longer jhum cycles of 20 years or more, continuous imposition of a short 5-year cycle as is very common now has resulted in an arrested succession at the weed stage with species such as (Eupatorium odoratum and Imperata cylindrica dominating.

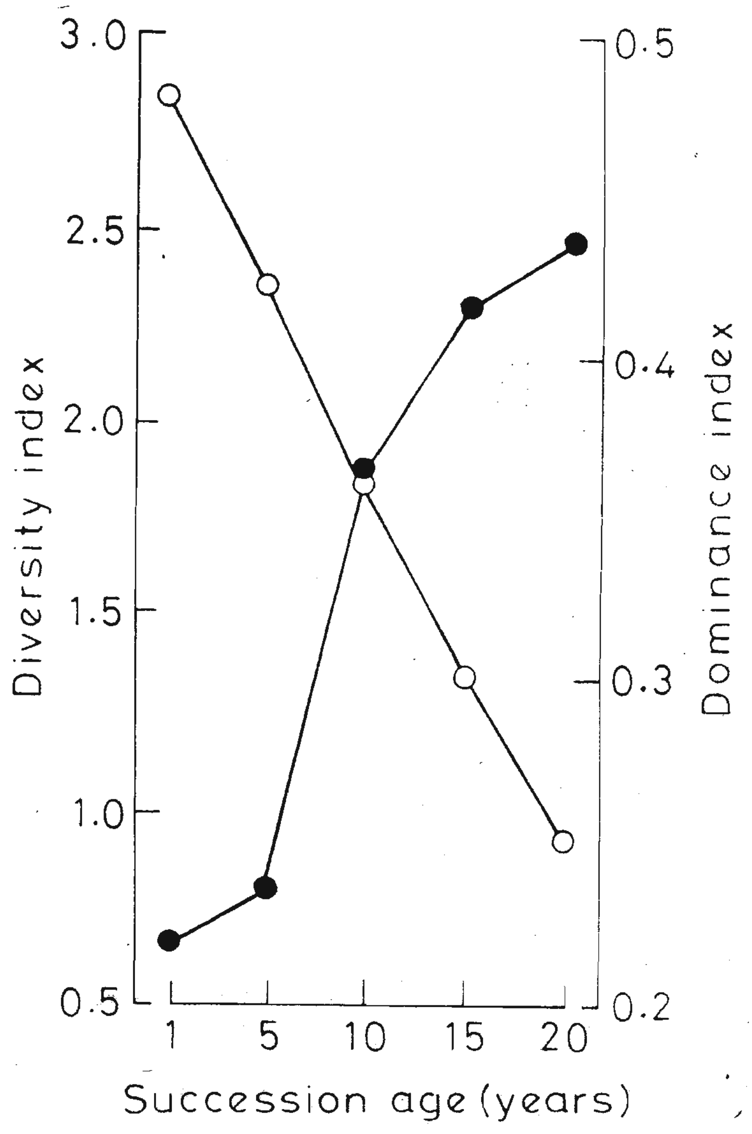

Fig. 1. Species diversity (●) and species dominance (O) in successional communities upto 20 years in Meghalaya, north-eastern India (after Toky and Ramakrishnan, 1983a).

Table 6: Changes in rates of accumulation of biomass, litterfall and net primary productivity in successional communities Meghalaya, north-eastern India, developed after slash and burn agriculture (after Toky and Ramakrishnan, 1983a)

Succession age (years)	1	5	10	15	20
Accumulation in bole and branches (kg m^{-2} $year^{-1}$)	0.4	0.4	0.7	0.9	0.8
Litterfall (kg m^{-2} year $^{-1}$)	0.1	0.4	0.7	0.8	1.0
Net primary production (kg m^{-2} $year^{-1}$)	0.5	0.8	1.4	1.7	1.8
Biomass accumulation quotient (standing biomass/net productivity)	0.9	2.5	4.3	5.9	8.3

High elevation

At high elevations, the secondary successional pattern is essentially the same as at low elevation except for differences in species composition (Mishra and Ramakrishnan, 1983a). The first five years have weeds such as Eupatorium adenophorum, and Pteridium aquilinum and others. The weeds are replaced by rapidly regenerating pine trees Pinus kesiya along with other broad-leaved trees such as Schima wallichii. A mature forest in the region would be a mixed broad-leaved forest as at the sacred grove at Mawphlang with species of Quercus, Castanopsis and others (Boojh and Ramakrishnan, 1983). The functional attributes related to biomass and litter production and net primary productivity remain essentially similar to the secondary succession at lower elevations discussed above.

HYDROLOGY AND NUTRIENT LOSSES DURING AND SUBSEQUENT TO JHUM

Low elevation jhum

The ecosystem components left after slash and burn lose their ability to hold the nutrients in the soil (Toky and Ramakrishnan, 1981b). During the slash and burn phase, nitrogen is volatalized and lost from the system alongwith carbon and sulphur (Nye and Greenland, 1960; Sales and Folster, 1976). Of the nutrients released into the soil through ash, much is lost through blow-off caused by strong winds during the dry months of March-April. The data presented in Table 7 for a 10-year jhum cycle along shows that the losses on this account is more than 50 per cent. The sediment loss during the cropping period could be as much as 30 tons ha^{-1} yr^{-1} which would be drastically reduced to about 1 ton ha^{-1} yr^{-1} even under a 5-year old fallow. The losses of nutrients through run-off and percolation water are heavy during the cropping phase (Table 8) and the proportional percolation losses are heavy inspite of the steep angle of the slope. In the fallow phase the losses are drastically reduced and the recovery of the system is fast.

Table 7: Nutrients released through ash and blow-off under a ten-year jhum cycles at lower elevation (after Toky and Ramakrishnan, 1981b)

Nutrients (kg ha^{-1} $year^{-1}$)	Release	Blow-off
P	262	156
K	2070	1229
Ca	193	115
Mg	152	90

Table 8: Nutrient losses through run-off and percolation water at lower elevation (after Toky and Ramakrishnan, 1981b)

Element (Kg ha^{-1} yr^{-1})	Agro-ecosystem Jhum cycle			Fallows (yr.)	
	30	10	5	5	10
PO_4-P	1.1(0.1)	1.3(0.1)	0.9(0.1)	0.1(0.02)	0.1(0.01)
NO_3-N	3.7(8.8)	4.2(10.6)	5.3(9.2)	0.8(1.1)	0.5(0.5)
K	64.7(15.1)	91.2(21.2)	51.0(13.7)	0.9(0.5)	1.7(0.2)
Ca	15.1(5.3)	15.9(4.8)	13.8($.6)	2.0(2.7)	1.1(1.6)
Mg	6.3(2.5)	5.4(2.1)	9.5(2.3)	1.3(0.9)	0.8(0.5)

Note: Values in parentheses are for percolation losses.

High elevation jhum

Inspite of the fact that during the jhum here, the slash is subjected to a controlled low intensity burn, the volatalization is very high. In one of our studies (Mishra and Ramakrishnan, 1984) we have shown that the volatalization may go upto about 500 kg ha^{-1} yr^{-1} under a 15-year cycle (Table 9). The losses from the high elevation system are much less than from the low elevation system except perhaps for potassium which is comparable to the low elevation system (Mishra and Ramakrishnan, 1983a). The losses would have been much higher had the land been not prepared into ridges with compacted furrows.

The hydrological studies (Toky and Ramakrishnan, 1981b; Mishra and Ramakrishnan, 1983a) of both low and high elevation jhum systems also suggest that much of the losses occur during the early monsoon period before the crop and weed cover is established and then drastically decline except for another smaller peaking at the time of the crop harvest (Fig. 2).

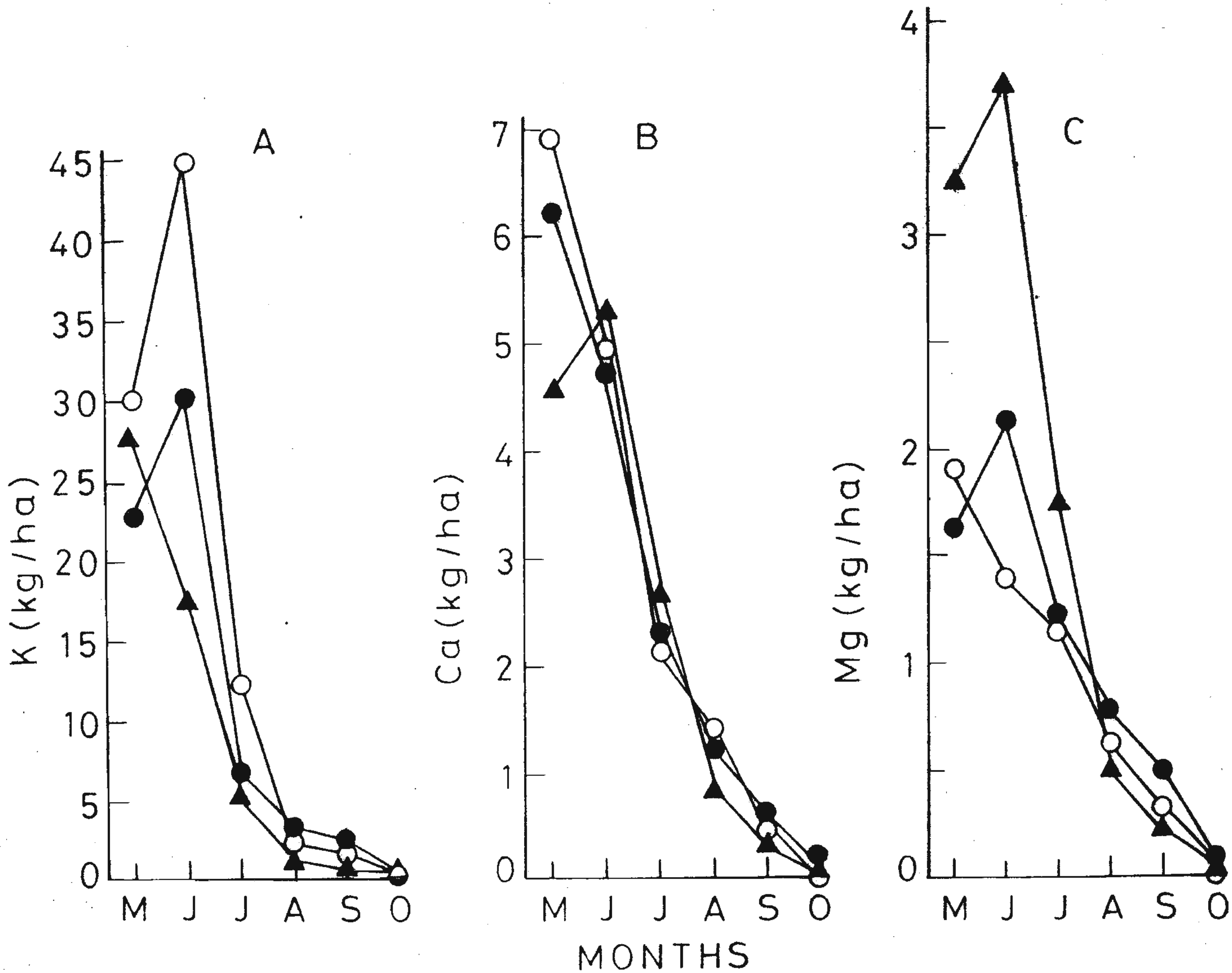

Fig. 2. Changes in concentration of potassium (A) calcium (B) and magnesium (C), in run-off water during the monsoon at time of cropping after burn on sites under 30- (●),10-(0) and 5-(▲) years' Jhum cycles (after Toky and Ramakrishnan, 1981b).

Terrace agro-ecosystem

Though the losses due to run-off water is reduced under terraces, the losses through percolation water could be still considerable (Mishra and Ramakrishnan, 1983a). The cationic losses, however, from terraces are low as there is no slash and burn operation and therefore there is no massive release of cations through ash.

SOIL FERTILITY CHANGES AND NUTRIENT CYCLING

Soil fertility

The soil fertility changes during the cropping phase and nutrient depletion and recovery processes have been studied for both long and short jhum cycles at low and high elevations (Ramakrishnan and Toky, 1981; Mishra and Ramakrishnan, 1983b) and the patterns and processes involved are essentially the same. Much of the changes occur on the surface layers of the soil only.

The quality and quantity of cations released into the soil depend upon the length of the jhum cycle. Under a short 5-year cycle the nutrient release is low compared to longer cycles. Under a 10-year cycle, at lower elevations, the release of potassium is high as the slash is predominantly of bamboo (Dendrocalamus hamiltonii) which is an accumulator of potassium (Toky and Ramakrishnan, 1982b). This is reflected in the loss pattern of potassium under a 10-year jhum cycle compared to 30 or 5-year cycles (cf. Table 8).

Though carbon and nitrogen losses are heavy due to volatalization during fire, the build up of the latter is rapid due to quick nitrification processes initiated in the soil (Mishra and Ramakrishnan, 1984) and both elements are also added through crop and weed biomass ploughed back into the soil. During cropping, depletion of nutrients is due to rapid uptake by weeds and crops and also due to heavy losses through hydrology (Fig. 3). In the early fallow regrowth phase there is a rapid transfer of nutrients from the soil to the vegetation component of the ecosystem as the plant cover develops, and the release of nutrients back into the soil does not start until after about 10 years of fallow regrowth when build up in the soil is effected through litterfall (Fig. 4). This would be another argument that could be advanced for a minimum cycle of 10 years or more. Frequent imposition of a short 5-year cycle would result in the system starting subsequently with a lower capital. Thus in one cropping phase the system could lose as much as 600kg of nitrogen per hectare. The natural replacement process would take about 10 to 15 years of fallow phase for total recovery of this nitrogen. Under a 5-year cycle at higher elevations,

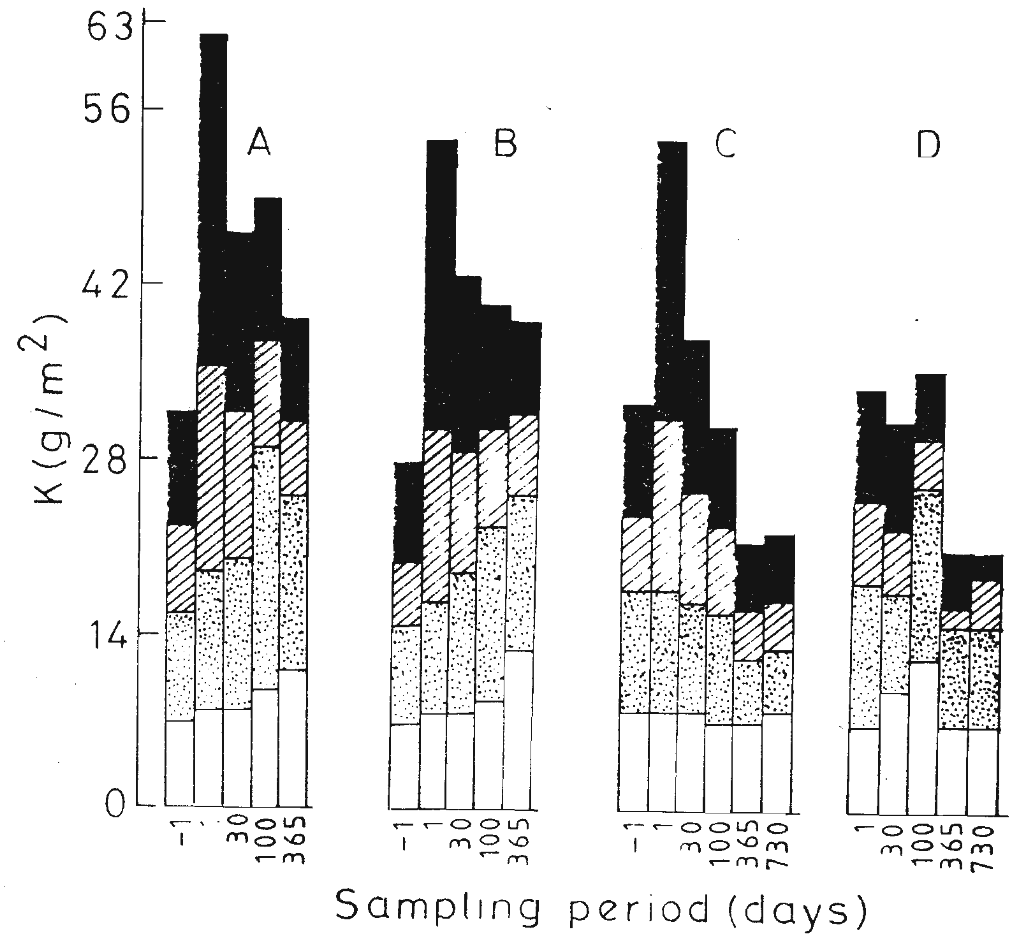

Fig. 3: Changes in total quantity of potassium (within a soil profile of 40 cm depth)during the various stages of jhum and terrace cultivation A, 15 year jhum cycle; B, 10 year jhum cycle; C, 5 year jhum cycle; D, terrace. Dark column, 0-7 cm; hatched column, 7-14 cm; stippled column, 14-28 cm; open column, 28-40 cm depth of soil (after Mishra and Ramakrishnan 1983b)

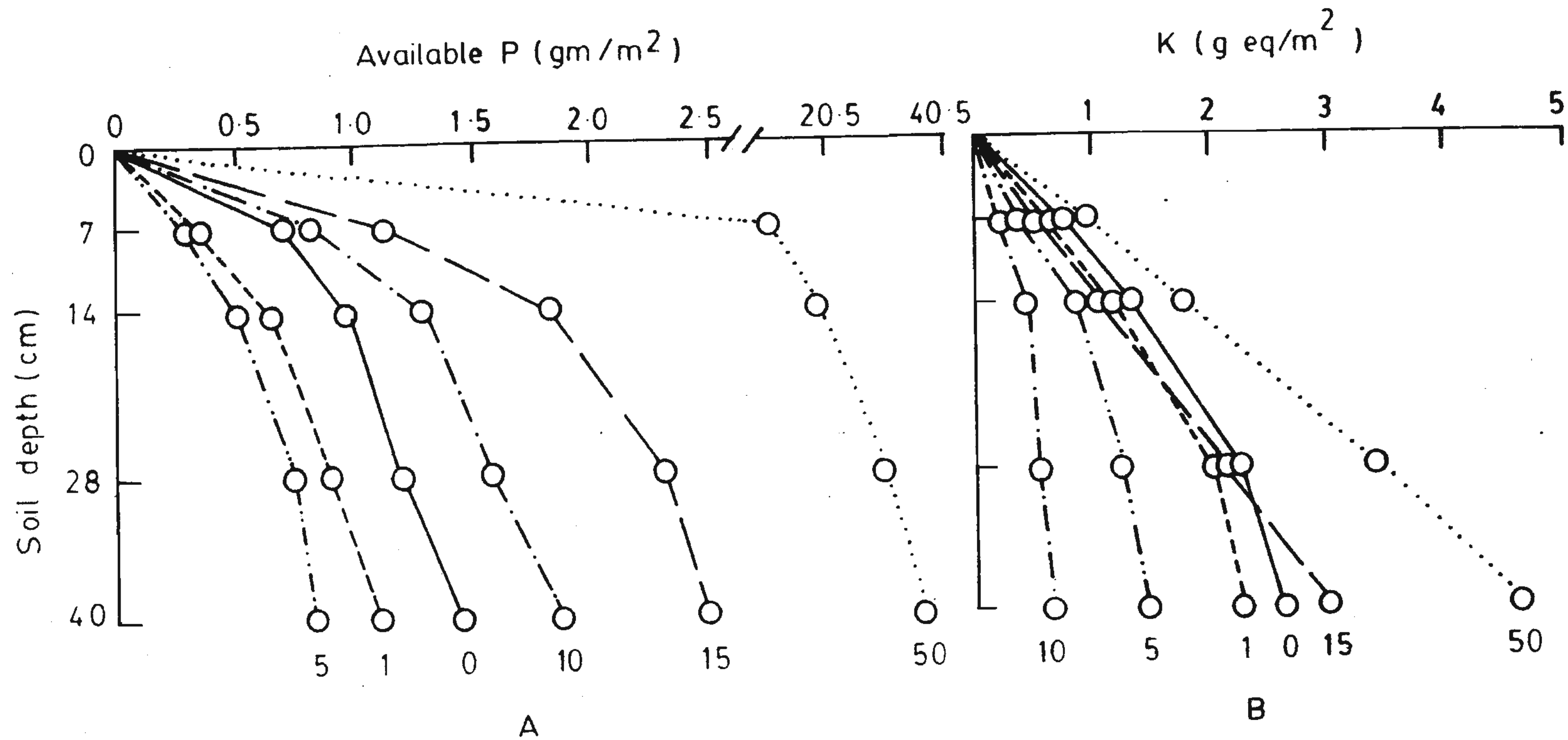

Fig. 4 : Changes in cumulative quantity of available phosphorus (A) potassium (B) within a soil column of 40 cm depth after fallows of various ages. 0 --------- 0, 0 year; 0 ------ 0, 1 year; 0 ------0, 5 year; 0 ------- 0, 10 years; 0 -------- 0, 15 years; 0 -------- 0, 50 years (after Ramakrishnan, 1981).

not more than half of this amount is recovered during the fallow phase. Thus an imposition of successive 5-year cycles four times over the same site would result in a net loss of over 1200 kg of nitrogen per hectare (Table 9) (Mishra and Ramakrishnan,1984). The land eventually would be desertified under such a short cycle (Ramakrishnan,1980; Ramakrishnan and Toky, 1978; Ramakrishnan et al., 1981a,b)..

Table 9: Net change of nitrogen (10^3 kg ha^{-1} yr^{-1})
(after Mishera and Ramakrishnan, 1984)

	Jhum cycle (yr)			
	15	10	5	
			1 yr crop	II yr crop
Soil pool before burning	7.68	7.14	6.40	5.98
Soil pool after the burn	7.17	6.78	6.14	-
Soil pool at the end of cropping	7.04	7.15	5.98	5.80
Net difference	0.64	0.59	0.42	0.18

Nutrient cycling in successional communities

The nutrient cycling pattern upto 20 years of fallow regrowth was done at lower elevations of Meghalaya (Toky and Ramakrishnan, 1983b) and upto 15 years of regrowth at higher elevations (Mishra and Ramakrishnan, 1983a). The pattern at these two sites are essentially similar. At lower elevations in Meghalaya the bioelements in the above ground living biomass increased linearly with the age of the fallow up to 20 years. In early successional communities, potassium is a predominant element over calcium. This is partly due to the higher potassium concentration in Dendrocalamus hamiltonii which also has a very large biomass as compared to other species (Toky and Ramakrishnan, 1982b). This is in contrast to that in a 50-year old forest at low elevation where clacium formed the predominant element in the living biomass (Singh and Ramakrishnan, 1983a,b,c) and agrees with other observations (Golley, et al., 1975; Grubb and Edwards, 1982). The rate of uptake of all the elements and the enrichment quotient (element held in the vegetation/ element uptake; Woodwell, et al., 1975) increased up to 20 years of secondary succession (Table 10). The annual percentage turnover of all nutrients in the soil tended to increase while that in the vegetation decreased (Toky and Ramakrishnan, 1983b). This is because of rapid uptake by the developing vegetation and storage in the living component of the ecosystem. The maximum fractional turnover for phosphorus in the soil occurred in 1 to 5 year old fallow due to its higher uptake by the herbaceous weeds and for potassium it occurred in a 10-year old fallow due to bamboo cover.

Table 10: Rates of uptake of elements (gm^{-2} year^{-1}) in the living aerial shoot biomass (including the annual litterfall) during 20 years succession following slash and burn agriculture in Meghalaya, north-eastern India. Values in parentheses are the enrichment quotients (element held in vegetation/ element uptake) of Woodwell, Whittaker & Houghton 1975) (after Ramakrishnan and Toky, 1983b).

Years	N	P	K	Ca	Mg
0-1	3.1 (0.9)	0.5 (1.0)	3.5 (0.9)	1.5 (0.9)	1.5 (1.0)
1-5	5.7	0.5 (4.0)	6.0 (3.0)	4.3 (1.8)	3.0 (2.1)
5-10	7.6 (2.5)	0.4 (6.2)	12.0 (4.5)	5.3 (3.1)	3.1 (2.8)
10-15	9.2 (3.7)	0.7 (6.3)	13.5 (7.2)	6.3 (4.5)	4.2 (3.7)
15-20	10.9 (4.5)	0.9 (7.1)	14.5 (9.5)	7.8 (5.6)	4.8 (4.7)

DEMOGRAPHY AND STRATEGIES OF EARLY SUCCESSIONAL COMMUNITIES

Weed potential in jhum

The land use history would determine to a great extent the weed potential of a given site. Thus in a cropped site the diversity and abundance of the weed community is low (Saxena and Ramakrishnan, 1984a). Besides, under a short jhum cycle of 4-5 years, weed potential of the jhum plots is higher compared to a plot under a longer cycle of 10 years or more. The larger weed population under short cycles is due to the high propagule production by these very early successional species during the intervening short fallow phase. Long fallow phase not only would control these weeds biologically but the following high intensity burn of long jhum cycle would also help in reduction of the propagules. Successive imposition of short jhum cycle of 4-5 years eventually would result in an arrested succession at the weed stage (Ramakrishnan, et al., 1982a,b). Terracing of plots for sedentary agriculture also tends to increase the weed potential due to migration of propagules as the terraces offer favourable sites for these light demanding weeds (Mishra and Ramakrishnan, 1982).

Demography and population dynamics during succession

During early successional phase, drastic changes occur in the soil fertility status and light conditions in the community. A number of studies were carried out by our group on the low elevation jhum system (Kushwaha, et al., 1981a, 1983b,c) and on the high elevation system (Ramakrishnan and Mishra, 1981) with respect to demography. All these studies suggest that there is a drastic decline in the recruitment of populations both through seeds and rhizomes in the successional phase after about 5-6 years after the land is abandoned subsequent to cropping. Three species which received particular attention were Eupatorium odoratum and Imperata cylindrica at lower elevations and Eupatorium adenophorum at higher elevations. These early successional weeds were shown to be biologically replaced after the first five years of secondary succession chiefly due to reduced light relations in the community as succession progresses (Kushwaha and Ramakrishnan, 1982). This is in contrast to the demographic behaviour of a relatively late successional herb such as Scleria tessellata (Kushwaha et al, 1981b) which is shade tolerant.

Growth strategies

Early successional herbaceous weeds such as Eupatorium odoratum have the ability for profuse seed production with some vegetative reproductive ability through root and stump sprouts (Saxena and Ramakrishnan, 1983a) or are chiefly reproducing vegetatively with an ability for sexual reproduction only under stress such as frequent cutting and burning regimes (Kushwaha and Ramakrishnan, 1982). Vegetatively reproducing species with extensive underground organs such as in the case of Imperata cylindrica could confer a selective advantage due to protection from fire. In fact our studies on the biomass and nutrient allocation strategy studies on this species suggests that in the early growth phase there is a rapid movement of nutrients from the below to above ground organs and this trend gets reversed after the first 2-3 years of fallow regrowth (Saxena and Ramakrishnan, 1983a). In fact early successional herbs allocate more for their vegetative effort while the late successional herbs tend to emphasize on vegetative growth for competitive advantage in a closed environment (Saxena and Ramakrishnan, 1981, 1982).

In a study of the resource allocation pattern of Eupatorium odoratum through successional stages upto 6 years of fallow regrowth (Saxena and Ramakrishnan, 1984b) it was shown that a higher proportion of the available resources was allocated to the supporting organs but a lower proportion to the photosynthetic organ in the older fields compared to recently fallowed fields. The allocation of biomass and nutrients to reproduction decreased during seral development. However, the cost of reproduction (considered as the proportion of increment in biomass or nutrient uptake during the current growing season) was much higher in older fallows than the younger ones.

A comparison of a number of early annual weeds with respect to their biomass and nutrient allocation strategies suggest that they are geared in such a manner that some species such as Erigeron linifolius with a high nutrient uptake efficiency could colonize nutrient deficient microsites of the jhum plots whereas species such as Ageratum conyzoides are better suited for relatively nutrient rich microsites of a highly heterogeneous jhum plot after cropping (Saxena and Ramakrishnan, 1983b). Such differential nutrient uptake efficiencies and ability to grow successfully on nutrient rich/poor microsites could have also implications in their life history processes. Thus in a comparative study of the growth strategies of Eupatorium odoratum and Imperata cylindrica (Saxena and Ramakrishnan, 1981) we were able to show that the former maintained their reproductive allocation, and the deployment of C_3/C_4 strategies was such that the entire spectrum of soil heterogeneity of the fallow plot is covered by species with high or low nutrient uptake and use efficiencies.

Table 11: Nutrient uptake efficiency (milligrams nutrient absorbed per gram root biomass) of different species (after Saxena and Ramakrishnan, 1983a)

	Nutrient uptake efficiency		
	Nitrogen	Phosphorus	Potassium
Eupatorium odoratum	71.02	9.21	72.40
Grewia elastica	30.80	6.51	35.00
Imprata cylindrica	125.70	15.02	156.12
Thysanolaena maxima	68.60	8.20	80.06
Least significant difference(P-0.05)	8.90	2.02	12.10

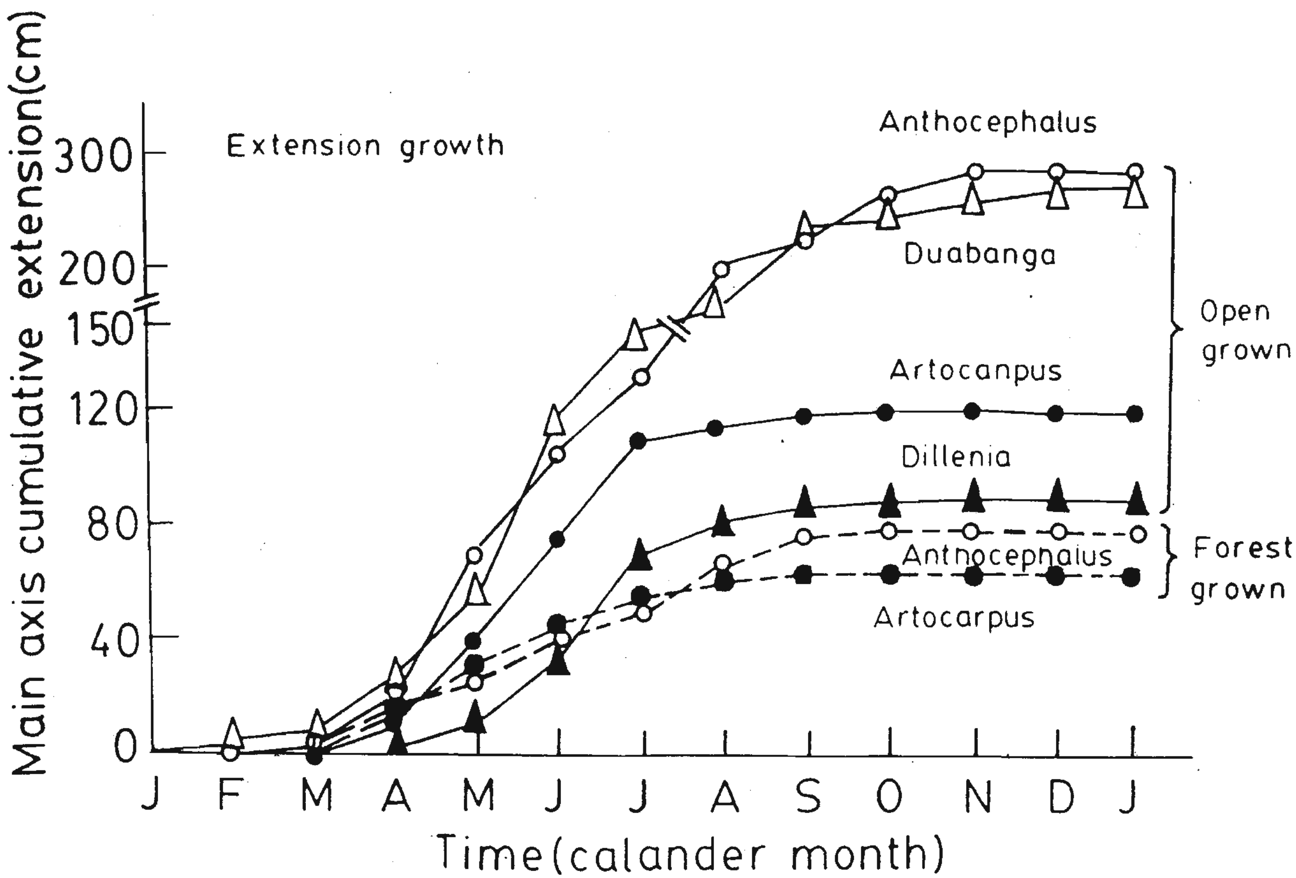

Fig. 5: Cumulative extension growth of the main axis of (———), open grown; and (- - - -), forest grown trees of early successional <u>Anthocephalus cadamba</u> (O) and <u>Duabanga sonneratiodes</u> (Δ); and late successional <u>Artocarpus chaplasha</u> (●) and <u>Dillenia pentagyna</u>(▲) in Meghalaya, northeast India (after Shukla and Ramakrishnan, 1986)

TREE ARCHITECTURE AND ECOSYSTEM REDEVELOPMENT

Forest ecosystem redevelopment has to consider introduction of tree species into the plant community after the initial phase of herbaceous colonizers. The concept of architecture of shrubs and trees forms an important basis for this. Architecture is a dynamic concept. The ultimate architectural sign of the tree is based on the rate of growth of the leader axis versus lateral branches, the bud dynamics and the pattern of production of branches of different order, the birth and death rates of leaves borne on them and the final display of the branches and leaves on the tree trunk. These characteristics are related to environmental conditions, a consequence of natural selection and therefore an evolutionary process which is species-specific. Light obviously is an important factor for shoot architecture as leaf display for maximal light use is an important attribute. Soil nutrients along with moisutre would be important for determining root architecture. Thus, there is a need for a greater appreciation of the physiological ecology of regeneration for better management of rainforests (Bazzaz, 1986).

An important characteristic of early successional species is to have rapid extension growth of the leader axis, as it helps in rapid upward movement of the canopy (Fig. 5). This helps them to exploit high light environment, unlike late successional species that have slower growth. Faster growth is partly because of a faster rate and a greater duration of growth activity (Boojh and Ramakrishnan, 1982a; Shukla and Ramakrishnan, 1986). Another attribute of early successionals is to produce relatively more branches and leaves, unlike late successionals that have restricted leaf and branch production. An excurrent (narrow) crown form is achieved by early successionals partly through stronger correlative growth inhibition with apical control over the growth of the branches beneath and partly through rapid extension of the first order branches at the expense of second order branches when this differential is compared with late successional species (Shukla and Ramakrishnan, 1986). In contrast, the contribution of the first order branch system for crown development when compared with subsequent orders of branches is lesser for late successionals and consequently a decurrent (broad) crown form with more peripherally placed leaves is obtained.

With large leaf population on the tree due to faster production and turnover rates, the early successional species have a larger proportion of younger leaves with a relatively shorter leaf life span (Boojh and Ramakrishnan, 1982b; Shukla and Ramakrishnan, 1984a). In contrast, late successional trees have a larger proportion of older leaves, a slower turnover rate and a longer leaf life span. It is concluded that the rapid growth of early successional trees is more related to their ability for unrestricted leaf production than to efficient energy conversion per unit leaf area.

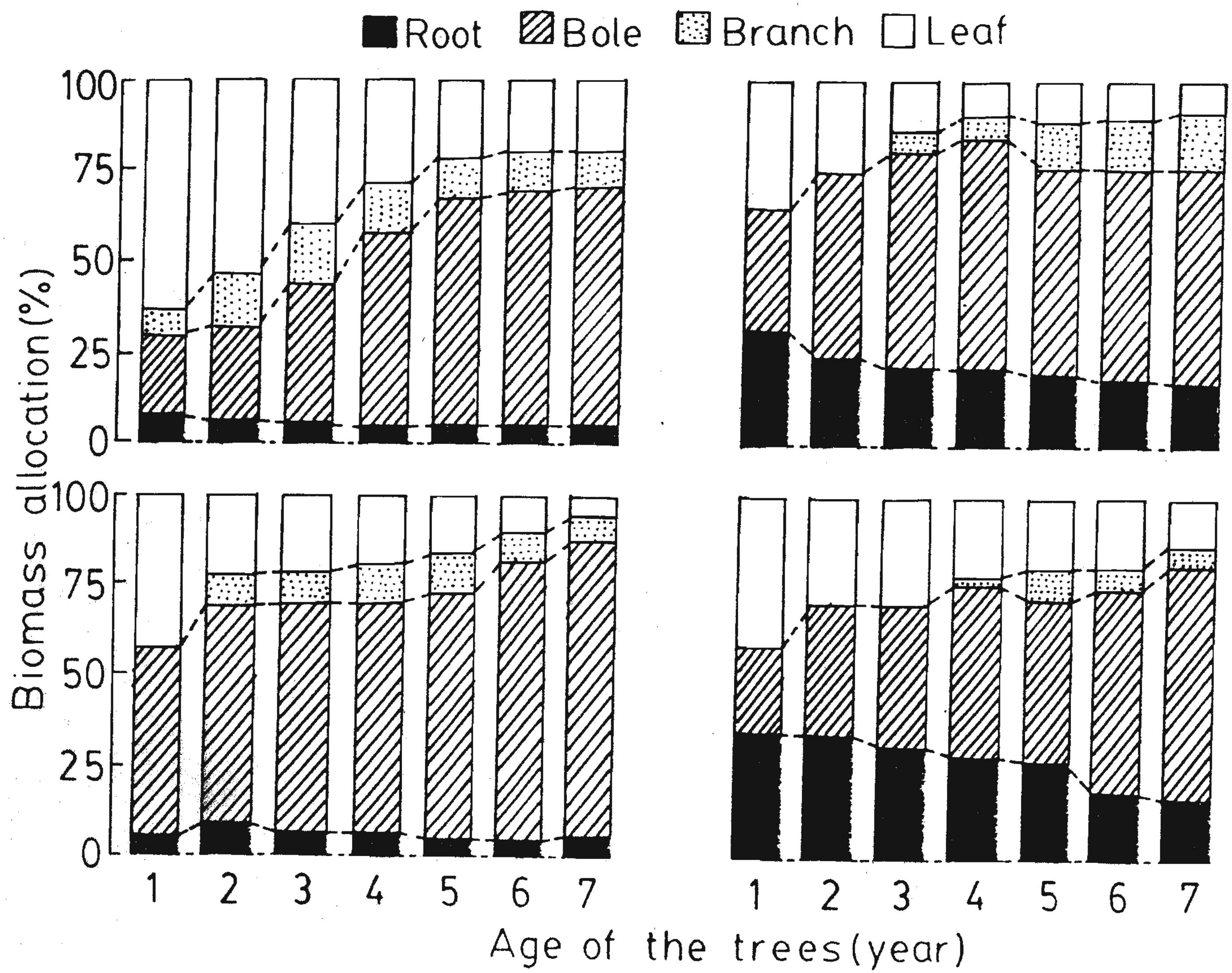

Fig. 6: Allocation pattern of biomass to four different components, viz., root, bole, branch and leaf of early and late successional species of different age groups. A, Duabanga sonneratiodies; B, Anthocephalus cadamba (both early successionals); and C, Dillenia pentagyna; and D, Artocarpus chaplasha (both late successionals) (after Shukla and Ramakrishnan, 1985b)

Biomass allocation strategy of early versus late successional trees (Fig. 6) are also geared to the 'exploitative' strategy of the former and the 'conservative' strategy of the latter. Between the shoot and root components, early successionals allocate more to the former compared to late successionals (Shukla an Ramakrishnan, 1984b), which enables early successionals to make faster growth for better exposure of the conopy. Further, the early successionals allocate more to the bold compared to the branches, unlike late successionals. The superficially placed root system of early successional trees helps in exploiting the nutrient rich surface soil layers of the gap environment whereas the deeply and more uniformly distributed root system of late successional trees is to exploit more deeply distributed nutrients of the soil profile.

Choosing appropriate architectural attributes would ensure complimentality of species. One could not only have a well designed mixed plantation programme (Fig 7) by varying the time of introduction of the species into the mixture, one could have a 'condensed succession'. Thus species such as Anthocephalus cadamba or Duabanga sonneratioides could be followed by mid-successionals like Dillenia indica with Artocarpus chaplasha being introduced later (Shukla and Ramakrishnan, 1986). As already discussed architectural attributes of early successionals are appropriate for agroforestry systems, as the loose organization of the leaves of these trees permit sufficient light penetration to the ground level and the fast leaf turnover enables efficient nutrient recycling within the system. With generally fast growth rates for these and with even faster rates for selected ecotypes of species such as that of Schima wallichii (Boojh and Ramakrishnan, 1982c, 1983b), this category of species could meet fodder, fuelwood and timber needs. Redevelopment of forested ecosystems based on architectural compatability in species mixtures and based on successional concepts represent a new viewpoint in ecosystem redevelopment of the northeastern region. This opens up possibilities for quicker regeneration of forests in other degraded areas too.

DESERTIFICATION

Desertification in its broadest sense encompasses the processes through which vast tracts of land are rendered useless through over-exploitation of the natural resources. Apart from that due to aridity in the environment, this could occur due to improper water management resulting in salinity conditions as is happening in the north-western parts of India in Uttar Pradesh, Haryana and Punjab -- what are termed as 'Usar' or 'Khallar' soils. Desertification in the north-east is due to deforestation of fragile forest ecosystems due to various causes discussed earlier. The degraded areas at Mawphlang in the Khasi Hills, a few kilometers away from Shillong which has small patch of luxuriant prime forest

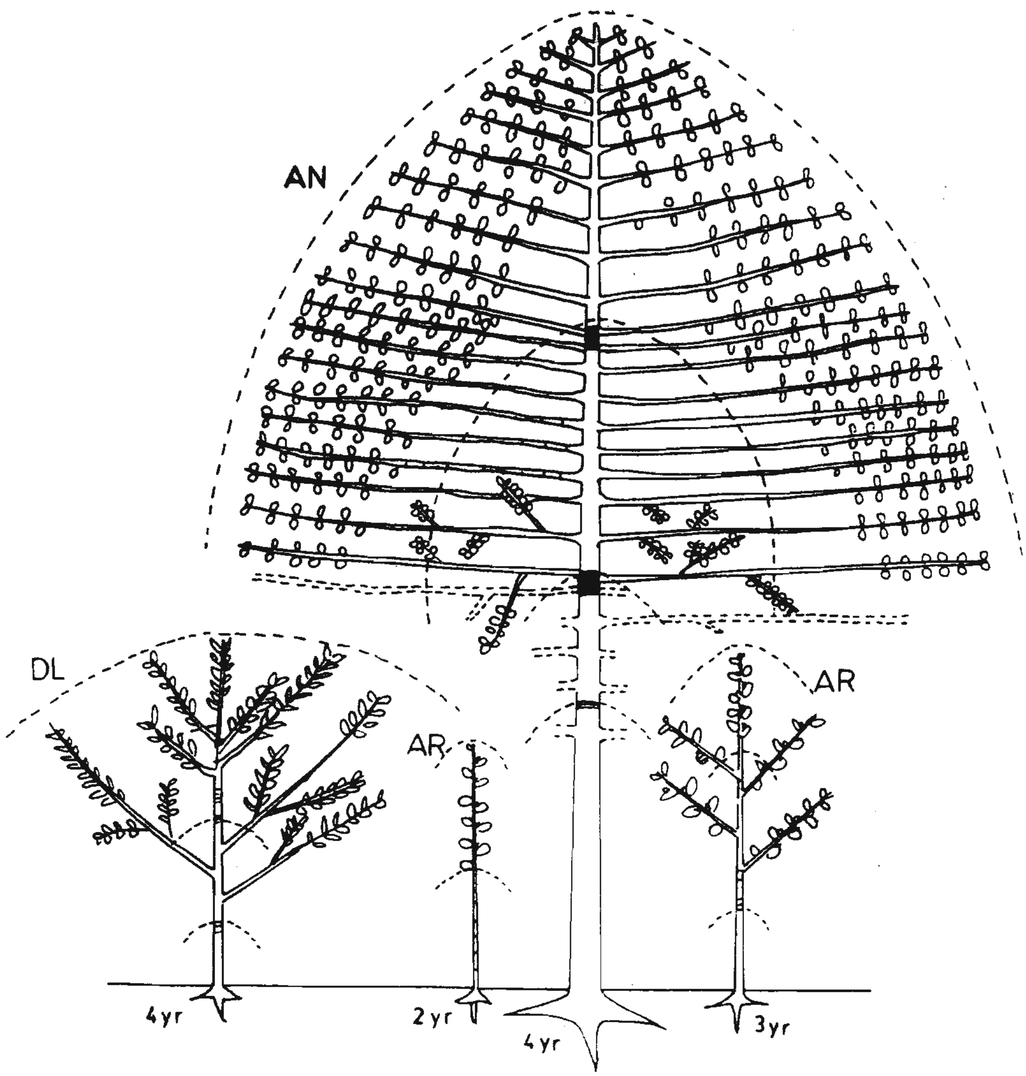

Fig. 7: Model of mixed tree plantation involving early successional Anthocephalus cadamba (AN) and late successional Dillenia pentagyna (DK) and Artocarpus chaplasha (AR).

in the form of the 'sacred grove' standing out as a small oasis in a vast desertified landscape is a vivid testimony to the rapid deterioration of the ecology of the region upsetting the delicate equilibrium of man of the humid tropics with nature. This process of desertification sometimes may often have a long gestation period of over-exploitation of the forest resources or it may happen at a single stroke as it has, perhaps, happened at Cherrapunji sometimes in the distant past. Exceptionally high rainfall, extremely nutrient deficient soils developed on limestone rocks and the extensive network of underground caves ('Krantz topography') have been additional factors for this instant desertification at Cherranpunji. In extreme cases of desertification the bare rock is exposed with practically no soil except in the crevices of rocks that would support a few scattered grasses. The more common situation in the region is development of grassy meadows with a mixture of weeds both native and exotic. When such a level of degradation is reached the land is unfit for jhum. Such degraded sites at the arrested weed stage will not regenerate a forest cover through natural processes as the germ plasm of trees have been totally eliminated from the vicinity. Artificial regeneration of forest cover here could be only at a great cost which we can ill afford. Perhaps, the immediate strategy should be to check further expansion of the process of desertification in the region. It may be mentioned here that the National Remote Sensing Agency (1983) data given in Table 12 would suggest that in most of the hill States other than Assam the desertified areas range between about 40 to 50 per cent. This evaluation could be a slight over-estimate as some allowance needs to be made for valley lands used for wet cultivation of rice.

Table 12: Landsat data for forest cover in the north-east (after National Remote Sensing Agency, 1983)

	1972-75	1980-82	Change
Total area under forest cover in (% of total geog.area)	51.09%	48.28%	(-)2.8% reduction
Categories Closed forest	46.72%	40.94%	(-)5.78% reduction
Ioen/degraded forest	4.37%	7.34%	(+)2.97% Increased degradation

VILLAGE ECOSYSTEM FUNCTION

One of the first studies done by us (Mishra and Ramakrishnan,1982) on the village ecosystem function was with respect to a Khasi tribal village near Shillong which apart from having a jhum under 10-year cycle had also valley cultivation as two of the sub-systems. Animal husbandry with swine husbandry and poultry was another sub-system. Finally the human sub-system was dependent upon these two sub-systems as well as on forests nearby for fuel wood and timber. Swine husbandry was an integral part of the agricultural systems as it was based on efficient recycling of resources in the form of biomass and non-edible food products unfit for human consumption derived from the latter. A detailed study done by us on energy flow through the village ecosystem (Fig. 8) suggests the inter-dependency of all these sub-systems on one another. Besides, the monetary input/output studies done here suggests that with a 10-year cycle the village is self-sufficient and is even able to earn additional income through export of protein in the form of poultry and pork. The major deficiency is with respect to the energy for cooking. The fuel wood is in short supply and a major part of the needs of the village has to be met from outside the village boundary. With the shortening of the jhum cycle, vast tracts of land all around are desertified except for restricted pine forests (Ramakrishnan and Das, 1983) or for sacred groves which once were abundant but now a rarity. These sacred groves once formed part of each village but now have been virtually wiped out. It may be noted here that these groves represent an integral part of the religious beliefs of the tribals (Boojh and Ramakrishnan, 1983).

While jhum under a 10-year cycle is able to stabilize village ecosystem function, the stability in terms of energy flow as well as economic well-being are adversely altered under shorter cycles, as shown through studies as yet unpublished. An important observation arising out of our village ecosystem studies pertain to the high efficiency of recycling of natural resources by the tribal communities which is getting more and more altered due to over-exploitation of the resources due to increased population pressure and the fast pace at which desertification is setting in this region (Ramakrishnan, 1985).

CONCLUSIONS

Agricultural systems

Jhum is a traditional form of agriculture of the humid tropics throughout the world and also of the north-east India. This agricultural system has much to offer to modern farming in terms of concepts and ideas (Ramakrishnan, 1984a). These are related to multiple cropping, recycling of resources within the jhum system, between jhum and animal husbandry, the non-weed concept where weed is not always considered to be undesirable but has a useful role in the agro-ecosystem function and efficiency in energy use. However, the drastic shortening of the jhum cycle due to population pressure and reduction in land area available due to desertification has brought in distortions that need to be corrected for the sake of obtaining optimum returns to the farmer (Toky and Ramakrishnan, 1981a; Mishra and Ramakrishnan, 1981) as well for environmental conservation (Ramakrishnan, 1983; Ramakrishnan. 1984; Toky and Ramakrishnan, 1982c).

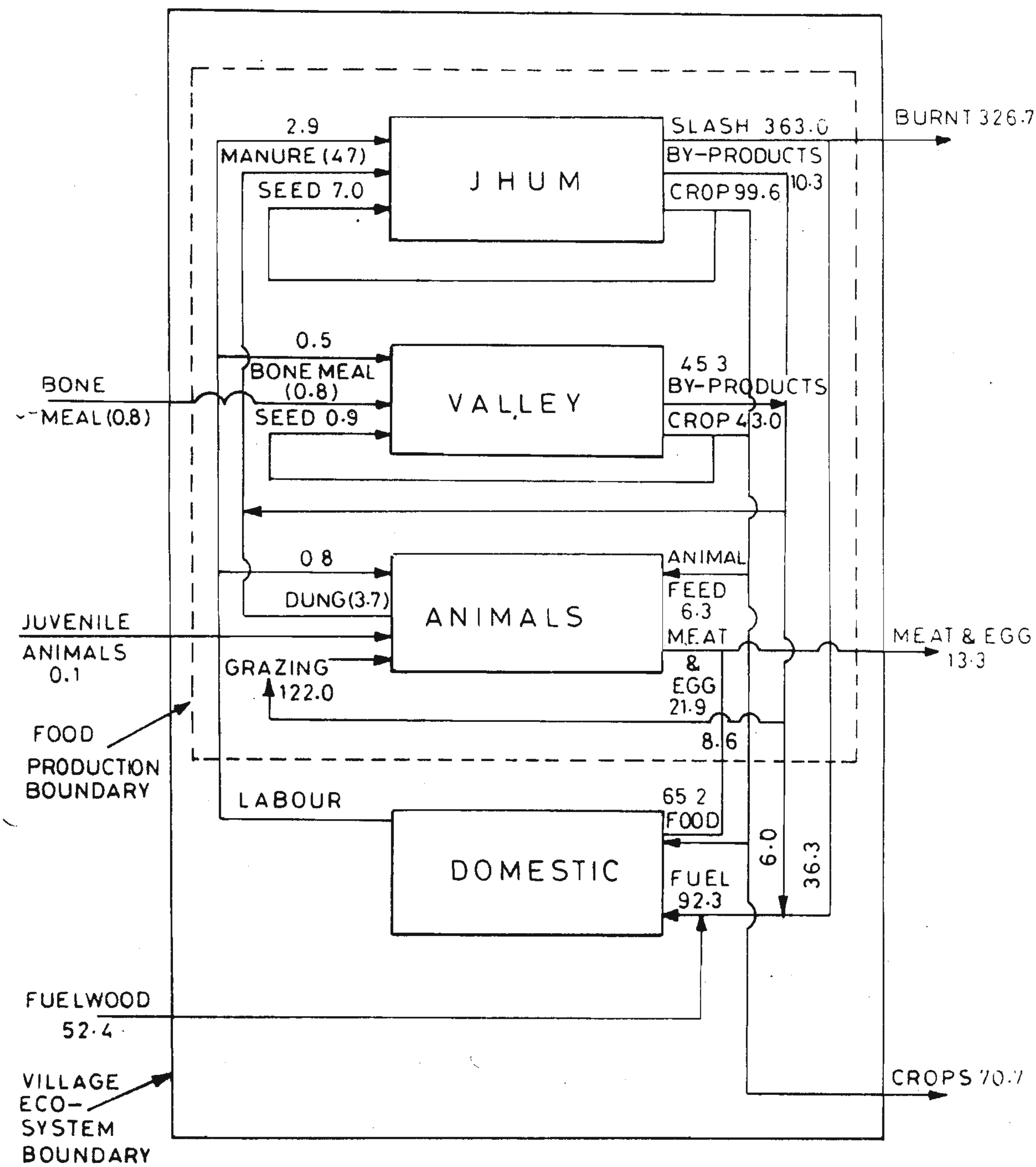

Fig. 8: Energy flow model for the village ecosystem at Setthliew. Values within parentheses refer to the replacement cost in terms of fossil fuel. Unit = $MJx10^3$ (after Mishra and Ramakrishnan, 1982).

Terracing is not a viable alternative (Ramakrishnan, 1984a). The ICAR models where the upper part of the slope is converted to forest, the middle part to plantation crops and lower part made into terraces may not find social acceptance as they are too rigid and would clash with the social structure of the tribal society (Ramakrishnan, 1984b, 1985b).

If that be so, then one ought to find ways and means to keep a jhum cycle that is economically and ecologically viable and at the same time have modifications incorporated into the system (Ramakrishnan, 1984b). In order to quickly recover soil fertility, leguminous shrubs and trees and non-legumes such as older (Alnus nepalensis) could be included into the cropping and fallow phases. A tree belt around the jhum plot could act as a wind break as well as check soil erosion losses. There is scope also for manipulating the crop mixture itself to enhance economic returns to the farmer.

Valley cultivation is a viable land use as it is a self-sustaining system. Nutrient input is not needed and the valleys act as nutrient sinks for the wash out from the hill slopes. The valley system could be managed on a scientific basis by introduction of better yielding crops which are of a short duration. A system of crop rotation could ensure land use all the year round without adversely affecting soil fertility.

Plantation and Horticulture

The north-eastern region can support a wide variety of fruit crops. Apart from pineapple, tropical fruit trees of the citrus group and others do very well in the region. Temperate fruit trees such as apple, pears and plums do well at higher elevations. In fact, the north-eastern hill region has the potential to be the fruit basket of India.

Tea, coffee and rubber have already been successfully introduced into this region. The chief advantage of these species is that the produce is non-perishable unlike horticultural tree crops. Therefore processing the produce will not pose any serious problem.

The main advantage of the tree crops lie in that they form a permanent cover on the soil surface and therefore would protect the soil more effectively than an annual crop cover which would expose the soil to erosion losses when the crop cover is not established. Besides, it would take the pressure off the land for jhum and enable a longer jhum cycle of 10 years or more. They could be the farmers' additional source of income and also give the region an export-oriented economy.

Animal husbandry

Swine husbandry is an important economic activity of the village ecosystem. Apart from meeting the protein needs of the village community it provides monetary benefit through export of meat outside the village boundary. There is scope for organizing this activity on a more scientific basis by introduction of improved strains. Recycling of resources into this sub-system in the village could further be strengthened. Poultry being another animal husbandry practice could be strengthened on more modern lines. Since cattle farming is alien to tribal culture, introduction of this should be done with great caution; otherwise environmental problems due to over-grazing as in the western Himalayas could arise in this region too.

Rural technology

Rural technology could be in the form of biogas as an energy source with efficient recycling of the waste produce. Fuel use efficiency for cooking could be improved through energy efficient stoves. Low level technology could be for semi-processing of tea, coffee, rubber, cashew nut, etc. that may be introduced into the village system. The semi-processed products could then be taken to city centres for final processing. Artisan activities such as black-smithy, leather works, etc. should also be encouraged. Rearing of silk worms for which this region is famous could be organized with semi-processing facilities in the village centre itself. The scope is unlimited.

Integrated village development

The tribals are independent by nature but at the same time have a cooperative organization for jhum activities involving heavy labour. This should be tapped to the maximum for any developmental programme. Family should be the basic unit. The plantation or horticultural plots of 1 or 2 ha should be a family enterprise with a multiplier effect through the village and a cluster of villages in a contiguous geographical territory. This would maintain the family as an independent unit and at the same time large plantations of 100 or 200 ha could be had through a cooperative effort. This would ensure economic viability for the plantations. Only a multi-pronged strategy tailor-made for each ecologic zone of the hill region could ensure economic well-being and ecologic harmony. If this strategy is based on an understanding of the ecologic processes operating in the traditional village ecosystem, as we have emphasized all along, then it would ensure ready acceptance by the people for whom it is designed and would ensure people's participation (Ramakrishnan, 1984a, b,c; 1985b). Alder as part of the jhum system by the tribals of Nagaland is an example of such acceptance.

Conservation strategies

With rapid conversion of rain forests in the region (Ramakrishnan, 1985), well conceived conservation strategies need urgent attention. Conservation of mature ecosystem types through a major 'biosphere reserve' programme is an important step in this direction for conserving the endangered plants and animals and to manage the rich germ plasm of wild species of human value such as orchids, wild ancestral varieties of cultivated crop plants and 'lesser known food plants' used extensively by the tribals. Recovery of damaged environment (Ramakrishnan and Toky, 1982) through a 'condensed succession' using indigenous tree species based on the architectural design as suggested by us through a series of study (Ramakrishnan, et al., 1982; Boojh and Ramakrishnan, 1982a,b,c, 1983; Ramakrishnan and Shukla, 1982; Shukla and Ramakrishnan, 1984a,b, 1986) should be undertaken. Agro-forestry, social forestry and mixed plantation forestry using indigenous species identified on the basis of their architectural design, fast growth strategies and complementability in mixtures would meet the fuel wood and timber needs of the local community and would provide a forest based export-oriented economy. It would also help in conservation of the forest resources of the region on which the man of the humid tropics (Ramakrishnan, 1985b) is so much dependent and of which he is an integral part.

ENVIRONMENTAL COMMUNICATION

Much of the environmental issues in developing countries are connected with poverty related environmental degradation. Exploitation of natural resources such as forests for fuel wood and fodder has been a critical factor contributing to degradation. Over population and related unhygenic living conditions and waste disposal problems, overgrazing often by unproductive cattle population are some of the major issues. In the ultimate analysis, environmental issues and developmental issues are closely interlinked. An integrated rural development approach is, therefore, the only sensible one, if environment and development are considered complementary to one another and if people's participation is to be ensured.

Such an approach to design developmental strategies of the tribal rural environment was considered by us in the north-eastern hill region (Ramakrishnan, 1984b, 1985b). In the hill areas of the north east, as in any other hill system, the ecological conditions are heterogenous. The socio-economic and socio-cultural background of the tribal communities are very diverse; indeed this is true for the rural population of this sub-continent as a whole. We realized the value of a personalized communication system for the hill areas. The traditional tribal farmer does shifting agriculture, which has much to offer to modern agriculture (Ramakrishnan, 1982). Many scientists, planners and administrators consider this to be an undesirable land use that should be eradicated. No doubt, distortions have come about due to shortening of the jhum cycle (the length of the fallow phase between two successive cropping from the same site). Realizing that jhum cannot be eliminated in the near future and many of the alterntives are not ecologically or economically viable, since the technology is not often suited for the humid tropics, we have considered the possibilities of improving upon jhum and at the same time develop alternatives that are viable. We have also considered improving upon other economic activities such as animal husbandry (Mishra and Ramakrishnan, 1982) and looked at environmentally harmonized domestic system through social and agroforstry systems. Since the ecological conditions are heterogeneous, the developmental packages have to be different for different situations.

In view of this heterogeneity of the tribal communities, a personalized communication system alone can be effective for development in harmony with ecology (Ramakrishnan, 1986). Mass communication, obviously, cannot be effective. Personalized communication at a micro-level has the advantage of a two-way interaction between the communicator and the recipient of the message. It helps in appreciating what the community wants. Only such an approach will be effective as then the developmental strategy on ecologic considerations is based on a value system the farmer can appreciate and therefore identify with. This would ensure people's participation in developmental process in harmony with environment.

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Summary of discussion following presentation

Philippines - Mr Jose O. Sargento: You seem to imply that shifting agricutlure is better than terracing and this is difficult for me to believe. In Philippines terracing has been more efficiently adopted than shifting agriculture.

Prof. P.S. Ramakrishnan: This involves the problem of specific and general cases. I am not saying that shifting agriculture is the best solution in all instances; terracing is perhaps the best form of agricultural practice in some places.

Bangladesh - Mr M. Kalimuddin Bhuiyan: In Bangladesh we believe that in shifting agriculture local knowledge of soil types and conditions affect site selection by cultivators.

Dr Bernd von Droste: You spoke about the village-rural ecosystem. How do you exactly define this.

Prof. P.S. Ramakrishnan: I am referring to the system where it is not only the human-physical environment relationship which must be considered but also the human-environment as well, therefore including socio-economic and cultural elements.

Dr N. Ishwaran: Do people who are practicing shifting cultivation recognise the decrease in yields and if so do they blame it on some groups or individuals.

Prof. P.S. Ramakrishnan: I think most of them do have an understanding of the limitations of their agricultural practice.

Dr Francis NG: Why is shifting agriculture practiced on lowlands and not on slopes?

Prof. P.S. Ramakrishnan: I think soil fertility maintenance would be more difficult in slopes and this perhaps affects site selection. In general I think in shifting agriculture the aim is make agriculture internally efficient and minimise dependancies on outside factors.

MYCORRHIZAL ASSOCIATIONS IN TROPICAL HUMID FORESTS

K. ABEYNAYAKE

Mycorrhizal association is the rule rather than the exception for most land plants. Hence in tropical humid forests too there is the occurrence of mycorrhizal associations.

Mycorrhizal associations are associations between roots and fungi which are non-pathological (Harley 1969). Mycorrhizal associations are very diverse but two main types of mycorrhizae have been recognized by Harley(1969),1. ectotrophic mycorrhizae or ectomycorrhizae characterized by a fungal sheath completely enveloping the roots and growing between the cortical cells and 2. endotrophic mycorrhizae or endomycorrhizae lacking a fungal sheath but showing considerable degree of intracellular penetration by the hyphae.

Studies on mycorrhizae in the tropics have not been as extensive as the work done in the temperate countries. In the tropics most work on mycorrhizae have been carried out on exotic tree species like Pinus,(Bakshi, 1974; , Sri Bharathie, 1973 , Ofosu-Asiedu, 1980) and not on the indigenous flora. In this paper attempts would be made to report the work done on the indigenous flora of the tropics. In the tropics most work has been done on two types of mycorrhizae and hence in this paper emphasis would be given to the ectomycorrhizae and the endomycorrhizae of the vesicular - arbuscular type (the VA mycorrhizae).

Meyer (1973) reported that in the tropical forests of the lowlands endomycorrhizal trees are abundant and ectomycorrhizal ones occur only sporadically while in the subalpine forests of the temperate region especially in the colder boreal forests, ectomycorrhizal trees dominate. Most surveys carried out in the tropics on the indigenous flora show that in natural tropical forests the more common type of mycorrhizal association is the endotrophic association of the vesicular arbuscular type. As reported by Redhead (1980) Janse in 1896 studied bryophytes, vascular cryptogams, monocotyledons and thirty eight species of woody dicotyledons in Java. He found that sixty nine of the seventy five species examined, including all the woody dicotyledons, had characteristic endotrophic mycorrhizal associations of the VA type. The next extensive survey of mycorrhizal associations in the tropics was carried out by Johnston in 1949 in Trinidad as again reported by Redhead (1980). Johnston examined ninety three species including thirteen species of forest trees and observed that eighty including all the forest tree species had endomycorrhizae. Redhead (1968) investigated the mycorrhizal associations in fifty one tree species indigenous to the lowland rain forests of Nigeria and in fifteen exotic tree species. All the exotic tree species and forty four of the indigenous species were found to have endomycorrhizae and three indigenous species belonging to the Caesalpiniaceae had ectomycorrhizae. Thomazini (1974) working with mycorrhizal associations of plants in Brazil found that forty six species had endotrophic associations, two species had ectotrophic associations and two species had ectendotrophic associations. The almost universal occurrence of the vesicular - arbuscular mycorrhizal association in the tropics has been confirmed from India (Thapar and Khan 1973), fromthe Philippines (Tupas and Sajise 1976) and from Sri Lanka (de Alwis and Abeynayake 1980 and Gunatilleke and Maheswaran 1986). Root material of sixty three tree species belonging to twenty six families in a lowland tropical rainforest was examined by de Alwis and Abeynayake (1980). In this survey too most of the tree species examined were mycorrhizae of the VA type - the data being presented in Table 1. Five species of trees belonging to family Dipterocarpaceae showed the presence of ectomycorrhizae.

Table 1. Types of mycorrhizae present in the lowland tropical rainforest tree species at Kottawa (Sri Lanka). (from de Alwis and Abeynayake, 1980)

Family	Species	Type of mycorrhiza
Anacardiaceae	Campnosperma zeylanica	endomycorrhiza
	Mangifera zeylanica	endomycorrhiza
	Semecarpus gardneri	endomycorrhiza
	S. subpeltata	endomycorrhiza
Annonaceae	Cyathocalyx zeylanicus	endomycorrhiza
	Xylopia championii	endomycorrhiza
Apocynaceae	Alstonia scholaris	endomycorrhiza
Burseraceae	Canarium zeylanicum	endomycorrhiza
Celastraceae	Kurrima ceylanica	endomycorrhiza
Cornaceae	Mastixia tetrandra	endomycorrhiza
Dilleniaceae	Dillenia retusa	endomycorrhiza
	Schumacheria castaneifolia	endomycorrhiza
	Wormia triquetra	endomycorrhiza
Dipterocarpaceae	Cotylelobium scarbriusculum	ectomycorrhiza
	Dipterocarpus hispidus	ectomycorrhiza
	D. zeylanicus	ectomycorrhiza
	Hopea jucunda	ectomycorrhiza
	Shorea affinis	ectomycorrhiza
Elaeocarpaceae	Elaeocarpus subvillosus	endomycorrhiza
Euphorbiaceae	Agrostistachys hookeri	endomycorrhiza
	Antidesma pyrifolium	endomycorrhiza
	Aporosa cardiosperma	endomycorrhiza
	Bridelea moonii	endomycorrhiza
	Chaetocarpus coriaceus	endomycorrhiza
	Ostodes zeylanica	endomycorrhiza

Flacourtiaceae	Hydnocarpus octandra	endomycorrhiza
Guttiferae	Calophyllum bracteatum	endomycorrhiza
	C. inophyllum	endomycorrhiza
	C. pulcherrimum	endomycorrhiza
	Garcinia cambogia	endomycorrhiza
	G. spicata	endomycorrhiza
	G. terpnophylla	endomycorrhiza
	Mesua thwaitesii	endomycorrhiza
Icacinaceae	Urandra apicalis	endomycorrhiza
Lauraceae	Cryptocarya membranacea	endomycorrhiza
	Neolitsea cassia	endomycorrhiza
Melastomataceae	Memecylon arnottianum	endomycorrhiza
	M. rhinophyllum	endomycorrhiza
Meliaceae	Amoora rohituka	endomycorrhiza
Moraceae	Artocarpus nobilis	endomycorrhiza
Myristicaceae	Horsfieldia irya	endomycorrhiza
	H. iryaghedhi	endomycorrhiza
	Myristica dactyloides	endomycorrhiza
Myrtaceae	Syzygium aqueum	endomycorrhiza
	S. makul	endomycorrhiza
Palmae	Areca catechu	-
	Caryota urens	endomycorrhiza
Rhizophoraceae	Anisophyllea cinnamomoides	endomycorrhiza
	Carallia brachiata	endomycorrhiza
	C. calycina	endomycorrhiza
Rubiaceae	Byrsophyllum ellipticum	endomycorrhiza
	Canthium dicoccum	endomycorrhiza
	Randia gardneri	endomycorrhiza
	Timonium jambosella	endomycorrhiza
	Tricalysia erythrospora	endomycorrhiza
Sapotaceae	Madhuca fulva	-
	Palaquium grande	endomycorrhiza
	P. pauciflorum	endomycorrhiza
	P. rubiginosuim	-
	P. thwaitesii	-
Symplocaceae	Symplocos coronata	endomycorrhiza
Thymelaeaceae	Gyrinopus walla	endomycorrhiza
Verbenaceae	Vitex pinnata	endomycorrhiza

Redhead (1980) tabulates the data available on the records of the naturally occurring ectotrophic mycorrhizal associations. This data combined with work done by de Alwis and Abeynayake (1980), Gunatilleke and Maheswaran (1986) and Becker (1983) is presented in table 2.

Table 2. Ectotrophic mycorrhizal associations reported in the tropics

Species	Country	Author
Caesalpiniaceae		
Afzelia africana	Ghana	Jenik and Mensah (1967)
	Nigeria	Redhead (1968)
Afzelia bella	Nigeria	Redhead (1960, 1968)
	Zaire	Fassi and Fontana (1962)
Anthonotha macrophylla	Zaire	Fassi and Fontana (1962)
Bauhinia holophylla	Brazil	Thomazini (1974)
Brachystegia eurycoma	Nigeria	Redhead (1968)
Brachystegia laurentii	Zaire	Fassi and Fontana (1962)
Gilbertiodendron dewerrei	Zaire	Fassi (1963)
Julbernardia seretii	Zaire	Fassi and Fontana (1961)
Monopetalanthus sp	Zaire	Fassi and Fontana (1962)
Paramacrolobium coeruleum	Zaire	Fassi and Fontana (1962)
Paramacrolobium fragrans	Zaire	Fassi and Fontana (1962)
Dipterocarpaceae		
Anisoptera laevis	Malaya	Singh (1966)
Balanocarpus heimii		
Dipterocarpus oblongifolius		
Dipterocarpus sublamellatus		
Dryobalanops aromatica		
Hopea ferruginea		
Shorea curtisii		
Shorea macroptera		
Shorea ovalis		
Shorea pauciflora		
Vatica papuara		
Shorea leprosula	Malaya	Singh (1966)
	Malaysia	Becker (1983)
Shorea maxwelliana	Malaysia	Becker (1983)
Shorea trapezifloia	Sri Lanka	Gunatilleke & Maheswaran
Shorea affinis	Sri Lanka	de Alwis and Abeynayake (1980)
Dipterocarpus zeylanicus		
Dipterocarpus hispidus		
Cotylelopium scrabisculum		
Hopea jucunda		

Euphorbiaceae		
Upaca togoensis	Nigeria	Redhead (1974)
Fagaceae		
Quercus spicata	Malaya	Singh (1966)
Myrtaceae		
Camponanesia coerulea	Brazil	Thomazini (1974)

In addition Janos (1983) cites the work of St. John (1980) for Nyctaginacea.

St. John and Uhl (1983) for Papilionoideae
Janos (1980) for Polygonaceae
Singer and Morello (1960) for Sapindaceae

From table 2 and Janos (1983) it is seen that the ectomycorrhizal associations are less common than endomycorrhizal associations shown in table 1 and that they are restricted to a few families like Caesalpiniaceae, Dipterocarpaceae , Euphorbiaceae, Fagaceae Mystaceae, Nictaginaceae, Papilionoideae, Polygonaceae and Sapindaceae. It can also be seen that in some families like Dipterocarpaceae, all genera surveyed had ectomycorrhizae with one genus Hopea having both ecto and endomycorrhizae as reported by Sasuddin (1979). Families like Euphorbiaceae and Myrtaceae have both ecto and endomycorrhizae in different genera while the evidence available for family Caesalpiniaceae is not sufficient at present to comment on any restriction of a particular type of mycorrhizae to the family.

Tropical Mycorrhizal Fungi

The fungi forming the VA mycorrhizae are species of the Endogonaceae. Redhead (1974, 1977) found numerous species of Endogonaceae including Glomus fasciculatus and six different kinds of Gigaspora in forest and savannah soils of Nigeria. Sanni (1976) also recorded Gigaspora gigantea and other species of Endoganaceae in Nigerian soils. Two mycorrhizae forming species Glomus multicaulis and Sclerocystis sinuosa have been isolated from forest trees in India by Gerdemann and Bakshi (1976). Thapar and Khan (1985) have isolated fourteen species of VA mycorrhizal fungi belonging to four genera Acaulospora, Gigaspora, Glomus and Sclerocystis from forest soils in India. Herrera and Ferrer (1980) working in Cuba have reported the presence of spores of Glomus, Gigaspora, Acaulospora and Sclerocystis.

They also report the richness of the Endogonaceae in Cuba reporting 18 species or types of spores of endogonaceous fungi. Herrera and Ferrer (1980) also point out that unlike in temperate countries where the spore types per soil sample was never higher than 5, they have found 5 - 11 spore types per soil sample. In Sri Lanka de Alwis and Abeynayake (1981) working on forest soils of the wet zone found fifteen spore types of the family Endoganaceae belonging to the four genera Acaulospora, Gigaspora, Glomus and Sclerocystis. The spore types per soil sample however seem much less than that reported by Herrera and Ferrer (1980) and in most cases three spore types and not more than five types per sample were recorded. The work reported so far indicate that many of the fungi forming VA mycorrhiza are cosmopolitan. Janos (1983) reports that some (Acaulospora foveata and A. tuberculata) may be strictly tropical.

Unlike in the case of endomycorrhizae the fungi involved in the formation of ectomycorrhizae are difficult to identify. Some of the fungi associated with ectomycorrhizae bear clamp connections and thus can be identified as Basidiomycetes. Becker (1983) reports ten types of ectomycorrhizae in Shorea leprosula and Shorea maxwelliana seedlings. de Alwis and Abeynayake (1980) report more than one type of ectomycorrhizae for Shorea affinis, Dipterocarpus zeylanicus and Hopea jucunda differing in colour, mantle thickness, presence of radiating structures from mantle and thickness of Hartig net. These indicate that more than one fungus could form mycorrhizae with the host. Various techniques are available for the identification of ectomycorrhizal symbionts like morphological comparison of isolates with known pure cultures or comparison of isolates with cultures obtained from sporocarps or spores of basidiomycetous fungi. Using some of these techniques tentative identifications of some of the associated fungi have been made. The most common fungus associated with ectomycorrhizae seems to be Coenococcum geophilum Fr. (Syn. C. graniforme (Sow.) Ferd. and Winge). Becker (1983) concludes that in Shorea leprosula and Shorea maxwelliana the associating fungus could be either Coenococcum geophilum or Elaphomyces. de Alwis and Abeynayake (1980) tentatively identify Coenococcum graniforme and Suillus species as being two fungal symbionts associated with ectomycorrhizae of forest trees examined. Redhead (1968) shows that the mycelium at the base of the stipe of an Inocybe species was identical to that of the mycorrhizal sheath suggesting that Inocybe could be a symbiont in the case of Afzelia bella seedlings. Singer and Aguair (1986) show that all ectotrophic mycorrhizal fungi in the Brazilian forest belonged to families Amanitaceae, Boletaceae and Russulaceae.

The Effect of the mycorrhizal Associations of Plant Growth under Tropical Conditions

It has been shown by many workers that infection of plants with mycorrhizal fungi can lead to a number of beneficial effects. Bowen (1973) demonstrated the increased uptake of N,P,K and other ions in mycorrhizal plants when compared with uninfected plants. Also mycorrhizae improve the host's resistance to drought (Bowen 1973, Harley 1969) and some root pathogens (Marx 1971). Most of the studies on mycorrhizal function have been made on extra tropical species or on crop plants. Only a few studies have been made on tropical forest species.

Janos (1975) showed that endomycorrhizal innoculation almost doubled the height of three tropical forest trees but had little effect on Sickingia maxonii (table 3).

Table 3 Effect of VA mycorrhiza on lowland rain forest trees in Costa Rica (From Janos 1975)

Species	Mean Height (cm) Treatment 1	2	3	No. of weeks after inoculation
Inga cerstediana	12.33	11.52	19.42	25
Sickingia maxinii	13.20	13.39	14.57	36
Vitex cooperi	6.52	7.40	16.53	24
Euphorbiaceous sp.	4.82	5.16	8.29	23

Key to treatments

1. sterilized soil
2. sterilized soil + microbial filterate + sterilized diced Cacao roots
3. sterilized soil + diced Cacao roots

Redhead (1975) in Nigeria found that Khaya gradifoliala with endotrophic mycorrhizal associations produced over six times as much dry matter as the slight or uninfected plants.

As with endomycorrhizal infections ectomycorrhizal infections too produce significant growth increases. Redhead (1974) grew Brachystegia eurycoma inoculated with two distinctly different mycorrhizal fungi from naturally growing B. eurycoma. The mycorrhizal plants produced significantly more dry matter than the non-mycorrhizal controls (table 4).

The work done on many legumes has shown that formation of VA mycorrhizae is a prerequisite for nodulation by nitrogen fixing bacteria. For the tropics most of this type of work has been carried out for crop plants. However, the work of Janos (1980) on three tropical leguminous species Pentaclethra macroloba, Pithecellobium longifolium and Stryphnodendron excelsum showed that mycorrhizae favoured nodulation in these species.

Table 4 Mean stem heights and dry weights of Brychystegia eurycoma, after inoculation with two different mycorrhizal fungi (From Redhead 1974)

Treatment	Stem height (cm)	Mean Dry weight (g)			
		Leaves	Stem	Roots	Total
No inoculation	22.4	0.74	1.07	1.10	2.91
White mycorrhiza	26.3+	1.23++	1.65++	2.25++	4.93++
Brown mycorrhiza	28.6+	1.54++	1.94++	2.08++	5.56++

+ Differences significant at 5% level
++ Differences significant at 1% level

Mycorrhizae have been attributed another important role in tropical forests. This is that they might be responsible for the closure of nutrient cycles minimizing mineral losses by decomposing litter directly and transporting the mineral nutrients thereby released to the hosts. This direct cycling requires that mycorrhizal fungi decompose cellulose and lignin in organic material or litter. Janos (1983) states that the ability of VA mycorrhizal fungi or ectomycorrhizal fungi to digest cellulose or lignin in the soil when associated with the host is unknown. However, work has been carried out to determine the presence of cellulolytic or lignin degrading enzymes in pure cultures of some fungi. There is little evidence for either the ability or the inability of VAM fungi to degrade cellulose or lignin, although they seem less likely than ectomycorrhizal fungi to have decomposing capability. Data on the ability of ectomycorrhizal fungi to produce cellulolytic or lignin-degrading enzymes is not very conclusive. Janos (1983) cites the work of Norkans (1950) who showed that a fungus producing cellulase and growing on cellulose in culture, could form ecto and ectendomycorrhizas. The scanty evidence however indicates that VA mycorrhizal fungi are less likely than ectomycorrhizal fungi to decompose litter.

Work has also been carried out to determine the degree of dependance on the host on mycorrhizae. For the tropics most of the work has been carried out by Janos. Janos (1980) in a series of pot experiments with seedlings of thirty two species of lowland tropical plants found that VA mycorrhiza improved growth of twenty eight species, including all the mature forest tree species. He also found that the species differed in their degree of dependence on VA mycorrhizae. Some species were able to grow without mycorrhizae although mycorrhizae improved the growth (facultatively mycotropic species) while the other species could neither grow nor survive without mycorrhizae (obligately mycotropic species). Janos concludes from this work that mature forest canopy and sub- tree species tend to be obligately mycotropic while many pioneer and early successional species are facultatively mycotropic. The work of Janos shows that mycorrhizae in addition to their influence on plant growth and nutrient cycling may also influence species diversity of seral and mature plant communities.

Trends in Research on the Mycorrhizal Associations of Natural Tropical Plants oriented towards Conservation

It has been demonstrated that inoculation of forest trees and agricultural plants with mycorrhizal fungi can stimulate their growth in nutritionally poor soils (Bowen 1980). Kormanik, Schultz and Bryan (1982) suggest that high quality seedling stock of eight hardwood tree species can be obtained in nurseries where cultural practices in the nursery encourage VAM development.

Harley (1969) states that most mycorrhizal fungi are not host specific and that therefore a number of mycorrhizal fungi can infect a plant species. It has also been demonstrated that some mycorrhizal fungi adapt the plant to a particular environmental condition than other mycorrhizal fungi (Ruehle 1980). Thus there is a possibility of modifying the efficiency of the plant by judicious selection of a fungus and increasing the ecological fitness of the plant.

This type of selection could be very useful especially in exsitu conservation efforts and also at efforts in reforestation with indigenous species. When the forest is cleared the soil conditions undergo change. The top soil temperature can increase by up to 11 ^{o}C and this is accompanied by an increased rate of organic matter decomposition, leaching of nutrients and potential degradation of soil resource (Bowen 1980). Thus the species with the usually associated fungi might not be suitable for the altered conditions.

Research should be directed towards isolation of symbionts (especially from ectomycorrhizae where identity of symbionts has been a problem). Once the symbionts are isolated mycorrhizae should be synthesized and experiments should be carried out to determine the efficiency of the symbiont under particular conditions. As mentioned by Ashton (1981) for Dipterocarpaceae, looking into any restrictions of particular mycorrhizal fungi to particular species, or whether there is a sequence of infection on individual species, could also prove useful for reforestation work and ex-situ conservation. This type of work would make it possible to select symbotic mycorrhizal fungai suitable for the modified environments.

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Summary of discussion following presentation

Philippines - Mr Jose O. Sargento: The topic of your presentation is a very important one. I think it will be very useful if mycorrhizae could be made available in a form useful for inoculation and in Philippines we are presently working on this aspect, particularly in relation to Dipterocarps.

Dr.(Mrs.) K. Abeynayake: Yes I agree this could be useful. It has already been achieved for several species and pellets for innoculation are avialable. In Sri Lanka too, we are hoping to start work in this regard in the near future.

Dr(Mrs.) W.G.A. Nissanka: But, if mycorrhizal associations are host-specific it is unlikely that this approach could develop into widespread use.

Dr(Mrs.) K. Abeynayake : True. But there are many known exampales where the mycorrhizal association is not host-specific and it could be useful for such species.

Prof. S. Balasubramaniam: Do you have any information or idea on mycorrhizal associations in the roots of Garcinia hermonii?

Dr(Mrs.) K. Abeynayake: I have no specific information on this but I suspect that it would probably be endomycorrhizal.

MINERAL NUTRITION OF TROPICAL TREES: PATTERNS OF FOLIAR NUTRIENT CONTENTS IN MAJOR FOREST FORMATIONS OF SRI LANKA

S. BALASUBRAMANIAM & G. GLATZEL

Abstract:

During a research project on tropical misteltoes data on the mineral content of leaf samples from host trees accumulated. These data were used as a basis for comparing foliar nutrient status in major forest formations. These were wet lowland evergreen rain forest, upper montane rain forest, monsoon forest, thornscrub and mangroves. A total of 64 woody species and 25 soil samples was considered in this study. The mineral contents of leaves from lowland evergreen and montane rain forests were much lower than those of leaves from monsoon forests from the seasonally dry regions of Sri Lanka. In lowland and montane rain forests the contents of key nutrient elements like P, K and Ca are low in foliar tissues while the amounts of N, K and Ca are low in the natural soils of these forests. Manganese contents were high in leaves of lowland and montane forest tree species as Doona trapezifolia, Garcinia hermonii and Rhododendron zeylanicum, while iron followed no special pattern. Gordonia ceylanica (Theaceae) and Symplocos major from the montane rain forest were found to be accumulators of aluminium, containing about 3 percent aluminium in their leaves. Mangroves had comparatively high contents of sodium, chloride and magnesium in their leaf tissues. The mangrove associate Heritiera littoralis was unusual in having low contents of sodium and chloride in its foliage). Over all the mineral status of the soils, climatic conditions and leaf structure seem to have the strongest influence on the contents of inorganic elements in foliar tissues of tree species of different forest formations.

Introduction

The existing natural forest cover of Sri Lanka can be assigned to seven seven formations. The distinction between these are based on features originally used by Champion (1936) and Burt-Davy (1938) for classifying the woody vegetation types of the tropics. These schemes were modified for Sri Lanka by Holmes (1956), Koelmeyer (1957-58), Fernando (1968) and Perera (1975). Schemes used by van Steenis (1950) were adopted by Whitmore (1984) for the tropical forests of the Far East. In this paper nomenclature published by Whitmore (1984) has been used for the forest formations of Sri Lanka. Table 1 summarises the major forest formations in the different climatic and altitudinal zones of the island.

During a research project on tropical mistletoes in 1983, leaf samples of mistletoes and host trees were collected and analysed for macronutrient elements and some trace elements. Even though this study was not intended to compare nutrient relations of trees in different forest formations and was therefore not systematically planned in this respect, the large body of data available justifies in our opinion a cautious interpretation of tree nutrition in major forest zones of Sri Lanka. In 1983 collections were made from the following locations:

(1) Sinharaja (Lowland Wet Zone)
(2) Hakgala, Horton Plains (Upper Montane Zone)
(3) Polonnaruwa, Sigiriya (Lowland Dry Zone)
(4) Kalpitiya, Yala (Semi-Arid Zone)
(5) Rekawa, Puttalam (Littoral Zone)

Additional leaf samples and some soil samples were collected and analysed during the period 1984 to 1986 to include more sites. However there are still some gaps, particularly as far as data from thorn scrub formations are concerned.

Material and methods

About 30 soil samples and over 150 plant samples were collected and analysed. The plant samples represent the leaves of 65 different native tree species of Sri Lanka. A list of the species investigated is given in table 2. Nomenclature follows Abeywickrema (1959) expect for species of Clasiaceae and Ebenaceae. For these two families names cited by Kosterman (1980) in the revised flora have been used. The 65 tree species investigated, belong to 49 general from 30 different families. About one third of these tree species are endemic to the island.

For foliar analysis leaf samples of all developmental stages found in the sun exposed crown were collected, as the determination of the age of leaves is difficult for many growth forms. Leaf samples were oven dried and milled for analysis. Nitrogen content was determined by a micro Kjeldhal procedure, sulphur by dry combustion and infrared SO_2-analysis (LECO SC-132 Sulfur Analyzer). For chloride analysis the samples were extracted with a mixture of 1 M nitric and acetic acid for 2 hours, then filtered and the chloride concentration measured by coulometric titration. For the determination of phosphorus, alkali and earth alkali cations and heavy metals samples were digested with a mixture of nitric and perchloric acid in a heating block. Phosphorus was determined colorimetrically, metals by atomic absorption flame photometry.

Soil was sampled from the upper portion of the mineral soil. As soil analytical data were used for a rough estimate of soil chemical status only, no attempt was made, to collect samples on an area or volume basis.

Air dried samples of fine soil were used for analysis. Exchangeable cations were determined in an 1 M ammoniumacetate extract, mineral reserves in an extract with 1 M hydrochloric acid (extracted at 40 C for 12 hours). The analyses for nitrogen and metals were the same as for plant samples.

Results and Discussion

Table 3 shows foliar contents of eight elements as means over all sampled trees within five forest formations of Sri Lanka. The lowest and highest value found are also shown. Table 4 gives the results of soil analysis using the hydrochloric acid extraction for soils from ten forest sites. Most of the leaf samples were collected from these sites.

The results of foliar analyses presented in Table 3 indicate that the mineral contents of leaves from lowland rain forest trees are low compared to those from the other forest formations. Leaves of montane rain forest tree species contain only marginally higher amounts of nutrients or mineral elements compared to native tree species of lowland rain forests. The mineral content of foliage of tree species representing monsoon forests are distinctly higher than those of lowland rain forests and montane rain forests. Only five woody species from thorn scrub formations were sampled in this study. All five are evergreen trees or treelets. These five species also occur in monsoon forests. The nitrogen and phosphorus contents of leaves from trees of thorn scrub sites are low compared to those of typical monsoon forest species but their potassium, calcium and magnesium contents are comparable to those of monsoon forest species. Mangroves as expected had consistently high amounts of sodium and chloride ions in their leaf tissues. Foliar contents of magnesium were also above average in mangrove tree species.

The mean phosphorus content of leaves from native lowland rain forest trees was very low. The lowest value recorded was 0.02 % for Garcinia hermonii kosterm., and Mesua nagassarium (Burm. f.) Kosterm., two widespread and dominant tree species in the lowland rain forests of Sri Lanka. The highest value observed was 0.1 % for Terminalia parviflora Thw. The contents of potassium and calcium were also generally low compared to those found in leaves of other forest formations. Climatic conditions are favourable for biomass production and the development of species rich natural forests on lateritic soils in the lowland wet zone of Sri Lanka. Indigineous tree species growing in wet lowland rain forests are appearently adapted to low level of nutrients in the soil and to nutrient dilution in a rather large stand biomass. It is generally accepted that fungi and mycorrhizal fungi, termites, earthworms and probably millipedes play an important role in lowland rain forest ecosystems. Rain forest trees have extensive shallow feeding mats of roots. Such roots close to the surface are effective in obtaining nutrients from leachates of fallen leaves and decomposing litter covering the forest floor. Mycorrhizal associations are important in the uptake of ions from nutrient-poor soils in tropical rain forests. Vesicular-arbuscular mycorrhizas have been reported (Abeynaike et al., ...) for endemic Dipterocarpaceae growing in Sri Lanka. The degree of involvement of these in nutrient uptake needs to be established. Data available for trees in Brazil (Klinge, 1975) and other tropical forests (Grubb, 1977) also indicate low amounts of phosphorus in foliar tissues of rain forest species. In natural forest ecosystems the component tree species may differ widely in their ability to take up phosphorus from soils. These differences between species reflect differences in rooting density, type of mycorrhizae, absorption rates and other factors (Bowen, 1980 and Chopin, 1980).

The soils of the wet evergreen lowland forests of Sri Lanka are acidic latosols, low in humus and plant nutrients. Compared to these, the soils of montane rain forests in Sri Lanka contain more humus and higher amounts of nitrogen, potassium, calcium and magnesium. These differences in the amounts of different elements can be seen by comparing the soil data for samples from Kottawa and Sinharaja with those of Horton Plains and Nuwara Eliya. Differences in the level of soil nutrients can account for the marginally higher contents of inorganic elements in the foliage of montane tree species as compared to those from lowland rain forests. Data for exchangeable cations (Table 5) and field examination of soil samples from various forest sites further indicate that montane forest soils contain more humus and nutrient elements compared to lowland rain forest soils. Higher humus content increases retention of mobile cations. Tanner's (1977) data on foliar mineral composition of montane rain forests in Jamaica showed nitrogen values ranging from 1.11 % to 1.61 % on a dry matter basis. The corresponding vaues for montane forests in Sri Lanka were 1.05 % to 1.80 %. Potassium content reported by Tanner (1977) ranged from 0.35 % to 1.23 %. Our data for the potassium content of leaves from montane forests were 0.40 % to 1.4 %. Data for magnesium in leaves of montane forest tree species are in close agreement with those of Tanner (1977). Calcium content of foliage of montane tree species in Sri Lanka were 0.24 % to 1.47 %, while the corresponding range of values for trees in Jamaica were 0.62 % to 0.93 %. Overall the mineral composition of leaves of a range of tree species examined from wet lowland and montane rain forests in Sri Lanka have values that are in good agreement with those summarized by Grubb (1977) for lowland, lower montane and upper montane rain forests of Asia, Australia and Central America.

The higher mineral content of foliage from trees of monsoon forest formations can be attributed to the comparatively higher level of nutrient elements found in soils of the seasonally dry regions of Sri Lanka. Trees growing in monsson forests have high transpirational throughput especially during the months following the peak of the north east monsoon rains when soil water is still abundant but the evaporative demand already very high. This is also the period of maximum leaf expansion and maturation. Soil data show (Table 4) that higher amounts of basic cations like K, ca and Mg are present in soils from monsoon forest sites compared to soils form lowland rain forest and montane rain forest sites. Jordan (1985) cites monsoon adapted forests as occuring on grumusol soils which have swelling-type clays. Broad soil classifications suggest homogeneity of great soil groups throughout a climatic zone but usually there can be mosaics of soils and vegetation types within major climatic zones. Under the seasonally dry climatic conditions prevailing in regions where monsoon forests occur there can be upward and downward movement of ions especially in the upper layers during alternate dry and wet seasons.

Both evergreen and deciduous tree species grow in mixed deciduous monsoon forests. The average mineral content of deciduous species with thin membranous leaves or leaflets (eg. Chloroxylon Swietenia, Holoptelea integrifolia) is well above that of evergreen tree species with thick leathery leaves (eg. Drypetes sepiaria, Manilkara hexandra etc.). This difference is largely due to the different ratio of cell wall to cytoplasmic material. Foliar mineral contents calculated on leaf water content basis would have been better for comparing the nutrient status of species growing in different climatic zones and for comparing species having different physiological strategies within the same forest (Cassidy, 1966 and 19..). While total mineral content in the foliar biomass or per unit leaf area index is more appropriate for comparing forest types.

Mangroves growing on halomorphic soils have unusually high amounts of sodium and chloride ions in their leaf tissues. Some mangrove associates like Heritiera littoralis and Excoecaria agallocha had comparatively low amounts of Na in their leaves. Popp (1984), also reported lower contents of Na in Heritiera littoralis leaves from Australian mangroves. On dry weight basis the Na content of leaves of the other mangroves examined in this survey range from 1.56 % in Lumnitzera littorea to 4.33 % in Sonneratia alba. Lumnitzera littorea was collected from an estuarine site at Balapitiya in the wet zone while the Sonneratia alba was collected from a lagoon fringing mangrove at Kalpitiya in the drier parts of the island. Chloride contents ranged from 0.54 % to 3.34 %. The lower value was for the brackish water mangrove associate Heritiera littoralis while higher values were found in Lumnitzera littorea (3.34 %), Bruguiera sexangula (3.32 %) and Sonneratia alba (3.23 %). Salt secreting species like Aegiceras corniculatum (0.35 %) and Avicennia officianalis (o.41 %) had lower amounts of calcium compared with Lumnitzera spp. (2.75 % and 2.28 %) and members of the Rhizophoraceae like Bruguiera sexangula (2.06 %) and Ceriops decandra (1.67 %). Potassium contents in leaves of mangroves ranged from 0.43 % in Bruguiera sexangula to 1.57 % in Excoecaria agallocha. Magnesium content in mangroves leaves was rather high and the values ranged from 0.17 % in Heritiera littoralis to 1.03 % in Ceriops tagal. Twelve out of the fifteen species examined had Mg values above 0.5 %. Besides being a component of chlorophyll molecules, magnesium was probably present as the free ion in the vacuoles of mangroves leaf tissues. The high sodium, magnesium, sulphur and chloride content of mangrove foliage reflects the relatively higher availability of these elements in soils periodically inundated by saline water. Our data on the foliar composition of mangroves like Aegiceras corniculatum, Excoecaria agallocha, Lumnitzera racemosa and Rhizophora mucronata compare well with values reported for the same set of species by Johsi and Bhosale (1982). Hertiera littoralis is a rather unusual mangrove associate with regard to foliar mineral contents. Though usually regarded as a back mangrove or a brackish water species, the leaves of this tree species contain relatively low amounts of sodium, magnesium and chloride ions compared to other backmangroves and mangal associates like Excoecaria agallocha, Thespesia populnea and Tamarix gallica. Data obtained for Thespesia populnea and Tamarix gallica have not been included in computing mean values of the different elements shown for mangrove formations in Table 3.

The trace element contents of leaves from tree species of the major forest formations in Sri Lanka are summarized in Table 6. The iron content in leaves of most native tree species ranged from 67 to 425 $mg.kg^{-1}$ dry leaves. Eleven out of fifteen lowland rain forest, montane rain forest and monsoon forest species had values above 100 $mg.kg^{-1}$. All five species collected from the thorn scrub sites had values for iron above 100 $mg.kg^{-1}$. The thorn scrub species were growing on sandy soil above a bed of clay. Their deep feeding roots probably had access to water and minerals. All mangrove species except Ceriops decandra and Lumnitzera littorea had foliar content of iron above 100 $mg.kg^{-1}$ dry weight. The highest amount of iron recorded in this study was for leaves of Dipterocarpus hispidus (425 mg/kg dry weight of tissue), from the lowland rain forest.

The manganese content was high for native tree species growing on acidic soils in lowland rain forests and montane rain forests. For both forest formations the values ranged from 16 to 960 mg/kg of dry plant foliage. The two outstanding lowland rain forest species were Doona trapezifolia Thw. (960 mg/kg) and Garcinia hermonii Kosterm (882 mg/kg). Of the montane forest species, Rhododendron zeylanicum (824 mg/kg) was remarkable in having above average amounts of manganese in its leaf tissues. Temperate species of Vaccinicun which like Rhododendron are members of the family Ericaceae are also known to contain above average amounts of manganese. Vaccinicum and Rhododendron spp., are characteristic of acid soils in temperate climates and upper montane forests in the old world tropics. Manganese values reported by Bhosale (1979) for Aegiceras corniculatum, Avicennia officianalis, Bruguiera gymnorhiza, Ceriops tagal, Lumnitzera racemosa and Rhizophora mucronata are rather low compared to the values obtained by us for these same species of mangroves. It is not clear if the soils from where these mangroves were collected in western India could account for the low values reported by Bhosale (1979).

Mean values for zinc in the leaves of trees of different forest formations ranged from 23 to 74 $mg.kg^{-1}$ dry matter of foliage. A low value of 6 mg/kg was recorded for the mangrove associate

Excoecaria agallocha while Michelia nilagirica (montane tree species) had an exceptionally high value of 446 mg/kg of dried leaves. One of the other notable examples was Doona trapezifolia Thw. This lowland rain forest tree species had values of 110 $mg.kg^{-1}$. Nine out of fifteen mangrove species had values less than 20 mg/kg of dry leaf tissue. In a recent study, Brooks et al. (1985) examined fourteen species of monsoon forest shrubs and trees growing on a copper-magnetite site near trincomalee, Sri Lanka for 18 elements. Brooks et al. (1985) report the following amounts of zinc in the leaves of two evergreen tree species of the monsoon forests. Lepisanthes tetraphylla had 58 $mg.kg^{-1}$ and the common Manilkara hexandra had 43 $mg.kg^{-1}$ of Zn. The somewhat higher values reported by Brooks et al. (1985) may be due to the generally higher levels of some of the heavy metals in the copper-magnetite sites from where the leaf samples were obtained for analyses.

Aluminium is not an essential element for plant growth but there are toxicities associated with excessive availability in many species. Since aluminum availability may be high in tropical soils, it was included in table 5. Chenery (...) designated plants containing more than 1000 ppm as aluminium accumulators. On this criterion Gordonia ceylanica (Theaceae) and Symplocos major (Symplocaceae) from the upper montane forests of Sri Lanka can be called accumulators. Webb (1954) reported high values for the related species Symplocos spicata. Earlier Chenery (1948) reported that the tea plant and other Theaceae are aluminium accumulators. Salt secreting mangroves (eg. Aegiceras corniculatum, Avicennia marina and A. officianalis) had low contents of aluminium in their leaves compared to other mangroves belonging to the Combretaceae, Rhizophorceae and Sonneratiaceae.

The data considered in this study show, that mineral availability in the soil as influenced by base saturation and redox, climatic conditions and foliar structure determine the nutritional composition of the leaves of most tree species. Species specific selective uptake and accumulation processes may account for the rather high contents of Mn in Doona trapezifolia Thw. and Rhododendron zeylanicum and the unusually high amounts of aluminium in some Symplocaceae and Theaceae. Polyphenolic compounds with chelating properties can also contribute to accumulation of heavy metals like Mn and Al in plants. Selective exclusion mechanisms may have to be invoked in interpreting the low contents of sodium and chloride ions in some mangal associates like littoralis.

Crateva religiosa (Capparidaceae),, Ferronia limonia (Rutaceae) and Salvadora persica (Salvadoraceae) were found in semi-arid regions on clayey soils as open scrub formations near thorn scrub or salt flat communities. These species have not been included in the five forest formations considered in this survey but leaf samples from these tree species have also been analysed. The three species mentioned above have unusually high contents of sulphur in their foliage (Crateva religiosa - 3.54 %), Ferronia limonia - 0.71 % and Salvadora persica - 3.35 %). Sulphur may be a constituent of organic compounds in these species.

Table 1 : The Forest Formations of Sri Lanka

Forest Formation (Synonyms)	Elevation (metres)	Climatic Zone (precipitation mm/yr)
1. Lowland Evergreen Rain Forest (Wet evergreen forest)	0 - 900 m	Lowland Wet Zone (2500-6000)
2. Lower Montane Rain Forest (Submontane rain forest)	900 - 1500 m	Midelevational Zone (2500-6000)
3. Upper Montane Rain Forest (Montane cloud forest)	1500 - 2500 m	Montane Zone (2500-6000)
4. a Semi-Evergreen Forest b Moist Deciduous Forest c Fire Savannahs	0 - 900 m	Intermediate Zone (2000-2500)
5. Mixed Deciduous Forest (Monsoon Forest)	lowlands	Dry-Zone (1000-2000)
6. Thorn Scrub Formation (Monsoon Scrub Jungle)	lowlands	Semi-Arid Zone (750-1000)
7. Mangrove Forest + Scrub (Mangals)	littoral fringes (lagoons & estuaries)	Littoral Zone (1000-6000)

Table 2 : List of species from which foliar samples were collected for analysis. Nomenclature follows Abeywickrema (1959) and Kostermans (1980)

Family	Species
1. Annonaceae	Xylopia championii Hook.f & Thoms.*
2. Avicenniaceae	Avicennia marina (Forsk.) Vierh.
	Avicennia officinalis L.
3. Bombacaceae	Cullenia ceylanica (Gardn.) K.Schum.*
	Cullenia rosayroana Kosterm.*
4. Caprifoliaceae	Viburnum coriaceum Bl.
5. Celastraceae	Elaeodendron glancum (Rottb.) Pers.
	Pleurostylia opposita (Wall.) Alston
6. Clusiaceae (Guttiferae)	Calophyllum moonii Wight*
	Calophyllum thwaitesii Planch. & Triana
	Calophyllum walkeri Wight*
	Mesua ferrea L.*
	Mesua nagassarium (Burm.f.). Kosterm.
	Garcinia echinocarpa Thw.
	Garcinia hermonii Kosterm.*
7, Combretaceae	Lumnitzera litterea (Jack) J.O Coigt.
	Lumnitzera racemosa Willd.
	Terminalia parviflora Thw.*
8. Dipterocarpaceae	Dipterocarpus hispidus Thw.*
	Doona congestiflora Thw.*
	Doona macrophylla Thw.*
	Doona trapezifolia Thw.*
9. Ebenaceae	Diospyros ebenum Koenig
	Diospyros ferrea (Willd.) Bakh.
10. Ericaceae	Rhododendron zeylanicum Booth
11. Euphorbiaceae	Bridelia retusa (L.) Spreng.Pax & Hoffm.
	Drypetes sepiaria (Wight & Arn.)
	Excoecaria agallocha L.
	Glochidion coriaceum Thw.*
	Mischoden zeylanicus Thw.

Family	Species
12. Fabaceae (Leguminosae)	Bauhinia racemosa Lam. Cassia fistula L.
13. Lauraceae	Actinodephne speciosa Nees.* Cinnamomum ovalifolium Wight* Neolitsea fuscata (Thw.) Alston.
14. Magnoliaceae	Michelia nilagirica Zenk.
15. Melastomataceae	Memecylon umbellatum Burm. f.
16. Meliaceae	Walsura piscidia Roxb.
17. Myrsinaceae	Aegiceras cormiculatum (L.) Blanco.
18. Myrtaceae	Syzygium revolutum (Wight) Walp. Syzygium rotundifolium Arn.* Syzygium sclerophyllum Thw.*
19. Rhizophoraceae	Anisophyllea cinnamomoides (Gardn & Champ) Alston* Bruguiera gymnorhiza (L.) Lam Bruguiera sexangula (Lour.) Poir. Ceriops decandra (Griff.) Ding Hou. Ceriops tagal (Perr.) C.B. Rob. Rhizophora apiculata Bl. Rhizophora mucronata Lam
20. Rubiaceae	Ixora arborea Roxb. ex Sm.
21. Rutaceae	Chloroxylon swietenia DC.
22. Sapindaceae	Lepisanthes tetraphylla (Vahl) Radik. Sapindus emaraginatus Vahl
23. Sapotaceae	Manilkara hexandra (Roxb.) Dubard Palaquium grande (Thw.) Engl.*
24. Sonneratiaceae	Sonneratia alba Sm. Sonneratia caseolaris (L.) Engl.
25 Sterculiaceae	Heritiera littoralis Dryand
26. Symplocaceae	Symplocos major (Thw.) Brandis (Symplocos obtusa Wall)

Family	Species
27. Theaceae	Adinandra lasiopetala (Wight) Choisy* Gordonia ceylanica Wight*
28. Tiliaceae	Grewia tiliifolia Vahl
29. Ulmaceae	Holoptelea integrifolia (Roxb.) Planch.
30. Verbenaceae	Premna tomentosa Willd. Vitex altissima L.f.

Table 3 : Mean elemental content in the foliage of trees from major forest formations in Sri Lanka

Forest Formation (No of Spp + Samples analysed)		Element content of leaves in % of dry matter N	P	S	K	Ca	Mg	Na	Cl
1 Lowland Rain Forest	min	.70	.02	.04	.22	.26	.11	.03	.01
(15 Spp.,	max	2.00	.10	.77	.85	1.55	.44	.66	.62
24 samples)	max	2.00	.10	.77	.85	1.55			
	mean	1.22	.06	.24	.49	.75	.25	.21	.20
2 Montane Rain Forest	min	1.05	.06	.04	.40	.24	.11	.01	.01
(15 Spp., 29 Samples)	max	1.80	.75	.10	1.40	1.47	.37	.23	.24
	mean	1.37	.08	.07	.80	.79	.21	.07	.08
3 Mixed Deciduous/ Monsoon Forest	min	1.28	.09	.04	.80	.75	.17	.01	.02
(15 Spp., 24 Samples)	max	3.23	.31	.25	2.50	3.49	.70	.17	.94
	mean	2.08	.17	.10	1.49	1.55	.37	.06	.28
4 Thorn Scrub Formation	min	.95	.09	.05	.85	1.38	.17	.02	.06
(5 Spp., 17 samples)	max	1.49	.16	.07	1.71	2.63	.42	.75	1.90
	mean	1.26	.08	.06	1.03	2.04	.30	.18	.77
5 Mangrove Formations	min	.82	.04	.10	.43	.35	.17	.05	.54
(15 Spp., 58 Samples)	max	2.20	.19	.44	1.57	2.75	1.03	4.33	3.34
	mean	1.27	.13	.24	1.01	1.38	.65	2.10	1.96

Table 4: Plant nutrients and sodium in the topsoil (upper 20 cm of mineral soil) from the major climatic zones in Sri Lanka
Nitrogent ... total nitrogen
Kations ... in 1 M ammoniumacetate extract

Climatic zone (locations)	N %	K	Ca	Mg	Na
		----mg.$100g^{-1}$			
1 Lowland Wet Zone					
a) Kottawa I (well drained site)	0.05	7.6	25.0	20.9	6.0
b) Kottawa II (well drained site)	0.10	3.3	6.9	7.4	6.4
c) Kottawa III (moist stream bank)	0.24	27.9	192	129	7.1
d) Sinharajah I (well drained site)	0.10	4.0	7.0	5.8	5.8
e) Sinharajah II (well drained site)	0.17	4.4	14.7	6.4	5.7
f) Sinharajah III (moist stream bank)	0.18	11.5	81	48	6.4
2 Upper Montane Wet Zone					
g) Horton Plains (Worlds End,well drained)	0.40	12.2	46	41	6.6
h) Horton Plains (Totapola, well drained)	0.58	12.8	34	33	6.6
i) Nuwara Eliya (slightly disturbed site)	0.28	12.1	13	8.1	6.0
3 Lowland Dry Zone					
j) Anuradhapura I	0.09	46	215	76	6.1
k) Anuradhapura II	0.13	44	235	71	5.6
l) Ritigala	0.17	45	340	71	5.6
4 Littoral Zone (Wet Zone Estuaries)					
m) Balapitiya I	0.80	50	490	550	690
n) Balapitiya II	0.86	81	540	670	1050
o) Hikkaduwa	0.37	67	290	405	920

Table 5: Comparison of the foliar mineral contents of selected forest trees of Sri Lanka

Species	Element content of leaves in % of dry matter							
	N	P	S	K	Ca	Mg	Na	Cl
<u>Deciduous Species</u> (Membranous Leaves)								
Bridelia retusa	2.04	.14	.14	1.50	1.65	.45	.02	.02
Cassia fistula	2.52	.13	.09	.95	3.49	.32	00	.03
Chloroxylon swietenia	2.17	.09	.07	1.18	1.24	.34	.17	.94
Grewia tilifolia	2.57	.19	.09	1.62	1.87	.45	.03	.36
Holoptelea integrifolia	2.40	.34	.04	1.85	2.69	.70	.06	.34
Premua tomentosa	3.23	.20	.25	2.57	2.23	.61	.34	.40
Mean	2.49	.18	.11	1.61	2.19	.48	.12	.35
<u>Evergreen Species</u> (Leathery Leaves)								
Diospyros ebenum	1.57	.19	--	1.04	2.44	.27	.01	.04
Drypetes sepiaria	1.33	.20	.13	1.14	1.10	.45	.03	.03
Ixora arborea	1.28	.08	.07	1.20	.75	.24	.03	.11
Lepisanthes tetraphylla	1.90	.14	.10	1.62	.97	.40	.06	.16
Manilkara hexandra	1.47	.17	.06	1.37	1.26	.17	.10	.85
Mischodon zeylanicus	1.88	.12	--	.80	.75	.19	.02	.24
Mean	1.57	.15	.09	1.20	1.21	.28	.04	.24

Table 6 : Trace element content of leaves from trees in the major forest formations in Sri Lanka

Forest Formation (Number of Spp + samples analysed)		Element content in $mg.kg^{-1}$ Fe	Mn	Zn	Al
1 Lowland Rain Forest (15 Species + 24 Samples)	min	67	16	10	60
	max	425	960	110	330
	mean	167	248	37	161
2 Montane Rain Forest (15 species + 29 samples)	min	76	24	24	74
	max	320	820	450	6700
	mean	155	282	74	1043
3 Mixed Deciduous or Monsoon Forest (15 species + 24 samples)	min	77	24	18	72
	max	410	530	80	190
	mean	160	141	33	149
4 Thorn Scrub Formation (5 species + 17 samples)	min	105	15	12	n.d.
	max	125	48	37	n.d.
	mean	115	23	25	n.d.
5 Mangrove Formation (15 species + 58 samples)	min	75	8	6	20
	max	300	450	47	290
	mean	180	140	23	135

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Summary of discussion following presentation

Malaysia - Mr Fong Foo Woon: Prof. Balasubramaniam you referred in the early part of your talk to the leaf nutrient contents with respect to age of leaves and season of the year. What sampling programme was adopted to get this information?

Prof. S. Balasubramaniam: Leaves from the sun exposed part of the crown were taken for analysis. We took a large number of replicates to even out any differences. What is given here is the overview of the whole study. However there is a lot of data available.

Bangladesh - Dr A.K.M. Nazrul Islam: You have classified the various zones in the study as agro-climatic zones. On what basis was this done.

Prof. S. Balasubramaniam: This classification was based on the annual precipitation. This is not very satisfactory. For example certain areas where the annual rainfall is 900 m.m. is taken as dry zone. However the bulk of this rainfall comes down as thunder storms and the distribution is very poor. That is why it has been termed as dry zone.

Mr V.R. Nanayakkara: In your lecture you used the term rain forest instead of humid forest. Could you explain why this term was used.

Prof. S. Balasubramaniam: That is why I gave synonims that are used. One may say that there are as many classifications as there are authors, and each one uses different terms. There is no uniformity. The tendency is for one set of terminology to be used in a certain region.

Dr(Mrs.) S. Gunatillake: You have given the nutrient contents of individual trees in the rain forest but would you say that the humid forests are rich in nutrients.

Prof. S. Balasubramaniam: I have expressed the nutrient contents as a percentage of the dry matter. If the dry matter per unit area of land is taken it shows that the humid forests are richer in nutrient than dry zone forests.

Session II (b)

(b) Diversity and Endemism in Tropical Humid Forests

Chairman: Dr Francis NG

Roles of Animals in Dispersal and Regeneration of Plants in Humid Tropical Forests	S.W. Kotagama, N.D. de Zoysa and W. Lyn E. de Alwis
Diversity and Endemism and the Need for Conserving Representative Areas within National Boundaries	B.A. Abeywickrema
Animal Diversity in Tropical Forests	S.W. Kotagama
Vegetation types of Peninsular India in Relation to Environmental conditions	V.M. Meher-Homji

ROLE OF ANIMALS IN DISPERSAL AND REGENERATION OF PLANTS IN HUMID TROPICAL FOREST

S.W. KOTAGAMA, N.D. de ZOYSA AND W. LYN E. de ALWIS

Introduction

All animals depend on plants, directly or indirectly to varying degrees either to provide them with their food or their habitat. In return these animals contribute towards important plant processes such as pollination and dispersal. These interactions range from being merely incidental and unspecialized to others which are highly specialized.

This paper looks at the process of plant dispersal. What exactly is plant dispersal? What is its importance? As explained by Van de Pijl (1969), dispersal is essentially the process by which propagules of plants (seeds and spores) are actively employed by the plant to reach sites where a new generation can be established. Through the dispersal of its seeds, the plant aims at keeping its descendants separate in space, while exploring new territories and maintaining its foot-hold on favourable sites. Next to pollen transport, seed dispersal is the most important factor promoting gene flow in populations, and thus represents the vital link in the continuity of plant life i.e. its regeneration.

Among rain forest tree species, it has been established that a greater number of the plants are dependant on animals for their seed dispersal. This is particularly true for understorey plant species, which may have evolved this adaptation as the only alternate means of dispersal in an environment within the forest interior that is least influenced by wind movement. Wind is usually the common dispersal agent for seeds of the tree species that reach the canopy layers of the forest but is not a viable agent of dispersal for those species that are confined to the understorey.

Methods of Dispersal

Dispersal of seeds by animals are carried out by one of two ways.

(a) Animals feed on the fruits and pass the seed intact either by defecation or regurgitation. Often, this process, makes the seed more fit for germination. Many of the fruits of such plant species are adapted for dispersal by this means. They are either developed into drupes, berries or have a conspicuous edible aril. This is the process of true dispersal particularly in the case of birds, by legitimate frugivores, as opposed to seed predation where animals either harm the seeds mechanically by biting, chewing etc, or digest them (Snow, 1981). Such legitimate frugivores digest only the pericarp or other soft parts of the fruit and expel the seeds intact, either by regurgitation or by defecation. The surprising rapidity with which most of these specialized frugivores can remove the edible parts and regurgitate the seed shows the high degree of their adaptation to such a diet (Snow, 1981).

(b) To a lesser extent dispersal is also carried out by adhesion of fruits or seeds to fur or feathers of animals. These fruits and seeds are often adapted for dispersal being armed with either hooks, bristles and spines or with viscous or gummy secretions (Ridley, 1930).

Dispersal in Relation to Faunal Trophic Structure

One way to determine which animal groups are most responsible for dispersal in an ecosystem, is to consider their trophic structure. i.e. the grouping of animals according to their food habits. In the rain forest the trophic structure is greatly dependant on the vegetation structure of the forst (Table 1, and Fig. 1). The frequent and strong wind movement in the upper canopy and emergent layers of the forest which does not favour seed dispersal by animals however provides a greater opportunity for seed dispersal by wind. The animals which live and feed in the middle canopy layers are mainly frugivorous and appear to contribute most towards seed dispersal. Scansorial animals that move up and down tree trunks as well as terrestrial animals may also contribute to seed dispersal to a lesser extent (Harrison, 1962).

Contribution by Different Animal Taxa

Almost all groups of animals help in dispersal in the rain forest. However, some groups play a far more important role than others. The most important dispersal group is the birds, followed by the mammals. The latter includes the primates and fruit bats which are less specialized than the birds in dispersal, but nevertheless make an important contribution. The remaining groups are of negligible importance, viz. mixed-feeding tetrapod reptiles (lizards and tortoises), and fish which may disperse seeds of plants associated with aquatic systems. Invertebrates such as snails, worms, insects (ants, flies) help disperse seeds of lower plant groups such as fungi. (Ridley, 1930; Van der Pijl, 1969).

(a) Dispersal by Birds

According to Snow (1981) fruit eating birds are undoubtedly the major dispersers of fruits and seeds. Their adaptation to a fruit diet mainly stems from the need to keep body weight down and aid in flight. They thus favour high energy, easily digestible food sources which can be handled by a short gut.

Fruit eating birds appear to fall clearly into two main groups. (a) Specialist frugivores and (b) non-specialist or opportunists. Specialist frugivoures eat either drupe or drupe-like fruits which have large edible flesh parts which are rich in oils and proteins and have usually only a single large seed. e.g. Burseraceae, Lauraceae, Myristicaceae and Palmae.

Alternatively they may also eat fruits which have brilliantly or contrastingly coloured capsules or follicles, which are most typically coloured red, black or yellow and have seeds which dangle.

The non-specialists or opportunists usually feed on fruits which are typically small, many seeded and often brilliantly coloured and juicy. Such fruits are characteristic of secondary shrubs. Being colonizers it is an important adaptation for attracting as many different species of frugivores as possible, and thereby aiding in its rapid dispersal.

(b) Dispersal by Mammals

As summarised by Whitmore (1984) among the mammalian groups, fruit bats are the most important seed dispersers in rain forests. Fruits which are dispersed by bats often have duller colours, strong musty odours and ripen on the tree itself, with the fruit conspicuously held away from the foliage. These fruits are large and are carried away in whole or part by the bats to their habitual feeding roosts where the seeds are dropped.

Although largely adapted to a leaf diet, primates also consume a fair proportion of fruits in the rainforest. They often contribute to dispersal by carrying away fruits to avoid them being snatched by others. However, by gathering unripe fruit, they could also damage a fair proportion of the seed crop (Ridley, 1930). Primates and bats tend to exploit fruits that are usually not eaten by birds and therefore competition among the groups is said to be low (Snow, 1981).

Fruit-eating carnivores such as civets, mongooses, and bears are also important fruit dispersers. The former two are usually nocturnal and are attracted by strong smelling fruits that contain lots of fats and oils.

Ground dwelling herbivores and mixed feeders such as Sambhur, deer, wild boar, and elephant and other mammals such as porcupines, squirrels, and rodents are non-specialized feeders. Although they contribute substantially to dispersal by consuming fallen fruit and seeds, particularly of the larger tree species, and browsing amongst the shrubs and herbs they also destroy much of the fruits and seeds by chewing and damaging them.

The rodents particularly the squirrels and mice also contribute to dispersal by scatter hoarding i.e. they hoard or store more seeds than they can subsequently recover.

Dispersal by mechanical means

The adhesion of seeds to feathers of birds and fur of mammals also aids in dispersal within the rain forest. Although these relationships are not as specialized as those of the frugivores the adaptation of the seed or fruit to this mode of dispersal may be quite elaborate.

Furthermore, primarily wind dispersed plant groups such as grasses are usually scarce or absent (except along clearings) due to the absence of wind within the forest; those species present are adapted for animal dispersal (Ridley 1930).

Conclusion

Plant-animal interactions as exemplified by seed dispersal, are vital processes in the functioning of the rain forest. When the interactions are highly specialized the dependance among one another may be so great, that the local or regional extirpation of a dispersal agent is likely to eventually alter the species composition in the area or even render some species extinct. This provides a glimpse of the complicated and inter-dependant nature of the system. This is an important factor that has to be taken into consideration in deciding areas for protection, in determining minimum viable population sizes for either in-situ or ex-situ conservation of plant species, and for breeding and domestication.

It is also speculated that species multiplication of plants may well have been favoured by plant relationships (Snow, 1981). This is of particular relevance in the case of birds, as it increases chances of long distance colonization and provides opportunities for plant populations to establish well beyond the normal range of the parental stock, leading to differentiation in isolation.

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Q. Could you explain the role of migrant birds in seed dispersal?

A. Of the 384 species of birds recorded in Sri Lanka, about 169 are migrant. The majority are waders and water fowl, while only about 20% are forest birds. Among these, a minute proportion of 2-3% are frugivorous. This is consistent with the food habits of migrant species in other countries too. Migrant species although they may be mixed feeders in their breeding ground, often become mainly insectivorous while migrating and in their winter grounds. As such their contribution to seed dispersal in general is negligible.

Q. Have you done any studies on bird migration by marking birds?

A. Yes. The only location in Sri Lanka where marking (using metal and coloured rings) of birds has been carried out is at Sinharaja. Regular studies during the last 3 years has led to the marking 16.4 birds.

Three such marked birds have been re-recorded in the same locality during two successive seasons. They are Layards Flycatcher (Muscicarpa muttui - Z15907), Brown Shrike (Lanius cirstatus - A16556), and Indian Blue Chat (Erithacus brunneus -Z15921, LL-Red + L.Green)

Thus at least for these three species site tenacity has been provided.

It is unfortunate however, that very little is known of migrants in Sri Lanka. The importance of such a study can be appreciated considering that Sri Lanka is the last land mass on the north-south migration route via the Indian subcontinent. The only information available is accidental recoveries of birds marked in India and the USSR.

Q. While recognizing the important role of animals in the natural processes such as regeneration, we must also be cautioned against the dangers of introducing strange animals; these can upset the ecological balance. Eg. The opposum in Indonesia and the deer in New Zealand. Do you have similar situations in Sri Lanka?

A. Fortunately we have not experienced such situations. The law does not permit introduction of animals. Such exercises in the past have been for reasons beside that of enriching our fauna. For instance the Indian Gaur, Bos gaurus was brought here for entertaining the kings at that time. The Europeans are said to have introduced the Hog deer Cervus porcimus, however it is now antiquated and there is no real proof as to whether it existed naturally or was introduced and is now naturalized.

Comment

Ceiba pentandra, the Silk Cotton Tree or Kapok originated in Burma and was introduced to Bangaladesh. The fruits and seed are dispersed by bats. Therefore the tree shows a distribution pattern which is largely dependant on bat feeding roosts. The seeds dropped at these roosts subsequently regenerate in to small group of trees.

Another interesting case of dispersal is from the Sind province in Pakistan, where the goats feed on the fruits of Cassia nilotica which after the process of digestion germinates easily, and is naturally dispersed with their faeces. For reforestation the seeds of this plant are collected, washed with warm water and sown artificially by air. This method may also be applicable in the case of species such as Leucina illicifolius from the Philippines.

Q. Are you familiar with any names of persons who are working on seed dispersal in the Indo-malayan Realm, such as Daniel Jansen in Central America?

A. Adrian Marshal from University of Aberdeen (?) has been working on seed dispersal, and feeding behaviour of animals that feed on seeds. There is also a student from Aberdeen (is he working under AM?) working on Birds and Figs.

Adivia Goc (?), whose subject is bats and dispersal.

Comment

What we are discussing is dispersal in terms of spatial relationships of plants. This is essentially a result of animals carrying the fruits away from the mother tree. For instance when a tree fruits all bats from a large area came to this tree. On taking the fruit away from the mother tree it takes it to a number of feeding roosts as well as drops it around before that. Also at their day-time roosts, they regurgitate(?) as well as expel seeds in their droppings. Therefore they assist in numerous different ways to effectively disperse the fruit.

Comment

It has been observed that elephants cause destruction to vegetation often in National Parks where elephants are common. The average height of trees is about the same as that reached by an elephant trunk.

Comment

The situation observed in Sri Lankan National Parks is somewhat different from usual. The vegetation appears to have reached a state of equilibrium with respect to the effects of elephant feeding, ie. crown distortion. For instance among Feronia acidissima (Wood Apple) individuals, the tall trees are not faced with this problem, while the young plants are the group which is subject to it. What needs to be emphasised is the fact that interaction cannot be considered destructive until it becomes a limiting factor such as a food shortage.

Comment

Termites, Earthworms, and other seed feeders also play a very important role in dispersal. There is also the instance where in the animals search-feed behaviour, there is a tendency to consume more seeds/fruits which are available in a single place (together) as it is convenient.

DIVERSITY AND ENDEMISM AND THE NEED FOR CONSERVING REPRESENTATIVE AREAS WITHIN NATIONAL BOUNDARIES

B.A. ABEYWICKRAMA

The diversity of living organisms constitutes the most valuable natural resource we have on this earth. Conservation of this resource is not a mere luxury concerned with the enhancement of man's quality of life. It is a very serious matter connected with our survival itself.

The present species diversity is the result of over three billion years of organic evolution. During this process life has followed from a primordial unity, repeated sequences of differentiations, specializations and re-integrations to form more and more complex patterns of unity-in-diversity. Numerous mutual relationships and interdependencies have developed making the organisms that are highest on the scale of evolution the most dependent. We are in a sense parasites in the biosphere. We are dependent not only on our fellow-beings and our physical environments but also on the microbes, plants and animals that have evolved with us. We are able to live and enjoy life only because numberless millions of other organisms have made this earth a habitable place for us and are now maintaining it as such. If we through our ignorance or arrogance destroy the organisms that keep in operation our life-support systems we will in due course be destroying our own selves.

Biological resources have been and still remain our only source of food. They provide much of our shelter and clothing; wood remains the cheapest and most readily available fuel. Living organisms provide medicines, fibres, spices, beverages and a host of other products. Technological progress has not reduced this dependence. On the contrary industry itself now draws much of its raw-material and its energy requirements from this resource. With rising populations and the resulting increasing demands biological productivity will have to be progressively increased.

The productivity of a biological system is a function of its total biological energy capital. This is not simply equivalent to the growing stock of one or a few selected species. It depends on species diversity, their biomass, soil organic content, microorganisms and several other factors. Biological systems are resilient to disturbances to some extent. They remain renewable if wisely managed. They appear to tolerate our abuses in the short term, but if we overdo them the systems collapse. Many of our so called development activities of the past have been carried out for immediate local monetary gain with little or no consideration for, or an understanding of, their consequences to total environments and thereby to man himself. Such activities have often resulted in large scale degradation, and even desertification of landscapes and the irreversible loss of many species.

About ten years ago the then President of the United States directed that a study be made of, among other matters, the probable changes in the world's natural resources through the end of the century. The report submitted to him estimates that:

> "between half-a-million and two million species - 15 per cent of all species on earth - could be extinguished by 2000, mainly because of loss of wild habitat but also in part because of pollution. Extinction of species on this scale is without precedent in human history.
>
> One-half to two-thirds of the extinctions projected to occur by 2000 will result from clearing or degradation of tropical forests. Insect, other invertebrate, and plant species - many of them unclassified and unexamined by scientists - will account for most of the losses. The potential value of this genetic reservoir is immense."
>
> - The Global 2000 Report to President (1980).

Tropical forests are some of the richest store-houses of genetic resources. We still know very little about the lower plants and animals in them. Of the now known flowering plants over half are in the tropics and about 35,000 of them are in South and South-east Asia. These are not evenly spread but show varying patterns of distribution.

Sri Lanka, even though it is a relatively small island, has as a result of its location, varied topography and climate, and the corresponding diversity of habitats, a very rich and interesting flora. Professor C.C.C.J. van Steenis once referred to the island as having "the Indo-malaysian flora in a nutshell". India, with a land area nearly fifty times as large as ours, has about 15,000 species of flowering plants and 600 of ferns and fern allies, (Jain, 1984). The corresponding figures for Sri Lanka are about 3000 and 314, of which over 850 of the former and 57 of the latter are endemic to the island. We also have about 26 endemic genera. Of them Hortonia (Monimiaceae) and Schumacheria (Dilleniaceae) are of very special scientific interest as some plant geographers are of the view that they are probably derived from the original Gondwanaland stock, and are relics of the few vascular plants that survived the passage of the South-Asian Plate northwards to Asia from its original southern location (Raven and Axelrod 1974).

Within the island itself there are several areas with high concentrations of rare and endemic species. These are mainly in the forests of the wet lowlands, the central highlands and some isolated hills and ridges. On the Knuckles Ridge situated to the north-east of Kandy, for example, in a small area of about 150 sq.km. there is a sequence of vegetation types ranging from lowland dry-mixed evergreen forest to extremely wet evergreen montane forest including patches of a unique pigmy forest with small much branched trees seldom exceeding a metre in height. One can get some idea of its enormous floristic wealth when one considers that, though it is still very incompletely botanized, over 100 species of ferns and fern allies have been recorded from it as against 314 for Sri Lanka 600 for India.

Land Areas and Plant Species

	India	Sri Lanka	Knuckles Ridge
Area in sq.km.	3260000	65600	150
Flowering plants	15000	3000	?
Ferns and fern allies	600	314	100

All species have some use. Their extinction is therefore the loss of a resource.

> "The preservation of genetic diversity is both a matter of insurance and investment - necessary to sustain and improve agricultural, forestry, and fisheries production, to keep open future options, as a buffer against harmful environmental change, and as a raw material for much scientific and industrial innovation - and a matter of moral principle" - World Conservation Strategy (1980).

So called "natural disasters" are now occurring at very frequent intervals and cause more and more damage. Floods, droughts, reduced dry-weather flows in rivers and streams, soil salinisation, fertility loss and desertification, forest fires, outbreaks of attacks by pests and pathogens etc. are very often not diseases by themselves. They are generally the symptoms of a deeper disease, the misuse of land and wanton destruction of biological resources.

Droughts, lightning and thunderstorms, predators and pathogens have all been with us throughout the ages. The difference is that the damage now caused is much more severe because we have destroyed the regulatory activities and the checks and balances in nature by extensive deforestations, destruction of species diversity and establishment over vast areas of even-aged monocultures often with ill adapted species and on unsuitable locations.

Genetic diversity in the tropics is now disappearing at an alarming rate. It is said that practically all the lowland forest of the Philippines and Peninsular Malaysia is likely to become logged over by 1990 or earlier; and almost all of Indonesia's lowland forests have been scheduled for timber exploitation by the year 2000 (Lucas and Synge, 1981). With that will disappear a major part of the floristic wealth of the Indo-malayan region.

The outlook for Sri Lanka is almost as gloomy. At the beginning of this century we had about 70 per cent of our land area under forest. By 1956 this had come down to 44 per cent; now it is estimated to be below 24 per cent (i.e. about 1.6 M hectares). A Forestry Master Plan for Sri Lanka prepared by a group of foreign "experts" is now under consideration. This envisages the total clearing of all the dry zone production forests and very heavy exploitation of the accessible areas of the production forests in the moist low country. This plan, if implemented, would ultimately lead to the total destruction of the island's forests and the conversion of a major part of the land area into semi-deserts or wastelands. (Abeywickrama, 1986).

Threatened Species

Plants which are likely to become extinct in the near future either because their numbers have now come down to critically low levels or because their habitats have been damaged or destroyed and drastically reduced are referred to as endangered plants. Those not endangered as yet but are likely to become so if the decline in their numbers continue as at present are called vulnerable. Those restricted to small areas or are thinly scattered over longer areas are termed rare. Species in all three categories are collectively referred to as threatened plants.

With our present limited knowledge of the local flora and its distribution it is not possible to categorise plants into exact groups as has been done in some of the developed countries. Great Britain, with around 1500 native species of which only 15 are endemic, has probably at least 1500 amateur and professional botanists who can identify plants in the field and books and papers on them occupy approximately 30 m of shelving at the Kew Library (Lucas and Synge, 1981). Sri Lanka with double that flora has hardly a dozen such botanists and books and papers on the subject would barely cover a metre of shelf space. It is best for us therefore to keep all plants in the three categories together as threatened plants for the time being.

The estimates of the threatened species in India have sharply risen from a few hundred species to a few thousand species during the last few years. About 15 per cent of the flowering plants, i.e. about 2500 species now fall into one or the other of the categories (Jain, 1984).

In Sri Lanka nearly 16 per cent of the flowering plants and 28 per cent of the ferns and fern allies are affected. About twelve of the endemic genera have threatened species. In all about 480 species of flowering plants and 90 species of ferns and fern allies could be considered as threatened. Some of them may already be extinct; nearly fifty or more of those species have not been collected for about a century (Abeywickrama, 1987). If present trends continue almost all the species referred to above and possibly many more will become extinct in a decade or two.

The main reasons for species loss are:

1. Habitat destruction or disturbance,
2. Selective removal or exploitation,
3. Introductions of alien species, and
4. Pollution.

Forests are the main storehouses of genetic reserves. They once covered practically the whole island but now they have been cleared from over three - quarters of the land area. The clearings are now going on at an accelerated pace.

The forest destruction is often attributed to the rural poor, but the major clearings are made by commercial interests for wood extraction. The villagers generally come in to the secondary jungles developing on these clearings.

During the last few decades a new factor has entered the scene. "Expert" advice and Equipment for forest destruction provided by Foreign Aid are accelerating the clearing process.

A massive woodwork complex was established in the early 1970's at Kosgama, east of Colombo. This was based on grossly exaggerated "expert" advice about wood availabilities in the island. To feed this monster, plans were drawn to exploit timber from Sinharaja forest - the last large extent of rain forest in the lowlands of the island. The efforts of local scientists and conservationists failed to stop the project; they only succeeded in scaling it down to some extent. Two thousand hectares of this priceless heritage were raped between 1972 and 1977. Fortunately H.E. the President, then Prime Minister intervened and ordered the immediate cessation of logging and the area was made a Strict Natural Reserve.

Some idea of the blunder that was made can be gauged from the fact that the island's plywood complexes now established require 113,000 m^3 peeler wood each year. The total annual availability in the island is only 20,000 m^3! (Pushparajah, 1985). The present foreign aided Forestry Master Plan could finish all our forests during the plan period.

Selective removal has endangered some of our most valuable timber trees. Calamander, Diospyros quaesita Thw., the finest of our variegated timbers is now extremely rare. Ebony, satin and other Dry zone timbers are becoming less and less common. Plants of medicinal value and ornamentals are becoming endangered or selectively degraded due to overexploitation. In secondary successions Eupatorium odoratum L., Mikania cordata (Burm.) Rob. etc. often exclude indigenous species. In ponds and waterways Eichhornia crassipes (Mart.) Solms. and Salvinia molesta Mitch., play a similar role. We have nc direct evidence of pollution killing or adversely effecting vascular plant distribution but several plants which were formerly common on land and in water have now become much less common especially in built up areas and plantations.

We still have a major part of the flora that has been recorded from the island, but the numbers of each of several hundred species are small or very small. Some are represented only by a few individuals. In some forests recently sampled 30 to 40 per cent of the component tree species were found with a density of only one individual per hectare (Gunatilleke and Gunatilleke, 1983). Mesua stylosa (Thw.) Kosterm. is known in the wild state only by a single plant, but three more of these are found in the Botanical Gardens, Peradeniya. A few species have apparently disappeared in their original natural habitats and are now know under cultivation or in the Botanic Gardens (Gunatilleke and Wijesundera, 1981).

A determined and concerted plan of action by the State, Conservationists and the Public could even at this late stage save what we still have from extinction. In any such action the endangered endemic genera and species should receive priority. The wides, i.e. the non-endemics, should however not be neglected. Even though they are said to be present in one or more other countries we have no guarantee that they are not endangered there as well.In fact several species considered as threatened in Sri Lanka, e.g. Psilotum nudum (L.) Beauv. and Ophioglossum pendulum l. are listed as threatened in India also (Jain and Sastry, 1980). Secondly all populations of a species are not necessarily genetically uniform. Differences exist to varying degrees of magnitude and the loss of a population in one country would mean the loss of the special genetic characteristics in that population.

Conservation

It is our duty to protect and to hand over to posterity the wealth we have inherited. It is our generation, more than any before us, that has destroyed or endangered most species.Every country should endeavour to conserve the maximum possible diversity of the species in that country.

A species cannot be saved by giving protection to it alone. It can survive only if its environment and its associated species are also protected. In our legislation some plant species are given total protection but this helps little to conserve them. One such plant is Dendrobium macarthiae Thw., popularly referred to as the Wesak orchid. This is an epiphyte on wet lowland forest trees. Removal of the plant is an offence.It is no offence, however, to cut down the host trees or the surrounding trees in the forests. In fact during logging operations many such trees are cut. Removal of the supporting host trees, and changes in microclimate even if they still remain destroys the orchids. Amending legislation to protect the environments have now been suggested.

Conservation is most effective in their own natural environments. The endangered species and their environments should both be protected. For this purpose each country should demarcate within its national boundaries adequate areas of:

a. representative ecosystems in the country, with as much topographical variation as possible in each region.

b. known locations with high concentrations of species, especially endemics.

c. known locations of rare and endangered species.

Such areas should be given total protection preferably with buffer zones around them within which limited socio-economic activities may be allowed under strictly controlled conditions.

This should be supplemented by conservation ex situ in Botanic Gardens, Arboreta, Seed banks etc. In addition the endangered endemics e.g. Kayea stylosa (Thw.) Kosterm. should be propagated by whatever methods possible in large numbers and reintroduced to suitable riches in their original habitats or nearest alternative reserve areas. This is the only way to ensure their continuity.

In Sri Lanka the wet zone forests - lowland and montane - which harbour practically all our endemics and endangered plants now cover only about 3 per cent of the total land area of the island. In addition to protecting these plants they play a major role in soil and water conservation and maintaining essential ecological processes. Even out of this area only about a third or less is still unlogged and totally undisturbed. Every effort should be made to prevent logging and other activities in these areas and to convert them all to strict Reserves.

Under the UNESCO - MAB Programme in Sri Lanka a number of Reserves have been established. These now cover an area of about 127000 hectares. Of them Sinharaja (8900 ha), in the Wet Zone, and Hurulu (55000 ha)in the Dry Zone have been declared as International Biosphere Reserves.

Forests and Culture

Man's civilization began with the development of culture. Culture and Environment are inextricably linked. "For me", says Anil Agarwal, Director of the Center for Science and the Environment in New Delhi, "understanding the subject of Environment has been a long journey into an understanding of my own culture. ... this journey has been full of shocks, of repeated self-recognition of my ignorance of my own culture, of my own people, and of my own land."

The South and South-East Asian Culture is essentially a rural and sylvan culture. Our traditional philosophy enjoined us to respect nature and even to revere it, and to feel our own nature in unity with the nature around us.

"A most wonderful thing we notice in India", says the Bengali Nobel Laureate Rabindranath Tagore, "is that here the forest, not the town, is the fountainhead of all its civilization.

"Wherever in India its earliest and most wonderful manifestations are noticed, we find that men have not come into such close contact as to be rolled or fused into a compact mass. There trees and plants, rivers and lakes, had ample opportunity to live in close relationship with men.

"In these forests, though there was human society, there was enough of open space, of aloofness; there was no jostling. Still the aloofness did not produce inertia in the Indian mind; rather it rendered it all the brighter.

"It is the forest that has nurtured the two great ancient ages of India. The Vaidic and the Buddhist.

"As did the vaidic Rishis, Lord Buddha also showered his teaching in the many woods of India.

"The current of civilization that flowed from its forests inundated the whole of India".

- (Mukerjee 1947).

In pre-colonial times forests were protected by Royal Edicts. Tree felling and use of forest products were strictly controlled. The delicate and fragile ecosystems of the wetter parts of the country were left practically undisturbed.Deforestation and overexploitation began during colonial times. We have continued it with even greater vigour.

Destruction of the forest is not merely a destruction of the fauna and flora. It is a destruction of our life support system and our way of life. It is a destruction of philosophies and concepts we have valued most for over 2000 years.

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Summary of discussion following presentation:

Dr T. Jayasingham: Can and should we protect all species that are rare, vulnerable etc; I think this is an impossible proposition and protection should be area , and not species, oriented.

Dr(Mrs.) C.V.S. Gunatillake: It is also important to consider conservation of the germ plasm of cultivated varieties of plants. Corn germ plasm, for example, comes from small populations in the wild which were conserved.

Prof. B.A. Abeywickrema : Vast areas of paddy lands in Sri Lanka are cultivated with high yielding varieties; several of these areas are now affected by the brown plant-hopper. There are now efforts to develop resistant varieties from smaller populations of wild and native strains;

Philippines- Mr Jose O. Sargento: What specific measures have you taken for protecting endangered plants?

Prof. B.A. Abeywickrema : There are several categories of protected areas which are important repositories of such plants. The MAB reserves, the two which are part of the international network (Sinharaja and Hurulu) as well as others, though relatively small in size are important areas for plant conservation.

Dr Meher Homji: It is perhaps useful to remind ourselves here that one of the major threats facing several rare species of plants is over-collectIon by botanists.

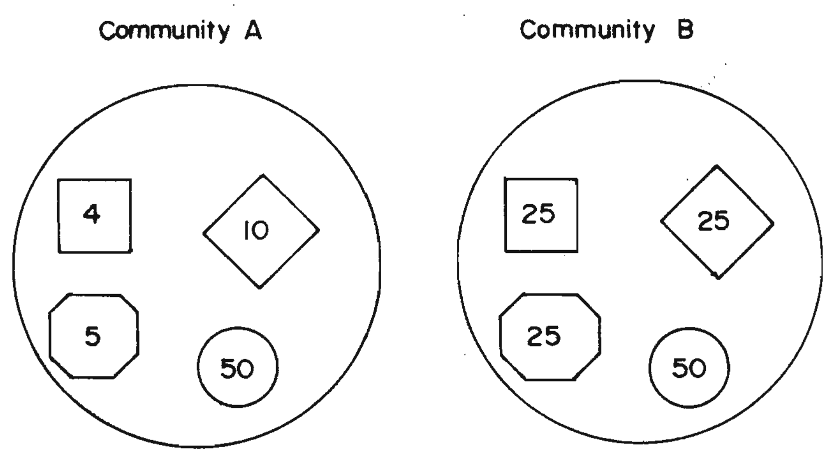
Dr(Mrs.) D. Nugegoda: I would also like to draw your attention to the problem of human population growth which has direct influence on the areas we can set aside for conservation but for some reason or the other seem to be less frequently spoken about than in the past.

ANIMAL DIVERSITY IN TROPICAL FORESTS

S. W. KOTAGAMA

Animal diversity is defined generally as the "Total number of species, usually of a specific taxon inhabiting a particular area". This is also often referred to as the SPECIES RICHNESS, and even equated to represent the species density too. However, the direct count of species does not give us the true picture of diversity. To explain this let us consider the hypothetical situation of two communities A and B (Figure 1). Both communities have the same number of species - Four (04). But the number of individuals of each species in the two communities differ, and yet the total number of individuals is the same. Such differences can mean big differences in the features of the community. Such differences are referred to as the ABUNDANCE, or RELATIVE ABUNDANCE or sometimes the RELATIVE IMPORTANCE VALUE. Measuring the abundance of an animal population is a very difficult task. Often this depends upon such factors as sample size and statistical approach, etc.

FIG. I - NUMBER OF SPECIES AND POPULATION OF EACH IN TWO HYPOTHETICAL COMMUNITIES A AND B

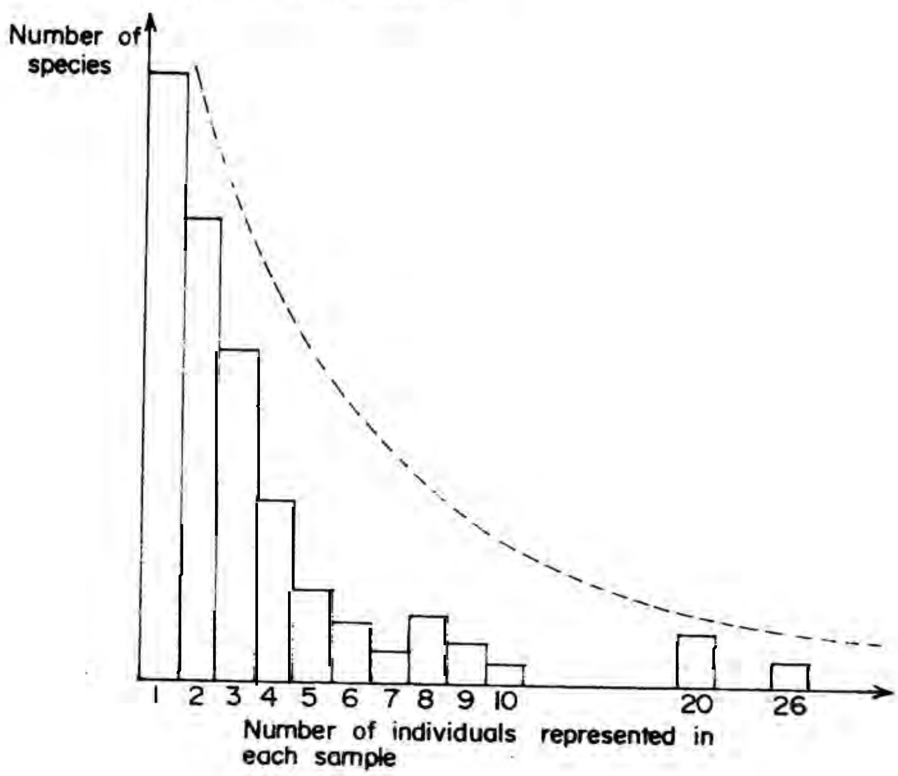


Density of species	4	4
Abundance of each species	vary	vary

Therefore, in order that the species diversity reflect both the number of different species, and the relative abundance of each species in one value, numerous methods have been employed, which are mostly based on statistical methods.

(1) Information collected on species, relative abundance is fitted to existing statistical distributions. For example Fisher, Cobert & Williams (1943) derived the - INDEX OF DIVERSITY by plotting the number of individuals represented in a sample against number of species. This relationship always gives the so called Hollow Curve (Fig. 2), where a few specimens will have large number of individuals while many will have less. This relationship was shown by the following equation: $S = \quad Log_e (1 + \underline{N})$, where is the Index of Diversity.

FIG. 2 - STANDARD HOLLOW CURVE
(Hypothetical numbers)



(2) In this method the relative abundance is combined with the number of species to obtain a measure called the HETEROGENEITY of the species.

One method is based on the information theory. This tries to determine "How difficult it would be to predict correctly, the species of the next individual collected". Using this idea/s as the basis, Shanon-Wiener developed their diversity index which is widely used to explain species diversity.

Another commonly used method is that based on probability, where the question "What is the probability that two specimens picked at random in a community of infinite size are the same species" is used. Many different indicies have been developed around this, and the most widely used is the Simpson's Index.

However, for most instances, for practical reasons, the species richness is considered fairly adequate as reflecting the species diversity. This is especially important as the diversity indices derived are difficult to understand without adequate background knowledge about the derivation of these indices, as they attempt to condense a lot of information into one set of figures. To understand the basic logic behind the usage, let us compare a paddy field and a tropical rainforest. There is no question that the number of species in the rainforest is high. This is reflected in the diversity index by a high value, which means that it is difficult to predict the species of a randomly chosen individual. While, the index of the paddy field will be low, as the next species can be predicted accurately. Thus it means that the species diversity is high when it is difficult to predict a species of a randomly chosen individual, and low when an accurate prediction can be made.

Now that we have understood very briefly the common usage of the diversity indices, let us reflect on the HUMID TROPICAL FOREST. It is a well known and proven fact that the rainforests along the equator have a very high diversity in almost all organisms except for a few invertebrates.

The question is why, or how this has come about. Many theories have been put forward to explain this. Figure 3 shows the complicated interaction of various factors, which are supposed to influence the diversity, while Table 1 summarises the same theories proposed. No one theory probably explains the actual reason, and it is likely that all act to produce the diversity observed.

FIG. 3 - SIMPLE DIAGRAM SHOWING THE POSSIBLE INTERACTIONS THAT INCREASE DIVERSITY

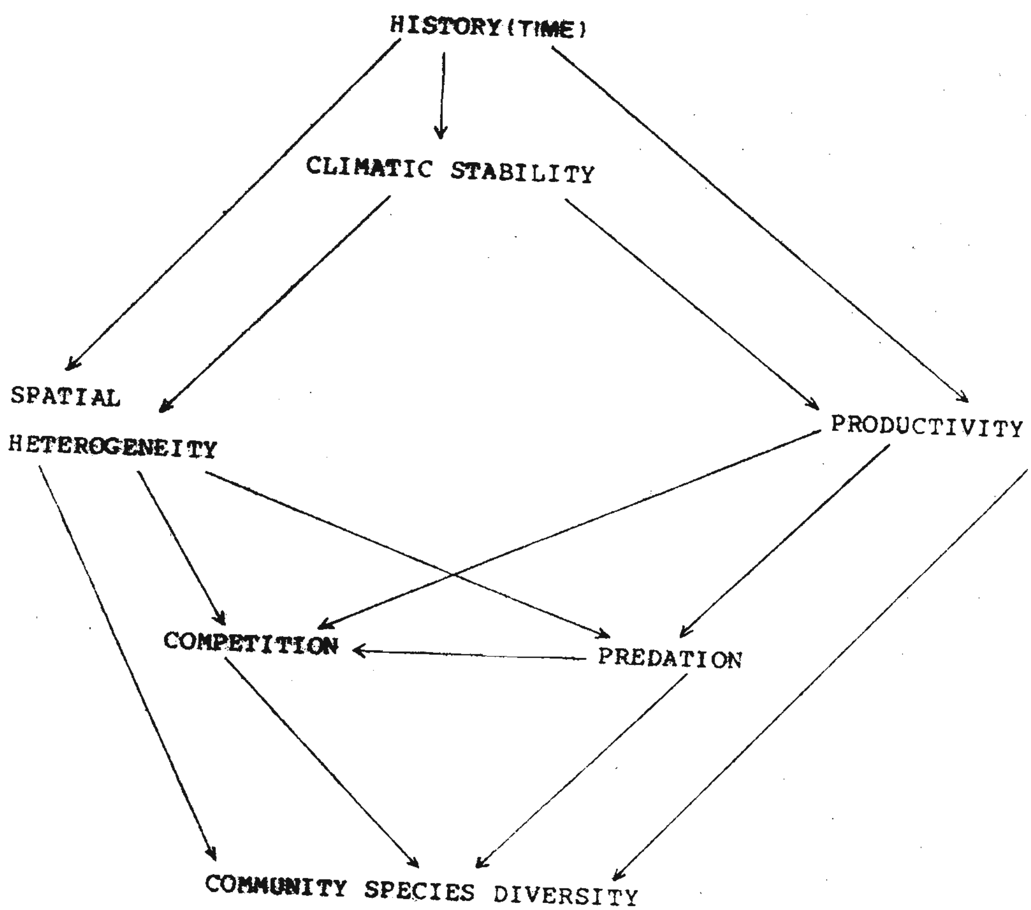


TABLE 1

SUMMARY OF THEORIES PROPOSED TO EXPLAIN HIGH SPECIES DIVERSITY IN THE TROPICS

	Theory	Summary
1.	EVOLUTIONARY TIME	Diversity increases with the age of the community.
2.	ECOLOGICAL TIME	Diversity increases in ecological systems as the time permits new animals to disperse to it.
3.	CLIMATIC STABILITY	Stable climates, require organisms to adjust to small fluctuations, thereby permitting larger number of niches and increase diversity.
4.	CLIMATIC PREDICTABILITY	Though variable, the changes can be predicted, which permit adaptation to the condition and hence increase diversity.
5.	SPATIAL HETEROGENEITY	Tropical forest is structurally more complex.
6.	PRODUCTIVITY	High productivity promotes high diversity because of more available food.
7.	STABILITY OF PRIMARY PRODUCTION	Increased food availability in a predictable pattern.
8.	COMPETITION	Increased competition reduces niche breadth thus increasing species diversity.
9.	RAREACTION	Continuous removal of organisms from the system promotes more species - Unsaturated at all times.
10.	PREDATION	Predators act as agents by selective or random removal of organisms, and thus promoting high species diversity.

Of these ideas, **SPATIAL HETEROGENEITY** has been the most widely used by many authors to explain the high species diversity in the tropics. Following this idea is that, large number of niches are present in the tropics and as such a large number of species. The concept of niche itself is difficult to comprehend. Hutchionson's definition of it as a "n-dimensional hypervolume" has over the years received acceptance, and according to this one could imagine, the vast potential for numerous niches. Accordingly, with large number of niches possible the diversity is high.

Communities can differ in species diversity by :
1. the communities having different niches,
2. the organisms occupying small niches,
3. the niches overlapping tighter,
and 4. by the unsaturated nature in which niches may be occupied.

With this theoretical background on species diversity, I will use the Sri Lanka situation to discuss the diversity in the Tropical rainforest in comparison to other vegetation types.

Among the vertebrate fauna, which has about 710 species, the numbers in the various classes are given in Table 2. It is evident that there is low endemicity among the highly mobile fauna, eg: Birds, while the Amphibia and Reptiles show high endemicity. The distribution

TABLE 2

NUMBER OF SPECIES OF VERTEBRATES AND THE ENDEMIC SPECIES OF SRI LANKA

Phylum	Number of species	Number of Endemic Species	Percentage Endemism
PISCES (Fishes)	64	17	27
AMPHIBIA (Frogs & Toads)	38	19	51
REPTILIA (Reptiles)	139	73	51
AVES (Birds)	384	20	08
MAMMALS (Mammals)	85	12	12

of these endemic species with respect to the climatic zones of the country (Fig. 4) is given in Table 3. It is very clear that the highest number of endemic species are found in the Low Country Wet Zone, where the rain forests are found.

FIG. 4 - MAJOR CLIMATIC ZONES OF SRI LANKA

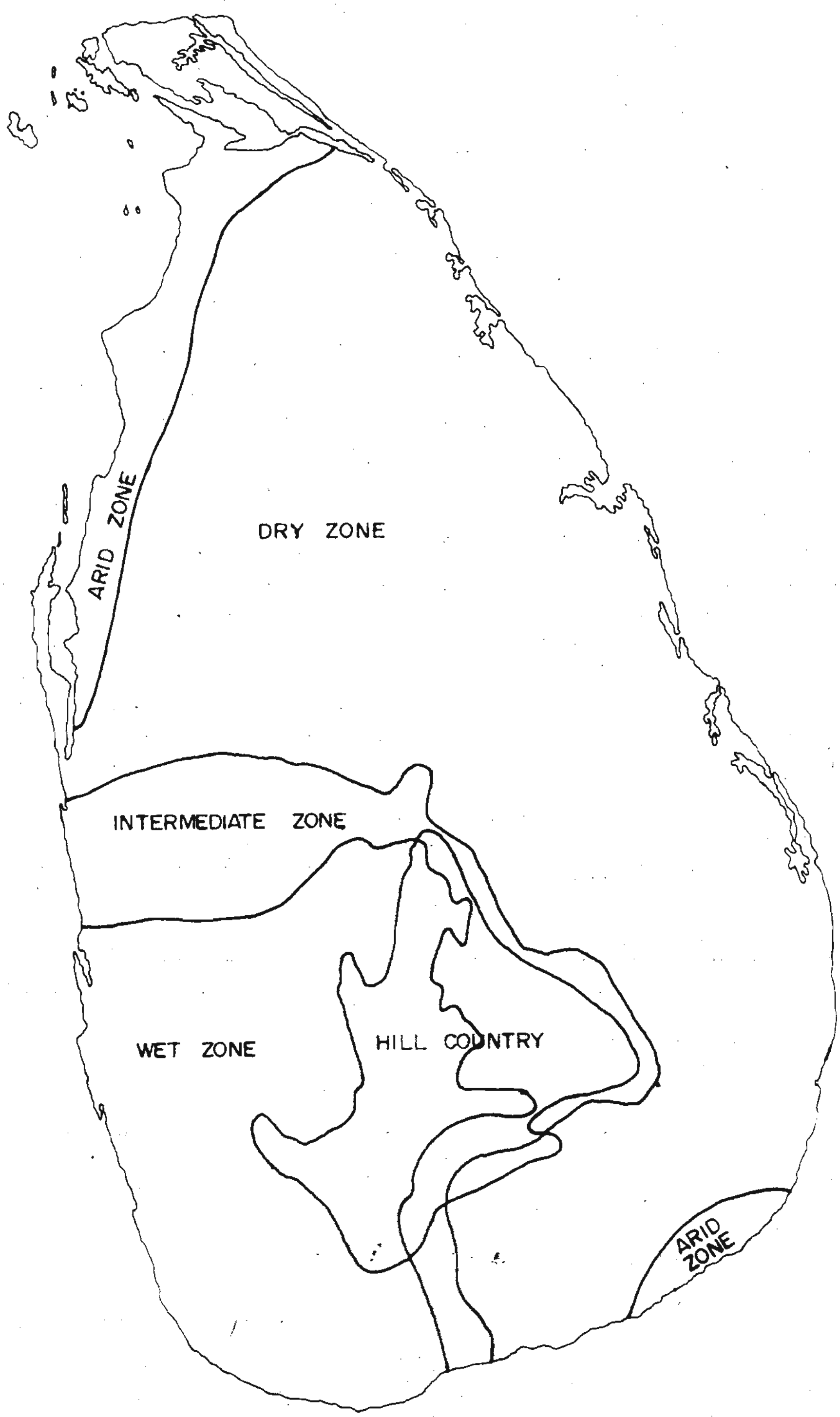


TABLE 3

DISTRIBUTION OF ENDEMIC VERTEBRATE SPECIES IN THE MAIN TOPOGRAPHIC & CLIMATIC ZONES

	Low Country Wet Zone	HillCountry	Low country Dry Zone	Islandwide
FISHES	15	04	03	02
AMPHIBIA	09	12	03	-
REPTILES	51	30	32	02
BIRDS	13	14	04	03
MAMMALS	06	09	03	02
Total	94	69	45	09

Therefore, within Sri Lanka the diversity of the fauna is highest in tropical rain forest, next in montane forests, followed by the dry evergreen forests.

From the work that I have done, next I will consider the birds to show the nature of diversity in the different habitats, Janson et al (1986) showed that the diversity of bird fauna in the dry zone was high among the Dammana - Grassland habitat, compared to the dry evergreen forests, in the same area. This Dammana-Grassland is a mosaic of short forest and open grassland, compared to the evergreen forest, and the numbers of birds probably indicate the diverse nature of Dammana-Grasslands (Table 4). A similar study comparing the

TABLE 04

SPECIES DIVERSITY OF BIRDS IN TWO HABITAT TYPES IN THE DRY ZONE

Jansen, Kotagama, Subasinghe & Karunaratne (1986)

Habitat	Number of Exclusive Species	Common Species	Total number for each habitat
Dammana grassland	21		81(2)*
Dry Zone Evergreen Forest	10	60(2)*	70(2)*

*Endemic species.

bird fauna in 3 different forest habitats in the Ruhuna National Park is given in Table 5. The three habitats differ in its two major aspects, which are:

(1) The presence of an aquatic system in the habitat tank and gallery forest, and
(2) The difference in the species composition and structure of the forest itself.

TABLE 5

SPECIES DIVERSITY OF BIRDS IN THREE HABITATS IN THE YALA NATIONAL PARK

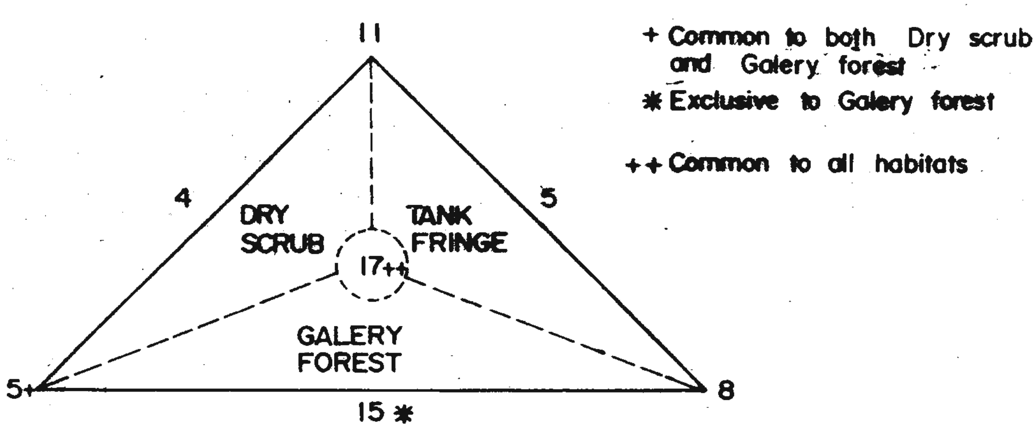
Watson, Kotagama and Dunnet (Aberdeen - Colombo 1977).

Habitat	Number of Species
Dry Shrub	37
Tank fringe	41
Gallery Forest	49

The gallery forest is the tallest and richest in species, while the dry scrubs is the shortest and poorest in species.

These differences, are reflected in the species richness of birds. The more exclusive birds indicate this much more as shown in Figure (5).

FIG. 5 - SPECIES (NUMBER) RELATIONSHIP AMONG HABITATS AT THE RUHUNA NATIONAL PARK
(Watson, Kotagama, Dunnet - 1977)



The final example, is that from the Sinharaja Rainforest area. A comparison of the species distribution sampled with a bias to forest habitats, in the western section of the Forest at Kudawa (Fig. 6). The results are given in Table 6. The forest has the highest number of species, especially with respect to endemic species. The difference is within a distance of about 4 - 5 miles, which indicate very clearly that species diversity is very dependant upon the extensiveness of the study area, the habitat diversity of the study area, and the length of the study period and on seasons. It is therefore meaningless to give the species diversity without giving the specific area, time and duration of the study.

TABLE 6

SPECIES DIVERSITY OF BIRDS AT THREE HABITAT TYPES AT THE SINHARAJA MAB RESERVE

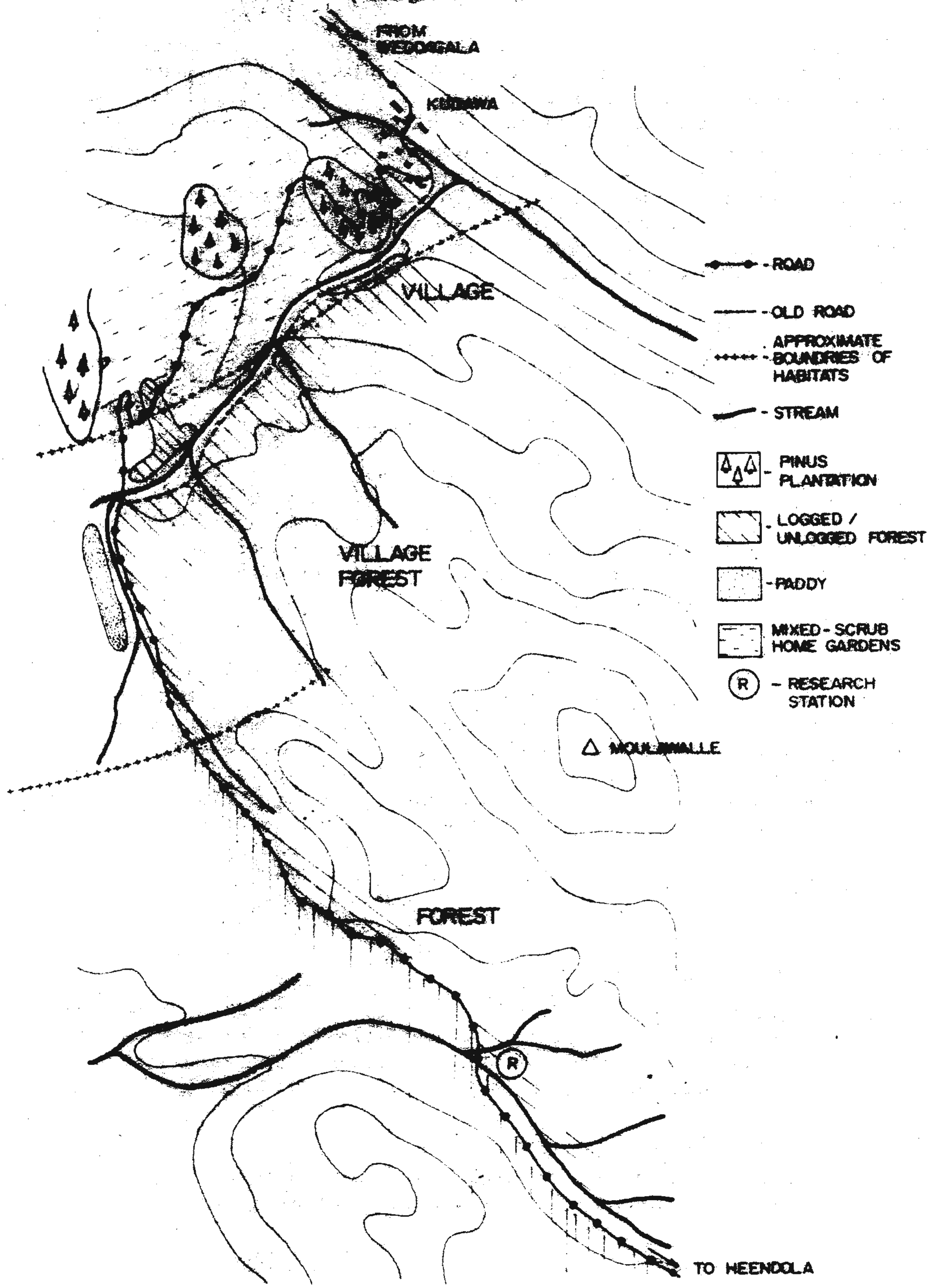
Kotagama and Thambiah (1986)

Habitat	Number of Species	Number of Endemic
Forest	60	16
Village-Forest	46	03
Village	12	-

How does this compare with use of indexes. Studies done on the effect of logging on small mammals at Sinharaja is given in Table 7. Three sets of experiments in unlogged, logged and selected special habitats using the line transect (Set 1), 100m x 100m quadrats (set 2) and 25m x 25m quadrats (set 3) were done. Small mammals were trapped using Sherman's traps and burnt coconut as bait. The Shanon-Wiener index, H' max and Equitability (J) index was calculated for each experiment separately. The index varied between 1 - highly diverse, and 0-low diversity, while J also varied between

1 - where all numbers are equally distributed, to 0-where some are dominant. Accordingly, in the first set, for the logged area (Damminigala) it gives a high diversity and equally well distributed faunal diversity; compared to the unlogged area (Watturawa) which has a low diversity and the species are also not equally distributed.

FIG.8 - HABITAT TYPES OF THE BIRD STUDY AT SINHARAJA
(Kotagama & Thambiah 1986)



The other indexes in the other experiments give similar interpretations, but this does not complete the diversity, because a closer examination of the species present and their numbers in each study plot is definitely different. Therefore, neither the simple species richness, nor the index seem to give us the true picture of animal diversity in a given habitat. However, these methods help us towards making comparisons, and generalisations etc., that help in the study of habitats. The species must also be considered. When one compares the unlogged areas with logged areas the following may be noticed from the data:

1. Except in the first set (live transect), the species Coelomys mayori is less in the unlogged plots.
2. The number of endemic species (marked with asterix) is less in the logged areas.
3. Logged areas record more commensal species (+).

This means that, generally logging decreases, the number of species of endemics, increases the commensal species, but Coelomys mayori an endemic species increases in numbers probably because this species prefers thicket bush/habitats (Phillips 1985, - common name Bush rat) which is prevelent in logged areas and not in unlogged areas. Therefore, habitat preference must also be considered if the species diversity is to be properly interpreted.

With this background to the complex interpretation of species diversity, let us ask the question, of what use is species diversity. The most practical use is in conservation. If it is known that a given habitat has very high species diversity, then whether one needs to conserve this species diversity or a single species could be determined, and accordingly the management strategy could be decided upon. But to make this decision, there are a number of other factors that need to be considered. These can be very broadly grouped under two categories (i) Suitability and (ii) Desirability.

(i) Suitability for selecting a species or species depend on:

(a) Site tenacity -

Which is the predictability of the species at a given site. Will it occur regularly in the given site, or seasonally, like migrant species which come back to the same site every season, or are they irregular and randomly occuring.

(b) Mobility of the species -

How mobile is the species; does this mobility vary seasonally - like migrant species. Species that are highly mobile like birds will be less suitable compared to amphibians, which are less mobile.

(c) Area, size needs of the species -
Species requiring large areas are going to create more problems hence are less suitable, eg: the elephant, while certain birds though mobile need small areas therefore more suitable. This is a very crucial criterion and many conservation problems are based around this factor.

(d) Spatial distribution -

Is the species concerned distributed as a single population in a single place or dispersed over a large area as smaller units, or is it distributed over a large area as small or large population? Any combination of these distribution patterns are possible and this needs to be considered in the suitability criteria.

Even if the species is/are suitable, it must also be desirable; i.e. Can you do it ! This second factor is determined by :

(a) Relative scarcity;

Widely separated small population, or a restricted population to a given place or a large population in a single place is considered as scarce ; as these will restrict reproductive capability and thereby result in population degeneration.

(b) Changes of status over the years;

Species whose population has decreased over the years will be desirable, (may even be too late) than a stable population - i.e. the status of the population over a period of time.

(c) Endemicity;

Endemic species, will be definitely more desirable, because of its localized nature in the region or world. Non endemics though decreasing in a given place, could be replaced by others from another place.

(d) Peripherality;

Are the species occupying ectone systems (peripheral areas habitats) or are they in the core of an ecosystem. For management this is important, as any change will throw the species into a more critical state or make it recover.

(e) Habitat specialisation;
Species that are highly specialised to a given habitat, needs much care, and needs to be considered differently from generalists.

(f) Habitat scarcity ;

How scarce is the habitat itself, apart from the species.

(g) Susceptibility to immediate interference ;

Often conservation needs some change to be made, and it is important to know how these changes will affect the species or how susceptible it will be, or can changes be made. We have seen that small changes in the forest can bring about radical changes in the species composition at Sinharaja. Similarly even the presence of humans itself can sometimes make a big difference.

(h) Other unusual or unique scientfic values which would increase the conservation value such as medicinal value etc.
and (i) Aesthetic and other 'use' which often is difficult to determine at present.

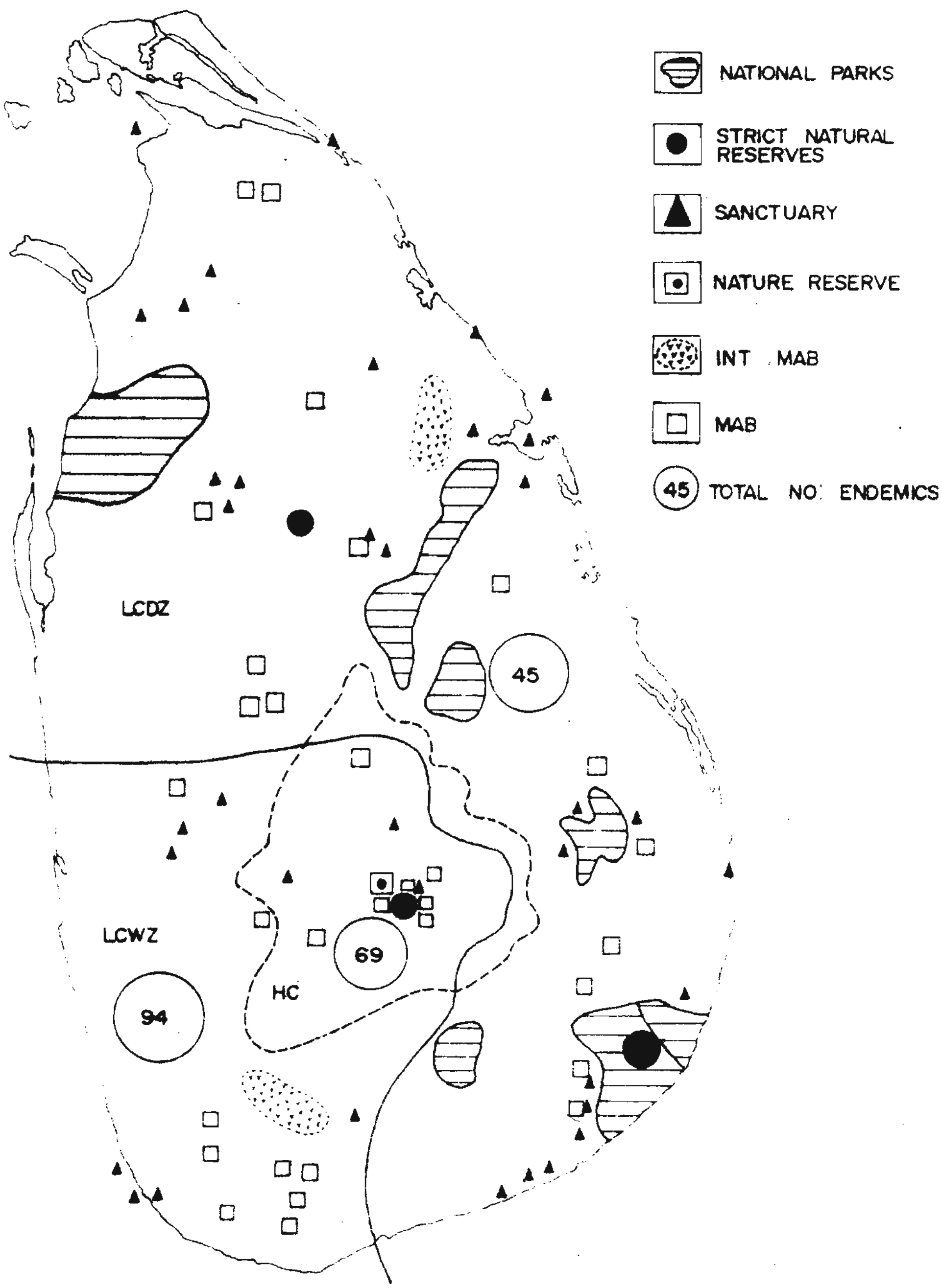
The next step is the site selection on the same basis. The area - (large or small) ;for high species diversity it is generally accepted that larger the size the better it is, while for specialised conditions it may be adequate in small areas. Again variety of habitats may mean a number of different sites of varying sizes. Thus this becomes a very difficult decision to make, unless the right question is asked and addressed.

Species richness or diversity, variety of species, the vulnerability of the species, educational, scientific value and finally the most important factor is management when considering the problem of conservation of species. This last factor is I think the most important, because even if all the factors show that a species needs to be protected, if the management is not possible all efforts will be futile.

With this background of species diversity, and the criteria for selecting species for conservation let us consider whether we in Sri Lanka are doing the right thing. Fig. 07 shows the protected areas in Sri Lanka. In terms of diversity as mentioned before the most critical area is the Hill country and the Wet Zone. But yet closer examination of the Figure 07 will show that there are very little completely protected areas in the Hill country and Wet Zone. Of the protected areas, Strict Nature Reserves and National Parks have total protection, while others have different status, where some activities are permitted.

Therefore, in the past when protected areas were declared, it appears that the criteria that was mentioned had not been considered. It appears that protecting species diversity was not the priority. Historically this is true. The main and oldest National Parks of today - Yala and Wilpattu were declared not to conserve any particular species or habitat but as 'Game Reserves' permitting 'Game shooting Subsequent National Parks - Gal-Oya, Udawalawe, Maduru Oya etc.,

FIG. 7 - PROTECTED AREAS IN SRI LANKA AND NUMBER OF ENDEMIC VERTEBRATE SPECIES IN EACH ZONE. (Protected areas are those declared under the Flora & Fauna protection ordinance - Dept. of wild life conservation)



were declared primarily for catchment areas, secondarily areas for displaced animals mainly elephant. It was only Ritigala, Hakgala and Wasgomuwa that was considered as 'special' sites in terms of flora, and made Strict Natural Reserves, while the Horton Plains Nature Reserve and the Peak Wilderness Sanctuary were declared for their habitat uniqueness. But these do not have the legal protection national parks have. Therefore, we in Sri Lanka have failed upto now to protect correctly the species diversity and the unique flora and fauna of our country completely. However, we hope that with the new thinking of the importance of diversity, endemicity etc., adequate Natural habitats will receive total protection in the future. The first in this direction will be Sinharaja, if and when it becomes the National Heritage Reserve. It must be reminded here that it is a very critical situation as the amount of natural forest cover in the most diverse habitats is only about 3% of the total country.

Acknowledgement

I wish to thank the organisers of this Symposium for granting me time to read this paper. To Ms. N.D. de Zoysa and Mr Malcom Janson for the useful comments.

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Summary of discussion following presentation

Indonesia - Mr Achmad Abdullah: In your analysis of data you have used species diversity among mammals and birds as the only indicators. Do you or are there information on other vertebrate groups and on invertebrates? What kind of method do you use in your data collection in respect of mammals?

Dr S. Kotagama: For mammals and birds line transects were used. Data on other animal groups are being collected but are not sufficient for analysis as in the case of birds and mammals.

Bangladesh - Mr M. Kalimuddin Bhuiyan: What kind of protective measures are being taken for the conservation of the species you mentioned? Has captive breeding been successful in any species?

Dr S. Kotagama: Conservation has been mainly focussed on in-situ efforts in variety of protected area types. We are now encouraging the setting up of core protected zones in multiple use reserves. It is also possible that manipulation of habitats for the conservation of one or a group of species could be attempted in any of these reserves. As far as captive breeding is concerned, our experience is still in the early stages though recent success with the elephant has been encouraging.

Philippines - Mr Jose O. Sargento: In Philippines poaching has been a major problem causing depletion in animal diversity but protected areas such as the Palawan reserve are aiding in reversing this trend.

VEGETATION TYPES OF PENINSULAR INDIA IN RELATION TO ENVIRONMENTAL CONDITIONS

V.M. MEHER-HOMJI

Abstract

Previous attempts to divide India into biogeographic regions were made on the basis of distribution of general flora and fauna or of certain taxa, migration of plants or yet endemics. The latter are very often rare plants of no particular significance in constitution of vegetational landscapes. The biogeographic classification proposed here is based on the vegetation types recognised in the vegetation maps of the ICAR - French Institute, Pondicherry. As these types show close links with the climatic and edaphic factors, the new classification proposed here acquires a multi-disciplinary character encompassing physiognomic, floristic, bioclimatic and edaphic criteria.

The 14 biogeographic regions are (1) Evergreen forests of Kerala - W. Karnataka, (2) Moist desiduous teak zone forming an ecotone between evergreen forests and dry teak zone, (3) Teak zone, (4) Miscellaneous deciduous forest zone, (5) Sal zone, (6) *Hardwickia* zone, (7) *Albigia amara* zone of Coromandel - Circar where the rainfall regime is dissymetric, (8) *Anogeissus pendula* semi-arid zone of E. Rajasthan, (9) Thorn forests of semi-arid Deccan, (10) Semi-arid Deccan - N. Gujarat, (11) Indian desert, (12) N.W. Himalaya, (13) E. Himalaya - N.E. India, (14) Andaman - Nicobar.

The vegetation types within each of these biogeographic regions have been discussed, justifying need of additional divisions in Chatterjee's (1939) classification.

Introduction

The Indian region is a well marked geographic assemblage, limited by effective barriers like the seas, the lofty Himalayan range and the Thar desert. The variety of its climates and its geographic position at the junction of important floristic currents have permitted the penetration of the Malesian, African, Temperate, Mediterranean and Chinese floristic elements.

The inventory of the Indian flora is yet incomplete but so far over 21,000 species of higher plants have been known from the Indian region; this number represents more than one-tenth of the total species in the world (Janaki Ammal, 1958). Besides the higher plants, there are more than 600 species of Pteridophytes.

Of about 11, 125 species of Dicotyledons, 61.5 per cent are endemic, confined exclusively to the sub-continent i.e. the erstwhile territory of British India, excluding Sri Lanka. However, these endemic species are not uniformly distributed throughout the sub-continent. The share of the Himalayas of the endemic dicots is 29 per cent, that of Peninsular India, south of the tropic of Cancer, is 18 and of Burma 10 per cent. Five per cent of the dicotyledonous endemics are confined to the whole of the sub-continent. The figures for endemic monocotyledons are 1000 species in the Himalayas and 500 in South India (Chatterjee, 1939, 1962).

The natural barriers have helped in the development of a large number of species which are either localised in the Himalayas or in the Peninsular India. The intervening area of the Indo-Gangetic plain, either because of its dry climate (in the Thar) or due to high population pressure and uniform climatic conditions (in the Gangetic valley) is poor in endemic species.

There have been several attempts to divide India into biogeographic regions according to the distribution of certain taxa, e.g. Cyperaceae by Clarke (1898), general flora by Hooker (1906) and Chatterjee (1939), migration of plants by Razi (1955) and animal distribution by Blanford.

Blasco (1979) designated the 8 divisions of Chatterjee as the ecofloristic zones enumerating the bioclimatic criteria, vegetation types and floristic peculiarities of each of these, but above all emphasising the characteristic flora (endemic species) of each zone (Table1). However, the endemics are very often rare plants of no particular significance in constituting the vegetational landscapes.

The Biogeographic Regions

In the present work, we have derived the phytogeographic regions mainly from the distribution of the vegetation types which themselves show close links with the climatic and edaphic factors. Groups of allied vegetation types constitute a phytogeographic region.

The vegetation types are determined by several environmental (climatic, edaphic, biotic) factors. Among the climatic parameters, those of prime importance are the rainfall amount, the length of its distribution in the course of the year (in other words, number of dry months), the regime of rains, i.e. the season of occurrence of rainfall, the mean temperature of the coldest month, and other secondary factors like dew, fog, relative humidity.

The vegetation types used in the present work are those shown in the 12 sheets of vegetation maps of Peninsular India published by the Indian Council of Agricultural Research in collaboration with the French Institute, Pondicherry. For the Himalayan region and Andaman-Nicobar, the types used are those of Champion and Seth (1968), Schweinfurth (1957) and National Atlas of India.

The science of phytocoenology is based on the principle that the plant groups are the best indicators of environmental conditions. If the species composition changes, it is because of a change in environmental factors, either climatic, edaphic or biotic. This fact makes the vegetation types the best indicators of ecological factors and in turn of biogeographic regions. Animals on the other hand are subject to migration and movements. Besides, their ability to seek out or build convenient niches makes them escape the extremes of the weather phenomena and hence they are not as suitable as vegetation for the demarcation of the biogeographic regions.

The equivalence of the 14 biogeographic regions proposed here with the earlier botanical provinces of Clarke (1898), Hooker (1906), Chatterjee (1939) and Razi (1955) is given in Table 2.

I. Biogeographic Region : Wet evergreen forests of Kerala and Western Karnataka, including some pockets of Western Tamil Nadu

This biogeographic region comprises five vegetation types :

(1) *Cullenia*-*Mesua*-*Palaquium* (from southern Kerala up to the Wynaad plateau Plateau).
(2) *Dipterocarpus*-*Mesua*-*Palaquium* (from Coorg up to Honavar).
(3) *Persea*-*Holigarna*-*Diospyros* (Parts of Shimoga, N. Kanara, Belgaum districts and of Goa).
(4) Montane shola (Hilltops of the Nilgiri, Palni, Anaimalai, Baba Budarigiri ranges above 1500 m).
(5) *Memecylon*-*Syzygium*-*Actinedaphne* (Above 700 m in North Kanara, Belgaum, Satara district).
(6) *Bridelia*-*Syzygium*-*Ficus*-*Terminalia* (Upper slopes above 600 m of the Western Ghats in Maharashtra, also at Mt. Abu and Ranthambor in Sawai Madhopur district).

All of these are evergreen except the last one which is semi-evergreen. The rainfall in this tract is generally very high with certain patches like Agumbe receiving over 7000 mm per annum. The length of the dry season increases from south to north along the Western Ghats. On an average it is of 2 months duratiion in southern Kerala but gradually increases northwards so that in the Sahyadri, i.e. the Maharashtra part of the Western Ghats, the dryness lasts for 8 months though the rainfall may be over 5000 mm.

The vegetation types within this biogeographic region are linked either to the variations in the length of the dry season or to the temperature gradients according to elevation. Thus the *Cullenia* type and the Montane shola occur where the average drynese is of less than 4 months, the former in the low elevation zone where the mean of the coldest month is more than 20°C and the latter in high elevation belt above 1500 m where the mean temperature of the coldest month may descend down to 10° C. *Dipterocarpus indicus* type is linked to dryness of 4 to 5 months, being replaced by the Persea-Holigarna-Diospyros type where dryness is of 6 months duration. Hemecylon - Sysygium-Actinodaphne sub-montane evergreen low forest is confined to the high rainfall zone of W. Ghats in northern Karnataka and Maharashtra with dryness of 6-7 months and mean temperature of the coldest month 15 to 20°C. Finally, Aridelia-Syzygium-Ficus-Terminalia is also a low montane type with dryness of 7 to 8 months and mean temperature of the coldest month around 20°C.

Inspite of wealth of information available on soils of cultivated lands, not much work has been done on soils under forests. These have been lumped together under one category viz. "Forest Soils" in soil-classifications derived for agricultural purposes. This biogeographic region is characterised by lateritic or ferrallitic soils.

The montane shola vegetation of the south Indian hills like the Palnis, Nilgiris and Anaimalai would need a particular mention because of several peculiarities. The first one is climatic. Though the average dry season is 0 to 1 month, in over 75% years there is a real dryness of 1 to 4 months, the actual spell of drought may last 30 to 60 days at Kodaikanal and upto 80 days at Octacamund (Logris and Blasco 1969). Mean temperature of the coldest month may reach 10°C but on winter nights, the minimum temperature may descend as low as - 9°C in the open grasslands; however, at the same time, the temperature under the forest cover remains above 0°C (Logris and Blasco l.c.). The climate of these hill-tops is often referred to as of temperate type but in view of peculiar temperature and photoperiodic regimes which differ considerably from the temperate climate, it is best to term this climate as of tropical montane type.

Plantations of tea and coffee dominate the landscape of the W. Ghats in South India from about 1000 to 1500 m and rubber below 1000 m (Dupuis 1957). Calceolaria mexicana is a very typical weed of tea and coffee plantations.

From vegetation point of view, the montane forests are restricted to the valleys and depressions where the moisture content is higher. Other sites carry grassy vegetation, the ligneous elements of which have their distribution range extending to the higher altitudes in the Himalayas or in the temperate regions. Whereas the winter cold proves deleterious to the regeneration of the forest species of tropical stock in the open areas, the woody species of the grasslands survive the low temperature. They are also heliophilous and some like Rhododendron are prophytes. This is one more reason for referring to the climate as of tropical montane type.

The prominence of Rhododendron and few other Himalayan plants like Gaultheria fragrantissima, Berberis tinctoria, Mahonia, Eurya japonica in the open landscape of the Southern hills prompted some authors to emphasise, rather enthustiastically, a link between the Himalayas and these hills (See Mukherjee 1935; Biswas 1949; Razi, 1955, 1955-56). Gupta (1962) went to the extent of including even the introduced species, besides the spontaneous ones and those occurring all over India and sometimes in Asia too in the list of 169 species cited as common to those two hilly areas. Blasco (1971), on the other hand, pointed out the rather strong individuality of these sothern hill-tops flora, the affinity with the Himalayan species being not so marked.

Meher-Homji (1967) recognised two eco-phytogeographic groups in the ligneous montane species occurring above an elevation of 1500 m on the S. Indian hills : (1) species of extra-tropical (temperate or Himalayan) stock like Rhododendron, Mahonia, Gaultheria occupying open areas like shrub-savanna or margins of sholas but never occurring in the forest; (2) species of tropical stock forming the montane forest proper. These latter species as a rule belong to ancient families and are delicate. Their regeneration is very difficult in open areas subject to winter frost, droughts and fire. Quite some species may have disappeared from the Palni, Nilgiri and Anaimalai hills. The regeneration of the montane forest, once disturbed, is practically impossible.

Amongst the genera of the montane (Shola) forests of the South Indian hills also occurring in the Himalayas, those in which the species are different in these two ranges are Beilschmiedia, Bhesa, Cinnamomum, Euonymus, Ilex, Lasianthus, Linociera, Microtropis, Psychotria, Sidoroxylon, Vaccinium, In case of Pygeum even the species of the hilly regions of the eastern part of the Peninsula are different from those of the hills of S. India. None of the species of Apodytes, Lssiosiphon, Happis, and Helicope occurs in the Himalayas.

The following genera have one link species between the Himalayas and the Southerm hills and Sri Lanka highlands. Furthermore, the link species also occurs in the hilly regions of E. India : Ardisia solanacea, Glochidion, velutimum, Heliosma simplifolia, Hicholia champaca, Phoebe lanceolata, Photinia noteniana, Pittosporum floribundum, Schefflera venulosa, Symplocoa goicata.

In case of Elgeocarpus ganitrus, Evodia lumi-ankanda, Glochidion heyneanum, Litsaea zeylanica, l. sebifera, Photinia notentana the link species does not occur in E. India.

The fact that as a rule not more than one species in a genus is common between the Himalayas and the Southern hills may suggest slow rate of migration which in turn seems to favour speciation. The rate of endemism may said to be relatively high in the South Indian montane forest flora as at the most only one species is common in the majority of the genera between these hills and the Himalayas.

The absence of the Himalayan conifers, members of Fagaceae, Betulaceae, Hamamelidaceas, etc from the S. Indian hill-tops may be explained by the differences in the temperature and photoperiod regimes due to the latitude factor. Quercus incana and Pinus roxburghii planted in the gardens of Kodai kanal do not produce viable seeds, nor have they shown the least tendency to become naturalised? Their absence may also be explained by the dry nature of the climate during the Pleistocene glaciations which did not permit these relatively humid elements to migrate southwards as it did permit the hardy Rhododendron, Mahonia, Gaultheria (Pers. Comm. P.S. Ashton). If the climate was dry during the glaciations and not corresponding to the Pluvials, the montane forests could well have been restricted to the moisture valleys and depressions as they are at present.

II. Biogeographic region : Moist deciduous forests forming an ecotone between the region I viz. Wet evergreen forests and region III -- Teak zone

It comprises two vegetation types :

(1) Tectona - Lagerstroemia lanceolata - Dillenia pentagyna - Terminalia paniculata type described by Champion (1936) as the "South Indian tropical moist deciduous teak forest" occurring on the western side of the Western Ghats in Kerala, Goa, Maharashtra and on the eastern fringe of the Western Ghats in Karnataka, extending up to an elevation of 1000 m.

The range of annual rainfall is 2000 to 4000 mm with a dry season of 3 to 7 months and mean temperature of the coldest month more than 15°C. Soils are red lateritic loam.

(2) The second type is named Tectona - Terminalia - Adina - Anogeissus corresponding to the slightly moist teak forest of Champion and Seth (1968). Confined to the Thana, Nasik, Dangs, Nagar Haveli and Bulsar districts of coastal Maharashtra and Gujarat, it forms a transition between the above mentioned moist deciduous forest and the dry deciduous teak forest with rainfall of 1800 - 2500 mm, dry season of 7 to 8 months and tropical ferruginous or ferrallitic soils.

At this juncture it may be pointed out that the difference between the moist deciduous forest and the dry deciduous forest is mainly one of structure and architecture. Trees are taller and of larger girth in the moist deciduous forests compared to the dry type of forests.

From floristic point of view, Lagerstroemia lanceolata and Terminalia paniculata are confined to the western half of the southernpart of the Peninsula (south of 17° latitude N) and serve as an indicator of moist type, being absent in the dry type.

However, in the Dharwar district of Karnataka, these species are encountered under low limit of rainfall of about 1000 mm where one would expect a dry deciduous forest. Albeit, under drier conditions, Lagerstroemia lanceolata manifests xeromorphic adaptations like spines on the trunk in younger stage. In conclusion, L. lanceolata and T. paniculata are not very fidel indicators of the moist deciduous forest, which leaves Dillenia pentagyna as the most characteristic tree of the moister type.

III. Biogeograhic Region : Teak Zone

The dry deciduous forests of India may be divided into 3 broad categories : Teak, Sal and Miscellaneous transitional zone between Teak and Sal.

The seeds of Sal (Shorea robusta), a Dipterocarpaceae has a very short period of viability like the other members of the family. One of the main factors accounting for the occurrence of this species is the timely arrival of rains to coincide with the short period of about 10 days when the viable seeds are available. Thus the Sal is confined to the eastern part of the peninsula receiving early monsoon and is eliminated from the regions lying further westwards where the summer rains are delayed.

Among all the biogeographic regions of India, the Teak zone occupies the second largest potential area of over 53 million ha (Gadgil and Meher-Homji 1982) extending from Kanya Kumari district in the South up to Jhansi and Guna districts in the north. Occupying a large area of the Central Deccan peninsula, it has outliers in the Gir (North Gujarat) and the Nalamalai hills (Andhra Pradesh).

The teak zone shares many a species in common with the Sal zone and the Miscellaneous deciduous forests (Legris and Meher-Homji, 1977). The dominance of the Teak in one type and of the Sal in the other type is brought about by the selective action of man. In the original forests, neither Teak nor Sal would have had the abundance that we note to-day as the result of preferential treatment provided by the Forest Department. These two species are favoured at the expense of many others. Dhareswar (1941) presents interesting data about the introduction of the Teak in the coastal Kanara tract of Karnataka 3 to 4 centuries ago and the dislike shown to the species then by the cultivators, a scenario reminiscent of the case of Eucalyptus today.

The main climatic and edaphic differences between the Teak zone and the Sal zone may be summed up as follows. The Sal withstands forest with the mean temperature of the coldest month descending down to $10^{o}C$ whereas the risk of frost is practically nil in the Teak zone with the mean of the coldest month above $15^{o}C$. The lower limit of rainfall in the Teak zone is 750 to 800 mm whereas it is above 1100 mm for the Sal. Besides, timely arrival of rains to coincide with the period of availability of seeds is a critical factor for Sal survival.

Length of the dry season is 4 to 8 months for the Teak zone but 5 to 7 for the latter. Soils are varied under the Teak type viz, alluvial, ferruginous, black soil on trap and thin lateritic whereas they are acidic ferrallitic or ferruginous for under the Sal forosts. Finally, Teak is a strong light demander whereas Sal is a shade bearer in early stages.

IV. Biogeographic Region : Transition zone of miscellaneous deciduous forest between Teak and Sal zones

Because of the earlier arrival of the south-west monsoon rains in the eastern half of the peninsula, the sal zone occupies the eastern half and the Teak zone occurs further westward. Rarely does the area of Teak and Sal overlap in what is called a "tension-belt". Sometimes the two zones occur side by side and sometimes two dominant forest species are separated by a miscellaneous deciduous forest in which both Teak and Sal are either missing or of very rare occurrence. In this miscellaneous forest, named Terminalia - Anogeissus latifolia- Cleistanthus type, separating Teak and Sal zones, as a rule Cleistanthus collinus is a prominent species of the under - storey. The rainfall in this tract of miscellaneous forest is of the order of 1000-1500 mm with 5 to 6 months dry and with the mean temperature of the coldest month above 20°C. Soils are sandy or loamy ferruginous, vertic brown or black on alluvia.

Under drier conditions (700 to 900 mm rainfall and dry season of 8 months) in parts of Gujarat, Rajasthan and Madhya Pradesh, Cleistanthus disappears and the forest type is termed Terminalia - Anogeissus latifolia. In this case, the distance separating the Teak type from the Sal type is quite considerable. Soils are either red ferruginous or brown.

V. Biogeographic Region : Sal zone

The largest potential area of over 56 million ha is under the Sal zone. Six floristic sub-divisions have been recognised in the Sal zone on the basis of dominant-abundant species.

(1) Shorea - Cleistanthus collinus - Croton oblongifolius type occurs in the Birbhum, Chaibasa, Dhanbad, Bankura, Bardhaman, Medinipur, Puruliya, Balasore and Koon jharghar districts at elevation of 100 to 400 m.

(2) The Shorea-Buchanania-Cloistanthus type is distinguished by the absence of Croton. It occurs in the Bastar, Raipur, Kanker, Bilaspur, Raigarh, Sundergarh, Dhenkanal, Sambalpur, Bolangir, Kalahandi districts.

(3) The largest area among the Sal types types (19.5 million ha) is under Shorea - Terminalia - Adina "series", covering a large part of the eastern peninsula and also occurring in the sub-Himalayan tract. The western most outlier is the Pachmarhi hill of Madhya Pradesh.

(4) Shorea - Dillenia - Pterospermum heynoanum - Cycas circinalis type constitutes the coastal Sal-evergreen forest. It is confined to the coastal belt of Orissa with rainfall of 1500 to 2000 mm, dry season of 5 to 6 months and mean temperature of the coldest month over 20°C.

(5) The moist peninsular hill Sal Forest type has been named Shorea - Syzygium operculatum - Toona ciliata - Symplocos spicata type. It is confined to elevation above 900 m over the plateaus and hills of Orissa and Bihar. Range of rainfall and dry months is the same as in the preceding Coastal Sal type but the mean temperature of the coldest month is lesser : 10 to 15°C. Soils are red ferruginous or ferrallitic and lithosols in both the types.

(6) Toona - Garuga - semi-evergreen forest of the hilly regions of Koraput, Biladila, Papikenda and Visakhapatnam hills though without Sal has been placed in the Sal zone because of the likely disappearances of Sal from this tract through over-exploitation in the historical times. In its ecological requirements (altitude, rainfall, dry season temperature and soil) this type closely agrees with the above-mentioned hill Sal type.

Vi. Biogeographic Region : Hardwickia binata zone

This is a deciduous forest with marked dominance of Hardwickia binata occurring over the plateau region of Andhra Pradesh, Karnataka state and Salem district of Tamil Nadu. After a long discontinuity, it reappears in the Dhulia, Jalgaon and Nasik districts, in the Satmala and the Satpura ranges of the Deccan Trap country, and in a few parts of the Vindhya and Mahadeo ranges.

A remarkable feature of its distribution is its complete absence in the Western Ghats. It occurs on the east-west oriented Satmala, Satpura Mahadeo and Vindhya ranges but is conspicuous by its absence in the north-south oriented Sahyadris. It is found in discontinuous patches in NE - SW oriented hills of the Eastern Ghats (in Andhra Pradesh and Tamil Nadu) and near Haveri, Harihar, Chitradurga, Hiriyur and Tumkur (Karnataka) just to the east of the Western Ghats.

Rainfall range is 500 to 1200 mm spread over a period of 4 to 6 months in the areas of Hardwickia but the distribution of the species has not been satisfactorily correlated with climatic and soil conditions.

Because of general aassociation of Hardwickiawith skeletal soils, this forest type has been considered as an edaphic facies though we have observed this species on deep black soil in Andhra Pradesh.

Mall (1968) comparing the forest of Daultapur - (in Dewas division at a distance of 113 km. from Bhopal) with that of Kalakund (in Mhov range about 40 km. from Indore), finds that Hardwickia istotally absent in the former. He attribute this difference to historical factor asserting that there is no significant difference in soil characters of the two forests. Meher-Homji (1970) emphasised the role of human interference and grazing. In the open forests of the Satpura and Satmala, Hardwickia is generally gregarious towards the borders of the forests but not so in the interior. Because of its very hard wood it is not so easy to fell. Whereas the other species become the victim of axe at the forest margin, Hardwickia escapes the maltreatment. In the interior where the forests are better protected not being easily accessible, other species have a fair chance of survival and the abundance of Hardwickia is not so striking.

Worthy of mention is the restricted occurrence of the economic endemic Red Sandors (Pterocarpus santalinus) in the elevated regions of the Guddapah, Kurnool districts and north-east portions of the Chittoor district of Andra Pradesh where geological tarrain is slate and quartzite and the rainfall regime (season of occurrence of rains) is of the transitional type between the tropical type of Kurnool (June -October rains from south-west monsoon) and the dissymetric type of Nellore (bulk of rains from the north-east monsoon in October to December) (Meher-Homji, 1980).

VII. Biogeographic Region : Albizia amara zone

It is encountered along the Coromandel Coast of Tamil Nadu and Circar coast of Andhra Pradesh. The most peculiar feature of this biogeographic zone is the rainfall regime. Some light rains are experienced from the south-west monsoon during June to September but the bulk of precipitation (over 60%) is received from the so-called north-east monsoon during October to December. In fact, these are the depressions and cyclones of the autumn-winter season formed in the Bay of Bengal which provide rains because the so-called north-east monsoon is a dry system.

The terminology "Tropical dry evergreen forest" coined by Champion (1936) to designate this biogeographic region is a misnomer because the regime (season of occurrence of rains) is not typically tropical but dissymetric as explained above. Again, climatic conditons are not particularly dry because the rainfall range is upto 1500 mm. Besides dew is an important source of moisture from November till April in the coastal region. The dry season lasts for 5 to 7 months. From phenology point of view the formation is not evergreen but semi-evergreen for at least 50 per cent species are deciduous (Balasubramanian, 1978). Finally, physiognomically, the best stands are encountered in the shape of scrub-woodlands or thickets but never as forest.

It appears that because of the peculiar rainfall regime, almost all the typical species of the deciduous forests have disappeared from the Coromandel - Circar coastal tract and in their absence have evolved a number of characteristic species like *Albizia amara*, *Pterospermum suberifolium*, *Drypetes sepiaria*, *Erythroxylon monogynum*, *Diospyros ferrea*, *Euphorbia antiquorum*, *Gmelina asiatica*, *Carmona microph microphylla*, *Hugenia mystax*, *Pterolobium hexapetalum* and *Cissus quadrangularis* among others.

Albizia amara avoids calcimorph soils and is therefore confined to acidic granite-gneiss rocks, avoiding the basic Deccan Trap. Soils are ferruginous or ferrallitic sandy loam. Over lateritic soil

is observed *Memecylon umbellatum* which is also encountered over the lateritic caps of Mahabaleshwar and elsewhere in the Western Ghats.

In the dry coastal pocket of Ramanathapuram Tirunelveli district where rainfall is as low as 500 mm and dry season as long as 9 months is seen the umbrella thorn tree *Acacia planifrons*. After a long discontinuity, this species is also met with near Porbandar in Kathiawar where the climatic conditions are analogous (Meher-Homji, 1970).

In the eastern part of this zone in Karnataka, the influence of the S.W. monsoon becomes more pronounced. This change is heralded by the presence of a typical species of the deciduous forest, *Anogeissus latifolia*. This floristic sub-type, marking a transition between the *Albizia amara* zone and the Teak zone is named *Anogeissus latifolia* - *Chloroxylon* -*Albizia amara* type.

VIII. Biogeographic region : Anogeissus pendula semi-arid zone of Eastern Rajasthan

This zone too is a deciduous forest. Champion (1936) considered it as an edaphic facies of tropical dry deciduous forest.

Meher-Homji (1978) pointed out that there was nothing peculiar in soil factor to merit the title of a special edaphic facies except the fact that *A. pendula* is never found on the Deccan Trap. On the other hand, from a geographic point of view. *Anogeissus pendula* is confined to subtropical latitude above 23½° N in the Aravallis and the Bundelkhand region of Madhya Pradesh.

Three eco-floristic sub-types have been distinguished according to climatic conditions and co-dominant species :

(1) Acacia senegal - Anogeissus pendula type occupying the drier western part of the zone : hillocks of Jalor, Jodhpur, Barmer, Magaur, Sirohi, Pali Ajmer, Sikar districts, where rainfall is 400 to 700 mm, dry season is of 8½ to 10 months duration .

(2) With moister conditions (rainfall of 550-900 mm, lesser dry season of 8 to 9 months), Acasia senegal is replaced by its vicariant Acacia catechu resulting inA. catechu - Anogeissus pendula type in the Aravallia.

(3) With further increase in rainfall (660-1000 mm) and lesser dry season of 8 months, Anogeissus latifolia associates itself with A. pendula in the relatively moister eastern and south eastern pair of the zone in the Bundi, Kota, Shivpuri districts and in the Khichiwara, Orcha and Bundelkhand uplands of Madhya Pradesh.

Biogeographic Regions IX (Deccan Thorn Forest), X (Deccan - Northern Gujarat) and XI (Indian desert)

These three biogeographic regions contain one vegetation type each and have one point in common : they are deprived of forest formations, the best stands of vegetation being in the form of thorny thickets to scattered shrubs.

The Acacia - Anogeissus latifolia type under the biogeographic region IX occurs in the Tapti - Purna valley and in Maharashtra Deccan on alluvial or black clayey soil Climatic conditions are not adverse (rainfall 600-8-00 mm with a dry season of 8 months) at the fertile soils with irrigation facilities have favoured agriculture.

The Acacia - Capparis decidua type of the biogeographic region X extends from Bijapur to Malegaon, covers nothern Gujarat, Kathiawar and piedmont plains west of the Aravalli, under rainfall of 400-800 mm and 7-9 months of dryness.

Along the increasing gradient of aridity in the Western Rajasthan (rainfall under 400 mm, dryness of 9 to 11 months), Acacia - Capparis type is replaced by the Prospis cineraria - Capparis - Ziziphus - Salvadora oleoides type (of the India Desert biogeographic regions) on sandy alluvial soils. The most typical plant of the sand dueness is Calligonum polygonbides.

This brief account presents the salient features of vegetation and environmental factors of Peninsular India, with which this author has been involved for over two decades.

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TABLE 1

Plant-geographic regions of Chatterjee (1939) with bioclimatic, vegetational and floristic criteria of Blasco (1979)

Phytogeographic	Bioclimatic parameters			Forest type	Typical flora	Endemics
	Annual average rainfall(MM)	Length of dry season in months	Mean temperature of the coldest month(°C)			
Halabar	2000	2 - 6	15 - 25	Evergreen, semi-evergreen and moist deciduous	Lagarstroemia lanceolata, Dalbergia latifolia, Toona ciliata, Chukrassia tabularis	Out of 700 dicotyledenous species at lower elevation, 400 are endemic, of which 150 are trees. In the Nilgiris:80 endemics. In Travancore:100 endemics
Deccan	700 - 1500	5 - 8	15 - 25	Dry deciduous	Tectona grandis, Anogeissus latifolia, Gmelina arborea, Pterocarpus marshpium, Terminalia spp.	Poor in endemic flora. Bharucha and Meher-Homji (1965) enumerated 21 endemics for the southern semiarid zone and Blasco 30 for the entire Deccan

Table 2. Equivalence of the biogeographic regions proposed here with the botanical provinces of the earlier authors

Proposed Biogeographic Regions	Correspondence with earlier Botanical Provinces of India			
	Clarke (1898)	Hooker (1906)	Chatterjee (1939)	Razi (1955)
Wet evergreen forests of Kerala- W. Karnataka	Malabaria	Malabar	Malabar	Malabar
Moist deciduous teak forest (forming ecotone between wet evergreen forest and Teak zone)	"	"	"	Concan
Teak zone	Malabaria-Coromandelia	Malabar-Deccan	Deccan	Deccan-Berar-Malwa-Partly Orissa
Miscellaneous deciduous forest(forming transitions between teak zone and sal zone)	Indian deserta-Gangetic plain-Coromandelia	Gangetic Plain-Indus Plain-Deccan	Gangetic Plain-Indus Plain Deccan	Partly Bundelkhand Upper Gangetic Plain-Malwa-Bihar
Sal zone	Coromandelia - Gangetic Plain	Deccan - Gangetic Plain	Decca - Gangetic Plain	Bengal-Partly Upper Gangetic Plain - Bihar-Orissa
<u>Hardwickia</u> zone	Coromandelia-Malabaria	Deccan-Malabar	Deccan	Deccan-Khandesh
<u>Albizia amara</u> zone of Coromandel-Circar	Coromandelia	Deccan	Deccan	Carnatic-Mysore
<u>Anogerissus pendula</u> semi-arid zone of E. Rajasthan	Indian deserta	Indus Plain	Indus Plain	Rajwara-Partly Bundelkhand
Thorn forests of semi-arid Deccan	Malabaria	Malabar	Malabar-Deccan	Deccan-Khandesh

Table 1 (Contd.)

Phytogeographic regions	Rainfall	Dry months	Temperature	Forest Type	Typical flora	Endemics
Gangetic Plain	1200-2000	6-8	15-25	Moist deciduous sal forest, almost completely destroy in the Ganga Valley because of intensive cultivation	Sal (*Shorea robusta*) *Terminalia* species, *Buchanania latifolia*	
Assam	2000	1-6	0-15	Tropical moist deciduous, semi-evergreen, Temperate montane forest	Sal, *Lagerstroemia, Tetrameles,* Oak (Guerous), Wallnut (*Juglans*), *Magnolia,* Conifers	Rate of endemism very high
W. Himalaya, Central Himalaya, Eastern Himalayas	Research is in progress at the University of Kashmir, Kumaun University, North-eastern Hill University, Botanical Survey of India. For Nepal, see Dobremez (1976, 1972).					

Indus plain or India Desert (Thar)	200-500	9-12	10-15	Thorny thicket	Acacia senegal, Acacia catechu, Prosopis cineraria, Capparis decidua, Ziziphus nummilaria, Calligonum	Bharucha and Meher-Homji(1965) recorded endemics for the northern semi-arid zone. Indian desert:64 endemics 11% of the flora, Bhandari 1976).

Semi-arid Deccan - North Gujarat	Malabaria-Coromandelia -Indian deserta	Deccan-Malabar-Indus Plain	Deccan-Malabar-Indus Plain	Deccan-Gujarat-Rajwara
Indian desert	Indian deserta	Indus Plain	Indus Plain	Indian desert-Punjab
North West Himalaya	West Himalaya	West Himalaya	Western Hima-	N.W. Himalaya
Eastern Himalaya - North East India	East Himalaya-Assam	Eastern Himalaya	Central and Eastern Himalaya-Assam	Central and Eastern Himalaya-N.E. India
Andaman-Nicobar				

Summary of discussion following presentation

Prof. P.S. Ramakrishnan: It is possible that some of the grasslands you were referring to originated due to degradation of the tropical rainforest but it need not be so in all cases. In the Anamalai region of Kerala, grasslands have always been there and probably originated due to eco-climatic factors but later spread owing to anthropomorphic reasons.

Dr Meher-Homji: In certain sites along the crest and margins of the Western Ghats area some sites with old soils support grasslands while in others where these old soils have been eroded away tropical humid forest types have established. It is probable that the old soils have factors which hindered the development of tropical humid forest types.

Session II (c)

(c) Useful Techniques and Methodologies

Chairman: Dr Francis NG

Quantitative Methods in Ecology	R.O.J. Thattil
Forest Map of South India	J.P. Pascal
Remote Sensing Applications for Vegetation Mapping	S.D.F.C. Nanayakkara
Vegetation Maps of Peninsular India and Sri Lanka at 1:1,000,000 Scale	V.M. Meher-Homji

QUANTITATIVE METHODS IN ECOLOGY

R.O.J. THATTIL

Introduction

Unlike in the early decades of this century the study of Ecology now necessitates a knowledge of many sciences in addition to Botany and Zoology. The rapid development made in the field of Statistics brings with it an extra problem to the student of Ecology. It is important for him to at least understand the commonly used statistical procedures. The early work in Plant Ecology was, of necessity, largely concerned with the description of vegetation in relation to the environment. But, it has now been realized that there is a need for sensitive sampling measures and statistical methods to extract from the large body of data the relevant information.

In addition the great strides made in the field of computers have also invaded biology and especially Ecology. Knowledge of statistical packages is now essential to any ecologist. Certain techniques such as multivariate procedures cannot be performed without the help of a computer.

Sampling Techniques

With large populations, results accurate enough to be useful can be obtained from samples that represent only a small fraction of the population. The importance of sampling a plant community so as to obtain the maximum amount of information from a single sample has been emphasized by many workers. However, it should be mentioned that an incorrect sampling procedure may lead to invalid conclusions. The sampling technique used will depend to a large extent on the specific problem in hand.

Random Sampling

In Ecology one of the common ways of obtaining samples is via the use of quadrats. The distribution of quadrats in an area is done such that the position of each quadrat is independent of all other quadrats and also independent of any prominent features of the area.

An effective method of obtaining a random sample is to lay out two lines at right angles to each other to serve as axes; each line is then marked by a convenient number of divisions. Random numbers are then selected and used pairwise as coordinates that locate each quadrat in turn.

It is impossible to enunciate a general rule as to the number of quadrats or the size of a quadrat. Both depend on the specific problem and the level of precision needed. To obtain a subjective assessment of the size of sample necessary a trial can be carried out with increasing sample size at each stage. A plot of the mean values versus the different sample sizes will reveal the point at which the mean value ceases to fluctuate. This point can then be chosen as the "optimum" sample size. In general it is recommended to take as large a sample as time will permit.

The problem with regard to the size of the quadrat crops up if individuals are not distributed at random. If the distribution was random it is immaterial what size is used. But non-randomness leads to the size of quadrat exerting a large influence on the variance of data. On theoretical ground the most suitable quadrat is the smallest possible relative to the type of vegetation and to the practicality of the enumeration of such a quadrat size. Stratified random sampling may solve the problem of sampling a very heterogenous plant population .

Regression and Correlation Techniques

Studies on association between species require the use of contingency table analysis for purpose of making valid statistical conclusions. However, in many cases the interest is the relationship between the quantities of species present rather than the qualitative index of presence or absence. In such instances the Pearson's product moment correlation coefficient is the simplest measure which detects relationship between quantities of species present. In many cases the relationship may not be linear and nonlinear regression techniques have to be used. Statistical software such as MINITAB and SYSTAT (microcomputer versions) are excellent packages that are not only useful for regression analysis but for a whole range of multivariate techniques.

In ecology there are occasions where sets of derived variables need to be correlated with each other, each set of derived variables representing a weighted combination of other variables. The procedure used to perform this is called CANONICAL CORRELATION. Consider, as an illustration the case given below:

The relationship between a set of 2 environmental factors (say x_1 and x_2) is to be related to quantities of 2 species (say y_1 and y_2)"

The criterion variables y_1 and y_2 are weighted then added together to obtain a composite score comprising a derived criterion variable. Similarly the values of x_1 and x_2 (predictor variables) are weighted and added together to form the composite scores of a derived predictor variable. These 2 sets of derived variables are then correlated with each other just as in a bivariate case. The canonical weights are derived in such a way that the correlation between the two derived variables is maximized. The square of the resulting canonical correlation coefficient, Rc^2, indicates the proportion of variance of one of the derived variables that is associated with the variance of the other derived variable. The squares of the canonical weights, tells us the relative contributions of the individual variables to the respective derived variables. Indeed, we can view multiple correlation as a special case of canonical correlation, a situation in which there is only one variable in one set and a number of variables in the other.

Principle Component Analysis (PCA)

P.C.A. is a very effective tool that can be used as method of ordination in Ecology. In ordination we attempt to simplify and condense the raw data yielded by vegetative sampling so that relationship among plant species and between them and the environmental variables will be manifested.

Conceptually P.C. A. is a technique whereby S variables are used to derive S factors. Each factor is a linear combination of the original variables that will yield the derived variates (the y's) with the following properties.

i) The variance of the y_1's is to be as great as possible.
ii) The variance of the y_2's is to be as great as possible subject to the restriction that the Y_2- axis must be orthogonal to the y_1- axis. The variates y_1 and y_e are uncorrelated.
iii) Similarly for Y_3, Y_4 .... Y_5.

The natural question that comes up is, "what is to be gained by extracting as many factors as we have variables if the original aim was data reduction?" The answer to this lies in the fact that the first extracted factor typically accounts for the largest part of the total variance inherent in the data collection. Each succeeding factor accounts for less and less of the total variance, so that by the time we get to the final factors they necessarily account for less variance than an individual variable.

Associated with each derived factor is a quantity known as an eigenvalue, which corresponds to the equivalent number of variables which the factor represents. For example a factor associated with an eigenvalue of 3.56 indicates that the factor accounts for as much variance in the data as would 3.56 variable, on the average. If for instance we are dealing with a ten variable problem in which each variable would account on average 10% of total variation, then a factor with an eigenvalue of 3.56 would account for 3.56x10% = 35.6% of total variation.

The importnce of this concept of an eigenvalue also rests on the decision we must make as to how many factors we will retain from the analysis. One frequently used rule of thumb is to retain factors to the point, where an additional factor would account for less variance than a typical variable; that is, less than one eigenvalue.

Cluster Analysis

Cluster analysis is technique for accomplishing the task of partitioning of a set of objects into relatively homogenous subsets based on inter object similarity. The objects in question may be varieties that are to be classified into several groups based on say some morphological characters (variables). In other words a set of n objects (say varieties) are measured with respect to k variables. Next a measure of the similarity (or, alternatively, the distance or difference) between each pair of objects must be obtained. The ultimate goal is to arrive at clusters of objects which display small within cluster variation, but large between cluster variation. An essential step in the cluster analysis procedure is to obtain a measure of similarity. Alternatively we can deal with a distance or difference between the pairs of objects. A commonly used measure is the Euclidean distance based on the object's value on each of the k variables. For example the Euclidean distance between two objects measured on two variables is given by:

$$d = \sqrt{(x_2 - x_1)^2 + (Y_2 - Y_1)^2}$$

There are different methods used for clustering. It is possible that these different methods may lead to different clusters. Therefore the final interpretation should be based after comparing the results from as many methods as possible. The microcomputer statistical software package SYSTAT can be recommended for cluster analysis as it uses 3 major methods of clustering.

Conclusion

There are numerous statistical packages available that are user friendly and does not require knowledge of computer programming for effective use. However, the biologist should not be dependant totally on the output obtained from such packages. Interpretation of data will rely heavily on knowledge of the biological field itself. The application of multivariate techniques to the field of ecology has resulted in a bewildering array of coefficients, techniques and terminology. However, in the final analysis it is the biologist himself who is responsible for giving meaning to the condensed output of data. Some useful statistical packages and reference books are listed below.

Useful Statistical Packages

MINITAB
SYSTAT
SAS
Micro computer versions for all three are available

Useful Reference Books

Chatfield, C; and Collins, A.J.; "Introduction to multivariate analysis" Chamman and Hall, London, 1983.

Kachigan, S.K; "Multivariate Statistical Analysis" Radius Press, New York, 1982.

Kendall, M; "Multivariate Analysis" Charles Griffin and Co.Ltd., London, 1975.

Kershaw, K.A; "Quantitative and dynamic plant Ecology" Edward Arnold (publishers) Ltd., London, 1979.

Pielou, E.C; "An introduction to Mathematical Ecology" John Wiley and Sons, New York, 1969.

Summary of discussion following presentation:

Philippines - Mr Jose O. Sargento: I think for proper data collection which can finally render itself to statistical analysis continuous interaction between statistician and biologist is necessary.

Dr Francis NG: In the planning stages of the study it is essential to probe and define the problem precisely to test a given set of alternative hypotheses. This is I think more important than testing for the significance of small differences at the stage of data analysis.

Dr R.O. Thattil: But, significance testing is only a small part of the statistical techniques which could be used in ecology.

Dr Francis NG: It is also important to realise the difference between statistical and practical significance. There may be differences, too small to be detected statistically but yet important in human terms. These differences might still be meaningful.

FOREST MAP OF SOUTH INDIA

J.P. PASCAL

Introduction

The Forest Map of South India plans to cover in six sheets, at the scales of 1 : 250,000, the main forest regions in Karnataka, Kerala, Tamil Nadu and Goa (Fig. 1).

Earlier, a vegetation map of Peninsular India at the scale of 1 : 1,000,000 was published by the French Institute of Pondicherry in collaboration with the Indian Council of Agricultural Research (GAUSSEN et al. 1961, 1965, 1966).

During the last twenty years, the forest area has changed considerably, mainly as a result of population growth. Deforestation takes place not only to settle the increasing population but also to accommodate the huge hydroelectric projects in the less populated regions. To this one should add the continuous increase in the requirement of wood by the industry and fuelwood by the population. This leads to an increased intensity of tree felling.

In view of this situation, the need for a more rational management of the forest heritage became necessary, mainly regarding the policies of deforestation and afforestation, conversions, the choice of areas to protected and the quota of exploitation. Therefore, during the last decade, a good number of schemes have been undertaken on ecology and on the functioning of different types of forests, the impact of the major development projects, the selection of species used in afforestation etc.

It also became necessary to have a new map of vegetation with a bigger scale, better adapted to the needs. Agreements were signed between the French Institute of Pondicherry and the Governments of Karnataka, Kerala and Tamil Nadu States for the preparation of forest map at the scale of 1 : 250,000 showing the actual state of the forests, their environmental conditions (climatic, edaphic, biotic, administrative) and their potentialities.

We will deal with the concepts and the methods used for this cartographic synthesis (for more details see Pascal 1986).

I. Sources of Information

Most of the knowledge on the forest cover was acquired by field studies. For the first three sheets of the map, nearly 250 reserved forests were visited within 5 years to collect data on the floristic composition of different formations and on their altitudinal and latitudinal limits. For most of the the forest

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types the structure has been studied on sampling plots (Pascal 1984).

The information obtained from field studies has been complemented with the existing literature and with the data supplied by the Forest Department : working plans, stock maps, enumeration data, location of plantations, legal status of the forests etc.

The actual limits of the formations have been taken from Landsat satellite imagery using enlargements at 1 : 250,000 of MSS 5 and false colour composite (FCC).

This satellite imagery enabled us to take also into account those forests not managed by the Forest Department (Revenue Department forests or private ones) for which there are no other sources of information. Hence we could give a complete picture of the forest cover.

II. Characterization of the Different Formations and their Cartographic Representation

The different plant formations are characterized by their physiognomy phenology and floristic composition.

1. Physiognomy

According to the stratification of the stand, the dominant biological form (trees, shrubs, undershrubs, herbs) and the density, the formations have been distinguished into :

- dense forest
- woodland to savanna woodland
- tree savanna to grass savanna
- scrub-woodland to dense thicket
- discontinuous thicket to low scattered shrubs.

We have considered a forest as dense when the canopy cover is more than 80%; between 50 and 80% it has been classified as woodland. The estimation of the density was made as follows : measure of the canopy cover on sampling plots and correlation with the density shown by the Landsat imagery at the same point, from which we have extrapolated density figures to the adjacent areas.

2. Phenology

According to the relative percentages of evergreen and deciduous species, the forests are separated into 3 categories : evergreen, semi-evergreen and deciduous forests.

Evergreen forest : the evergreen species constitute at least 95% of the stand. The deciduous species, found mainly in the openings, do not exceed 5% of the individuals.

Deciduous forests : all the individuals of the top canopy shed their leaves at the same time.

Semi-evergreen forests : these are of two main types :
- the dominant stratum includes a mixture of evergreen and deciduous species, the latter making up more than 5%.
- the evergreen species are either absent or rare in the dominant stratum but they constitute practically the whole of the lower strata as is often the case in the secondary forests in humid environment.

3. Floristic Composition

Formations with the same physiognomy and the same phenology are further divided into forest types according to the main differences in their floristic composition. 15 types have been recognized in the evergreen and semi-evergreen climax forests and 3 types in the deciduous climax forests.

The types are named after some species selected for the abundance or their characterizing value, or both (for example in evergreen forests : Dipterocarpus indicus - Kingiodendron pinnatum - Humboldtia brunonis type or Mesua ferrea - Palaquium ellipticum type).

In the deciduous climax forests, the floristic differences are not very important and they are mainly expressed by the relative abundance of certain characteristic species such as Lagerstroemia microcarpa, Anogeissus latifolia, Terminalia paniculata. Except under peculiar edaphic conditions, these changes depend on the west-east rainfall gradient.

From a cartographic point of view, the opening of the formations is indicated by symbols : plain colour (dense forest), oblique thick bands (woodlands), crossed stripes (dense thicket), big dots (grass savanna, scattered shrubs).

iii. REPRESENTATION OF ECOLOGICAL CONDITIONS

1) Climatic Conditions

Although there are many publications on the bioclimates of the mapped area, the scale of the map made it necessary to collect additional climatic information. The data from nearly 3000 rainguage stations and about 50 temperature recording stations have been synthesized in a bioclimatic map of the Western Ghats at 1/500 000 (Pascal, 1982).

The climatic conditions are expressed on the forest map by means of colours according to GAUSSEN's method recommended by UNESCO (1973).

- thus the decrease of temperature with the altitude appears on the map, in the humid zone, by change of colours from purple to blue - green and then green.

- The decrease in rainfall from west to east is expressed by the sequence of colours : purple (or blue - green, or green according to the altitude), brown, yellow, orange. The evergreen and semi-evergreen forests growing in wet or wet conditions therefore appear in purple, blue - green or green ; the moist deciduous forests growing in less humid environment are shown in brown and the dry deciduous forests in yellow or orange, according to the degree of dryness of their environment.

2. Edaphic Conditions

The edaphic conditions are shown on the map only when the soil becomes a predominant ecological factor; which we have shown with symbols. For example L indicates a soil indurated by iron - oxides (laterite cap) which generally does not permit the regrowth of a forest. P indicates the Poeciloneuron indicum gregarious facies in the Western Ghats from 13° N to 14° N (Shimoga sheet). This peculiar facies develops under a very high rainfall on soils derived from rocks of the Dharwar system.

3. Biotic Pressure

The degradation of forests is mainly related to the intensity of the anthropic pressure.

The density of the population has been shown on the map to give an estimate of its needs (firewood, grazing-ground...). Towns and villages with a population of over 1000 are represented by circles the sizes of which are propotional to the population. The figures used are from the 1971 census corrected by the preliminary report of the 1981 census. The development of human activities often takes place along roads. The accessibility of forests may indicate greater exploitation facility but also a higher risk of degradation. Therefore, the road network including the main forest tracks has been shown on the map.

4. Administrative Information

The legal status of the forests is also an important information. Among the forest managed by the Forest Department (reserved forests, minor forest, "betha", revenue land etc...) only the reserved forests (sometimes called state forests) are outlined on the map by a thick black line and identified by a number. This number refers to a list at the bottom of the sheet in which the forests are classified according to their situation in the territorial division of the Forest Administration (Range, Division Circle, State).

The administrative information is supplemented by the limits of Division and Circles and by the location of Ranges, Divisions and

Circles headquarters. To avoid any confusion, these are the only names appearing in black on the map. A small scale inset also depicts the boundaries of Circles and Divisions.

IV. Dynamic Relationships and Potentialities

The dynamic relationships between the formations appear from their classification in the legend.

The formations have been divided into two groups corresponding to the two broad categories of climax formations in the mapped region, and to the stages of secondary succession related to them.

1. Group 1 : Evergreen or semi-evergreen climax forests and their degradations

The formations have been separated into 2 sub-groups :

1.1 Sub-group A includes the climax forests which are in equilibrium with the environmental conditions (a in Fig. 2) and the forests potentiality linked to climax. These forests have been moderately logged and the characteristic species are still present (b in Fig. 2). Prevention of exploitation and prolonged protection will allow the reconstitution of a forest structurally and floristically similar to the initial climax.

1.2 Sub-group B corresponds to the formations for which a natural return to the climax forest is no longer probable. It is subdivided according to the intensity of degradation.

1.2.1 Evergreen and Semi-evergreen Forests

They are devided into two categories :

* The disturbed forests : These are heavily exploited forests showing structural disturbances and a considerable change in the floristic composition (c in Fig. 2). If protected they may progress - under favourable conditions - towards a formation whose structure would be identical to that of the initial forest but whose floristic composition would be different because of the remotness of the seedbearers of the sensitive characteristic species. However, these species could grow if planted (g in Fig. 2).

* The secondary forests : They represent stages of regrowth after a more less complete destruction of the initial evergreen formation. They are found generally in the areas where the anthropic activities have been very intensive, followed by a relative protection. They correspond essentially to forests (f in Fig. 2) as well as to the intermediate stages (between d and f on one hand, and f and g on the other).

1.2.2 Deciduous Secondary Formations

These formations develop when, through anthropic action, the opening of the stands results in important changes in soil conditions and in humidity (d in Fig. 2).

Floristically and structurally these formations are close to the moist deciduous climax forests (group II), but they mainly differ in the composition of the under storey.

Under heavy anthropic pressure, the stand becomes more open, low and twisted. The progressive degradation of the exposed soil and the more intense dryness eliminate more species favouring an enrichment of more species favouring an enrichment of more resistent species such as Xylia xylocarpa (e in Fig. 2).

The protection at the level of the secondary deciduous forest (d in Fig. 2) results in gradual closing of the canopy. This evolution leads to an enrichment in evergreen species and the forest progresses towards the f stage. All the intermediate stages can be observed and it is often difficult to classify a forest in one category or the other.

1.2.3 Other Degraded Stages

Under this title we grouped even more degraded formations which cannot be considered as forests.

* Tree savanna to grass savanna (i and partly j in Fig. 2)
They constitute the stages resulting from the process of opening of the secondary deciduous forests when fires are frequent and grazing moderate.

Tree and shrubs savannas appear over the entire distribution area of evergreen forests. Although most of them result from degradation, some grass-savannas are probably climax formations due to peculiar edaphic conditions.

* Thicket to low scattered shrubs (h and k in Fig. 2)
These degraded stages appear under high anthropic pressure and when overgrazing becomes the dominant factor. It is not uncommon to see them alternate with savanna, especially on the moist border of the plateau.

In the hills of the coastal zone of North and South Kanara, the thickets are generally low and scattered formations, developed on very indurated soils.

2. Group II : Deciduous Climax Forests and Their Degradations

Mainly located on the plateau in the mapped area, the deciduous climax forests are generally easily accessible and have been subject to heavy and continuous anthropic pressure for a long time. Shifting cultivation, over-exploitation, over-grazing and repeated fires are responsible for severe degradation. Except in very protected areas, dense forest is rare.

According to the more important cause of degradation, the structure gets altered in two different ways :

- open forest, savanna woodland, tree savanna, when fire is the dominant factor;
- scrub woodland, dense thicket, low discontinuous thicket, scattered under-shrubs, when over-grazing dominates and illicit felling is important.

V. Conclusion : Interest and Applications

The possibilities of using this kind of map are numerous. They result from the synthesis, in the same document, of data concerning vegetation on one hand, and the physical and biotic environment on the other. The cartographic synthesis of these data brings out correlation which constitute new information. This type of cartography is therefore not only a graphic means of representation of data but also a tool for new information research.

- For example the map provides essential guidelines for forest management plans, especially for the selection of the suitable zones for plantation or conversion. These zones can be traced out taking into account the optimal ecology of the selected species and their natural areas of distribution.

- It may help in evaluating the impact of high development projects in forested regions. For example to estimate the eventual consequences of a dam project (numerous in this region) or the impact of major mining operations : quantification of the wooded area likely to disappear, consequences of the opening of new roads, best sites for the settlement of labour population and of those to be shifted from the places of new projects.

- It can be also used for the determination of the sensitive zones and the area to be protected on a priority basis. For example, in the southern part of Wayanad division and northern part of Kozhikode division (cf. Mercara-Mysore sheet), the existing forests are subject to great anthropic pressure. From the eastern hilly side, coffee plantations are replacing the forests, whereas on the heavily populated western side the forests recede upto the mid-slopes. Thus the remaining forests are confined to a narrow track along the western ghats; most of these forests are not classified as Reserved or State Forest. Unless immediate steps are taken for their conservation, they are likely to disappear leaving a gap in the continuity of the evergreen continum with adverse consequences like the acceleration of erosion and the hampering of the movement of the large herbivores.

- Most of the parameters involved in the selection of the biosphere reserves are to be found in the map: continuity and extent of forest cover, nature of plant formations, location of the habitats of animal populations and probable migration routes, distance from main roads and populated zones etc....

The best way of using a map of forest resources would be to initiate a dialogue between the cartographers who also know the ecological environment and the users who face a series of particular problems. The comprehensive maps where the maximum information is available can then be used for the elaboration of very simple thematic maps of specific purposes, as for example the maps of the vulnerability of forest formations in Western Karnataka which is now under preparation.

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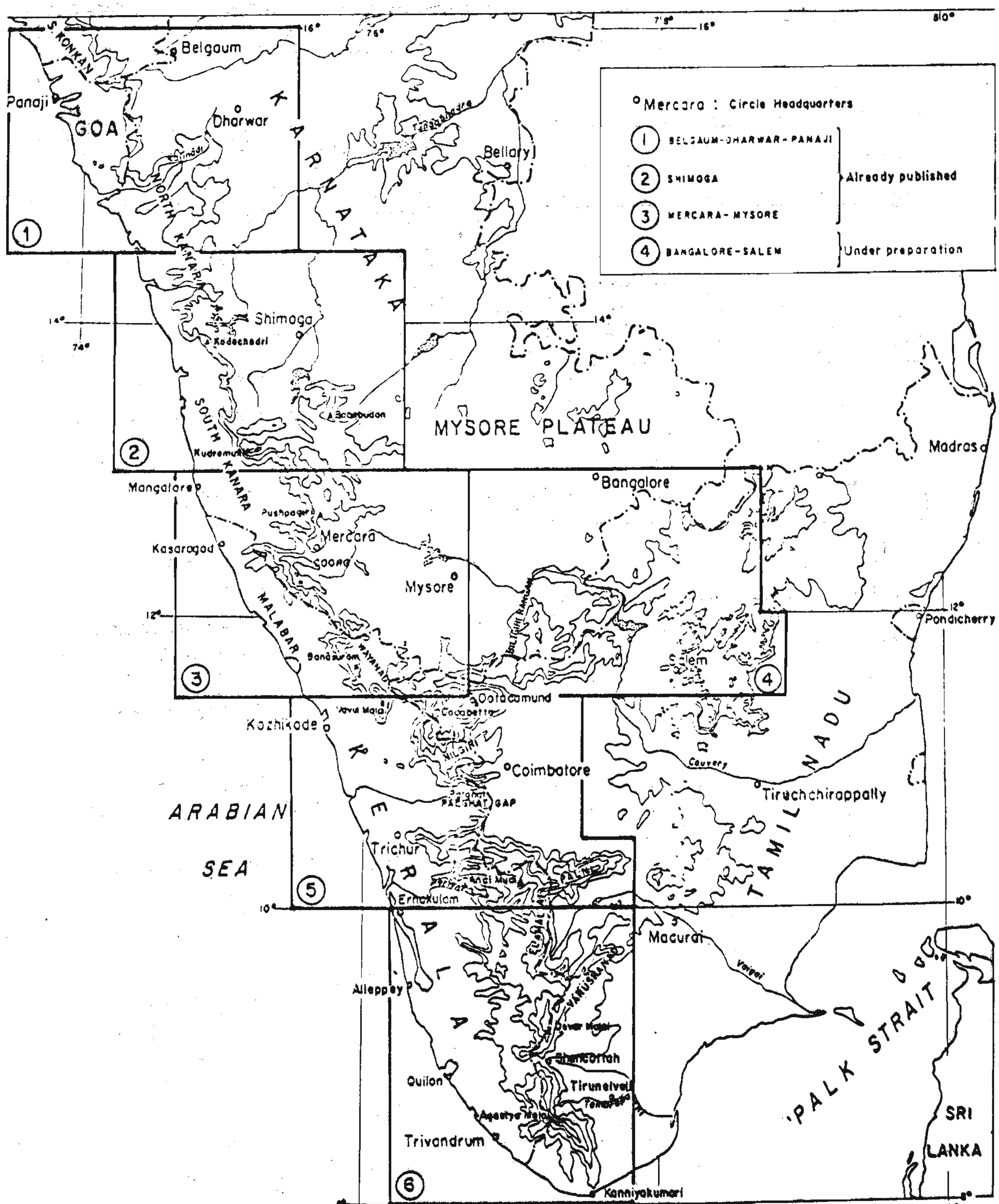


Fig. 1. Forest Map of South India : Key Map

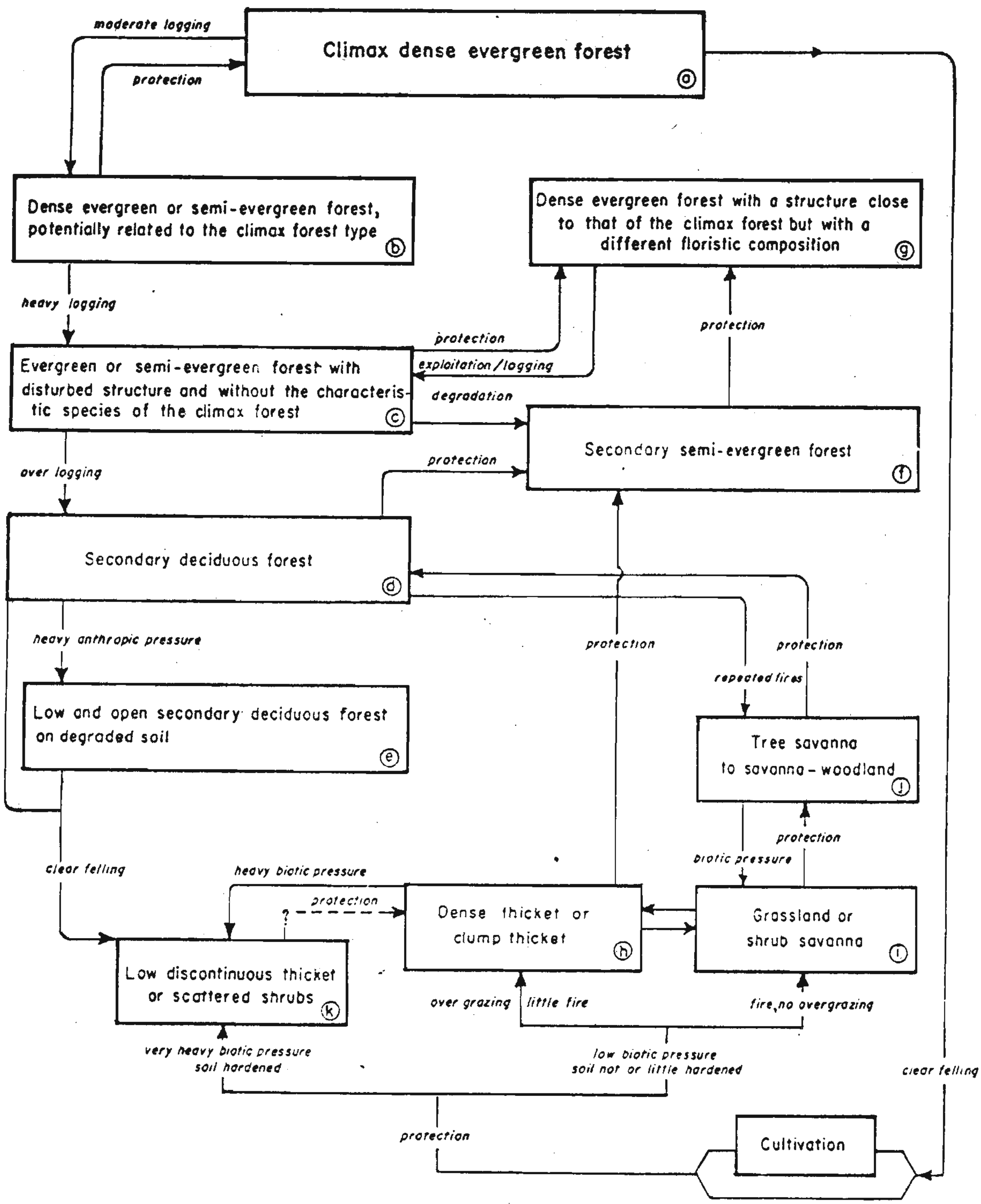


Fig. 2. Dynamic relationships of the stages of succession derived from a wet evergreen forest (dry season > 4 months)

Summary of discussion following presentation

Dr Bernd von Droste: Could you give us some information on the systems of classification used, extents of forests remaining within the realm and the techniques used in mapping?

Dr J.P. Pascal: There are many classification systems used but we have generally adopted that of the Toulose school which is based on climax systems. We have not really attempted to interpret forest cover changes at the level of the realm although this is certainly possible. This could even be done using Landstat images where resolution is high and interpretation accurate. We could use present images and maps for rainforests and provide information which has fairly high degree of accuracy but in case of thickets and grasslands accuracy may not be that high. Spot mapping is another technique whose use is becoming increasingly popular but for the present its use in this part of the world is constrained by cost factors.

REMOTE SENSING APPLICATIONS FOR VEGETATION MAPPING

S.D.F.C. NANAYAKKARA

Introduction

The proper management of our natural resources and their optimum utilisation has been accorded high priority in Sri Lanka. Mapping of land use and vegetation (including forests) is a major component of this exercise. The developments in remote sensing technology achieved during the last few decades provide a variety of options to the natural resources manager.

Objectives

Mapping, which is considered essential in order to develop a systematic management plan that will ensure optimum utilization of our natural resources, is one of the major applications of remote sensing. The preparation of management plans based on remote sensing data take into account the sustained utilization of our natural resources, the conservation of the resources, the environmental impact of development activities, the equitable distribution of resource benefits, and so on.

The availability of non-renewable mineral resources in Sri Lanka is considered to be extremely limited. Therefore, we have to concentrate mainly on the systematic management of our renewable resources such as land and water, paying special attention to agriculture, forestry and the study of land use problems.

Data Requirements

In order to evolve plans for the proper management of our resources tomeet the above objectives we have to provide the necessary information. This information requirement can be met by providing answers to a series of questions such as:

What are the resources we have?
Where are they found?
What quantity?
What quality

Provision of answers to these questions involve exploration, mapping and inventorising.

Once the plans are prepared, we go over to the management phase. During this stage there is need for regular review, and answers are required to questions such as: What is the rate of illustration? What is the impact of this utilization or exploitation on the environment and on the sustenance of the resource itself? This is a monitoring exercise. Hence, not only in the planning phase, but throughout the management operations data on the resources are regularly required.

Acquisition, Processing and Presentation of Data

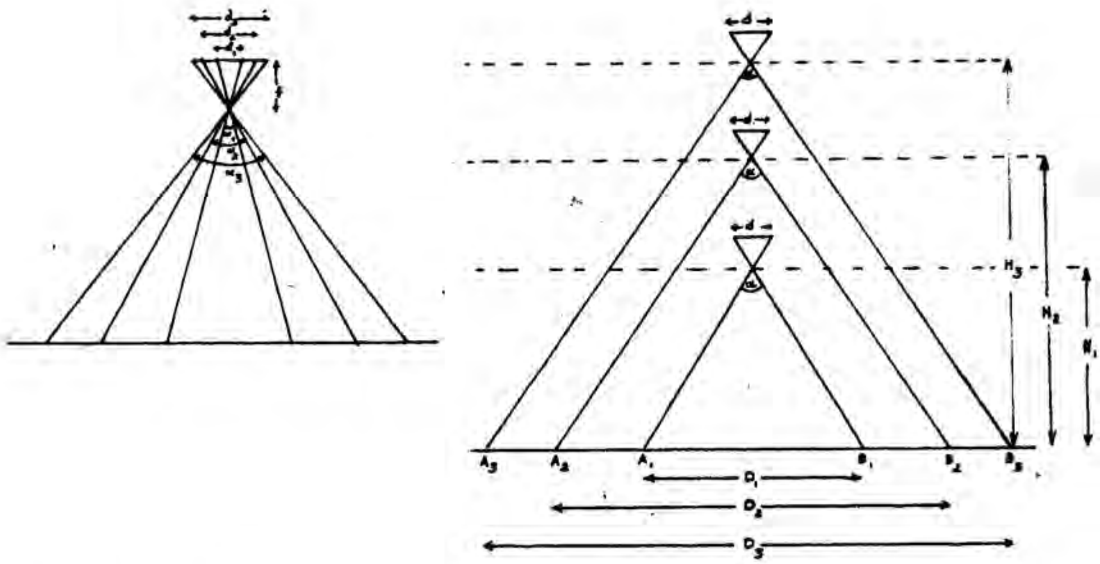
In order to provide data in an appropriate manner, a study of the systems available for data acquisition, data processing and data presentation should be undertaken. The costs involved as well as the time frame for completion of each of these operations must be considered. Discussions should be held with the data users and resource managers to decide on the specifications for the data. The resource managers will define their needs and the actual use to which the data will be put. With this information, the data providers will decide on the intensity of survey, the scale of mapping, and whether macro, regional, or micro-level data are to be acquired. It is to be noted that the expenditure and time involved in data acquisition and presentation increase tremendously with increased survey intensity, scale, and area to be mapped. Taking into account expenditure and time constraints, data specifications are drawn up to provide adequate information for the overall planning of resource management at least at the basic level. Thereafter data collection could be intensified in specific areas for detailed project planning and implementation.

Data Acquisition Systems

The systems available can be categorised broadly as follows:

1. Ground based systems
2. Airborne (aircraft) systems at different altitudes to suit special needs
3. Space systems: satellite remote sensing systems

The decision may be to use either a single type or a combination of two or three types. The concept of greater area coverage with increased height of camera position or increased view angle of the camera is illustrated below.



Definition of Remote Sensing

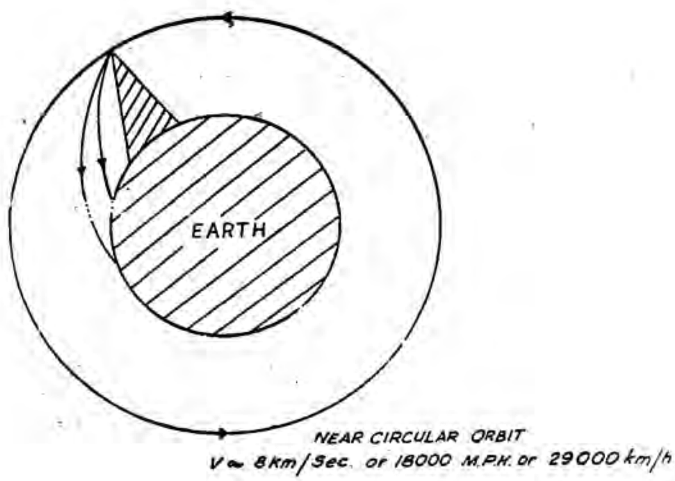
The field of remote sensing may be defined very broadly to include techniques that obtain reliable information about the properties of surfaces and objects from a distance. This may be accomplished by measuring (1) electromagnetic radiation emitted or reflected from surfaces or objects, (2) other force fields, such as gravity or magnetic, created or modified by them, or (3) mechanical (acoustic, seismic) vibrations or waves emanating from, being transmitted through, or reflected from them. An easy short definition would be: getting information on objects (ex surfaces) by measuring their emitted or reflected electromagnetic radiation from a fairly large distance (some hundred metres or more).

Earth Orbits

Effect of Gravity

When the centrifugal force equals the gravitational force of the earth the object will be placed in earth orbit. The period of revolution is approximately 90 minutes when the orbit is close to the earth's surface.

A satellite in near-earth orbit will undergo loss of speed due to resistance from the atmosphere and will therefore fall back to the earth soon. (Vide diagram). Hence it is necessary to boost a satellite above the earth's atmosphere. Most earth resource satellite are placed in orbit at a height of approximately 900 km above the earth's surface.

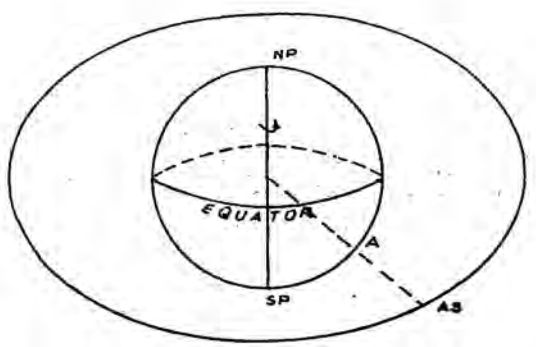


The Clark Orbit

This was described by Dr Arthur C. Clark 40 years ago in his technical paper: "Extra terrestrial relays".

Satellite 'AS' placed in Clark orbit above 'A' on the earth's surface would appear to be stationary with respect to an observer on the earth's surface.

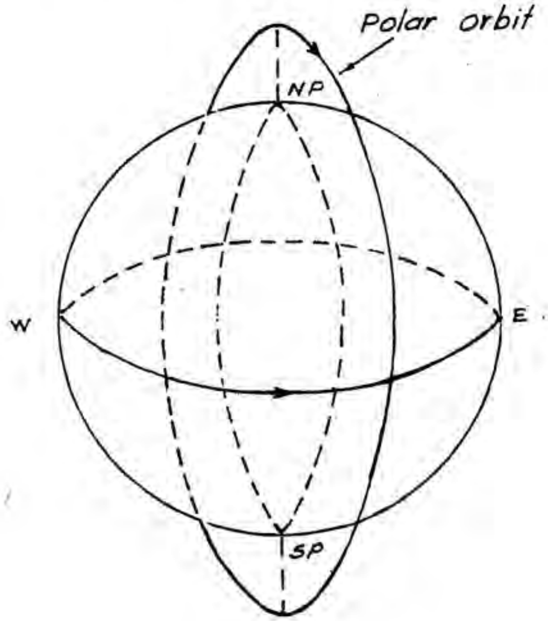
An equatorial orbit with a radius of 42000 km has a period of exactly 24 hours and would revolve with the earth and would be stationary above a definite point on the earth. Such satellites are used for telecommunication and meteorology. Vide diagram.



Polar Orbit

If we assume the polar orbit to be fixed in space then the earth's west to east rotation inside this orbit exposes north-south strips of the earth to a camera on the polar orbiting satellite looking vertically down.

Earth resource satellites (eg. Landsat) are in near-polar orbit and are at about 900 km above the earth's surface. Vide diagram.



The time taken for one orbit is approximately 100 minutes and is so synchronized as to give sequential repetitive coverage of the entire globe every 14 - 18 days.

These satellites are also sun synchronous so that they overpass a given point on the earth's surface at the same time of day in a 14 - 18 day cycle.

Other Orbits

Equatorial orbit at about 900 km altitude will cover only the equatorial region in every orbit of approximately 100 minutes. This gives a very high rate of repetitive coverage. There will be many passes per day. Other, inclined orbits, give spiral/complex coverage due to the interplay of satellite orbit with the earth's rotation.

Remote Sensing

The following systems are available for remote sensing:-

Aerial photography interpretation
B/W, colour, multiband photography
Airborne panoramic cameras
Airborne scanners including multispectral scanners with many spectral bands
Satellite remote sensing

Multispectral Imaging

The radiation emanating from sequential area units of the earth's surface can be split up to discrete bands through filtering devices and the intensity of radiation in each of these bands can be measured. If we have five such bands, each ground area unit or picture element (Pixel) will have five radiation intensity values. Other ground area units will have five different sets of values if their surface characteristics are different from each other.

Remote sensing is based on the premise that radiation emanating from different types of surfaces on the earth have different combinations of radiation intensities in the band cluster. That is, each surface type has a unique series of numbers representing the intensities of radiation in each band of the electromagnetic spectrum. This enables surface characteristics to be observed by studying the combination of radiation values in the different spectral bands. This combination of radiation values is called the Spectral Signature. Each surface type is linked with a unique spectral signature.

Remote sensing, through multispectral imaging devices, utilises bands of the electromagnetic spectrum within the visual band as well as outside the visual band e.g. infrared, thermal, radar and macrowave bands.

Thus we begin to 'see' objects outside our human vision capability. This enables better interpretability and better discrimination of surface types e.g. crop types, soils, forest types, irrigated areas, rice crop in different stages of growth, water sedimentation, etc.

The capacity to discriminate between surface types using a minimum number of spectral bands is called Spectral Resolution.

To perform good discrimination of earth surface types, satellite imaging has to be supplemented with air photography sampling and ground sampling and verification.

Many surface types (such as a rice crop) are dynamic as regards their surface properties and are also seasonal. Hence imaging of such areas at different times is required - multi-temporal aspect. This also helps in locating changes, disasters, etc. - change detection techniques.

Ground Receiving Systems

If we take a Landsat MSS frame 180km x 180 km, assuming that the smallest earth area unit (pixel) is 60m x 60m - (Spatial resolution), in each frame we have 9 million pixels. If we have 4 bands, the number of radiation values for each pixel being 4, the total number of discrete data units in one frame of Landsat would be 36 million.

These data are acquired within the space of time required for the satellite to overpass a 180 km N to S strip of the earth's surface which is equivalent to less than a minute. Hence the data acquisition may be in the region of millions of units per second.

The satellite normally does not carry data devices. It telemeters or transmits the data as observed. Hence a ground receiving station should have the capability to receive up to 100 mega bits of data per second if it is to receive high resolution data such as Thematic - Mappoer & Spot (ESA) data which have ground resolution of about 30m x 30m or less.

Once such data are received by the ground receiving station, the processing, interpreting, analysing, etc. can be done by playing the recorded tape at any regular speed, much slower than the data acquisition rate. One can work at leisure and analyse small areas and get in-depth information.

Data Processing Systems

Such data consisting of tens of millions of units per frame can now be processed through computer systems. Various algorithms for data smoothing, enhancement (e.g. edge enchancement), analysis etc. are developed.

Image processing technology has achieved a very high level of sophistication today and a wide variety of equipment and processes are available.

In spite of all these systems, the visual image influenced by the complex interplay of greytone discrimination, spatial relationships, pattern discrimination, etc. by the trained scientist or technician provide by far the best tool for interpretation and analysis of such data.

This human capability has its own limitations; a photographic image of reasonable size tends to crowd a vast amount of data on a limited surface area of film, and generalisation tends to take place resulting in loss of detail.

While this is ideal for regional or macro conceptualisation, more detailed analysis for micro studies by overlaying of multitemporal data, or by matching of different scales, etc. require highly sophisticated digital processing techniques.

Therefore, for speed of processing, for data storage and retrieval, for developing geographical land information systems, etc. the digital processing technique combined with visual mode guidance is indispensable.

Data Presentation Modes

One has to realise that data are required for decision making. Decision making is a multi-disciplinary exercise. It is a team effort. The data acquisition and data processing people are not the only ones involved in the decision making process. Therefore data have to be presented on a thematic basis, as charts and statistics, as maps, etc. Data in raw form or in digital mode are not useful immediately. The geographic location of the data on an administrative or project area basis is also required. Different scales of presentation are required.

The following additional factors have to be taken into account:
(a) The need for proper multidisciplinary integrated land use systems with thematic capability
(b) Data matching capability
(c) Multitemporal capability
(d) Incooperation of available map data and statistics into new data

Taking all these factors into account one has to organize a good, flexible digital processing system with good recording/archival/data retrieval systems combined with digitising technology to introduce available map data.

This is the present trend and the future is likely to yield further improvements in image processing and land information systems with increased use of digitising systems. The trend is towards digital terrain models and sophisticated land information systems embodying all themes of data which are physical, economic, social and political in nature.

Further development in satellite imaging systems and micro-processor based image processing systems together with digital and interactive land information systems are the modern and future trends. These systems are getting cheaper as more and more earth resources scientists and earth resources managers are beginning to use them.

Vegetation Mapping Using Remote Sensing

Vegetation mapping using remote sensing methodologies in Sri Lanka dates back to 1956 when air survey techniques were introduced. At present there are three types of vegetation mapping been undertaken, namely:

(a) Agricultural Base Mapping
(b) Land Use Mapping
(c) Forest Mapping

Agricultural Base Mapping

Air photographs are used for producing the agricultural base maps at the scale of 1 : 10,000 and 1 : 50,000. The 1 : 50,000 series will be prepared to cover the entire country while the 1:10,000 series will only cover selected areas. Out of the 92 sheets in the 1:50,000 series to-date 29 have been printed. In the 1:10,000 series, out of 1834 map sheets covering Sri Lanka, only 131 sheets have been printed.

These maps are basically topographical maps showing basic vegetation patterns and height information in the form of contours.

Land Use Maps

Using aerial photographs and satellite images, 1 : 100,000 land use maps are prepared to cover the island on a district basis. Statistical information on each Additional Government Agent's division is also printed on this map. Altogether 16 districts (out of 25) have already been printed. It is expected that the entire mapping programme would be completed by the end of this year.

Forest Mapping

Forest mapping is undertaken at two levels. At the national level this map is printed on a 1:500,000 scale, while on the district level the maps are printed on a 1:100,000 scale. For the national level only satellite images are used for the mapping while for the 1:100,000 scale air photography is used, complemented with satellite data.

Summary of discussion following presentation

Indonesia - Mr Achmad Abdullah: Computer analysed vegetation maps (photographs) can only be useful if there is a good set of classification system for vegetation and good mapping system on ground with which computer analysed maps could be compared.

Mr S.D.F.C. Nanayakkara: It is essential that there are such kinds of interactive analysis involving the verification of aerial photographs, satellite images etc., using ground truth.

Dr A.H. Perera: In the forest cover maps you showed what is the smallest area recognised?

Mr S.D.F.C. Nanayakkara: In theory it is 70 x 70 m2; but I would say, in reality it would be about 5-10 acres owing to overlap of adjacent units. It does not include plantation and degraded forest cover.

Pakistan - Mr Mirza Mohammad Ashraf: How can the use of aerial photographs and related techniques be of value in marine ecosystem studies?

Mr S.D.F.C.Nanayakkara: It may be possible to detect several physical and biological phenomena such as dwellings and plankton concentrations and movement. I would assume that it could of potential value in identifying potential fishing areas.

Dr N. Ishwaran: Is there any plans for using these techniques in studying movements of marine mammals?

Mr S.D.F.C. Nanayakkara: They can be very useful in this sense. But, very often they detect effects of movement, e.g. increase in temperature, turbidity etc., rather than movement itself.

VEGETATION MAPS OF PENINSULAR INDIA AND SRI LANKA AT 1:1,000,000 SCALE

V.M. MEHER-HOMJI

Introduction

Within the framework of a technical cooperation with the Indian Council of Agricultural Research, the Scientific Section of the French Institute, Pondicherry had taken up a scheme of mapping vegetation and environmental conditions of India. A dozen sheets have been published so far according to the methods of Gaussen (1959). These are entitled "Cape Comorin", "Madras", "Godavari", "Jagannath", "Mysore", "Bombay", "Kathiawar", "Satpura Mts", "Rajasthan", "Wainganga", "Orissa" and "Allahabad" (Gaussen et al, 1961 a, b; 1963 a,b; 1965 a, b; 1968 a, b; 1971; 1972; 1973; 1978). The present article reviews the principles involved in the preparation of these maps and the main forest types mapped.

Each sheet includes a main map of vegetation at 1:1,000,000 scale. It is accompanied by six inset maps showing either environmental features like hypsometry (relief), geology, soil types and bioclimates or land use: agricultural regions and potential vegetation types. The insets are at the scale of 1: 5,000,000. The main vegetation map shows all the features pertaining to the natural vegetation and introduced or transformed types like agriculture and plantations. Each map is accompanied by an explanatory booklet.

Facts shown on the Vegetation Map

In the main vegetation map, a clear cut difference is maintained between the cultivated areas and the uncultivated ones. The cultivated areas are left in white so that their location and importance can easily be made out, as they contrast sharply with the coloured background of the natural vegetational areas. This convention also adds to the clarity of the map in that the symbols of the cultivated crops come out distinctly over the white background. Some of the symbols carry a statistical value, each sign representing an area of 10,000 hectares.

The horizontal lines on the map indicate human action in the landscape. For example, the plantations are shown by horizontal lines, and the practice of shifting cultivation by leaving white horizontal blanks in the coloured area of the vegetation. The irrigation canals are depicted in fine blue lines and the projects under construction by blue dashes. The hedge-lined landscape is represented by means of red squares. Whereas the horizontal bands indicate the landscapes created by man, the vertical bands indicate the proportions: proportions of the crops of first importance, second importance and third importance of every agricultural region in the inset of Agriculture, or porportions of the length of rainy season and dry season in the inset of Bioclimates.

Land use of every district is shown by the letters C.F.P.U. where C stands for cultivation, F for forests, P for fallows and U for uncultivable waste. Typography of these letters shows percentages of forests, cultivated, cultivable and uncultivable areas. Whereas the agricultural landscape is presented in white, the uncultivated areas are shown in colours. These represent either the forests or the different stages of their degradation, like scrub-woodland, thicket, savanna-woodland, tree-savanna, shrub-savanna and scattered shrubs. Man has clear-felled forests, ploughed fields, left, areas in fallows and managed pastures for the livestock. Thus he has created a series of landscapes ranging between forest and barren lands.Various physiognomic stages like forest, open forest, scrub-woodland, thicket, savanna-woodland, tree-savanna, shrub-savanna and scattered shrubs are recognised.

If a piece of land with scattered shrubs is left free from human activity and grazing, it gradually gets covered with more and more vegetation; passing through successive stages of grasses, shrubs, thickets, woodland, it may eventually reach the forest stage. The different physiognomic stages of vegetation encountered in a region leading to a same forest type go to form what Gaussen (1959) calls a series of vegetation. The final, maximum stage of the series is called plesioclimax. Theoretically, it is defined as the stage a given plot of vegetation would reach in a sufficiently long period of time, without human interference. In practice it is recognised as the most developed formation met with in an ecological region. A series is named after two to four species chosen from its plesioclimax stage, some for their dominance, abundance, some for their value as characteristics and others for their economic importance. Each of the physiognomic stage is represented by a definite pattern. For example, the grasslands are indicated by a fine network of small dots. If shrubs are scattered through out the grassland, they are represented by big dots. Thickets are shown by crosses, woodlands by strokes and the forest type, i.e. plesioclimax, in full tone colour. Thus the more advanced the stage of degradation the lesser is the intensity of colour.

The Climatic Complex and the Colour Scheme

The series of vegetation are determined by the climatic conditions. Therefore it is logical to assign a colour to the series according to the climatic conditions.

An important principle of Gaussen's (1959) school of cartography is the rational use of the colours of the spectrum to represnt the ecological conditions. High rainfall($>$ 2000 mm per year) is represented in blue-the colour of water, and very poor rainfall ($<$ 100 mm per year) of the desertic countries in red, the colour of heat and burning. Similarly high temperature-mean of the coldest month > 20°C is shown in reddish colour; orange is used if the mean of the coldest month lies between 15 and 20°C and yellow if it is between 10 and 15°C. By super-imposing the colours of rainfall and temperature, the resultant colour of the ecological complex is obtained. Thus for the equatorial and tropical humid regions blue will be used for high rainfall and red for high temperature (mean of the coldest months 20°C). Super-imposition of blue and red will result in violet colour. For desertic countries red will be used (red for poor rainfall+high temperature); for tropical mountains, the resultant colour will be green: blue for rainfall and yellow for temperature.

The final colour given by the climatic complex is applied in full tone for the plesioclimax stage of the series. Other stages of degradation are represented by definite patterns mentioned above but in the same general colour as that of the series. This convention brings out the dynamic tendency. Some cartographers use green colour for forests, yellow for grasslands. Thus a teak, a sal, montane "shola" a pine and an oak forest will all be shown in green, and grasslands having different evolutive potentialities in yellow. Such a map loses much interest. The soil factor may at times be included in the climatic factors. An impermeable soil in a moist country increases the degree of wetness. This may be indicated by adding a shade of blue to the colour given by the rainfall + temperature complex. Sometimes the soil has such an importance that it is necessary to give it a special graphical representation. Saline soils are represented by a mixture of red and blue dashes; their relative frequencies can be adjusted according to percentage of salinity. The crops of dry ecology like millets, cotton, pulses and palmyra palm are shown in red and orange colours, those of wetter ecology like paddy, sugarcane and coconut in blue and violet.

Bioclimatic Map

Based on the ombrothermic diagrams, a detailed bioclimatic map of the Indian sub-continent has been prepared (Labroue et al., 1965). It takes into consideration the regime (seasonal occurrence of rainfall), the annual total precipitation, the length of the dry and rainy seasons and the mean temperature of the coldest month.

The alternation of the rainy and the dry seasons is shown on the map by means of two bands, one corresponding to the rainy season, the other to the dry, their relative widths being proportional to the length of the two seasons.

The resultant colour of climatic complex (rainfall+temperature) is used for the band of rainy season; for the band of dry season, the colour of the temperature class is used.

Equatorial and tropical montane climate without any dry season are shown in violet and green respectively without any bands of the dry season. On the other hand, the arid zone of Thar is presented in red without any band of rainy season.

Thus every bioclimatic region with its regime, annual average rainfall, mean temperature of the coldest month and length of rainy and dry season is indicated with ecological significance of the colours.

Potential Vegetation

Whereas the main map shows the actual state of vegetation, the inset of potential vegetation type depicts the potential area under each series. As every series is determined by a definite set of climatic and edaphic factors, the potential area of the series is derived from the ecological conditions besides the remnants of the characteristic species of the plesioclimax, if any. Thus the cultivated lands have also been classified according to the potential area of the series. A comparison between the main map and this inset gives and ideas of degree of degradation brought by man. Knowing the potential area of the series helps in selection of suitable species for plantation in wastelands and other degraded areas.

Uses of Vegetation Map

They are inventories of plant resources showing their distribution in the landscape and thereby the extent of what is calcuable and what deserves attention.

Through proper interpretation of the data mapped it is possible to make suggestions regarding the optimal land use.

As the same standards are used throughout the world in these types of International Vegetation Maps, as regards both the representation of the physiognomy by definite patterns and the climatic analogies by colours, the work of comparing any two countries is facilitated.

The five countries mapped so far at the French Institute, Pondicherry, are India (South of 28° Lat. N.), Sri Lanka, Malagasy Republic, Cambodia and Mexico. The floristic composition will naturally vary between India and Madagascar in view of the geological history, yet similarities in the climate and physiognomy provide useful indications for exchange of economic species.

The Karnataka and Kerala Forest Departments are interested in introducing some species of economic value like the clove tree (<u>Eugenia caryophyllata</u>, the oil palm (<u>Elaeis guineensis</u>) and other valuable timber species from Africa. An ecological project is in progress in collaboration with the French Institute to provide the guidelines and a detailed map of natural resources has been planned at 1 : 250,000 scale.

Gaussen (1977) has discussed further practical uses of the vegetation maps. The high cost involved in field-surveys, working of cartographic laboratory and coloured printing would be prohibitive if only a handful of scientists were to benefit from the vegetation maps.

For the botanists they are evidently helpful to explain the distribution of vegetation patterns. They are equally useful to the geographers. For the study of climate, the meterorological data are not sufficient especially in the hilly terrain. If the vegetation has been accurately mapped and bears appropriate ecological colours, it gives much precise information on the climate than the maps published by the meteorologists. Oriented more towards physics than natural sciences, climatologists often join together by curves the points where the data are analogous without studying gradients in relation to altitude; they ignore the existence of mountains. As a matter of fact, better maps of climate (precipitation, temperature) have been prepared by botanists. If on one slope there is a beech (Fagus sylvatica) forest and on the other pine (Pinus silvestris) in Europe, one can immediately know that the latter is drier and warmer than the former without consulting the meteorological data, which if existing were provided under shade without the direct action of the sun. The climate is extremely complex and nothing is better than understanding the vegetation for understanding the climate. The vegetational landscape provides much better indication about the climate than the meteorological figures.

One of the most interesting economic applications of the map lies in the data it furnishes for agriculture. One could very precisely reconstitute the agricultural statistics of each administrative unit.

The crops are shown by symbols, the colour of which indicates the ecological conditions and each has a statistical value. The statistics of this type of agriculture can be obtained with sufficient accuracy and the location of the crops is given on the map which would not be indicated by the figures of the statistics.

Large regions of the world are still unexploited for agriculture. Besides the present-day agriculture, we may envisage cultivating waste areas. Here the vegetation map can provide precious guidelines. Communities of Salicornia and Suaeda reveal on the map saline land and may may even give an idea of degree of salinity and the possibility of desalting and cultivating these areas.

Certain plant communities reveal the nature of the soil and consequently the chances of success of clearing the land. Their study should precede the preparation of management plans to avoid disappointments caused by the ignorance of habitat conditions which are revealed by the vegetation.

We may recall the importance attributed to the topographic maps by the military. These maps often contain useful indications on the vegetation. A deciduous forest during dry summer season in the tropics and during winter in the temperate countries does not shelter a troup as effectively as an evergreen coniferous forest. Sometimes possibilities of circulation are limited due to marshes. A good example is that of the allied army in Algeria during the Second World War trying to catch up with General Rommel's army in Tunisia. The traject was through steppes of Stipa and of Artemisia herbaalba. The former permitted the passage of tanks after the rains but not the latter. A vegetation map would have enabled the Allies to follow the itinerary through the Stipa steppe avoiding their tanks getting bogged down in the mud.

Vegetation maps are of equal use to the engineers for constructing roads, selection of sites for laying railway lines.

The insets are included to seek correlations of the vegetation types and agricultural crops with the various environmental factors. They also help in establishing multidisciplinary relationships. For example, in the map entitled "Godavari" (Gaussen et al. 1963a), one is struck by the concerntration of the irrigation tanks in the agricultural landscape of the central halt of the main map; they are conspicuous by their absence in the north-west part (Pers. Comm.S.M. Virmani). If comparison is made with the insets, it will be noticed that geology explains the above enigma. The region of tanks corresponds to gneissic complex, and the Deccan Trap geological terrain is not favourable for retaining water in tanks.

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Session II (d)

(d) Energy Flow

Chairman : Prof. S. Balasubramaniam

Tree Architecture Dr Francis NG

TREE ARCHITECTURE

F.S.P. Ng

Introduction to architectural models

Trees stand out or differ from other plants mainly in having one main stem, also known as the trunk or bole, upon which other stems may be borne as branches.

In the study of tree form, particular attention is paid to the form of the trunk, the form of the branches, and the spatial relationship between branches and trunk. Arising from such a study, Halle, Oldeman and Tomlinson (1978) have concluded that all trees can be fitted into 23 architectural models, at least during the juvenile stage of their life history. Their system of tree architectural models has gained world-wide acceptance.

A summary of the Halle, Oldemann and Tomlinson system is provided in the appexdix.

As trees increase in size and age there are often secondary changes in their form. These changes are explained in the context of two concepts:

Reiteration

"Reiteration" is the term applied to a repetition of an architectural model.

The most simple form of reiteration is seen when a young tree is damaged e.g. by breaking off its top. A lateral bud grows as a response, to produce a new crown of the same model as the old one. This is called "traumatic reiteration". Sometimes two or more traumatic reiterations may develop. Foresters do not like this because it reduces the value of the trunk. When a young tree is blown down, quite often, a series of buds will grow upwards from the reclining trunk, to produce a series of traumatic reiterations. Traumatic reiterations are so called because they develop in response to a traumatic experience.

The reiteration concept supposes that trees may also reiterate as an adaptive process as they grow taller. Under this concept the crown of a mature tree is believed to be made up of repetitions of the original model, with successive models smaller than previous ones (Halle, Oldeman, Tomlinson, 1978).

Metamorphosis

In many cases the crown of a mature tree does not bear any resemblance at all to the juvenile crown. Instead, during the passage from juvenile to adult stage, the crown seems to go through a transformation. This phenomenon, first described for the dipterocarp Dryobalanops aromatica (Halle and Ng 1981) has been given the name "metamorphosis".

According to Ng (1987), the architectural models themselves do not provide any explanation for the different sizes of trees. Within each model there are dwarfs and giants. We must conclude that the attainment of height cannot be a matter of tree architecture. In fact, there are many plants, notably in the genera Phyllanthus (Euphorbiaceae) and Ardisia (Myrsinaceae), which develop a single leading erect stem bearing lateral horizontal branches, thereby closely resembling trees in form but lacking the ability to grow to 3 m; some even stop at c. 30 cm.

Insight may be found by analysis of the way in which forest giants develop. Even giants must begin as seedlings, but a mature tree of the upper canopy is not merely a seedling magnified a thousand times, any more than a skyscraper is a house magnified a thousand times. A big tree experiences a different environment, is subjected to different stresses and, consequently, has different structural and physiological requirements. However, whereas a skyscraper and house can be designed and built separately, an upper canopy tree must have the inherent ability or genetic programme to adapt itself to a vastly different environment as it emerges from the understorey into the upper canopy. The word 'metamorphosis' is applied to express the physio-morphological changes involved as an upper canopy species makes such a transition. Species that cannot make the transition are presumably unable to adapt to more than a single environment, and thus some remain permanently in the understorey while others, the pioneer species, are confined to the open.

The juvenile form of a canopy species shows all the characteristics of an understorey species. The leaves are shade-tolerant and long-lived. The branches are slender and diverge from the trunk at large angles, and as they elongate may even become horizontal or drooping. As the juvenile crown accumulates one layer of foliage after another, it becomes narrow-oblong in shape. As it approaches the upper canopy, the upper branches are produced at sharper angles from the trunk. Such branches tend to grow upwards rather than sideways and eventually behave as competing leaders, putting on conspicuous secondary thickening, while development of the original leader slows. In this way, a crown is produced with a rounded top, supported by large branches diverging from a transition zone on the trunk. Above this zone, branch breakage (if it occurs) leaves large knobbly scars. Below it, the branches of the juvenile phase are cleanly shed, leaving the majestic cylindrical columns that are so highly valued by the timber industry.

Meanwhile the leaves too undergo a drastic change. They become sun-demanding and short lived, limited in distribution to a narrow zone around the periphery of the mature crown. When viewed from below, the branches and twigs are revealed clearly, to their extremities, because the foliage lacks depth. The aversion of upper canopy leaves to shade is dramatically underscored by the phenomenon of crown-shyness (Ng, 1977) whereby crowns of adjecent trees avoid each other, leaving a halo of open space around each and every one. Viewed directly from below, the upper canopy appears as a gigantic jigsaw puzzle, in which the crowns fit with no overlap. The phenomenon is all the more remarkable when compared to the behaviour of a "wolf" species such as the coastal Terminalia catappa (Combretaceae), in which the crowns of adjacent trees will grow straight into each other.

The life stages of an upper canopy tree

An upper canopy tree is one which spreads its crown in the uppermost level of the forest canopy. It receives full sun, while all the plants below it are shaded to various degrees. In the course of its life, the upper-canopy tree passes through the following stages:-

i. Germination on the forest floor

ii. Juvenile growth in the understorey; deep narrow crown conforming to its model; development of the bole.

iii. Adaptive reiteration or metamorphosis as the top approaches the main canopy level, presumably as a result of increase in available radiant energy.

iv. Mature tree with expanded crown of many crownlets; monolayered foliage; juvenile branches shed to reveal full extent of clear bole.

v. Overmature tree with parts of crown broken off leaving behind large branch stumps.

In the terminology of Halle, Oldemann and Tomlinson, the juvenile trees are trees of the future, mature trees are trees of the present, overmature trees are trees of the past.

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APPENDIX

Guide to Architectural models in the System of Halle Oldeman and Tomlinson (1978)

1a	Trunk unbranched	2
1b	Trunk branched	3
2a	Inflorescence terminal, <u>Holttum's model</u> (Example: Corypha umbraculifera)	
	<u>Corner's model</u> (Example: Cocos nucifera)	
3a	Branches similar to trunk	4
3b	Branches dissimilar to trunk	7
4a	Branches arising from base, <u>Tomlinson's model</u> (Example: Metroxylon sagu)	
4b	Branches arising at higher levels...	5
5a	Branching by dichotomy, <u>Schoute's model</u> (Example: Hyphaenae thebaica)	
5b	Branching axillary	6
6a	One branch at a time, in linear sequence, <u>Chamberlain's model</u>	
6b	Two or more branches at a time, <u>Leeuwenberg's model</u> (Example: Plumeria rubra)	
7a	Stems differentiated into two types: Orthotropic and plagiotropic	8
7b	Stems of one type, all orthotropic or all mixed	17
8a	Growth of trunks continued by basal branching <u>McClure's model</u> (Example: Bamboos)	
8b	Growth of trunks continued by above-ground branchng	9
9a	Construction by modules terminated by inflorescences	10
9b	Construction not by inflorescence - terminating modules	13
10a	Modular construction of branches and trunk ...	11
10b	Modular construction restricted to branches ...	12

11a Modules initially all equal but one later becoming a trunk, <u>Koriba's model</u>
(Example: Alstonia macrophylla)

11b Modules unequal from the start, trunk module quite distinct and appearing later than branch modules, <u>Prevost's model</u>
(Example: Alstonia angustiloba)

12a Trunk growth rhythmic, <u>Fagerlind's model</u>
(Example: Fagraea crenulata)

12b Trunk growth continuous, <u>Petit's model</u>
(Example: Morinda citrifolia)

13a Trunk a sympodium of orthotropic segments, <u>Nozeran's model</u>
(Example: Theobroma cacao)

13b Trunk an orthotropic monopodium 14

14a Trunk with rhythymic branching 15

14b Trunk with diffuse branching 16

15a Branches plagiotropic by apposition <u>Aubreville's model</u>
(Example: Terminalia catappa)

15b Branches plagiotropic but not by apposition, <u>Massart's model</u>
(Example: Araucaria heterophylla)

16a Branches long-lived, <u>Roux's model</u>
(Example: Shorea spp)

16b Branches short-lived, <u>Cook's model</u>
(Example: Phyllanthus)

17a Trunk and branches all orthotropic... 18

17b Trunk and branches all mixed orthotropic-plagiotropic 21

18a Inflorescences terminal 19

18b Inflorescences lateral 20

19a Trunk growth rhythmic, <u>Scarrone's model</u>
(Example: Mangifera indica)

19b Trunk growth continuous, <u>Stone's model</u>
(Example: Pandanus tectarius)

20a Trunk growth rhythmic, <u>Rauh's model</u>
(Example: Pinus caribaea)

20b Trunk growth continuous, <u>Attim's model</u>
(Example: Rhizophora)

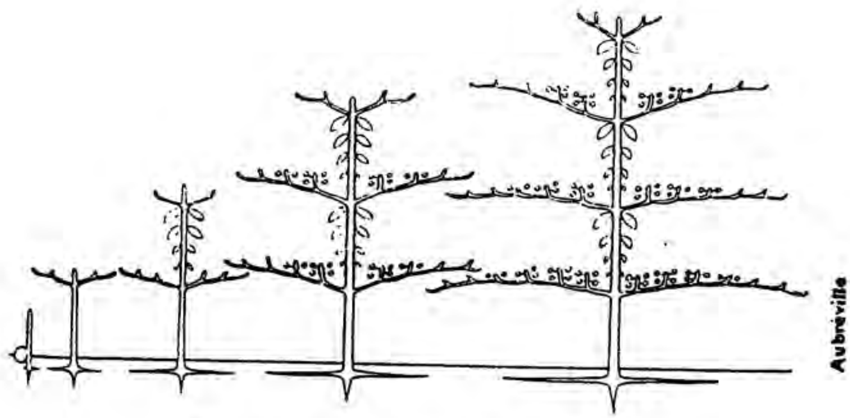
21a Stem proximally orthotropic, distally plagiotropic,
<u>Margenot's model</u>

b Stem orthotropic, becoming plagiotropic by bending due to gravity, <u>Champagnat's model</u>

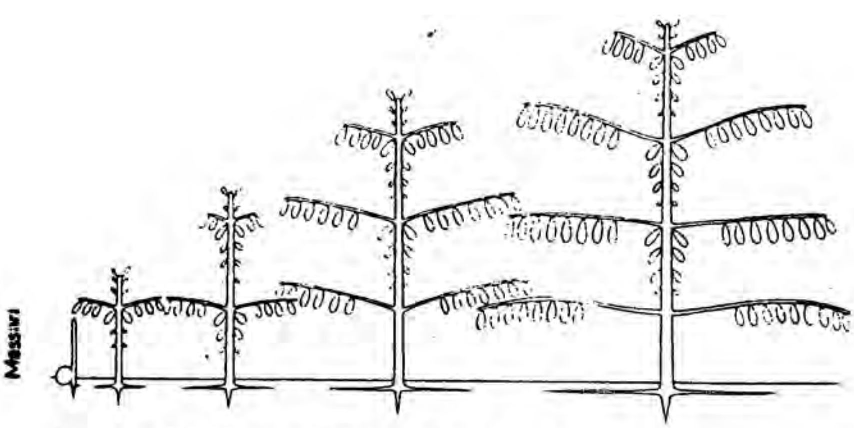
(Example: Bouganvillea)

c Stem plagiotropic, becoming erect secondarily
<u>Troll's model</u>

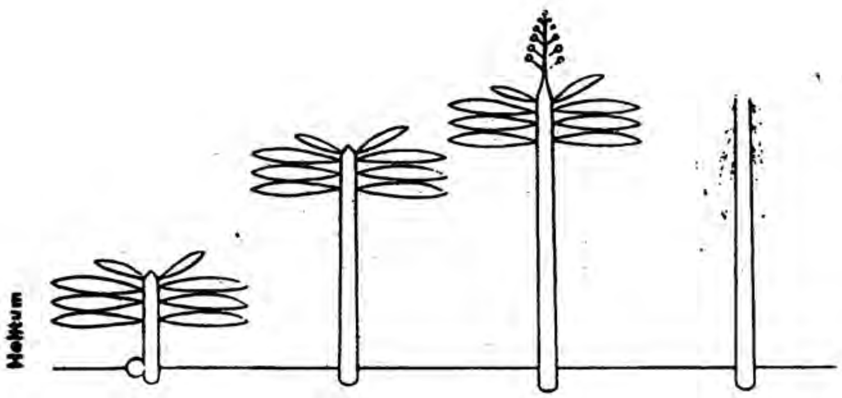
(Example: Annona muricata)



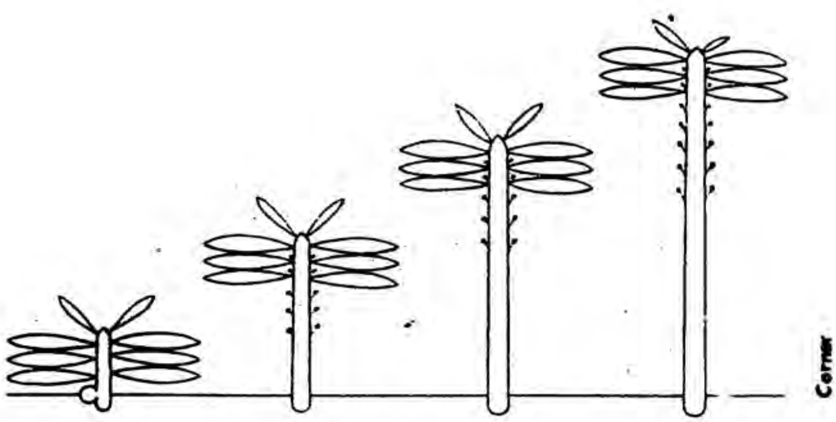
Branches plagiotropic by apposition



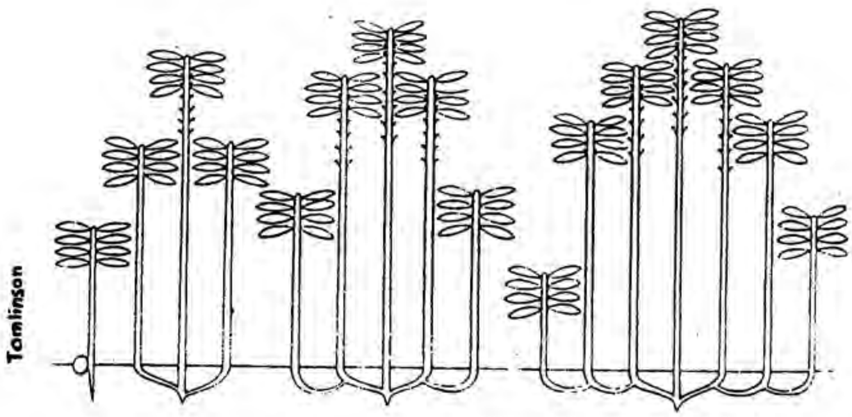
Branches plagiotropic but not by apposition



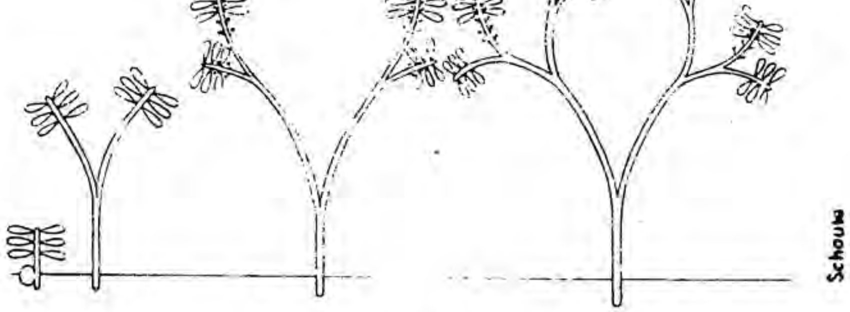
Inflorescence terminal



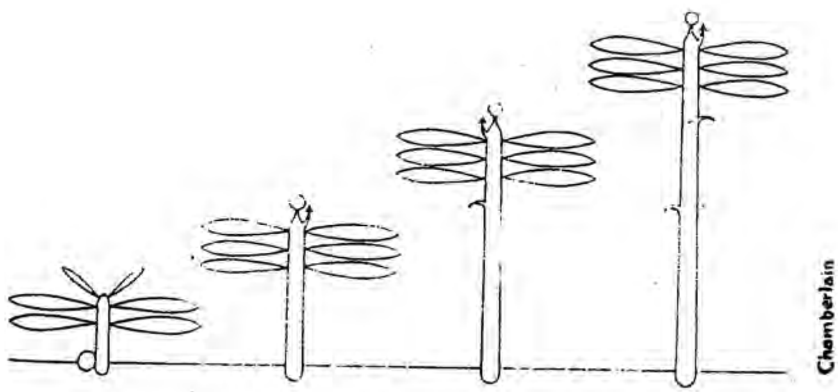
Inflorescence terminal



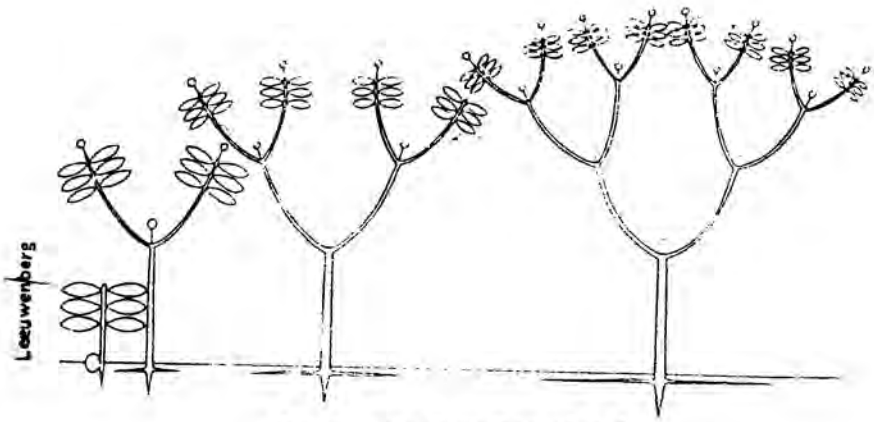
Branches arising from base



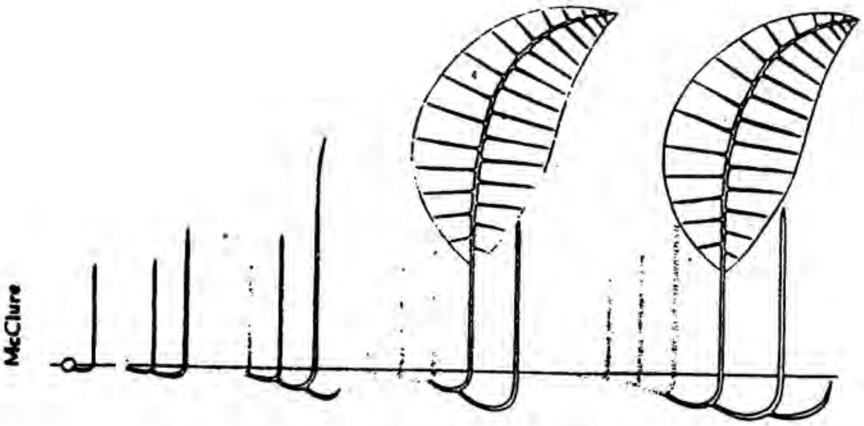
Branching by dichotomy



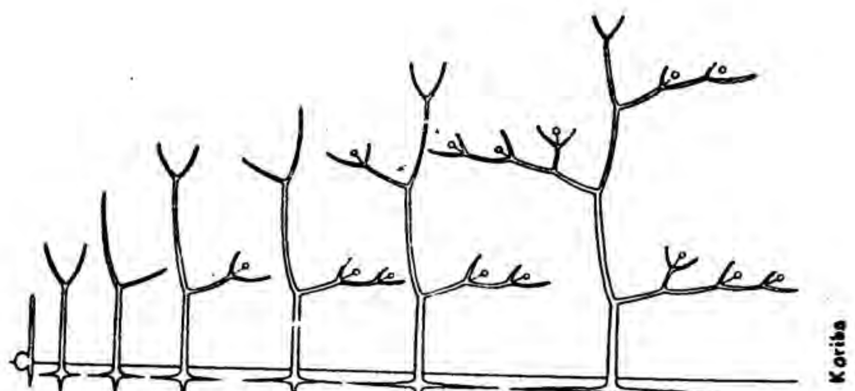
One branch at a time, in linear sequence



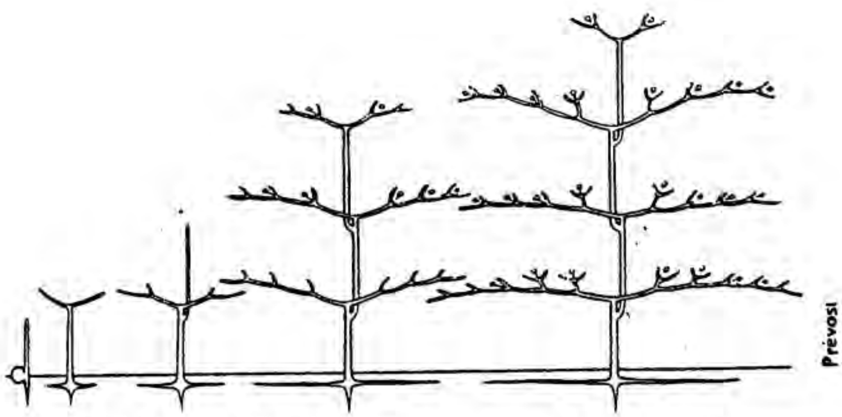
Two or more branches at a time



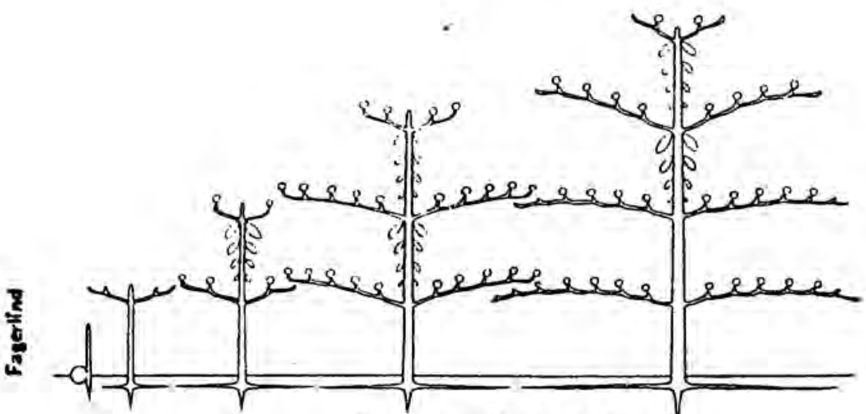
Growth of trunks continued by basal branching



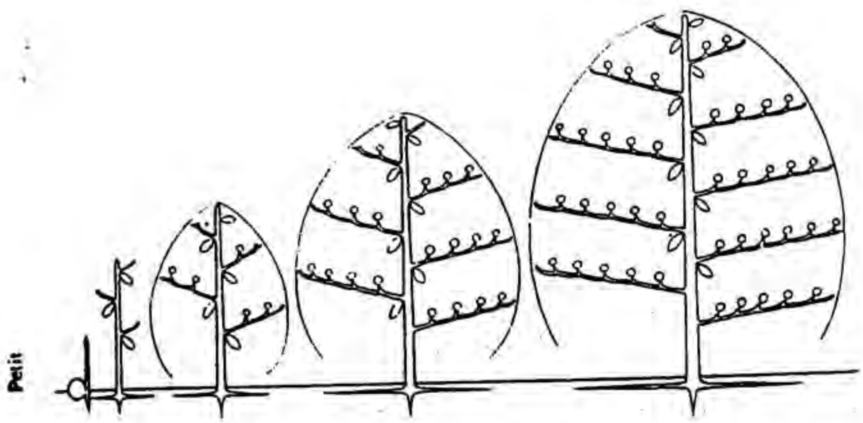
Modules initially all equal but one later becoming a trunk



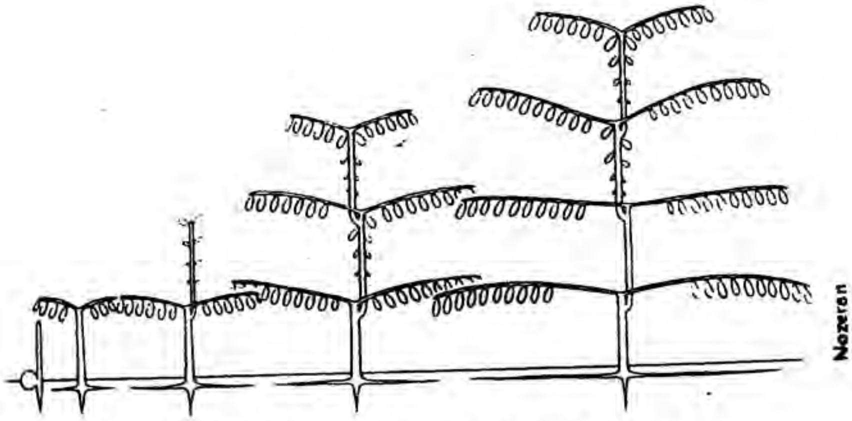
Modules unequal from the start, trunk module quite distinct and appearing later than branch modules



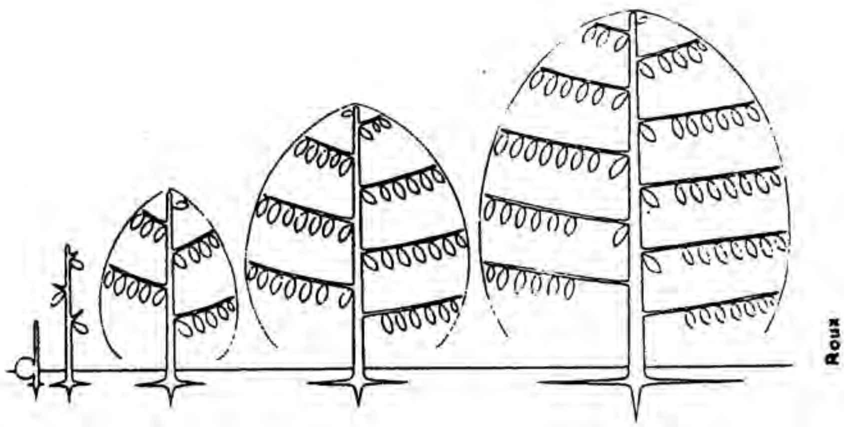
Trunk growth rhythmic



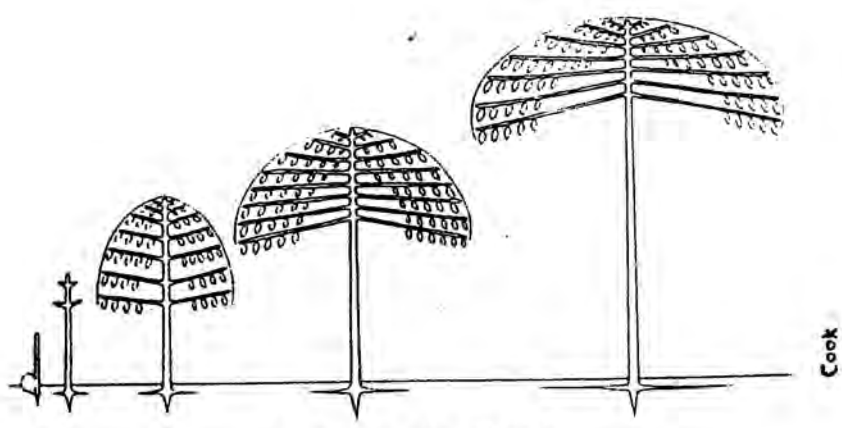
Trunk growth continuous



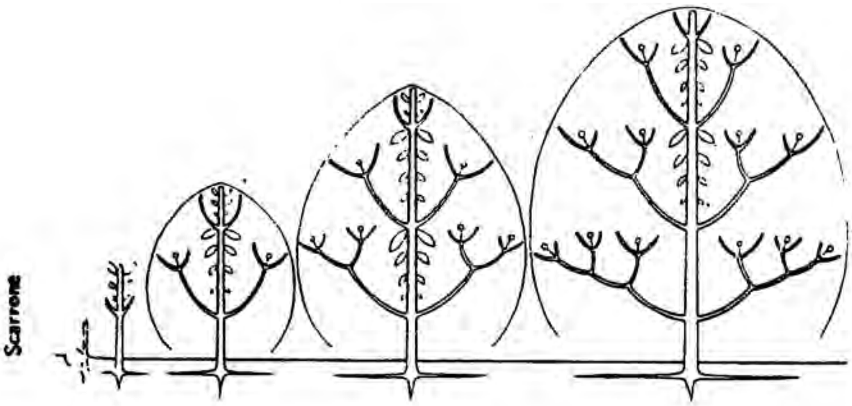
Trunk a sympodium of orthotropic segments



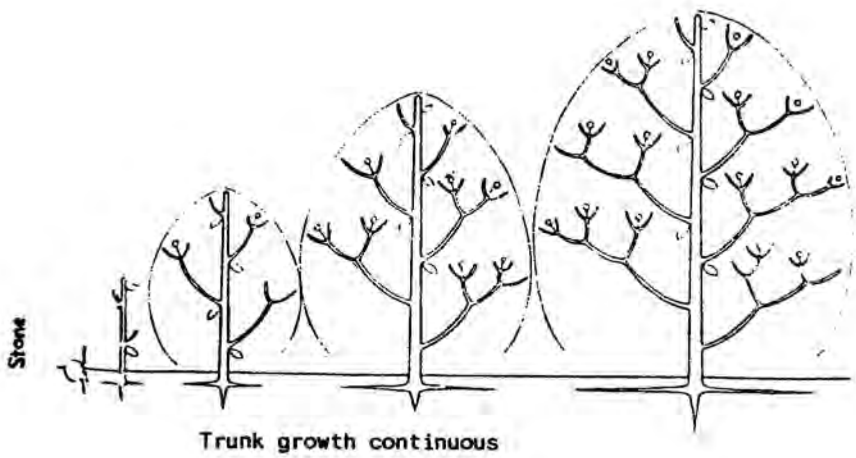
Branches long-lived



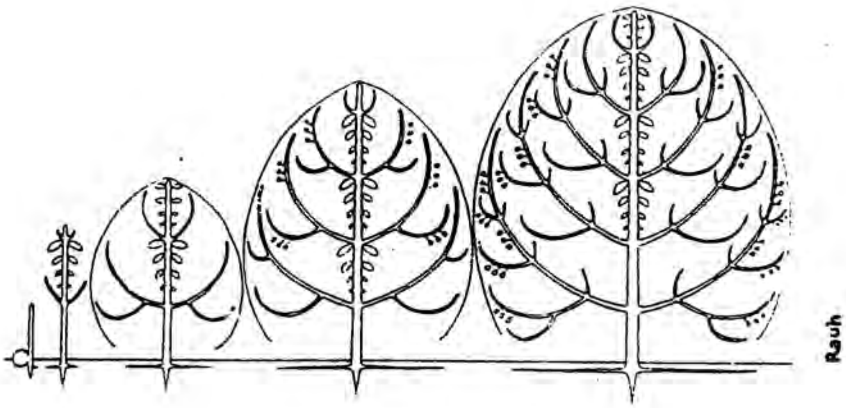
Branches short-lived



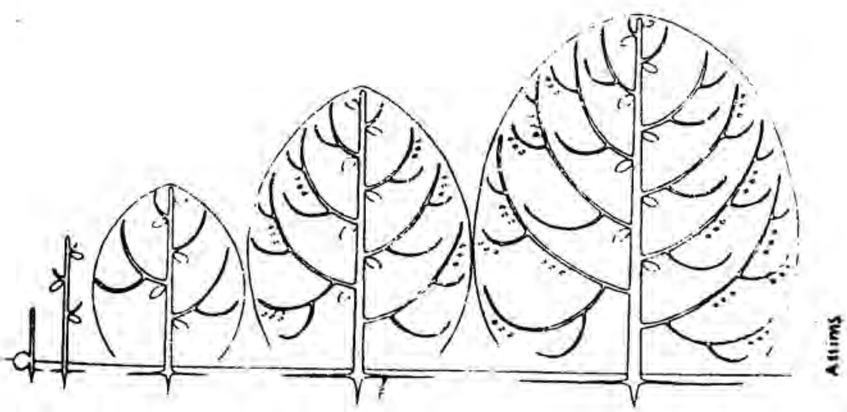
Trunk growth rhythmic



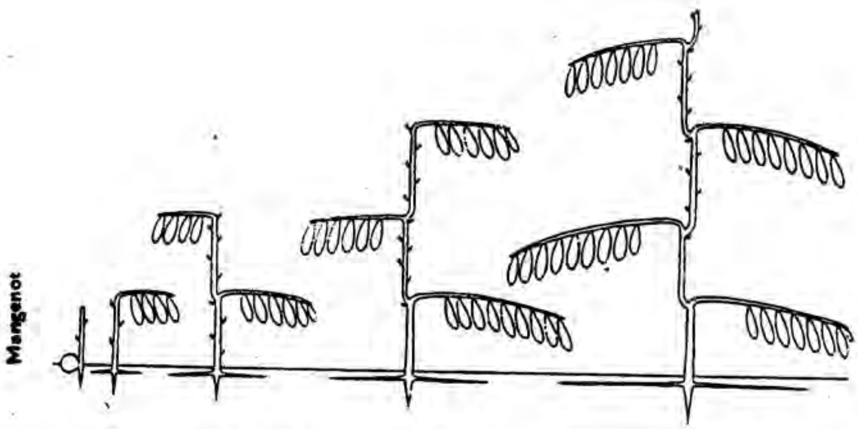
Trunk growth continuous



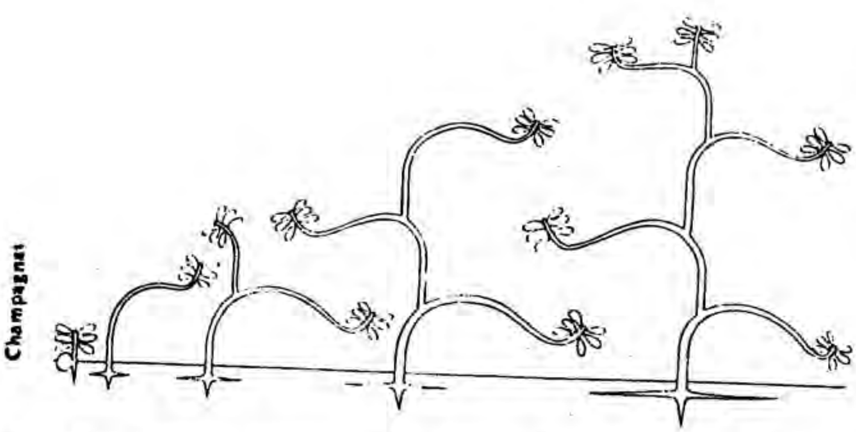
Trunk growth rhythmic



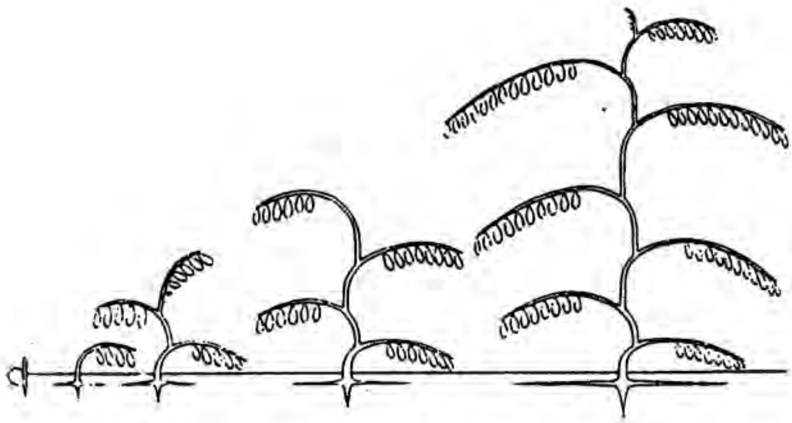
Trunk growth continuous

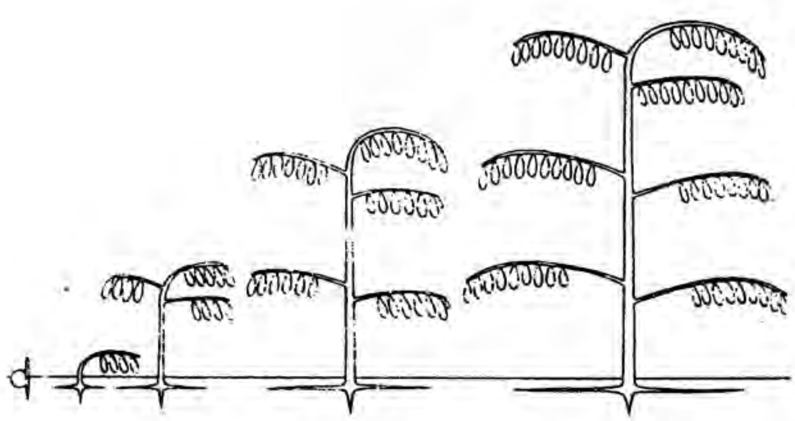


Stem proximally orthotropic, distally plagiotropic

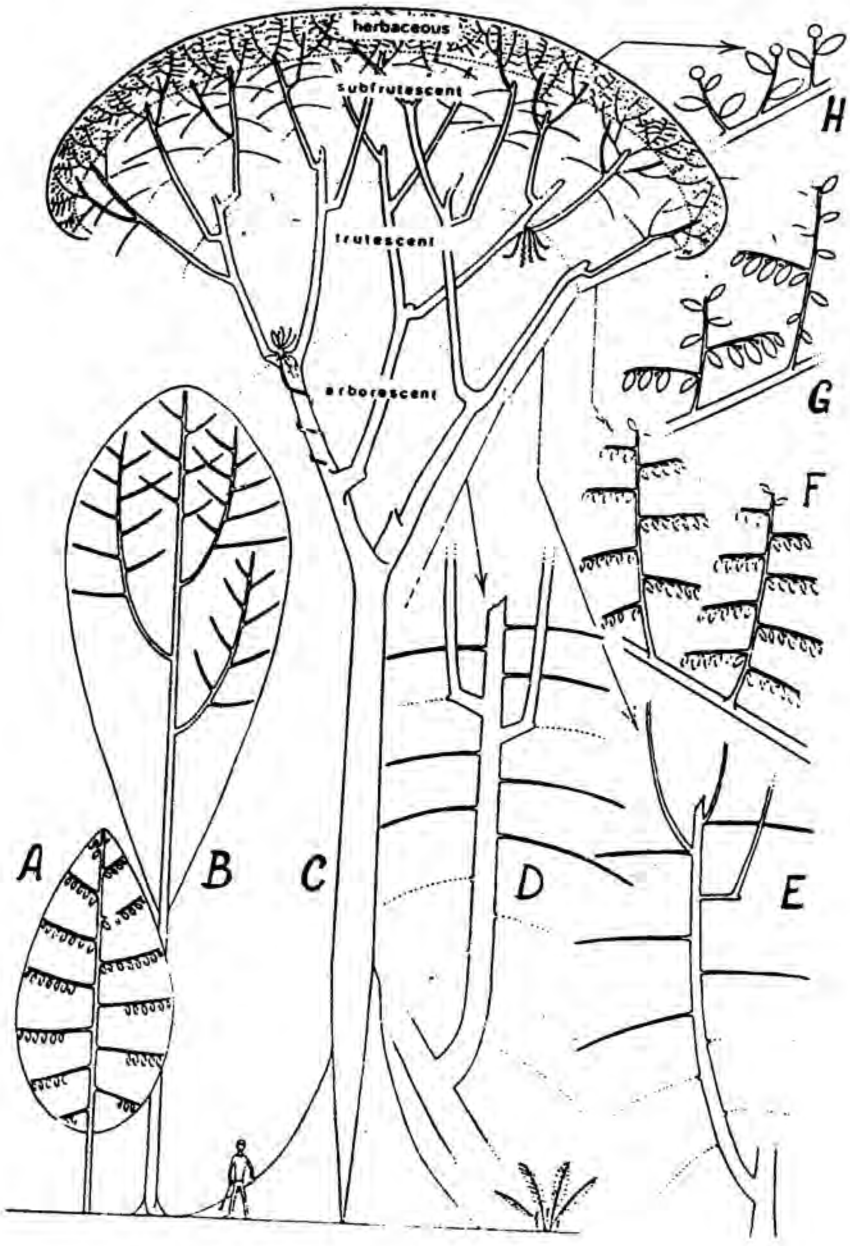


Stem orthotropic, becoming plagiotropic by bending due to gravity





Stem plagiotropic, becoming erect secondarily



Role of reiteration in the development of the mature crown.

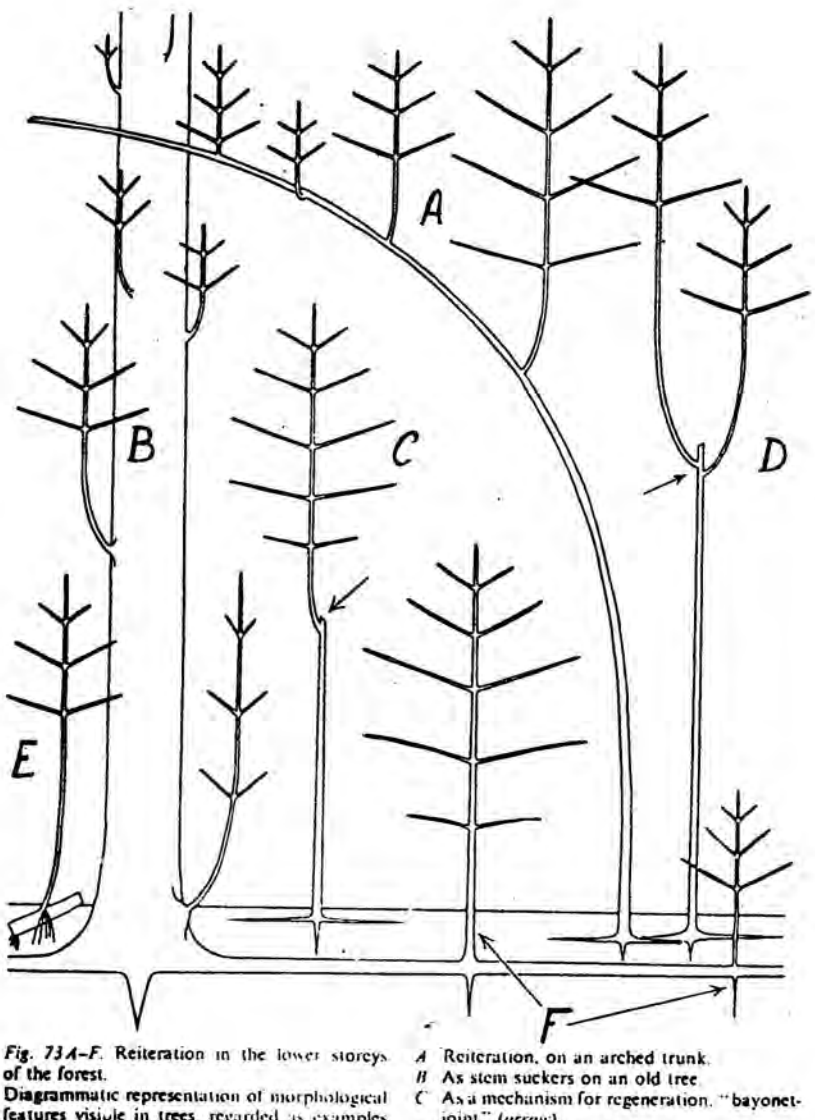


Fig. 73A–F. Reiteration in the lower storeys of the forest.
Diagrammatic representation of morphological features visible in trees, regarded as examples of reiteration usually involving reactivation of latent meristems.

A Reiteration, on an arched trunk.
B As stem suckers on an old tree.
C As a mechanism for regeneration, "bayonet-joint" (*arrow*).
D Same but twice, producing a fork (*arrow*).
E From a cutting.
F As root suckers.

Summary of discussion following presentation

Indonesia - Mr Achmad Abdullah: Is architecture of trees related to their taxonomical status and if so could it be maintained within a certain range of variation?

Dr Francis NG: Yes, they are to a certain extent taxon-related; but architecture could mutate; e.g. aberrant forms could originate which may or may not last.

Philippines - Mr Jose O. Sargento: In your opinion what are the applications of the information on tree architecture for forestry?

Dr Francis NG: It is difficult to speculate about this now because so far tree architecture deals only with form and not about size or factors dealing with size and productivity.

Prof. P.S. Ramakrishnan: The architectural models by Halle et.al., are qualitative and therefore have limited applications. All what they have done is to find an order in forms of growth among trees but very little information on the ecological adaptations of such order is available.

Dr N. Gunatillake: If tree architecture patterns are built in from young stages, should not there be similar patterns among shrubs and herbs as well?

Dr Francis NG: Yes; this is possible and it is up to somebody to develop some guidelines in this regard.

Dr N. Ishwaran: In a patch of a Dipterocarp forest how many architectural forms might be there and do you expect any association between specific forms?

Dr T. Jayasingham: Can we use the same models developed for bamboos? These just seem to be different types of branching!

Malaysia - Mr Fong Foo Woon: In higher canopy layers of montane areas what would be the effect of factors such as wind on the architectural models described for trees?

Dr Francis NG: You have all asked very perceptive questions which can only be answered by future research. I have to agree with the fact that treating the branching pattern of bamboos in relations to models developed for trees is arbitrary. A lot of work needs to be done in relation to the influence of ecological factors on the architectural models described so far and on application of these models, development of new models to shrubs, herbs and lianas.

Session II (e)

(e) Reproductive Ecology

Chairman: Dr Meher Homji

Phenology of Tropical Forest Species	Francis NG
Reproductive Biology of Tropical Humid Forest Plants (Sinharaja Project)	C.V.S. Gunatilleke

PHENOLOGY OF TROPICAL FOREST SPECIES

FRANCIS NG

Introduction

Phenology is the study of recurrent phenomena such as leaf-change, flowering and fruiting.

In those parts of the world where extremes of cold or drought recur annually, plant activity is forced into the climatic mould. Consequently phenological patterns are annual and self-evident, closely following the cycle of seasons. Because vegetative growth and reproduction have to be squeezed within a few months, all species in such climatic situations have to grow and flower on the onset of favourable weather, leaving little room for interspecific variation; often, only a few weeks separate the early-flowering from the late-flowering species.

In climates that are less extreme, interspecific differences have more opportunity to develop. Thus we find that in the monsoonal tropics, where wet and dry seasons alternate, some species flower in the wet season and some in the dry and some in between.Things happen throughout the year and phenology becomes more interesting.

But it is in the humid tropics, where the climate is almost aseasonal, that phenology becomes most difficult and challenging. In the absence of a strong climatic mould, recurrent events need not be annual; they may not even follow any fixed cycles at all. Furthermore, intraspecific variation i.e. differences between trees of the same species, may be as great as the differences between species. On top of that, different branches of the same tree may be out-of-synchrony with each other.

A visiting Japanese botanist, Koriba (1958) was so amazed to see lack of synchronization between branches on the same tree, as well as between trees of the same species in Singapore, that he coined the terms "branchwise manifold growth" for the first category of behaviour and "stockwise manifold growth" for the second. Had Koriba stayed longer, he would have realised that loss of synchrony between branches can occur on any tree and that non-synchronization between individuals can occur in any species.

In contrast, in Japan, when cherries, for example, are in bloom, all trees of the same species and all branches of each tree would be in synchrony, hence there is no need to consider separately the phenology of branches, trees and species.

. In the humid tropics, we must consider these things separately. For example, in Malaysia, when we say tht the durian Durio zibethinus or rambutan Nephelium lappaceum has two fruiting seasons a year, we mean that the species fruits twice a year. What individual durian or rambutan trees do is quite a different matter. Some fruit in both the seasons, some fruit annually in one or the other season, some fruit irregularly. Furthermore one branch may be out of phase with another.

Therefore, in any rigorous discussion of phenology in the humid tropics, one should distinguish several levels of organization:-

(i) the behaviour of the unit shoot

(ii) the behaviour of the tree as a population of shoots

(iii) the behaviour of a species as a population of individual trees.

(iv) the behaviour of a forest as a population of species and individual trees.

For our purpose we will not be so rigorous but is it well to bear in mind that for any generalizations we make, there will be much room for deviations from the norm. Indeed, in the humid tropics, it may not be easy to even define the norm.

Applications of phenology

Because plants are the primary producers of food, the availability of foliage (especially young foliage), flowers, and fruits, determine the quantity, type and seasonality of animal activity.

Animal migrations are determined by scarcity of food in one region and availability of food in some other regions. Migratory birds provide outstanding and well-known examples on a global scale.

For managers of wild life an understanding of forest phenology helps also to explain seasonality in animal reproduction and causes of population increase and decline. An abundance of food, whether it be fruits for birds and bats, pollen for insects, leaves for herbivores, or seeds for rats, leads to a population explosion, especially in the case of fast-reacting animals such as bees and rats.

Their populations decline just as rapidly as food sources dwindle away. Under most circumstances, the cyclical rise and fall of natural populations is something we observe but can seldom do anything about. However, because many natural populations of plants and animals have already become critically small and endangered because of the destruction of forests, any further decline can be a cause of serious concern. The most celebrated example lately is the plight of the giant panda population in China which is endangered by the synchronous flowering and death of the bamboos upon which they feed.

The course of human history has sometimes been altered by phenological events. The simultaneous flowering of bamboos in southern and eastern Asia have at various times led to explosions in the populations of rats feeding on the abundance of bamboo seeds. The rats next turned to cereals and other field crops. The resultant crop failures, famines, failure to pay taxes, and political turmoil have been part of Asian history for two thousand years (Corner 1964).

On a positive note, phenology is applied whenever knowledgeable gardeners plan their gardens so that new patches of colour appear every month. Farmers make use of this knowledge to obtain sequential crops in the most time-efficient manner. For example a combination of bananas and durians in Malaysia would yield bananas throughout the year and two crops of durians as a bonus. A more conservative farmer would plant at least ten species of fruits in a mixture so that something good to eat is available every month.

Taking advantage of the inherent variability found in plants, scientists and growers have been searching for early-flowering varieties, late-flowering varieties, ever - flowering varieties etc., in order to fit crops into various environments and various production schedules. Many advances in modern agriculture and horticulture have resulted from successful searches.

Finally with the advent of new tools in biotechnology, the time will soon come when we will be able to unlock the biochemical and genetic secrets of phenology, thereby giving us the means to directly manipulate growth, flowering and fruiting. Already without biotechnology, horticulturists have become very skillful in getting flowers to bloom exactly to coincide with major festival occassions. We can expect such control to be extended to more and more crops in future.

Evergreen versus deciduous

On a global scale, forests are generally classified as evergreen or deciduous. Evergreen forests are those which are generally leafy throughout the year. Deciduous forests are those which, in a dry or cold season lose most of their leaves.

In the tropics, we have deciduous forests in areas that experience seasonal drought e.g. E. Indonesia, N and NE Thailand, Central Burma, N and E Sri Lanka. Evergreen forests cover the whole of Malaysia, W. Indonesia, and Papua New-Guinea, where the climate is humid throughout the year.

The deciduous condition is relatively simple to describe. As a general rule, leaves are produced once a year. They mature, senesce and are shed as the unfavourable season approaches. The trees then stand bare of leaves for several months before starting the next cycle.

The evergreen condition is a lot more complicated. There are basically three ways in which a tree can stay evergreen.

The first is by continuous growth, whereby shoot growth and new leaf development proceeds without interruption throughout the vegetative life of the plant so long as it remains in good health, or until terminated by flowering. In the humid tropics, plants can develop to large size through continuous growth, e.g. the timber species Shorea platyclados and Dryobalanops aromatica. Continuous growth is also the habit of practically all palms, most climbers, most pioneers, most shrubs and all herbs. The rate of continuous leaf production has been measured for several species: the papaya Carica papaya produces leaves at a steady rate of 13-15 per month; Macaranga tanarius, 7-8 per month; Dillenia grandifolia, 2-3 per month; Shorea platyclados and Shorea ovalis about 1-1.5 per month (Ng, 1979), These rates were measured for juvenile trees that could be reached with a stepladder. Tall trees are difficult to measure directly but we can assume leaf production to be continuous if the trees have young expanding leaves at all times, as opposed to dormant buds or dead ends.

The second way of maintaining the evergreen condition is exemplified by the conifer. New leaves are produced in flushes interrupted by distinct periods of bud dormancy, but each flush of leaves has a life span well in excess of the interval between flushes. In other words, a flush of new leaves is added while one, two or more previous sets of leaves are still on the tree. The interval between flushes can be anything between 6 months and 2 years for mature trees, and the periodicity is not necessarily constant for a given species or individual tree.

The 'conifer' type of evergreen behaviour, when expressed in dicots, is mainly (but not exclusively) a phenomenon of understorey trees, i.e. trees that belong permanently in the understorey and juvenile individuals of canopy species. In a study of flush production in juvenile trees, Ng (1979) obtained a rate of 10 flushes in 24 months for Harpullia confusa, each flush consisting of 6-16 leaves, and 13 flushes in 29 months for Dacryodes rostrata, each flush consisting of 3-12 leaves. Mature trees flush at longer intervals than juveniles. We know this because it so happens that the sapling of Dacryodes rostrata referred to above was the offspring of a mother tree in Bukit Lanjan (Hill Transect, tree L') which was kept under observation from March 1972 to March 1974. This tree was recorded flushing new leaves in May 1972, October 1972, March 1973, September 1973, March 1974 and October 1974, i.e. at 5-7 month intervals compared to two-month intervals in the sapling.

The third way of maintaining an evergreen appearance has been termed 'leaf-exchange' by Longman & Jenik (1974). It involves flushing a new set of leaves at the same time that the previous set is shed. The coincidence of leaf flushing and leaf shedding is not necessarily exact. There can be occassions when both sets briefly coexist or when the two sets are separated by a brief period of bare crown. Leaf-exchange is the behaviour of most trees in the upper canopy of tropical rain forest. It is astonishing that such a dominant phenomenon did not get a name until 1974, after observations by Longman and Jenik in tropical Africa. Previously, such trees were sometimes referred to as deciduous, sometimes as evergreen. For example many of the 'deciduous' species studied by Holttum in his pioneering work on Malayan tree phenology (1930,1940) were actually of the leaf-exchanging type.

Continuous flowring versus intermittent flowering

Some species flower or fruit throughout the year. In general there are two ways in which this can happen.

Firstly, on an evergrowing shoot, new axillary positions for flowers may be continually created and used. This happens in the papaya Carica papaya and the coconut Cocos nucifera. It happens also on many species of Hibiscus.

Alternatively the flowers may terminate a shoot but the tree itself produces many shoots, all out of synchrony with each other so that some of the shoots will flower while others are producing leaves. Examples are Dillenia suffructicosa and the frangipanni Plumeria spp. The latter is everflowering only in the humid tropics. In the more seasonal tropics the trees go through a synchronised cycle of leaf-loss, flowering, and new shoot production.

On the whole, continuous flowering is not a common phenomenon among tropical trees. The majority of trees flower intermittently.

When a tree that has been vegetative for several months or years suddenly produces flowers, the question arises: what has caused the flowering?

For trees in the seasonal tropics, the flowering is usually correlated with the resumption of growth and production of new leaves; the stimulus for such flowering is obviously macroclimatic.

For trees in the humid tropics, the stimulus is not so obvious. In a study carried out in Malaysia, Yap (1982) monitored populations of 18 understorey species, comprising 5 to 48 adult trees per species, for 40 months, in Pasoh Forest Reserve. His observations are summarized in Figure 1, form which we learn that, instead of all-or-nothing responses, the percentage activity can vary enormously between one flowering pulse and the next, as in Baccaurea parviflora among which 21 % of individuals flowered in 1974, 2 % in 1975 and 62 % in 1976. Seldom did a flowering pulse involve 100 % of the mature individuals of a species. Most times, the response was below 50%. This illustrates one of the biggest paradoxes in reproductive biology, that humid tropical species, occuring in low population densities, are the most poorly synchronized in flowering, whereas species in limiting climates, occuring in high population densities, are the most highly synchronized. If there are advantages in synchronous flowering and cross-pollination, one would expect species with low-density populations to be best synchronized, to compensate for their spatial disadvantage.

Gregarious flowering and mast fruiting

Gregarious flowering is when an exceptionally high proportion of the trees in a forest flower together. This is followed by a "mast" crop of fruits. A mast crop means abundant food for animals hence mast years attract a great deal of attention. Typically, a mast crop occurs at supra-annual intervals. In Europe and North America, mast fruiting is displayed by many canopy-member trees e.g. Abies, Carya, Fagus, Pinus, quercus, Tsuga (Janzen 1974). In S.E. Asia gregarious flowering and mast fruiting occurs most notably in the family Dipterocarpaceae. Mast years in recent times for Peninsular Malaysia were 1957, 1958, 1963, 1968, 1970 and 1976 (Ng 1981). Typically, a mast year for dipterocarps is also a mast year for many other canopy species, so that the forest becomes an extremely active place. People in towns become aware of it indirectly by the abundance of wild honey and jungle fruits appearing for sale in the markets.

The coincident flowering and fruiting of many trees during a gregarious flowering event indicates that some widespread climatic factor must act as the stimulant. But most years, the flowering and fruiting is below peak levels, indicating that there is considerable variation between trees such that only the strongest stimulus will bring forth a strongly unified response; weaker stimuli will elicit responses from fewer trees.

Endogenous control of flowering

Of trees that flower independently of external stimuli; the best known are those that flower continuously such as the coconut, oil palm and papaya. The progressive production of flowers is linked, in these cases, to the progressive production of leaves. In other cases, a plant may flower as it approaches the end of its life, the most celebrated examples being certain bamboos and palms (e.g. Corypha). In a less drastic way, a stem may flower after reaching its full development, e.g. the palms Metroxylon, Caryota and Arenga, but new stems arise from below to take their place. In some trees e.g. Dillenia suffructicosa and Kopsia arborea, a stem flowers after it has produced a relatively fixed number of leaves, and new stems arise from below the inflorescences.

I studied the flowering periodicities of two trees of Peltophorum pterocarpum in the central courtyard of the Forest Research Institute of Malaysia from 1972 to 1979 and found that one tree had a periodicity of 6 months while the other tree had a periodicity of 9 months; they flowered together only by mathematical coincidence (Ng 1980).

Making phenological studies

In principle, all it needs to carry out phenological studies is a good pair of eyes (and binoculars) and a notebook in which to record observations.

General observations such as "mangoes flowered in District A in July 1986" are not as useful as detailed observations in which a record is kept for each tree for several years. One should be able to answer questions like

(i) What percentage of mango trees flowered in District A in July 1986.

(ii) What was the flowering history of each tree over the past few years?

(iii) Which tree was the most frequent flowering and which was least frequent?

The frequency of observation depends on the kind of data one wishes to obtain. Data on leaf change can be obtained by monthly or fortnighty observations since leaf change usually occurs in cycles of 6 months or more. Data on how long it takes for fruit to mature after pollination should be based on weekly observations because some species mature in a few weeks. Data on the timing of flowers opening on a raceme may need daily observation while data on time of opening and fading of flowers may require observation at various hours of the day and night.

If one wishes to correlate phenological events with climatic data, the studies should be carried out near a meteorological station.

The student of phenology must find a motivation for such studies, which may take many years. I began my own studies in the hope of finding the causes of gregarious flowering in dipterocarps, and thereby to find, perhaps, better ways to manage the regeneration of dipterocarp forests.

In the meantime I use the phenological records of trees to select those with desirable characteristics e.g. early flowering, frequent flowering and heavy fruit-bearing, for propagation as flowering trees or fruit trees. Such selection is the most important step in the domestication of forest trees for flower or fruit production. On the other hand for timber production, one may want to look for trees that flower late or seldom so that most of the growth effort is expended on building up the trunk.

We are very fortunate that, with plants, we can propagate chosen individuals by various methods of cloning such as bud-grafting, marcotting, cutting and tissue culture. What we need to do is to choose our individuals carefully for cloning, and this involves knowledge of their behaviour and properties, preferably observed over a period of time.

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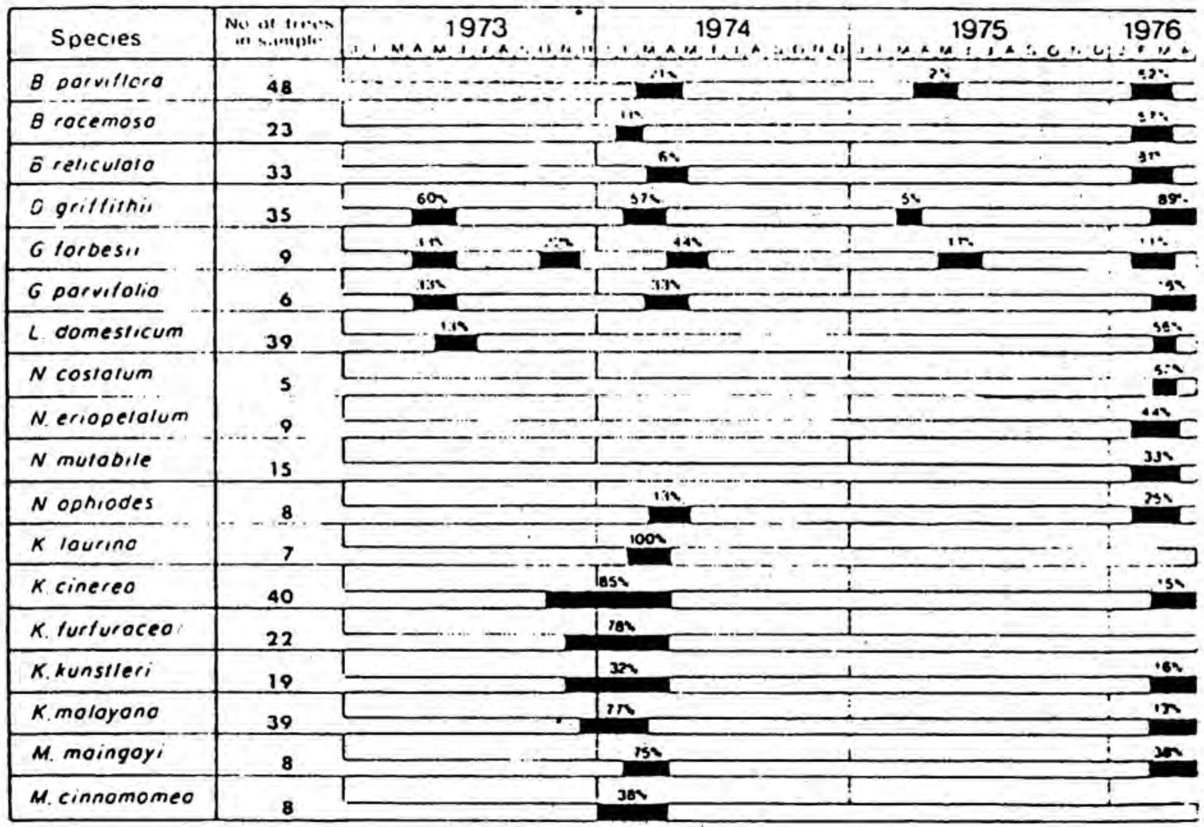

Fig : 1 - Flowering periods and percentages of trees involved in forest populations of Buccaurea. Durio. Garcinia. Lansium. Nephelium. Knema and Myristica (after Yap 1982)

Summary of discussion following presentation

Prof. P.S. Ramakrishnan: In the seasonal forest of northeast India extensiveness of internodal regions has been observed to be a periodical phenomenon. I think both intrinsic and external factors are important for such phenomena. Have you observed any correlations, in relation to such phenomena and environmental factors.

Dr Francis NG: I agree that both intrinsic and external factors are important; however, external factors some time could induce patterns of flowering though I do not have specific data in this regard.

Philippines - Mr Jose O. Sargento: Dipterocarps flower and fruit intermittently. Is it possible to induce flowering. In Philippines there other plants where flowering had been induced by chemicals.

Dr Francis NG: If the critical endocrinal substances could be identified and synthesized I presume this should be possible. As far as dipterocarps are concerned attempts at isolation of endocrines have not been successful.

REPRODUCTIVE BIOLOGY OF TROPICAL HUMID FOREST PLANTS (SINHARAJA PROJECT)

C.V.S. GUNATILLEKE

Introduction

A historical account of the origin, past studies and present trends on the subject of Reproductive Biology has been aptly described by Baker (1983). Although it is a field that has gained much interest in recent times, it is one that has not taken long to gather a wealth of information. In the first part of this present paper an attempt has been made to introduce the subject in broad outline to the beginner in the field, making use of our own studies at Sinharaja. In the second part the rationale for embarking on the Sinharaja reproductive biology project has been discussed.

Importance of Reproductive Biology

Basically the subject is of importance to two groups of people.

(1) Evolutionary Biologists due to the following: Most species in lowland tropical rainforests are represented by small densities, e.g. at Sinharaja in Sri Lanka 40% of all the tree species above 10 cm diameter at breast height (dbh) have in each case, only 1 individual in 2.5 ha (Gunatilleke & Gunatilleke, 1985). In the Panamanian lowland tropical rainforests 50% of all tree species over 20 cm dbh, have in each case 2-3 individuals per ha (Hubbel & Foster, 1983).

In Southeast Asian Dipterocarp forests the population sizes of most of the constituent species is no different (Poore, 1968; Ashton, 1984). It is these low density species that contribute to the species richness of these forests.

It is also believed that the majority of rain forest species are animal pollinated. Since most of these species also have low population densities, and their conspecifics are widely spaced, how successfully are they cross pollinated? This has led to much speculation not only about pollinator activity, but also on the degree of selfing and crossing between and within populations of a species, by many authors including Federov (1966), Ashton (1969) and Bawa (1974, 1977).

(2) Plant breeders and silviculturists who are interested in identifying desirable qualities in plants and then bringing them together through successful breeding programmes. Qualities or characters available to the plant breeder, are determined by the variability within and between populations. Whether such qualities could be combined would largely depend on successful, pollinations between the selected parent trees, fertilization and subsequent development of the offspring with the desired qualities.

Tropical trees have a greater interpopulation variation attributed to one or more of the following reasons: a) Reduced gene flow; i.e. the movement of genes within and between populations. This is influenced by the i) breeding system, ii) pollen and seed dispersal patterns iii) flowering pattern and iv) fruiting failure. b) Variation in selection intensity over a very small geographical scale. Even over small distances, variations between closely related species may be maintained. c) Genetic drift; i.e. loss of genes in the population due to small population sizes. Small populations provide less opportunities for exchange of genes and consequently they could be altogether lost from the population, e.g. population density and the number of possible pollinations may be compared to the number of times a coin may be tossed. If the coin is tossed a few times one might end with heads up every time it has been tossed. On the other hand if it has been tossed over 2000 times, the chances are that the ratio of heads to tails would be 1:1. In other words, if the opportunities for pollination are few due to the small population density of a given species, genetic attributes of that population may be lost with time. This is called genetic drift. On the other hand, large population sizes provide many more opportunities for pollinations and therefore, almost all the genetic attributes of that population may be maintained over time. The subject of genetic drift, in relation to speciation among tropical forest trees has been discussed at length by Ashton (1969).

The study of reproductive biology of plant species, very broadly, includes an understanding of the events that take place from bud initiation through blooming, fruiting, seed formation, germination and eventually seedling establishment. It also includes, examination of the breeding systems, pollination mechanisms and fertilization as well. The pattern of flowering and fruiting (as well as the production of new leaves) is generally referred to as phenology.

Not only must these events be examined from the point of a single individual, but they must be extended to the higher levels of organisation as well, viz., to the population and community.

The study of a single individual of a particular species is not representative of that species. The behaviour of different individuals in the same population might vary. Likewise individuals between different populations, e.g. on studies of Vateria copallifera carried out in Sinharaja, Sri Lanka, a home garden population and a forest population were examined. Individuals constituting the former flowered every year during the period of observation, but not those of the forest population. Similarly, studies on roadside individuals of Shorea trapezifolia at Sinharaja showed that neighbouring trees may flower at different times. Thus, it is important to understand the events related to the reproductive biology of a species, at all three levels viz., individuals, populations and community.

For the purpose of this paper, of the many events related to reproductive biology, particular attention would be paid to a) Flowering phenology, b) Breeding or mating systems and c) Pollination, for want of time.

a. Flowering Phenology

Three main aspects are generally examined in relation to the flowering phenology of a species. They are, timing, duration and frequency of flowering, all of which are important in understanding the flowering pattern of a species. The subject has been exhaustively documented by Bawa (1983).

Timing of Flowering

The timing of flowering provides information on when a species comes into flower. This is important for several reasons, some of them being, the availability of pollinators to ensure effective pollinations, suitable weather for presentation of the flowers to pollinators and consequent development of young fruits.

Duration of Flowering

The duration of flowering examines the length of the blooming period which could be restricted to one day or a few weeks or even prolonged over several months. The period of blooming is generally studied with respect to the whole population itself. If the particular species being examined is dioecious, then the blooming periods of male and female plants in the population must be separately examined.

Depending upon the duration and number of flowers produced per day (i.e. intensity of flowering) two types of flowering may be recognised; i) Extended blooming where few flowers are produced each day throughout the year (or over a long period of time) as in Muntingia calabura of the family Elaeocarpaceae and even Cocos nucifera (Palmae). ii) Mass blooming where an individual may produce a large number of flowers each day for a short period of time. In such species there is, in general, synchrony in flowering among conspecifics. Examples of mass flowering species are Shorea spp.(Chan and Appanah 1980).

In the Pasoh Forest Reserve, Malaysia, the Shorea species of section Muticae (Red Meranti Group), bloomed sequentially in the following order: S. macroptera, S. dasyphylla, S. lepidota, S. parvifolia, S. acuminata and S. leprosula. The duration of bloom of individual species varied from 15 days in S. macroptera to 25 days in S. leprosula (Chan & Appanah, 1980). In the case of Casearia praecox (Flacourtiaceae),the whole population flowers synchronously for only one day (Opler et al., 1976).

Opler et al. (1980) have also shown that extended flowering is prevalent in successional species as exemplified by some species of the Euphorbiaceae, Dilleniaceae and Melastomataceae. On the other hand mass blooming is shown to be prevalent in canopy species (Bawa, 1983), as depicted by some species of the families, Dipterocarpaceae, Bombacaceae, Polygalaceae, Myristicaceae and Leguminosae.

Advantages of Extended Flowering and Mass Flowering

In brief the following advantages, among others, have been shown for extended flowering.

a) Rate of flower production may be matched by resource availability for fruit production.

b) In outcrossing populations, a single individual may receive pollen from a large number of donars in the neighbourhood. In extended flowering, relatively few flowers are produced each day. This means that a pollinator would have to visit many more individuals, to gather adequate food for itself. Consequently however, pollen brought by it would be from several different individuals. On the other hand in the case of mass blooming species, because there are adequate number of flowers within easy reach on the same individual, the pollinator may retrieve all its food requirements from one or few individuals.

c) Reproductive failure due to lack of pollinators or bad weather would be minimized by an extended blooming pattern. In contrast, in mass blooming the individual may be badly affected if the requirements for successful pollination are not available during the short period of blooming.

The advantages of mass flowering, among others, are the following:

i) Build up of flower herbivores may be avoided.

ii) Increases the variation between and within populations. Much pollen exchange between and within populations, would tend towards uniformity, whereas restricted pollen exchange due to movement of pollinators over short distances, would lead to greater variations between individuals of a population and those between populations.

iii) Pollinators may be easily attracted to mass flowering species.

Frequency of Flowering

The frequency of flowering refers to the number of times a species may bloom within a given period of time. Frequency of flowering ranges between Monocarpic species, where each individual blooms only once in its life time, eg. bamboos and some palms (Corypha umbraculata), to those that are Polycarpic, where individuals bloom on several occasions during their lifetime. In polycarpic species the interval of blooming may vary. Some bloom more than once each year, others once a year and yet others once in several years.

2. Mating or Breeding Systems in Plants

For the purpose of this paper mating or breeding systems may be considered, in broad outline, as the expression of sex in plants and the consequent method of breeding (Wyatt, 1983).

Among the angiosperms, sex is expressed by the flower where the androecium comprising the stamens depicts the male structures and the gynoecium comprising ovary, style and stigma displays its female organs. The outer calyx serves many functions. They may protect the young flowers before blooming (anthesis), or young fruits in early development or they may be useful in successful dispersal of mature fruits. On the other hand, the inner corolla generally is much more conspicuous and showy. It serves to attract pollinators by "long-distance advertising" (Faegri & Van Der Pijl, 1966).

Depending upon the structural arrangement of the androecium and gynoecium within a flower or floral sexuality, the nature of flowers borne by individuals and the manner in which they function, a whole range of mating systems have been recognised in plants (Wyatt, 1983; Bawa and Beach, 1981).

Basically three mating systems may be recognised in plants. They are a) hermophroditic, b) monoecious and c) dioecious systems. In the hermophroditic system, all the flowers borne by the individuals are structurally bisexual. Functionally however, the two sexes may be separated in time or spece. e.g. In avocado , the flowers are bisexual, but functionally they are separated because anthers mature first releasing the pollen prior to the receptivity of the stigma. This system is referred to as protandry. In avocado two varieties of plants are present. In one of them the stamens mature in the morning and its stigma becomes receptive only on the afternoon of the subsequent day. In the second one, stamens mature in the afternoon while stigma becomes receptive the following morning. Thus, not only is pollination within each flower prevented, but that between individuals of the same variety as well. Successful pollinations are only possible between individuals of the 2 varieties. Protandry is also widespread among some species in Leguminosae, Compositae, Labiatae, Malvaceae and Caryophyllaceae. Protogyny (i.e. maturation of the stigma and loss of its receptivity before that of the anther) is exhibited by some members of the Cruciferae, Rosaceae, Berberidaceae and Thymellaeaceae (Faegri & Van Der Pijl, 1966). In plant species exhibiting protandry or protogyny there is a male-female or female-male transition respectively, within a period of a few days or even hours (Bawa & Beach, 1981). Heterostyly also prevents selfing. This is exhibited by flowers that have variable style and stamen lengths. Pollination occurs only when pollen from stamens of the same length as the style are placed upon its stigma. Pollinations are not successful when pollen from anthers at a different length are placed upon the stigma borne on the style which is not of similar length.

Unisexual only or unisexual and hermophrodite flowers may be borne on a single individual. A good example of this condition is exemplified by, some palms as in <u>Cocos nucifera</u> and <u>Caryota urens,</u> and dicotyledenous plants as <u>Sweitenia macrophylla</u> (Mahogony), species of the family Euphorbiaceae (Rubber-<u>Hevea brasiliensis,</u> Cassava or

- Manihot utilissima, Castor oil - Ricinus communis), Moraceae (Jak-Artocarpus heterophyllus, Ficus sp.) and Araceae (Anthurium sp.) Among some species with monoecious mating systems, there may be a time difference in the maturation of the different sexes, so that self pollination may be avoided; e.g. in Caryota urens the male flowers have dehisced when the female flowers of the same inflorescence becomes functional. There are species where female flowers mature first followed by the male flowers. Some species of the Compositae belong to this group. Thus, although flowers of both sexes are borne on the same inflorescence, the functionally effective period of each of them is different, avoiding self pollination.

In dioecious mating systems separate male and female flowers are borne on differnt trees, e.g. some species of Diospyros (Calamander - Diospyros quaesita), members of the Nepenthaceae (Pitcher plant - Nepenthus distillatoria), and Menispermaceae (Coscinium fenestratum). In such species self pollination cannot take place.

The proportion of dioecious species in tropical lowland rainforests is relatively high. In mixed Dipterocarp Forest at Bt. Raya, Central Sarawak, 26% of the tree species exceeding 1 foot girth are reported dioecious (Ashton, 1969); In the lowland rain forest of Costa Rica the corresponding value is 25% (Bawa et al., 1985).

The study of mating systems in rainforest species is becoming increasingly important as a first step to understand their breeding biology.

3. Pollination

Pollination has been described as a mechanism devised by nature to bring about breeding success in plants. Among the angiosperms or flowering plants, it involves 3 steps. They are a) release of pollen from the anthers, (b) transfer of pollen from the anthers to the stigmatic surface and c) successful germination of pollen grains.

The first of these steps may be brought about by both extrinsic and intrinsic factors related to the plant. The former may include changes in temperature, or humidity of the surroundings, water stress, or even animal activity at the flowers. The latter may include features related to the plant itself, viz., time of maturation of the anthers.

The second of these steps may be a passive mechanism, as in the case of wind pollinated flowers, or an active mechanism as in animal pollinated flowers. Among the latter various groups of animals have been reported as pollinating agents, viz., insects, birds and mammals.

The third step in pollination depends to a large extent on the intrinsic features of the parent plants, viz., the compatibility between the pollen received and the mother plant.

In this paper the second of these steps would be considered, because it can be relatively easily studied in the field. However, the importance of steps 1 and 3 cannot be underscored, for effective pollinations are the result of all these phenomena.

Based upon the floral presentations of plants, some are better adapted for pollination by wind than by animals, and vice versa. Species that favour wind pollination are reported to have the following features. Well exposed flowers either due to flowering during the deciduous period of the tree when all the leaves are shed or by having long inflorescence or flower stalks that raise the flowers well above the foliage, the perianth of flowers themselves may be insignificant, small or absent, but the anthers and stigma are generally well exposed. Attractants or rewards such as nectar may be absent. Pollen grains are small, smooth walled, dry and produced in large quantities. Pollen arresting or trapping mechanisms may be frequent. In general there is a reduction in the number of ovules per flower, usually 1 ovule per flower. As compared to these features animal pollinated flowers show the following: In general flowers are attractive, elaborate and showy. They have some kind of reward viz., pollen, nectar, perfume, fats or oils, and a way of making it known to the pollinator by sight or smell. Pollen release of such flowers and the production of the attractant are generally synchronised. Pollen itself is variable in size, sculptured and sticky, the stigma is simple and unbranched (Faegri & Van Der Pijl, 1966).

Wind pollination is generally favoured in vegetation types where (i) conspecific individuals are closely placed, (ii) pollen filtration within the vegetation is low and (iii) low rainfall limited to a short period of the year (Whitehead, 1983). The aerodynamic considerations and geographic aspects of wind pollination have also been considered by Whitehead (1983), and Faegri & Van Der Pijl (1966).

Animal visitors to flowers vary considerably and depending upon their activity at the flowers, they may be either pollinators or non-pollinators. Visual observations of the behaviour pattern of the animal provides valuable information to discern between the two groups of flower visitors. Faegri and Van Der Pijl (1966) have recognised groups of floral characters, which are called syndromes, that favour pollination by a particular type of animal, some of these syndromes are the following: Cantherophily (Beetles), Sapromyophily (Carrion & dung flies), Melittophyily (bees), Sphingophily (Hawkmoths), Psychophily (Butterflies), Ornithophily (Birds), Chiropterophily (Bats). Wyatt (1983) tabulates floral characteristics associated with each of these pollinators.

The insect groups that visit flowers, the floral attractants and rewards, how the physical environment affects the activities of the insects and pollination ecology in relation to communities and ecosystems have been reviewed by Kevan & Baker (1983).

Our own studies on Shorea megistophylla in the Sinharaja forest showed that as many as 21 different insect species visited its floral presentations. They included 11 Hymenopterans, 3 Coleopterans, 2 Dipterans and 5 other species. Since flowers of Shorea megistophylla begin blooming between 6.00 - 6.30 am and are shed after 8-12 hours the same day, insect activity is mostly restricted to the morning.

The visiting time and activity of these different insect species vary. The larger Hymenopteran bees, Apis dorsata and Apis indica are the first to arrive at the inflorescences when the anthers are just begining to dehisce and shed their pollen. The smaller bees, Trigona sp., Pachyhalictus and Nomia sp., visit shortly after. The peak activity time of the larger bees coincides with the time when pollen is available in plenty. That of the smaller bees however, is when the larger bees have left. Possibly their foraging patterns are related to body size and availability of pollen. In addition to the many pollen feeders there were predators, two species of wasps, and even a few spiders that found this microhabitat an ideal site to catch its prey.

Of the many flower visitors of Shorea megistophylla only Apis dorsata, Apis indica and Nomia sp. were efficient pollinators because, having large body sizes, they always touched the stigma of the flower while foraging for pollen. The other bees, being small pollinated these flowers only occassionally.

Thus, animal-flower interactions present a facinating field of Reproductive Biology. Yet it is one that demands much patience and time, nevertheless one that is greatly rewarding.

Finally, let me tell you the rationale of the Sinharaja pollination biology project. During our studies on the phytosociology of the tree species at Sinharaja, it became quite evident to us that villagers in its vicinity always collected non-timber minor products from the natural forest, but never attempted to cultivate these species in their own home gardens. They depended on the forest for their livelihood. However, once the Sinharaja Forest was declared an International Man & Biosphere reserve, the activity of these villagers in the forest was curtailed. In many ways this seems quite unreasonable, for it is certainly not the fault of these villages that the forest has dwindled. They were just continuing the activity of their forefathers. This prompted us to study the biology of some species that were of much importance to the village economy around Sinharaja, in order to encourage and guide these villagers to plant these species in their own home gardens. Thus, the following species were selected for study.

1. Shorea spp. Some of these species provide resin, while the bark of S. stipularis having antibacterial properties is used in the preparation of a sugar substitute. The cotyledons of S. distica, S. megistophylla and S. cordifolia are also used as an alternate source of carbohydrate by these villagers.

2. Vateria copallifera. The Cotyledons are used as an alternate source of carbohydrate.

3. Elattaria cardomum. Seeds are used as a spice.

4. Coscinium fenestratum. A liana of medicinal value. The water extract of the stem has anti-tetanous properties. It is widely used in the island, even as a remedy for common colds, body ache etc. Its demand is met by harvesting the product from the forest. It is not known to be cultivated.

5. **Caryota urens.** Phloem sap obtained from the inflorescence of this species is used in the preparation of a sugar candy. Its trunk may be used as a source of carbohydrates. Its trunk may be used for rafters and the leaves and trunk are also relished by elephants.

Studies on the reproductive biology of these species will provide valuable information to bring them into cultivation. e.g. studies on the variations within and between populations of these species will be important in the selection of good planting material with desirable qualities. Studies on pollination mechanisms are useful particularly if fruits are the product collected either for consumption or as silvicultural material. Hence, information about flowering, pollinators, predators breeding systems and fruit losses and development will enlighten us as to how the species may be manipulated to obtain maximum fruit set. Germination and establishment studies provide information on the viability and dormancy periods of the seeds of these species, their requirements for successful germination and establishment, as well as the practical problems that may arise in bringing them into cultivation.

Making use of all these studies and experience, we would eventually like to raise these species in nurseries and introduce them into the buffer zone of the Sinharaja reserve as well as encourage villagers to grow them in their own gardens. This way while the dependency of the villagers will be removed from the natural forest itself, the day may not be far when one or two of these species will no longer be considered as under-utilized plants but instead as important economic plants.

Last, it must be said that this project is being done in collaboration with Profs. P.S. Ashton, and K.S. Bawa of the Universities of Harvard, and Massachusetts, U.S.A. respectively, and it is funded by US AID.

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Summary of Discussion following Presentation:

Philippines- Mr Jose O. Sargento: In natural/artificial regeneration of endangered plants adequate supply of seeds and populations of pollinators are important. Did you find any major factors affecting numbers and types of insects present in your styudy area.

Dr.(Mrs.) C.V.S. Gunatillaka: No detail studies have been carried out to this effect but I would presume predators to be important.

Session III

FOREST MANAGEMENT

(a) Humid Forest as a Timber Resource

Chairman: Mr V.R. Nanayakkara

Tropical Humid Forests as Timber Resources and its Implications on Conservation with particular reference to Sri Lanka	M. Pushparajah
Significance of Seed Technology in Relation to the Natural Growth and Development of Forests and in Reforestation Programmes	A.K. Kandya

TROPICAL HUMID FORESTS AS TIMBER RESOURCES AND ITS IMPLICATIONS ON CONSERVATION WITH PARTICULAR REFERENCE TO SRI LANKA

M. PUSHPARAJAH

Tropical Forests

The tropical forests are, certainly, the world's richest ecosystem and one of the most valuable natural resources in the developing countries. These forests supply fuelwood and industrial wood, generate foreign exchange earnings and offer numerous other goods and environmental benefits for the human needs. It can continue to play a vital role, in the socio-economic development of the developing countries, provided, that this resource is recognized as an important renewable resource, protected and managed on a rational basis.

Tropical forests cover about 1935 million ha. of land area which is about 55% of the total world's forest area (FAO 1985). 1200 million ha. of the tropical forests are considered as closed forests with tropical America having the largest share 56%, followed by Asia 25% and Africa 18%. In addition, there are about 735 million ha. of open tree formation and 410 million ha. of forest fallow land, in the tropics.

Deforestation in the Tropics

The FAO/UNEP report (1982) estimates that an area of about 7.1 million ha. of tropical broadleaved forest is deforested annually. Seventy percent of deforestation in Africa is said to be caused by shifting cultivation. In Asia shifting cultivation is responsible, for about 50% of all deforestation, and it is estimated to affect about 23% of the closed forest areas. The second major cause of deforestation is large scale land development schemes. For example, in Malaysia the projected land development for the period 1971-1990 is about 1.8 million ha. (MOK, 1980). In Sri Lanka the forested area in the Accelerated Research Development Program area comprised 114,700 ha. (TAMS 1980).

Another reason for deforestation, which needs critical evaluation, is the forestry practice of clearing of forests for reforestation. One of the strategies, to achieve the Forestry Sector Objectives in Bangladesh is, accelerated cutting of high forests in the hills. The existing management plan for the hill forests totalling 0.5 million ha. envisages clear felling and replanting of 0.25 million ha. with fast growing species over the period 1980 to 2000. The management plan need to be looked at from a socio-economic point of view prevailing in the country. While this strategy may be applicable to Bangladesh, it is certainly not applicable to most of the other countries, in the tropics. Unless, thereis effective forest protection and forest management, the rate of tropical forest deforestation may even increase in the future, due to increasing population and demand for forest lands.

Growth Potential & Utilization

The growth rate of tropical forests varies from 0.5 m^3/Yr/ha to 4 m^3/Yr/ha, depending on the growing stock and climatic conditions. Assuming, an average growth rate of 2 to 3 m^3/Yr/ha, provided that the 1200 ha. of closed forests are managed on a sustained yield basis, the potential yield capacity per annum would be 2400 to 3600 million m^3 of wood per annum. Inspite of this high potential to produce wood, the total annual production is only about 1400 million m^3 which is less than half of the world's total output.

There are two very disappointing features of tropical forestry, which needs to be highlighted. Firstly, all the removals of roundwood do not come from forests which are managed on a sustained yield basis. Only about 5% of the total production forests, of about 881 million hectares, are under management. It means, there is no planned felling to sustain the yield in 95% of the production forest. The inevitable result would be, degradation of the growing stock and gradual loss of opportunity, for sustainable yield management, which is happening in most of the countries in the tropics. Further, a fair amount of the output comes from lands that are cleared for development and for reforestation. The estimated yield of timber and fuelwood from the hill forests clearing in Bangladesh for the period 1980-2000 is 40 million m^3. The second disappointing feature is regards timber utilization. Only about 200 million m^3 which is just 15% of the total output, is used for industrial purposes other than for fuel. There is also high waste of wood from development areas due to lack of coordination and most often, the relatively short time period, available for recovering wood from these areas. The extremely selective nature of harvesting practices also results in low average outturn per hectare and wastage of vast amount of timber.

The tropical forests yield hardwoods valued at 7 billion US $ per year and tropical timber exports contribute significantly to the foreign exchange earnings of a number of countries. The USA, Japan and Western Europe buy some 66 million cubic metres of tropical hardwoods annually, compared to about 4 million cubic metres 30 years ago. Some countries in the tropics consider as a necessity to exploit the forest natural resources to the optimum for socio-economic advancement. Malaysia has been following these lines ever since independence, the forests generating much meeded capital for development while the land providing opportunities for gainful employment and creation of new wealth. About 14% of Malaysia's total export earnings are from forest products.

The Indomalayan Realm

A map of the Biogeographical Provinces of the Indomalayan Biogeographical Realm as per Udvardy,(1975) is given in Fig. 1 along with Table 1. I have considered only the following eleven countries for the purpose of our discussion - Bangladesh, Burma, India, Indonesia, Kampuchea, Laos, Malaysia, Philippines, Sri Lanka, Thailand and Vietnam. Only two countries, namely Malaysia and Indonesia are richly endowed with tropical humid forests. But all the countries are characterised by high population density and high population pressure on arable land.

Forest Area, Roundwood Production & Exports

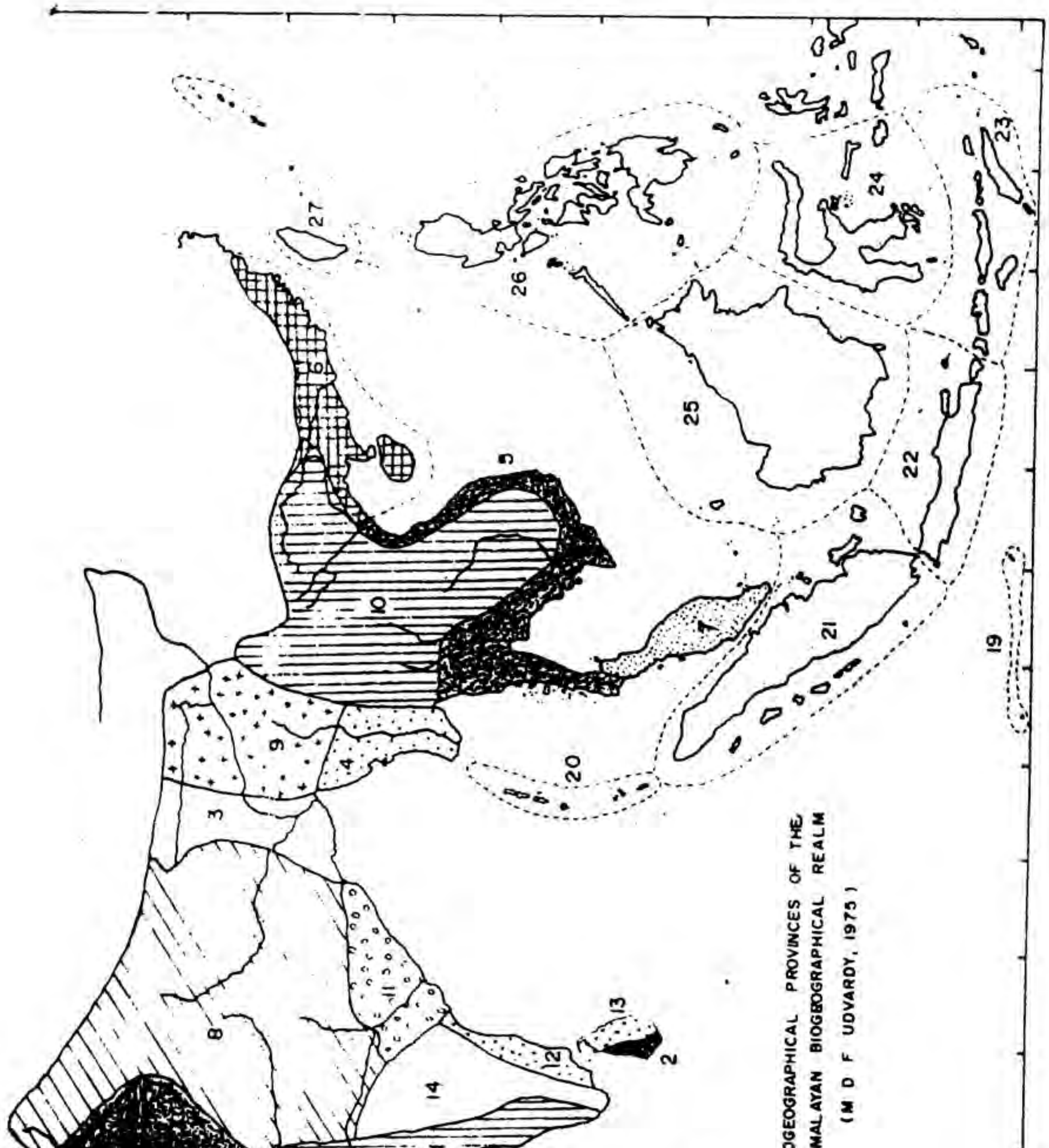
The complications in scientific terminology and classification of forest types combined with lack of data, makes the task difficult to give an estimate of the total extent of tropical forest by different forest types, in the realm. The total forest area of the eleven countries, under consideration, is about 330 million ha. occupying about 41.5% of the total land area (Table 2). Applying, a growth rate figure of 1.5 to 3 m^3/yr/ha. for the 292 million ha. of closed hardwood forests, for these countries, the potential sustained yield capacity would be 438 to 876 million cubic metres per annum. This figure is on the higher side, since the actual operable area would be less than the total forest area and the growing stock has depleted in most of the forests in the realm, over the years. The average total round wood output, for the years 1973-1984 is about 500 million cubic metres per annum, of which only about 19%, 95 million m^3 is industrial wood (Table 3). Though, the output is within the limits of annual growth potential for the region, only a fraction, comes from managed forests. To, realistically assess, whether the production is within the limits of annual growth, the extent of operable forests, yield from land clearings, status of growing stock and a number of other factors will also have to be considered.

The total export of industrial roundwood from the region is about 21 million cubic metres valued at 1727 million US $ in 1984 (Table 3). There has been a gradual decline in the export of roundwood, since 1978. Thailand, Philippines and Malaysia were the first to make decision to halt roundwood export in late seventies and Indonesia followed suit in 1985. The export of forest products from the region amounted to 3.7 billion US $ in, 1984 (Table 4).

Source of Energy

The contribution of tropical forest in the region as a source of energy, to the total energy consumption, is very significant. Nearly, 81% of the total roundwood output from the forests in the region is used as fuel. Figures, ranging from 40 to 70 percent are given in the literature as the 'fuelwood' contribution to the total national energy consumption for the selected countries. Though, the share of the 'fuelwood' as a source of energy is decreasing in most of the countries because of increased usage of other forms of energy, the total consumption of 'firewood' contribution was 67.5%

FIGURE. I



BIOGEOGRAPHICAL PROVINCES OF THE INDOMALAYAN BIOGEOGRAPHICAL REALM

(M D F UDVARDY, 1975)

TABLE : 1

THE INDOMALAYAN REALM

No.	Biogeographic Province
4.1.1	Malabar Rainforest
4.2.1	Ceylonese Rainforest
4.3.1	Bengalian Rainforest
4.4.1	Burman Rainforest
4.5.1	Indochinese Rainforest
4.6.1	South Chinese Rainforest
4.7.1	Malayan Rainforest
4.8.4	Indus-Ganges Monsoon Forest
4.9.4	Burma Monsoon Forest
4.10.4	Thailandian Monsoon Forest
4.11.4	Mahanadian
4.12.4	Coromandel
4.13.4	Ceylonese Monsoon Forest
4.14.4	Deccan Thorn Forest
4.15.7	Thar Desert
4.16.12	Seychelles and Amirantes Islands
4.17.12	Laccadives Islands
4.18.12	Maldives and Chagos Islands
4.19.12	Cocos-Keeling and Christmas Islands
4.20.12	Andaman and Nicobar Islands
4.21.12	Sumatra
4.22.12	Java
4.23.12	Lesser Sunda Islands
4.24.12	Celebes
4.25.12	Borneo
4.26.12	Philippines
4.27.12	Taiwan

TABLE : 2

FOREST AREA (1000 ha.)

Country	Land Area	Hardwoods		Coniferous		Forest Area	
		closed	open	closed	open	Total	%
Bangladesh	14425	2207	-	-	-	2207	15.3
Burma	67724	31985	-	116	-	32101	44.7
India	328751	67584	5393	4937	-	77914	23.7
Indonesia	190400	118955	3000	4280	-	126235	66.3
Kampuchea	18114	7595	5100	21	-	12716	70.2
Laos	23681	8270	5215	250	-	13735	58.0
Malaysia	32955	21147	-	109	-	21256	64.5
Philipine	30000	11660	-	850	-	12510	41.7
Sri Lanka	6561	2726	-	56	-	2782	42.4
Thailand	51422	10155	6440	220	-	16815	32.7
Vietnam	32927	9970	1340	840	-	12150	36.9
T O T A L	796960	292254	26488	11679	-	330421	41.5

(Source : Forest Resources Assessment Project FAO/UNEP 1981, 1982).

TABLE : 3

ROUNDWOOD (Hardwood)*
(1000)

Year	Production		Export	Value
	Total (cum.)	Industrial (cum.)	(cum.)	(US $)
1973	458702	91492	40798	1340899
1974	459950	83963	35776	1428866
1975	459814	74829	31833	948284
1976	485233	91459	39410	1622527
1977	494667	92060	39935	1748831
1978	508011	96517	40945	1872622
1979	516430	95965	38421	3180409
1980	528468	98937	34424	3010718
1981	529668	90967	26260	1950046
1982	541418	93470	26245	2040674
1983	556727	99476	25157	1921361
1984	565234	98671	21729	1727610

(Source : FAO year book of Forest Products, 1984)

* yearly totals for the eleven countries considered.

TABLE : 4

EXPORT OF FOREST PRODUCTS *

(1000)

Year	Exports value (US $)
1973	1848427
1974	1886105
1975	1333383
1976	2321200
1977	2450381
1978	2666493
1979	4631898
1980	4530903
1981	3242280
1982	3454452
1983	3876589
1984	3773089

* yearly totals for the eleven countries considered.

to the total energy consumption compared to 52% in 1976, although there was 8.5% increase in fuelwood consumption during the corresponding period (Hariyanto and Boen, 1982).

In the light of findings of the study by Wijesinghe,(1984) and the Wood Demand & Market Study and Non-Forest Wood Resouces Study (1986), carried out for the preparation of the Forestry Master Plan in Sri Lanka, the figures on 'fuelwood' contribution from forests to the energy sector in the region has become questionable. The term 'fuelwood' is being used at present, loosely, for the various types of biomass fuel, which consist of fuelwood from forests and non-forests such as; rubber, homegarden trees etc., and agricultural residues, crop wastes etc.

Biomass fuel accounts for about 71% of the total energy consumption in Sri Lanka (Sepalage, 1985). One of the interesting findings of the Master Plan Studies in Sri Lanka is that 80% of the biomass fuel comes from sources outside the forests. Thus, it is only 20% of the biomass fuel, that comes from our forests, which is the natural forest fuelwood. Hence, the contribution of the forests to the total energy consumption would be only 14.2% from the forests.

It is necessary for the other countries also to study the estimated contribution of the forests and non-forests to the total energy consumption, as it would be of valuable assistance, for programming fuelwood strategies.

The estimated consumption of biomass fuel in 1985 in Sri Lanka is equivalent to 11.35 million cubic metres of fuelwood, 20% (2.27 million m^3) of which is the contribution from the forest. The annual production of fuelwood by the State Timber Corporation is about 0.5 million cubic metres. Thus, the estimated quantity that is collected freely or unauthorised from forests, annually, is about 1.77 million m^3, which is valued at 177 million rupees (6.5 million US $).

Sri Lanka Situation

The National Forest Inventory of Sri Lanka was completed in late 1985, which gives the most recent and reliable data on the forest resources of the country. Sri Lanka, is also fortunate in that as a result of the Forestry Master Plan preparation reliable data are available, not only for the forest resources but also for the non-forest wood resources and the demand for forest products at present and in the future.

Forest Resources

Results of the National Forest Inventory are given in Annexure 1. The total extent of natural forest cover is 1.75 million ha. or 27% of the total land area of 6.56 million ha. 973,500 ha., 40% of all forest lands is dedicated as protection areas. From the point of phyto-climatology and forest management planning the 1982-85 inventory recognises only a Wet Zone and Dry Zone on the monsoonal rain basis the dividing line of which is roughly 2000 mm rainfall per year. On this basis, the the extent of the natural forest cover in the Wet Zone is 278,000 ha. and in the Dry Zone is 1.472 million ha.

Out of the total extent of 278,000 ha. in the Wet Zone only 119,000 ha. (43%) is classified as production forest, the remainder, 159,000 ha., being protection forests. 66,500 ha. of the production forest are over-cut forest, where the growing stock is badly depleted and no exploitation would be undertaken for several future years. Management of these forests will consist of safeguarding, enrichment or patch planting till adequate growing stock is built up. The currently productive area is only 52,500 ha. which are grouped into 15 management units. The annual coupe for the Wet Zone forest is only 840 ha. log out-turn per ha. is estimated as 40 m^3/ha, and 33,680 m^3, the total annual yield in log volume from the Wet Zone Lowland forests.

Silvicultural System

The common management practice in the tropical lowland rain forest has been a Modified Selection System, where all the trees of commercial species over a certain diameter limit are removed at regular intervals. The operation is generally known as selective cutting. In Sri Lanka, the diameter limit is 60 cm DBH and the cutting cycle is 30 years. Selective felling as practised in the past has adverse consequences, particularly on the species composition leading to disappearance of valuable commercial species. The genetic quality of the tree species also deteriorates under selective felling since, it is only the poorest individuals and inferior species that have the best chance to seed and regenerate the area. The present measures, include silvicultural treatments soon after selective fellings, enrichment planting mostly with *Dipterocarpus zeylanicus* and Mahogany. Improvement cuttings, once or twice during the cycle is also practised with aim of removing poor individuals and inferior species of the over-storey and to promote young growth.

The Tropical Shelterwood System has been practised, on a smaller scale in a number of tropical Wet Zone lowland forests around the world and the results have been very positive. The general principles of the tropical shelterwood system are to regenerate the forests by natural means under a shelterwood which is exploited after the establishment of the regeneration and to concentrate the latter so that the age classes will be confined by area and not scattered throughout the forest.

Experiments which have been conducted in Sri Lanka have shown that many of the valuable species are shade-tolerant at sapling stage but light-demanding afterwards for good development, and there is potential for practising of this system (Holmes, 1957).

Sustained Yield

The concept of sustained yield in tropical forests is being questioned, and referred to many as "empty words", by many. Forest management in the tropics requires professional skill, competence and dedication.

"Standing of that level is hard to come by in tropical forestry; our knowledge of the stand dynamics of tropical forests, even after a century or more of so called management is still too rudimentary, too inconclusive and too ambiguous for it be otherwise (Leslie, 1979). The foresters, in the tropics face the chanllenge to manage the forest resource rationally on a sustained yield basis and if we do not, the people will be justified in saying that "the forestry profession has proved that it cannot be trusted with the management of the tropical forests" (Leslie, 1979).

The cutting limit of 60 cm DBH and felling cycle of 30 years for the Wet Zone lowland forest, for sustained yield management has been based on past and recent growth data for these forests. The data gives a growth rate of gross bole volume of 2.4 m^3/ha/yr for all trees over 30 cm DBH, and calculations show the required felling cycle for sustained yield will be 35 years with a diameter limit of 50 cm and 27.5 years with 60 cm DBH limit. The Sri Lankan foresters have the opportunity to show that sustained yield management can be practiced, in the tropical Wet Zone lowland forests.

Demand on Forests and Conservation

Demand for forest products in Sri Lanka is given in Table 5. It is the demand for the forest resources, land as well as the forest products, that causes problem for conservation. These pressures are growing because the population is growing increasing and its expectations are rising. But the land resource cannot be increased and the forest resource is shrinking. If there were no pressure there would be no problem. They are not the pressures of timber contractors and timber merchants, that is far too easy a scapegoat, but of each and every one of us, even if we do the damage second or third hand by buying firewood or furniture or building a house or even buying a bread board!

Table : 5
Demand for Logs and Biomass Fuel

	1986-90	1991-95	1996-00	2001-10	2011-20
Biomass fuel (1000 tons/a)	9675	10359	10950	11435	11714
Logs (m^3 sub/a)	1050	1230	1390	1680	2050

Can we effectively conserve our natural resources if people do not have fuelwood to cook and timber for shelter? It is easy to equate demand with consumerism when you are in a comfortable salaried position with most of the necessities of life provided for. Then the impression is of air-conditioners in every bed-room, T.V. set, and a 'throw-away' society. But the view is a little different, if you live in a mud hut without water, sanitation, education or reliable supply of food and income. The Mahaweli Development Scheme and the Million Houses Programme are meant for upliftment of the rural poor. Yet, the first inevitably reduces forest area and the second, as inevitably, increases the demand for timber.

'Development' in its simplest definition means giving people the chance to rise from dust. Expectations rise, and even the most modest demand is comparatively enormous:

a reasonable house	- timber for the roof fuel to fire bricks and tiles
Furniture	- timber
Education	- buildings, paper
Agricultural land	- that much less forest
Cooking	- fuelwood

The demand for wood in Sri Lanka is almost self-contained. Export of wood products is insignificant and the only significant imports are of paper and pulp and plywood. By far the biggest pressure for wood is for <u>fuel</u> (85%). This would increase with increase in population (Table 5). By far the biggest pressure for wood is for fuel. Biomass fuel provides 71% of the national energy use and to replace it with oil would require 4.2 million tonnes of oil or about three times the present import figure. How to pay for that? The use of biomass fuel ahead of other forms of energy is directly influenced by price and availability. People would, or mightbe change from wood if the price of alternative was less, and also if they had the choice. Often the alternative is not available or there is not the money to exercise it.

Compared to the demand for fuel, <u>other wood use</u> is small, only 15% of the national use. But, the demand exceeds supply, so prices are high and consequently the temptation for illicit felling is high.

The forests that have disappeared in Sri Lanka are not due to selective felling. They were cleared for agriculture, either by plan as in the large settlement scheme, or casually felled by shifting cultivators and encroachers. In the process, some timber was taken out for milling, some firewood was used, and a lot of wood was burnt to clear the land. Forests are being nibbled away by axe and mammoty. The forests have not gone down the road on the back of timber truck. As consumers we all share the responsibility and the blame. There is no scapegoat.

The process continues, and in our options we have looked at how by better organisations, wasteful use of wood may be avoided, and more of the agricultural expansion directed to areas where the forest has already gone. But how much of this is likely to be achieved? Forest importance may not weigh very highly with agricultural developer, and carries little weight for the shifting cultivator. The deforestation rate in Sri Lanka during the last two decades has been 42,000 ha. per annum. It we have to stop this trend, there is an immediate need to take decisive steps with polical will and strong public support.

Forest Conservation

Sri Lanka has 973,500 ha. of forests and grassland, which is about 40 percent of all forestry lands (2.75 million ha.) in the island, dedicated as protection lands. The protected area consists of 796,000 ha. of strict Natural Reserves, National Parks, Wildlife Reserves, Sanctuaries and Jungle Corridors under the Department of Wildlife

Conservation and 177,500 ha. of Man and Biosphere Reserves, forests on steep slopes and elevations over 1500 m, under the Forest Department (Annex 1). The main tropical forest ecosystems in Sri Lanka are all represented in the protected areas. The National Forest Inventory Report of Sri Lanka (1986) considers the present protected area to be adequate for purposes of nature and wildlife conservation.

The problem in Sri Lanka is how to effectively protect and manage these protected areas. The benefits of the forest, be they the fulfilment of rural needs, a source of land and timber, regulation of water flows, and holding the hills are all seen as common benefits. Everyone wants to share in these benefits, but there is a lack of a sense of duty to maintain them. Apart, from the fact that the disappearance of forests is due to development schemes and the results of actions of the people themselves - abuse of the 'common good' - so that the free benefits are no longer available, a population set to double in the next 100 years will lead to more demand on forest land and forest products. The demand for wood is derived demand and the increase in demand forecast is the direct consequence of a rapidly growing population and rising expectations. The problem of conservation of meeting peoples' need for timber and fuelwood is being acknowledged, late in the day and the courses of actions available are difficult and limited. As long as there is problem of pressure on forest resources by the people effective conservation of our protected areas will be a very difficult task.

The opportunity cost of conserving 10,000 ha. of productive Wet Zone lowland forests, per annum is estimated as Rs. 45 million. If the multiplier effect is also considered which is about three times higher than the primary value, the benefits foregone to the National Economy would be Rs. 135 million rupees (Rs. 13,500 per ha.) which is the cost of conservation per annum. This is on the assumption that the land use is not altered. If this 10,000 ha. could be converted to high-yielding, high value plantations of Mahogany or agricultural crop the picture would be somewhat different. With broad-leaved Mahogany (Swietenia macrophylla) the benefit foregone would be Rs. 240 million (Rs. 24,000 per ha.) without the multiplier effect and Rs. 720 million (Rs. 72,000 per ha.) considering, the multiplier effect, too, per annum.

The cost of conservation of the protected areas will increase with increase in population and demand. The availability of forest products, in meeting people is basic needs, outside the conservation areas, both from the production forests and non-forest wood resources would decide the increase in opportunity cost of conservation and ultimately the success or failure of our conservation efforts. Pressure, to take wood from National Parks and Wildlife Reserves has already begun!

The strategy that us followed by the Sri Lanka Government in the forest sector are :

* Institution strengthening, human resources development, through
  - Professional training in Forestry at the University of Sri Jayewardenepura
  - Technician level training at the Sri Lanka Forest College
* Education, extension and awareness programmes
  - Peoples' participation in forestry
* Annual reforestation of 10,000 ha.
* Man & Biosphere programme
* Intensification of forest management
* Restricting agricultural and other lands development to areas cleared largely of forest
* Increasing the non-forest wood resource base & yield
* Efficient utilization of wood both as fuel & timber
* Stoppage of converting natural forests to plantations
  Stoppage of issue of permits for shifting cultivation
* Watershed protection
* Agro-forestry
* Forestry Research
* Strengthening law enforcement
* National Heritage wilderness legislation
* Tree planting programmes
* Provision of adequate funds for forestry programme
* Long term plan for the forestry sector

It is only such a strategy, that takes production into account, to meet the basic needs of people while ensuring adequate conservation of the protected areas, that can solve the problems of conservation of any country. The strategy, is in full accord with the recommendation of the FAO's "Tropical Forestry Action Plan (1985)" and "Tropical Forests : A call for Action by the World Resources Institute (1985)", and augurs well for the conservation of our forest resources.

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Currently inoperable and specially protected Forest Department areas include :

forests on steep slopes (over 30^{o})	:	86,000 ha
forest in elevations above 1,500 m	:	36,000 ha
protected high forests including plantations	:	19,000 ha
mangroves	:	7,000 ha
protected shrubforests	:	22,000 ha
protected grasslands	:	7,000 ha
protected other non-forests	:	500 ha
		177,500 ha

Currently timber productive forests under Forest Department include :

unlogged natural forests of the wet zone	:	13,000 ha
logged natural forests of the wet zone	:	39,500 ha
forest plantations of the wet zone lowland/hills	:	11,000 ha
forest plantations of the up-country	:	13,500 ha
dry zone natural forests	:	735,000 ha
forest plantations of the dry zone	:	40,500 ha
		852,500 ha

STATISTICS ON FOREST RESOURCES OF SRI LANKA

Source : GOSL/UNDP/FAO Forest Inventory for Management Planning, Forest Department March, 1986

Annexure I - INVENTORY RESULTS (PG. 1-3)

Total area of forestry lands is	: 2.75 M ha. or 42% of land area
under the Forest Department	: 1.95 M ha. or 30% of land area
under the Wildlife Department	: 0.6 M ha. or 9% of land area
proposed under the Wildlife Dept.	: 0.2 M ha. or 3% of land area

Total area under forest vegetation cover is	: 2.45 M ha. or 37.5% of land area
natural high forests inclusive of mangroves	: 1.75 M ha. or 27% of land area
forest plantations 5 years and older	: 0.075 M ha. or 1% of land area
secondary shrubforests and scrublands	: 0.625 M ha. or 9.5% of land area

The Wildlife Department areas include following cover types :

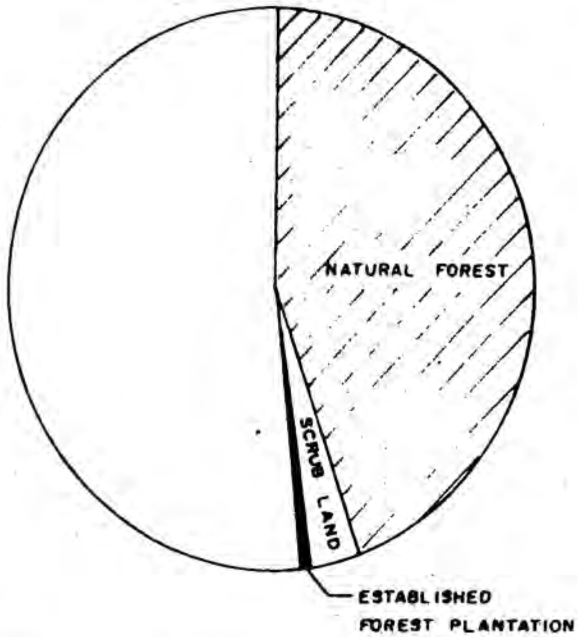
dry zone lowland and hill forests	: 461,000 ha
wet zone hill forests	: 19,000 ha
forest on steep slopes and elevation above 1,500 m	: 61,000 ha
mangroves	: 1,000 ha
forest plantations	: 12,500 ha
wet zone shrubforests	: 2,000 ha
dry zone scrublands	: 106,000 ha
up-country grasslands	: 2,000 ha
dry zone grasslands	: 29,500 ha
wet zone fallowlands	: 21,000 ha
dry zone sparsely used croplands	: 81,000 ha
	796,000 ha

The major categories of forestry land under the Forest Department are :

currently inoperable and specially protected areas	: 178,000 ha
currently timber productive areas	: 853,000 ha
currently degraded & unstocked areas	: 924,000 ha
	1,955,000 ha

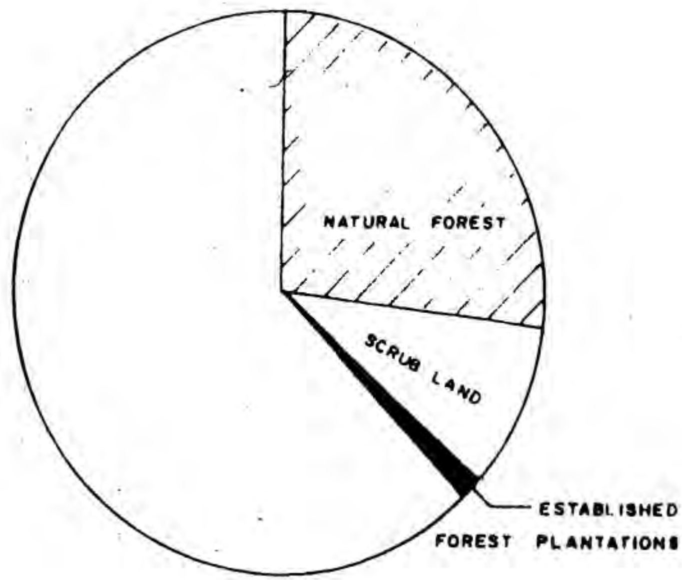
THE SRI LANKAN FOREST COVER SITUATION

1956
HUNTING'S INVENTORY



TOTAL LAND AREA	6,557,470 ha	=	100·0 %
NATURAL FOREST	2,874,400 ha.	=	44·0 %
SCRUB LAND	177,900 ha.	=	2·7 %
FOREST PLANTATIONS	20,200 ha	=	0·3 %

1982 / 83
F A O INVENTORY



TOTAL LAND AREA	6,561,000 ha	=	100·0 %
NATURAL FOREST	1,758,000 ha.	=	26·8 %
SCRUB LAND	624,900 ha	=	9·6 %
FOREST PLANTATIONS	75,300 ha	=	1.1 %

Currently degraded and unstocked areas under Forest Department include:

wet zone over-cut high forests	:	66,500 ha
wet zone shrubforests	:	48,500 ha
dry zone open high forests	:	219,000 ha
dry zone scrublands	:	485,000 ha
grasslands	:	105,000 ha
		924,000 ha

Summary of discussion following presentation

Mr V.R. Nanayakkara: I think it is worth noting that when natural and man-made forests are considered together Sri Lanka has one of the largest percentage forest cover among countries of the realm.

Dr A.H. Perera: National Forestry Inventory; who conducted this study for Sri Lanka and when was it done?

Mr V.R. Nanayakkara: National Forest Inventory was first conducted in 1956 by the Hunting's Survey Corporation; a second one has been conducted by a FAO/UNDP study in 1981.

Dr A.H. Perera: Do you think there are enough protection forests in Sri Lanka?

Mr M. Pushparajah: It seems adequate except in the upcountry.

India - Dr Mathew George: What is the basis for your criterion of selectively felling trees having a girth of 60 cm? The 27% natural forest cover is suppose to include areas with 70% forest cover. Some rubber plantaitons could have 70% cover!

Mr M. Pushparajah: The criterion for selective felling was established using available data on growth rates of tree species which were used in projections from existing amounts of growing stock available.

Mr V.R. Nanayakkara: The 27% figure refers to natural forest. Man-made forests and tea, rubber and coconut plantations have been considered separately.

Pakistan - Mr Mirza Mohammad Ashraf: What is the amount of watershed area under natural forest cover?

Mr M. Pushparajah: Exact figures are not available but we feel the situation is not satisfactory. We plan to plant about 11,000 ha in vulnerable areas.

Mr V.R. **Nanayakkara:** I think the problem had been complicated by the fact that several land development projects of the past did not have any planning for forestry or afforestation.

Mr L.C.A. de S. Wijesinghe: There are several types of biomass fuel in Sri Lanka, e.g. coir, products, paddy-husk, bio-gas etc. which are under utilized. Although greater utilisation of these products could relieve pressures from other sources such as fuelwood, so far the impact of these biomass fuel on the national scene has been minimal.

Dr N. Gunatillake: You stress the need for experience and data; how do you use limited for planning?

Mr M. Pushparajah: Rational decisions are made with available data.

Indonesia - Mr Achmad Abdullah: Can you give us some ideal value for conservation forest in a country?

Mr M. Pushparajah: This depends upon what you would call 'ideal'. 40% seems to be reasonable to me but I don't think that you can make these generalisation for every country.

SIGNIFICANCE OF SEED TECHNOLOGY IN RELATION TO THE NATURAL GROWTH AND DEVELOPMENT OF FORESTS AND IN REFORESTATION PROGRAMMES

A.K. KANDYA

A seed is the greatest miracle of Nature. In this small grain of only a few milligrams in weight, an admirable programme for the creation of a tree weighing several tons is stored. This programme, controlled by the chromosomes of the seed's embryo, starts its precision work in cooperation with the environment. i.e. when suitable conditions for the germination of the seed are provided. Consequently, the future properties of a tree depend upon the interaction between the internal constitution of the seed and the environment.

It is now well recognised that the population of the world is continuously increasing and with it also the demands for forest products. Plants are essential for all living beings on this globe as they are the only natural machinery producing the oxygen and fixing the carbon-di-oxide of air into food material thus cleaning the atmosphere. Without plants, there will be an imbalance in the natural carbon cycle resulting in the poisoning of the atmosphere. Thus, protection of atmosphere mostly depends upon the vegetational cover of the soil. A clear understanding of the quality and germination behaviour of seeds is absolutely necessary for establishing such a cover in any part of the earth.

Afforestation and/or reforestation in various geographical regions of the world are very much needed now-a-days to control the disturbing climatic and soil conditions due to the indiscriminate felling of the trees. A large area of the land has become bare due to this. It will become more if left unplanted. But, plantation in various climatic and soil conditions is not an easy task. It needs a clear and complete understanding of the forest tree seeds particularly about their vitality, viability, vigour, presowing treatments, purity and capacity to germinate and grow well in various climatic and soil conditions. In the present paper some preliminary methods have been discussed with their significance to know the above aspects of seeds by some chemical, biochemical or physiological techniques. At each step, starting from the collection to the sowing of seeds, care is needed in their handling so as to ensure vigourous growth of the growing seedlings.

Seed Collection

Seeds are collected for the purpose of raising seedlings which can grow into trees. The exploitation of forests and recognition of the need for their replacement by plantations gave rise to the afforestation and reforestation programmes.

Time of Seed Collection

It depends upon the special weather conditions of the year and varying climatic conditions throughout the natural range of distribution of any species. Care should be taken on the progress towards ripening and dispersal time of the seeds. Generally, a a turn from a green to a brown colour of the fruit denotes its maturity. Good yield of the seeds are obtained only when collection is made in advance of the beginning of dispersal. Almost all tree seeds attain their best quality only when they are allowed to ripen fully on the tree.

Methods of Seed Collection

1. From felled trees, 2. From the ground, 3. From standing trees. While collecting the seeds, beyond the above aspects, the following data should be recorded carefully as every factor of it has some impact on the seeds and might be needed while using them.

Identification of Species ....,Season of seed maturity ....
Place of collection ....,Date of collection ....
Altitude (m,asl) ....,Soil ....
Latitude ....,Longitude ....
Age of tree ....,Situation ....
Branching ....,Leaf position ....
Height of tree ....,DBH ....
Mean temperature ....,Rainfall ....
De-winging ....,Cleaning ....
Air/Kiln drying ....,Storage (Type of container)..
Temperature during storage............,Quantity ....
Collected by ....,Seed Lot Number alloted .....

Extraction of Seeds

Seeds are extracted from the fruits just after the collection of fruits or some times the fruits are left in the sun for air drying. Many capsular fruits open in the sun to liberate the seeds. Some hard pods of legumes are beaten with a hammer or stone to liberate the seeds. Seeds are separated from the foreign material and then kept in the sun for air drying or can be dried in artificial kilns. When seeds are fully dried, they are ready to be stored. Length of time for drying depends upon the size and nature of the seeds.

Seed Storage

Storage means the preservation of seeds until they are desired to germinate. The prime object of storage is to preserve the seed with their viability as little impaired as possible.

Reasons for Seed Storage

Seeds are needed for plantation at least once or even several times in a year however, trees of many of the most desired species produce the seeds irregularly and often at rather long intervals. Some trees flower only once in their life time, i.e., Bamboos. Storage of seeds thus bridges the gap and large enough quantities of seeds are collected in good seed years. They supply the needs during the barren years.

Factors affecting storage life of seeds

Genetic characteristics make seed of some genera, species or varieties long-lived than the seeds of others. Generally, 'Hard Seeds' (seeds with seed-coats impervious to water) have a longer life than do seeds that are not hard. (Plant families of which some species are known to produce hard seeds include Cannaceae, Chenopodiaceae, Convolvulaceae, Geraniaceae, Gramineae, Labiateae, Liliaceae, Malvaceae and Solanaceae etc.). Short-lived seeds are produced by the soft maple and cocoa etc.

Treatment during harvesting and processing also influence the storage life of seeds. Rough handling ruptures seed-coats and cracks or breaks seeds. Mechanically damaged seeds do not remain viable so long as do the undamaged seeds, even under controlled storage conditions.

Because of seasonal variations in growing and harvesting conditions, year of production can also affect seed storage life. Other characteristics such as a high incidence of fungi in the seeds or too high a moisture content may affect storage life. Seeds with high moisture content may not be complete mature. If so, they will not live so long as the mature seeds. The most important factors in determining the life of seeds are:

1. Protection from water (sealed moisture-proof containers be used)
2. Protection from fungal contamination (fungicides be used)
3. Protection from rodents (rodenticides be used)
4. Protection from fire (necessary care be taken)
5. Protection from insects (insecticides be used)

As a rule, seeds must be stored in an atmosphere where storage temperature in ^{o}F plus the Relative Humidity should not exceed 100 (where temperature should not be more than half of the sum). Following are some containers used for seed storage :

1. Tin containers (Moisture proof), 2. Polythene bags (Moisture proof),
3. Paper packets, 4. Jute bags, 5. Glass bottles (moisture proof),
6. Cloth bags.

To provide a suitable temperature condition to retain the viability, Seeds may be stored:

1. In refridgerator at 0 to 5^{o}C temperature
2. At a fixed temperature in an incubator
3. At room temperature

The first and second conditions are useful only for a limited quantity of seeds specially for experimental purposes only. By proper storage, microbiotic seeds may become mesobiotic or even macrobiotic.

Impurities of seeds

1. Seeds of other species
2. Pieces of seeds half or lesser than the original size
3. Seeds with seed coats entirely removed
4. Broken and detached wings
5. Attached wings
6. Other matter such as soil, sand, stones, stems, leaves, pieces of bark, fruits and all other materials which are not seed.

Percentage Purity

It is the percentage (by weight) of the clean, whole seeds (pure seeds) in a seed lot and can be determined by the following ways:

$$\text{Purity percentage} = \frac{\text{Weight of pure seeds}}{\text{Weight of total seed sample}} \times 100$$

Number of pure seeds per Kg can be determined by the following formula:

$$\text{No. of pure seeds in a Kg} = \frac{100 \times \text{No. of pure seeds in a sample}}{\text{Grams of pure seeds in a sample}}$$

Pure seeds may be of the following categories

1. Mature undamaged seeds
2. Immature, under-sized, shrivelled and germinated seeds
3. Pieces of seeds more than half of the original size
4. Seeds without damage to the testa regardless of whether they are empty or full
5. Seeds (Botanically fruits) regardless whether they contain true seed
6. Diseased seeds
7. Seeds or fruits with attached wings.

Testing the quality of seeds

After finding out the purity of a seedlot, the pure seeds are tested for their germinability, viability, and vigour by several tests. Before coming to these tests, we should know the exact definition of these terms.

VIABILITY : It is an abstract term referring to the potential capacity of seed to germinate (Baldwin, 1942).

It is the condition of seed in the sense of being capable of growth and survival (Barton, 1961).

It is the potentiality of seed to germinate (Schopmeyer, 1974).

Ability of seed to live, grow and develop. (Agrawal, 1980).

State of being capable of germination and subsequent growth and development of seedling (Bonner, 1984).

VIGOUR : It is the sum total of all those properties in seeds which, upon planting, result in rapid and uniform porduction of healthy, seedlings under a wide range of environment including both favourable and stress conditions. (Woodstock, 1976)

It is the sum total of all those properties of seeds which determine the potential level of performance and activity of non-dormant seed or seedlot during germination and seedling emergence, (Perry, 1978).

Those seed properties which determine the potential for rapid, uniform emergence and development of normal seedlings under a wide range of field conditions. (Bonner, 1984).

Tests for Seed Viability

(Germinability without germination)

1. Physical tests - Cutting test, Floatation test.
2. Biochemical tests - Catalase activity test, X-ray radiography test, Excise embryo test, Tetrazolium staining test, Potassium iodide staining test, Indigocarmine staining test, Sodium selenite staining test, Sodium telurate staining test.

Seed Germination

Germination of seed, in a laboratory test, is the emergence and development from seed embryo, of those essential structures which, for the kind of seed being tested, indicate the ability to develop into a normal plant under favourable conditions in the soil.

Necessity of germination test

Often, filled seeds that are apparantly sound but do not germinate, are too old and have rudimentary embryos or they are not fertilized and have abortive embryos. Germination of such seeds is tested by subjecting them to favourable germination conditions. Test may be made in containers, i.e., pots, tins, simple covered dish of glass (petri dish) etc. Seeds are spread on a water holding substratum, i.e. blotting/filter paper or sometimes sterilized cotton. Adequate moisture is achieved by barely moistening the substratum. Petri dishes are easy to keep themselves and the seeds sterilized. But, seed germinators are more useful as the environmental factors can be controlled in them, and several samples can be tested simultaneously.

International rules of seed testing prescribe 20^{o} to $30^{0}C$ temperature for most of the species. Also, exposure to light is necessary. Germination is also tested in sand. Seed sample should be large enough to ensure that at least a few seeds germinate. If seeds are known for high germination 25 to 50 seeds are sufficient. But for those having difficult germination, 100, 200 or 400 seeds are needed in a sample. Most seeds germinate 7 to 14 days after the start of the test otherwise it can be concluded that they possess some kind of dormancy (physical or physiological; Physical dormancy is primarily imposed by the seed covering structure , normally impermeable to water; Physiological dormancy is caused by many physiological conditions and is rather complicated).

Germinative Energy

Percentage of seeds that germinate within a specified period is known as the germinative energy of that seedlot. (The term 'Energy' is not treated here in that sense as Ergs or Calories. It is not physical form of energy but is the biological form thus the term may appear somewhat vague). Germinative energy is expressed as 90% in 7 days or 31% in 14 days or so. It includes only the vigorous seeds, most likely to develop into useful trees. Thus, arbitrarily, period may be fixed as 1 week or 2 weeks or when the highest mean-daily-germination is reached.

After the germination test, cutting test of the ungerminated seeds should be made to find out the condition whether they are hard seeds or blind (empty) seeds. The seeds attacked by some fungus may indicate that they were dead when the test started. Number of sound seeds remained ungerminated helps us to know the Germinative Capacity of a seedlot (GC = Percentage of seeds germinated plus the percentage of sound seeds remained ungerminated).

To find out the necessary quantity of seeds for planting at a site, 'Effective germination per Kg' and 'Utilisation value' of seeds should be known. They are determined as follows:

$$\text{Utilization value of seeds} = \frac{\text{Purity percentage} \times \text{Germinative Energy \%}}{100}$$

Effective germination of seeds per Kg = Utilization value x Average No.of pure seeds in a Kg.

$$\text{Kgs. of seeds required} = \frac{\text{Number of seedlings required}}{\text{Effective germination of seeds}}$$

But, embryo dormancy, seed coat dormancy, induced or secondary dormancy, double dormancy combining two or more kinds of dormancy, immature embryos and mechanical resistance of seed coat may deviate the expected results from the determined quantity of seeds.

The ultimate object of testing the seeds for germination is to gain information in respect to field planting value of the seed and to provide results which can be used to compare the values of different seedlots.

Methods of Germination Tests

At least 400 seeds (4 replications of 100 each) should be tested for germination. They should be taken indiscriminately from a representative portion of a bulk. Counting of seeds without discrimination of size or appearance should be done by hand or by a counting board.

1. Germination test using paper

a) At the top of paper - The seeds are germinated at the top of one or more layers which should be water absorbant like blotters or filter papers. the papers should be placed in any of the following ways :

1. Enclosed in transparant petri-dishes or boxes.
2. In the Jacobson apparatus or a belljar with an opening at the top is inverted on each replicate.
3. Directly on germination trays in cabinet or room type germinators

Moisture is continuously supplied to the papers and relative humidity in the germinator or room should be maintained as close as possible to saturation.

b) Germination test between papers - The seeds are germinated between two layers of germination papers which can be folded or rolled and can be placed in a flat or an upright position.

2. Germination test using sand

Like paper, sand is used as a substratum and seeds can be germinated at the top of sand or in the sand.

1. At the top of sand - Seeds are pressed into the surface of moistened sand.
2. In the sand - Seeds are placed on a uniform layer of moistened sand and then covered by another layer of sand, 1 to 3 cm. thick, which should be left loose.

The amount of water to be added to the sand for moistening depends upon the characteristics and size of the seeds to be tested. Mostly, sand is moistened at 50 to 60% over its water holding capacity. The data on germination test can be easily and condensedly recorded in the following table :

Observation Table for Germination Tests

Tested by	Sample A	Sample B
Name of the germinator used		
Date when test started		
Seed soaked (hrs) before test		
Seed disinfectant used		
Temperature during test °C		

	Observations	Replications									
Date	Days after test started	A	B	C	D	Total	A	B	C	D	Total
	2										
	3										
	4										
Total Germinative Energy											
Average Germinative Energy %											
Average variation between samples											
Tolerance (%)											
Hard but sound seeds (%)											
Average Germinative Capacity (Average GE + Hard Seeds %)											

3. Germination test using soil

Soil or an artificial compost (saw dust + farm yard manure etc.) can be used instead of sand although it is more difficult to standardise and is therefore liable to cause variation in result. Seeds can be tested at the top of soil or in the soil, like sand.

Spacing the Seeds

The proper spacing of seeds is necessary to reduce to a minimum, the contact of the emerging seedlings during germination. This is specially important for large or fungal-infected seeds. The distance between two adjacent seeds should not be less than 1 to 5 times the width or diameter of the seed (AOSA, 1970).

Test Condition

Moisture and aeration : At all times, the substratum must contain sufficient moisture to meet the water requirements of seeds for the germination. It shoud not be in excess also and the substratum should not be so wet that a film of water is formed around the seed.

Temperature : It is determined at the level of seeds in the substratum. For most seeds, its range is from 20 to 35 ^{o}C however, optimum temperature is from 25 to 30 ^{o}C. The temperature should be as uniform as possible throughout the germination apparatus or chamber. Sometimes, alternating temperature is also necessary. In this condition, the lower temperature should be maintained for 16 hours and the higher for 8 hours.

Light : It may be provided either from a natural or from an artificial source. Care must be taken to ensure that an even intensity is received over the entire testing surface and that any heating by light does not affect the prescribed temperature of the seeds.

Methods of Tests for Seed Viability

Whenever time does not permit for lengthy germination tests, the viability of forest tree seeds can be evaluated to some degree by direct examination or various physical and biochemical tests.

Physical Tests

1. Cutting test - This is the simplest and oldest method of testing the seed-quality. A desired number of seeds is counted out or drawn at random from a seed lot. The seeds are cut into two with a scalpel or broken into two halves or crushed by a light hammer. The technique varies with the size of the seed and character of the seed coat. Cutting test almost invariably gives higher results than

the germination test of the same seed lot, but it gives immediately the percentage of empty seeds.

2. Floatation Test : It has long been a custom to test and separate large and heavy seeds by placing them in water or any other liquid medium, i.e. kerosin, alcohol etc. because sound seeds sink whereas empty seeds float on the medium. Immature, hollow and insect eaten seeds also float on the surface of floatation medium, which is selected according to the specific gravity of the seeds.

3. X-ray radiographic test - This is the only non-destructive method for testing the seed structure and seed germinability. After this test, the seeds can be germinated. Informations about the internal seed quality i.e. emptyness, insect attack, mechanical damage and quality of the ungerminated seeds at the end of germination test can be obtained by this test. To test the viability of seeds, Simak (1980) made five classes of the seeds on the basis of embryo development and two classes on the basis of endosperm development, as the variability in anatomical constitution severally affects the germination potential of a seed lot. This method gives exact counts of sound, healthy and viable seeds and for this purpose, it is better than all other methods in use.

Direct radiography examines the seeds without any pretreatment but for contrast radiography some contrasting agent like $BaCl_2$ is used as a pretreatment and can be applied in aqueous or vapourous condition. Following are the Developmental classes (based on embryo development) and germination percentage of seeds in them :

DC O - 0% Germination, Neither embryo nor endosperm present (Empty seed)
DC I - 0% Germination, Endosperm and embryo cavity developed but no embryo.
DC II- 50% Germination, endosperm and one or more point-embryos (very small).
DC III - 88% Germination, Endosperm and one or more embryos, longest of which fills more than half of the embryo cavity.
DC IV - 99% Germination, Endosperm with one fully developed embryo present.

Using the Reduction Factor (RF = Number of seeds in Development class x Percentage germination in that Development Class), the Anatomical Potential of any seed sample can be determined by the following formula:

$$Ap = \frac{RF.O + RF.I + RF.II + RF.III + RF.IV}{100}$$

On the basis of endosperm development, following two classes of seeds are made:

Class A - The endosperm almost completely fills the seed coat and absorbs the X-rays easily.

Class B - **The endosperm** incompletely fills the seed coat and is often shrunken or deformed and X-ray absorption is inferior to that of A.

Considering the development of both embryo and endosperm together, all the five Developmental Classes (DCs) are divided into DC-A and DC-B.

Technical Details : Using various x-ray equipments and methods, the seeds can be radiographed in various ways e.g. the radiographic image can be projected and studied on a fluorescent screen, on x-ray film or on photographic paper. Using the stereoradiography or tomography, seed anatomy can be studied three dimensionally. The following aspects are critically fixed-up before making a radiograph of the seed :

Kilovoltage (Kv) : It determines the contrast of the image on the radiograph. A higher Kv diminishes the density differences whereas a lower Kv improves the brilliance (increased Kv means harder x-rays or short wavelength).

Milli-amperage (mA) : It is a measure of the number of x-rays which determine the density of the image of the radiograph e.g. at high mA, the image will be too dark (over-exposed) and vice-versa. The contrast is not influenced by changing the mA.

Exposure time (seconds) : The time during which a specimen is exposed to x-rays for making a radiograph is called exposure time. The exposure time and mA applied are together called mAs (milliampere-seconds). This value is constant for the same radiographic result because by changing the exposure time, density of the image is affected, as also by mA.

Focus-Film - Distance (FFD) : The distance between the focal spot and the film surface is known as FFD. Increasing the FFD decreases the intensity as well as the density of the radiation. As a result, size and sharpness of the image are changed, (better sharpness and large radiographed area).

Object-film surface distance (OFD) : In radiography, the object is usually placed directly on the film-cover. Incomplete contact can cause blurred details.

X-ray film : There are several types used for different purposes. Suitable films for seeds are those used in industrial radiography. The speed of the film depends upon the grain-size of silver bromide crystals suspended in the gelatinous emulsion with which the transparent plastic filmsheet is coated. Larger size and greater number of crystals result in the fast film which needs short exposure time and radiobiological effects on the radiographed material will be less. However, contrast will also be less and small details will be less recognisable in the image. Thus, a correct choice of film is an important point.

Biological effects of radiation - Seeds when radiographed are exposed to x-ray radiation which can cause physiological and genetical damage to the living cells. The x-ray dose, i.e. the amount of radiation absorbed by the seed per unit mass during the time of taking a radiograph is about 2 rads. However, it should be kept in mind that the effect produced by radiation increases accumulatively in the living tissue after each new exposure to x-rays. Thus, it is recommended to avoid un-necessary, long or repeated exposure of seed material which is to be used further for a biological experiment specially a genetical one. Normally used film and conditions are 15 Kv - 15 mAs - 30 cm FFD.

Determination of seed viability - This is done only by X-ray contrast method using $BaCl_2$(an aqueous contrasting agent) or $CHCl_3$ (a vaporous contrasting agent). The details of both the methods are following :

1. $BaCl_2$ - The seeds are steeped in tap-water for 16 hours, dried superficially and then steeped in a saturated aqueous solution of $BaCl_2$ for 1 hour. After superficial washing for about 2 minutes in running water, the seeds are dried until the water, penetrated during $BaCl_2$ treatment into the seeds, evaporates. The dried seeds are radiographed. the seeds which have more than 25% of the whole area of the endosperm impregnated by $BaCl_2$ are thought to have lost their germinability. If the embryo alone shows any small impregnation patch on the radiograph, the seed is definitely non-germinable. But, if the impregnation area on the endosperm is less than 25% of the endosperm, it means the seed viability is decreasing although the seed is still germinable.

2. $CHCl_3$ - The seeds are placed on the bottom of a bottle fitted with a hollow, ground-glass stopper, in which a cotton plug slightly soaked in $CHCl_3$ or any other halogen derivative, is inserted. This contrasting agent must not drip from the cotton, on the seeds. In the closed bottle, heavy vapors of the contrasting agent move down to the bottom and uniformly impregnate the seeds. After 2-4 hour treatment, the seeds are radiographed within 1-2 hours as the contrasting agent disappears from the seeds after about 6 hours. An increasing impregnation can be interpreted as the sign of the beginning of deterioration of seed viability which is not necessarily observable on seed germinability. However, not much conclusive research on correlation between impregnation pattern and seed germinability has been carried out.

BIOCHEMICAL TESTS

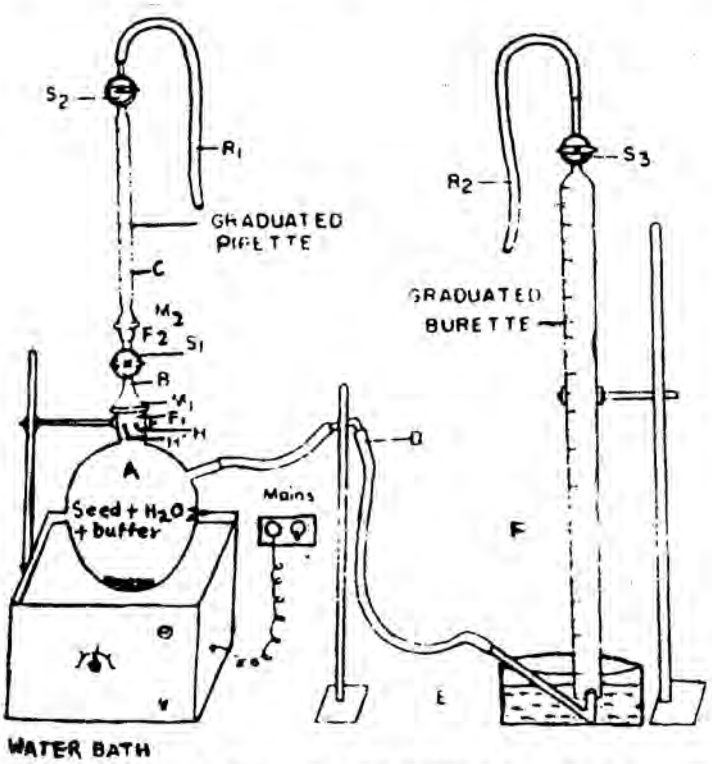
Catalase Activity Test : Catalase activity of seed can be a measure of seed viability. Seeds soaked in water at 54 $^{\circ}C$ for one hour and dry, fresh seeds are used in this test. They are ground separately in a mortar and pestle. A simple catalase apparatus is used in this test which can be assembled in the laboratory.

The essential feature of the apparatus is a reaction flask (A) connected by a suitable delivery tube (D) to the graduated burette(F) inverted in a bath of distilled water. Catalase is an enzyme which decomposes H_2O_2 to liberate oxygen which is collected in the burette. Pulverized seeds are kept in the reaction chamber with 20 ml of buffer. Five ml of H_2O_2 were added to it and quantity of liberated oxygen is measured in the burette. Catalase ratio is determined by the following formulae:

$$\text{(CQ) Catalase ratio} = \frac{\text{Average oxygen liberated by soaked seeds in a particular duration}}{\text{Average oxygen liberated by same quantity of dry seed in the same duration}}$$

$$\text{(CQ) Catalase ratio} = \frac{\text{Time taken by dry seeds to liberate 100 ml oxygen}}{\text{Time taken by same quantity of stimulated (soaked) seeds to liberate 100 ml of Oxygen.}}$$

If the CQ is more than one, the seed lot is considered to be good.



S_1, S_2, S_3 - Stop cooks
A - Reaction Flask
B - Connecting glass tube
D - Delievery tube
F - Collecting graduated burette
C - Graduatted pipette
R_1, R_2 - Rubber tubes

APPARATUS TO DETERMINE CATALASE ACTIVITY

Excised Embryo Test : This test is useful for those seeds which germinate slowly. In this test, the seed coat is removed and the excised embryos are maintained under prescribed conditions suitable for germination, for a period to develop a sign of non-viability, i.e. decay. Viable embryos either show evidence of growth or remain firm and fresh.

The test shall be performed on 4 replicates of 100 seeds each, drawn at random from the seed lot. They should be soaked from 5 to 24 hours in water at room temperature, until completely swollen. Seeds with hard coats should be cracked or mechanically scarified before soaking. The embryos are excised from these seeds under moderately sterile conditions. The instruments, i.e. needle and forceps etc. and the working surface shall be sterilized with 50% ethanol solution.

The excised embryos should be placed on a filter paper under normal conditions of moisture and light, at a temperature of 25°C. As far as possible, the whole sample should start incubation at the same time. The embryos should be examined daily and the test should be terminated as soon as a distinct differentiation between viable and non-viable embryos is made, but upto a maximum of 14 days. The following categories are considered to be VIABLE: (Figure 2)

1. Germinating embryos
2. Embryos with one or more cotyledons exhibiting growth or greening.
3. Embryos remaining firm, slightly enlarged and either white or pale yellow according to species.

NON-VIABLE:

1. Embryos rapidly developing severe mould, deteriorate and decay.
2. Degenerating embryos.
3. Embryos exhibiting extreme brown or black discolouration, an off-grey colour or white watery appearance.
4. Dead or embryo-less seeds detected during preparation of seeds with deformed embryos.

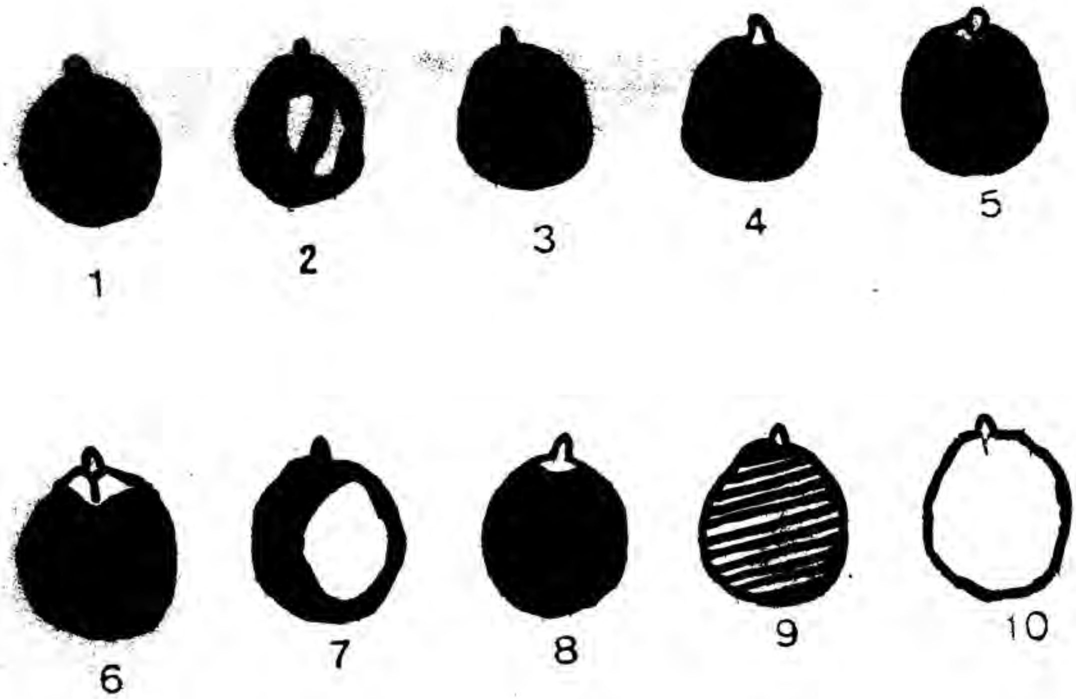
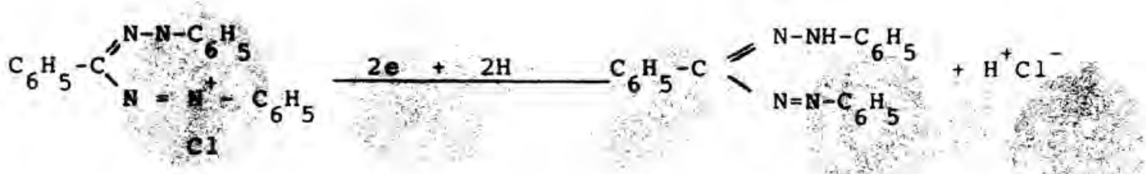


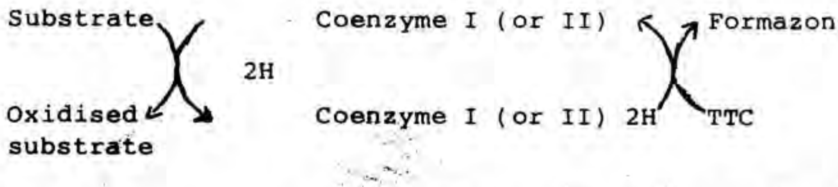
Fig 2 : Seed categories having received various topographical patterns of staining by Triphenyl Tetrazolium Chloride

Tetrazolium staining test : Tetrazolium salts when they come in contact with the living tissue in seed embryos, they are reduced to an insoluble, red coloured pigment called formazon, which stains the tissue. Non-living tissue does not affect the reduction of TZ salts and remains white. This indication of living and non-living tissues is the basis of TZ test, as Tetrazolium salt (2-3-5 triphenyle tetrazolium chloride or bromide etc) is an oxidation-reduction indicator. It has been well established that the development of the non-diffusible red colour in the tissue, is the result of reduction of the chemical by some definite enzymatic action. One or more enzymes of the dehydrogenase system is involved in this reaction.

This test should also be performed in 4 samples of 100 seeds each drawn randomly from the seed lot. Staining dishes or beakers with lids or petridishes, cutting devices (razor or blade), piercing devices (needle forceps) and magnifying devices are necessary in this test.



2-3-5 Triphenyle tetrazolium Red Triphenyle Formazon



Normally chloride derivative of triphenyle tetrazolium salt is used in a solution of 1% prepared in distilled or tap water. From this stock 0.5% or 0.1% dilutions can be made. The pH of the solution should be between 6 to 8 for best staining to occur. If the pH of water is not in the neutral range, TZ salt should be dissolved in a phosphate buffer prepared in the following way:

Solution 1 - dissolve 9,078 g of KH_2PO_4 in 1000 ml of water

Solution 2 - dissolve 11,876 g of Na_2HPO_4 in 1000 ml of water

Take 400 ml of solution 1 and 600 ml of solution 2 and mix them together. In this one litre buffer solution, dissolve 10 gm. of tetrazolium salt to get 1% solution of PH 7, which should be preserved in a dark or amber coloured bottle to prevent its deterioration from light. The solution used in one test should be discarded. Temperature during the test may be maintained between 25 to 45°C as it has no effect on the accuracy of the test. However, higher temperature promotes faster staining.

Preparation of seeds for staining : Seeds are prepared (softened) for sectioning by placing them on top or between moistened blotters or paper-towels overnight or by placing them in water for 4 to 20 hours depending upon the nature of seeds. Hard coated seeds should be filed (scarified) before soaking in water.

The seeds must be cut in such a way that the TZ solution can come in contact with the embryes. Following are the commonest methods -

1. Bisecting the seeds longitudenally
2. Bisecting laterally
3. Piercing with a needle
4. Removing the seed coat and
5. Conditioning (Soaking or softening) only

Small seeds like those of some legumes are placed in the TZ solution directly. Staining can be done in a petridish or beaker. Sufficient solution should be used to cover the seeds. As a rule, concentrated solution (1%) be used for those seeds which are not bisected through the embryo. For bisected seeds, .1% or 0.25% solution is sufficient.

Staining time is also an important factor and should be decided according to the nature of seed, conditioning of seeds, and the concentration and temperature of the TZ solution. Generally, 1% solution with 30-35 ^{0}C temperature gives complete staining of average seeds in 4-5 hours.

When staining is complete, TZ solution is drained off and seeds are washed many times with tap water. The staining can be evaluated immediately or the seeds can be placed in water at a very low temperature (inside a refrigerator) where no effect on the staining pattern is observed. Following conclusions (Fig. 2) can be drawn:

1. Seed completely stained - Germinable and vigourous
2. Minor unstained areas on cotyledons - Germinable but less vigourous
3. Extreme tip of radicle unstained - Germinable and least vigourous
4. More than extreme tip of radicle unstained - Non-germinable
5. Unstained area at the juncture of cotyledon and radicle-hypocotyl axis - NG
6. Radicle-hypocotyl axis bisected by an unstained area - Nongerminable.
7, More than half of the cotyledenary tissue unstained - Nongerminable.
8. Radicle unstained - Nongerminable.
9. Staining of seed in off-grey, greyish-red, orange-red, transparant-red or glassy-red/colour - Nongerminable
   / very light pinks
10. Seed completely unstained - Nongerminable.

Other chemical stains :

Potassium iodide stains living tissue - Blue
Indigo carmine (o.5 to 1 part per 1000) stains dead tissue- Blue
Sodium selenite stains living tissue - Red)
Sodium telurate stains living tissue - Black) Highly poisonous.

Pretreatments

Many seeds do not germinate even when placed under conditions normally regarded as favourable for germination, i.e. adequate water supply, suitable temperature and relative humidity means favourable composition of atmosphere. Such seeds, if germinate through any means are said to be dormant or to be in a state of dormancy.

Dormancy in seeds is defined as a condition of perfect and viable seeds which makes them resistant for germination under favourable environmental conditions. This character is very much desirable for the continuance of any species. Such seeds not only remain viable for a long time but under natural conditions, individual seed becomes permeable at different times thus most of the seed-lots are capable of producing some seedlings over a period of several years.

Dormancy which is physical is primarily imposed by hard, impermeable seed coat and can be overcome by some kind of pre-sowing treatment to the seeds. Sulfuric acid of different concentrations, sodium nitrite and ammonium nitrate solutions are some of these chemicals. Duration of the treatment is also an important factor which is decided according to the thickness and hardness of seedcoat.

Beyond the above chemicals, boiling water, hot water and continuous heat treatments are also common to break the dormancy of seeds. But, mechanical scarification (abrasing on a file) is practiced for breaking the dormancy. Following are the details of various pre-sowing treatments 1) H_2SO_4 (98%) for 5 minutes, 2) for 10 minutes, 3) for 20 minutes, 4) H_2SO_4 (10%) for 18 hrs., 5) Boiling water for 5 minutes, 6) Just dipping 7) 10% ammonium nitrate for 18 hrs. 8) 5% sodium nitrate for 5 minutes. 9) Hot water (35^{o}C) to room temp. 10) Hot water (50^{o}C) to room temp., 11) Hot water(70^{0}C) to room temp., 12) Hot water (100^{0}C) to room temp., 13) Heat treatment (50^{o}C) 1hr in oven 14) Heat treatment (50^{o}C , 2 hrs), 15) Heat treatment (50^{o}C, 3 hrs). 16) Heat treatment (50^{o}C for 15 hrs), 17) IAA 250 ppm for 18 hrs, 18) Soaking in IAA 500 ppm for 18 hrs., 19) Soaking in IAA 1000 ppm for 18 hrs. 20) Mechanical scarification (filing).

Seed Vigour

It is the sum total of all those properties in seeds which, upon planting result in rapid and uniform production of healthy seedlings under a wide range of environment including both favourable and stress conditions.

Production of a visible radicle from a seed was used earlier as a physiological measure of germination. But, in the present state of knowledge, it appears an inappropriate criterion of germination because it does not give any idea of subsequently developing seedling which may be abnormal in structure and incapable of producing a normal plant in the field. Thus, according to ISTA, seeds are allowed to germinate upto that point where a clear judgement of the abnormal seedlings can be made (those, in which parts are damaged, rotting or missing). Such seedlings are excluded from the final count of germination percentage. It was also decided that germination test should be performed universally on inert media so that seed vigour can also be estimated. Seed vigour is a highly complex characteristic. At biochemical level, it involves energy and biosynthetic metabolism, coordination of cellular activities, and transportation of reserve foods. At the level of seed germination, it involves speed and totality of germination, pushing power of the seedling, range of bearable environmental conditions and disease resistance of seeds. To evaluate the seed vigour, there are reproducible laboratory methods which differentiate high vigour seeds from low vigour seeds. The following causes are responsible for seed vigour :

1. Genetic constitution of seed, 2. Environment and nutrition of mother plant, 3. Stage of maturity of seed at the harvest, 4. seed size, weight or specific gravity, 5. Mechanical integrity of seed, 6. deterioration or ageing of seed, 7. pathogens. Seed vigour is measured by the following ways:

1. Formation of vigour classes of seedlings - measuring the length or biomass of seedlings after a certain period of growth and dividing them into definite vigour classes thus calculating percentage of high and low vigour seeds.

This test is an expansion of the routine germination test in which we classify normal seedlings into strong and weak categories. This test has been approved by ISTA (Perry, 1981) and also by AOSA Weedstock, 1976).

2. Determination of Germination Velocity Index (GVI) - Speed of germination is the simplest method for measuring seed vigour. In this test, germination counts are taken every day until germination of a seed lot is completed,and GVI is determined by the following formula:

$$GVI = \frac{A}{1} + \frac{B}{2} + \frac{C}{3} + \frac{D}{4} + \frac{E}{5} + \frac{F}{6} + \frac{G}{7} \text{ and so on}$$

where A,B,C, etc. are the numbers of newly germinated seeds and 1,2,3, etc. are the serial numbaers of germination days. In this test, two seed lots having similar germination percentage may have different GVI values. High GVI value indicates a vigourous seed lot.

3. Tetrazolium staining test - This test is based on the same principle as for determining seed viability. The only difference is that seeds judged to be viable are further evaluated for their vigour. This is done by locating weak and dead tissues of the seeds and rating them according to the possible influences of them on subsequent field performance of seeds. The following categories of staining indicate vigorous seeds:

a) Embryo completely stained with bright red colour - Most vigorous.
b) Minor unstained areas on cotyledons opposite to the radicle may be present.
c) Embryo completely stained with central portion of cotyledon dark coloured.

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Summary of discussion following presentation:

Philippines - Mr Jose O. Sargento: Have you conducted experiments to lengthen the viability of seeds, particularly in relation to Dipterocarps?

Dr A.K. Kandya: Seeds with short viability (recalcitrant) is the characteristic among most dipterocarps. It could be lengthened by keeping seeds at low temperatures. In some dipterocarps viability could be about nine months.

India - Dr Mathew George: Is there any correlation between vigour and establishment in either the nursery or field.

Dr A.K. Kandya: Most seeds have a sensitive phase within the first few days of their establishment. It is essential to select sites which may be similar to sites in which they are expected to grow. We have done very few studies on this aspect.

Mr V.R. Nanayakkara: What about seed availability? How can one be sure of obtaining seeds?

Dr A.K. Kandya: It is definitely a problem for obtaining seeds for some species we desire to propogate. Furthermore, sometimes seeds obtained are used without adequate care about site specificity and other factors. Collection of seeds could also be cheaper if it is done in a systematic manner.

India - Dr Mathew George: We can get certification of seeds from seed banks, but are there any steps taken to do this at the national level in India.

Dr A.K. Kandya: Forest Department should develop its own seed collecting capabilities. In some countries like Costa Rica or Oxford/UK (Commonwealth Forestry Organization), a limited number of species are available to an international audience. But there is no substitute for developing your own capacities.

Session III

(b) Tropical Humid Forests as a Resource for Local People and as Conservation Areas

Chairperson: Dr(Mrs.) S. Gunatilleke

PROTECTED AREAS IN THE TROPICS: AN OVERVIEW

JIM THORSELL

Introduction

In the year 252 B.C. the Emperor Asoka of India passed an edict for the protection of animals, fish and forests. This may be the earliest documented instance of the deliberate establishment of what we today call protected areas, but the practice of setting aside sacred areas as religious sanctuaries or exclusive hunting reserves is much older and the tradition has been continued in many widely different cultures to the present day. In 1804 A.D., for instance, King William I of England ordered the preparation of the Domesday Book -- an inventory of all the lands, forests, fishing areas, agricultural areas, hunting preserves and productive resources of his Kingdom -- as the basis for making rational plans for the country's management and development.

The modern concept of conservation -- the wise maintenance and utilisation of the earth's resources -- is no more than the combination of these two ancient principles, the need to plan resource management on the basis of accurate inventory, and the need to take protective measures to ensure that resources do not become exhausted.

Conservation has sometimes been thought of as a protective "locking away" of resources by a powerful elite who have time to enjoy the beauty of nature, an essentially selfish and anti-development activity. On the contraty, protected areas, when designed and managed appropriately, are now recognised as offering as major sustainable benefits to society. They play a central role in the soical and economic development of rural environments and contribute to the economic well-being of urban centres and the quality of life of their inhabitants.

In view of rapid development and population increases in many tropical areas of the world, and the great speed with which natural resources are being depleted, there is considerable urgency in establishing adequate protected areas if we are to achieve the objectives of the World Conservation Strategy. In addition, the increasing pressure for land for agriculture and other uses forces conservation managers to review existing protected areas, clarify the justifications and objectives for each reserve, increase management efficiency to use these natural resources wisely for conservation, and make increasing efforts to accommodate other forms of utilization if these are compatible with the protection requirements.

The first national park -- Yellowstone, in the United States -- was established in 1872. This was a milestone in the evolution of the concept of national parks as we know them today. At this point parks became "for people" rather than the preserve of elitist groups, as, for example, royal hunting grounds had been. Since Yellowstone's establishment, most governments have recognised the value of protected areas to their people. To date, there are more than 2600 protected areas in the world, covering nearly four million sq. km, established by 124 countries. During the 1970s, the number of protected areas increased by 46 per cent and the total area protected increased by over 80 per cent (Harrision et al., 1984). Many of these recently created protected areas lie in newly-independent and tropical countries.

For most countries, the subject of protected area management is still new. The first contemporary international conference on the subject was held as recently as 1962 in Seattle. The second conference was held in 1972, appropriately in Yellowstone National Park on the occasion of its Hundredth Anniversary. The third, the World Congress on National Parks and Protected Areas was held on the island of Bali, Indonesia in October, 1982. It was the first of these congresses to be held in a tropical country, in itself a significant tribute to the role of many developing countries in allocating land for protection.

Most tropical countries have established protected areas. The exceptions includes several small island nations: Comoros, Grenada, Maldives, Nauru, Niue, Tuvalu, and Vanuatu, and a few larger mainland countries: Bahrain, Burundi, Iraq, Lao People's Democratic Republic, Qatar, and both Yemens (data from IUCN 1984b). Even the most densely populated parts of the tropics have significant areas under protection. Java, for example, an island the size of Greece or the state of New York inhabited by 90 million people, has more than 100 protected areas which cover over 650,000 ha, large mammals such as Javan rhinoceros (Rhinoceros sondaicus) and leopard (Panthera pardus) still survive there although the Javan tiger (P. tigris javanicus) has become extinct in the past few years.

A brief summary of protected areas in the major tropical realms is presented in Table 1. A summary of coverage by biome is given in Annex I.

Table 1. Coverage of Protected Areasin the Tropics

Realm	Number of Units	Area protected (ha)
Afrotropical	426	88,166,096
Indomalayan	572	27,568,406
Oceanian	51	4,108,584
Neotropical	296	43,503,474
Australian	75	10,752,012
Totals	1,420 Units	174,098,572 ha

Source: IUCN, 1985

The total of 174 million hectares -- the size of Iran and nearly twice the size of Venezuela, Pakistan, or Tanzania -- seems quite respectable, especially since virtually all major countries are represented. But is this area really adequate to conserve the species, ecosystems, and ecosystem functions that the areas are established to protect? Leaving aside the question of how effectively the existing areas are managed, biogeography and population genetics suggest that the answer is still a clear "no".

1.2 Challenges of Managing Tropical Ecosystems

There are a number of major biophysical differences between temperate and tropical regions which dictate different approaches to protected area management.

a) Climatic Conditions

Although the ranges of diurnal and annual temperatures found in tropical habitats are generally less than experienced in temperate regions, overall climatic conditions are more servere. Rainfall in the tropics is much heavier (when it does rain), while the tropical sun makes conditions hotter and drier. These factors make tropical soils highly prone to erosion and the vegetation susceptible to wildfire. Tropical soils are far more fragile than temperate soils and generally far less fertile.

b) Susceptability to Degradation

Natural tropical ecosystems are often very susceptible to degradation. Fire, overgrazing, and cultivation make it difficult for the original vegetation ever to return. The weakness of tropical soils and their inability to support intensive agriculture causes people to adopt destructive and unstable forms of agriculture and pastoralism which further threaten remaining natural areas. Shifting agriculture is practised in many parts of the tropics not only because fertility drops fast on newly-cleared lands, but because weeds choke out the fields to to point that the labour needed to keep them open is intolerable. The land is soon abandoned left to return to its natural state but the period of agriculture leaves a permanent scar. Topsoil is lost and under some conditions (e.g. lateritic soils) the exposed soils become a hard pan which cannot easily be recolonised by desirable natural vegetation.

c) Species Richness

Most tropical ecosystems are very species-rich, particularly those in rain forests and savannas. This means that most species occur only at very low density so that the area needed to conserve viable populations is large. In temperate regions, forest reserves of a few thousand hectares can be highly species-stable and even a stand of a few hectares may be a valuable wildlife refuge. This is rarely so in the tropics where such island patches would quickly lose most of their constituent species, as indeed occurred on Barro Colorado Island in Panama, where over 20 per cent of breeding bird species had vanished within 50 years of the reserve's creation (Willis, 1974).

d) Management Factors

Effective management of protected areas in the tropics is also limited by our state of knowledge and the complexity of tropical ecosystems. As we have far less understanding of tropical rather than temperate ecology (even basic resource inventories are often not available), the manager is often faced with management decisions that have not been tested previously or are subject to considerable uncertainty.

It follows that the protected area manager in the tropics must be a generalist. Compared to the well-developed and intensively-managed systems in most temperate countries where a park staff may include specialists in various fields of management (e.g. planners, interpreters, law enforcement officers), the tropical reserve manager rarely has sufficient trained staff to allot to specific duties. Instead, he or she must be more of a multidisciplinary manager with at least a general understanding of all facets of protected area management.

1.3 Tropical RainForest Protected Areas: A Special Urgency

Within the tropics, particular attention is being focussed on conserving rain forest ecosystems. This argument is forcibly presented in a paper by Roth and Merz (1980) from which much of the following discussion is drawn. For many years there has been alarm at the rate of rain forest clearance.

Lanly (1982) estimates a global figure for the area being cleared every year of 157,000 sq km (about the area of England and Wales combined). Unless this destruction can be halted, the final demise of this irresplaceble sector of our planet will occur in only 72 years (Guppy, 1984).

The picture is just as gloomy on a regional basis. Tropical moist forests have been reduced by 45 per cent in Central Africa and by 72 per cent in West Africa, and the process of deforestation continues. In Ivory Coast alone, Roth and Merz (1980) estimate that by 1982 more than 90 per cent of the country's original rain forest will have been transformed into modified man-made landscapes. In the Indian sub-continent 18 per cent of the land is still forested but according to Mani (1974) the area remaining as undisturbed primary habitat is certainly less than 1 per cent. In Java only 2 per cent of the lowland forests survive.

These figures highlight the special urgency of conserving biotic communities representative of the different types of tropical humid forest, the most species-rich terrestrial habitats on earth. Unfortunately those rain forests which are most important from a conservation point of view due to their great diversity of plant and animal life -- the lowland rain forests -- usually also contain the most valuable timber. For example, the Taman Negara, a lowland forest park in West Malaysia, contains 60 per cent of the endemic mammal species of the entire Sunda region, 142 of the 198 species being dependent on rain forest for their existence (Medway, 1971). Of the 241 lowland bird species in Peninsular Malaysia, 172 have been recorded within this area (Wells, 1971). At the same time, this forest contains timber valued, in 1971, at about $US 3000 per hectare. Foregoing this revenue is part of the price of conserving the Taman Negara National Park.

Compared to rain forests, savanna areas, which particularly merit conservation because of their spectacular wildlife, are usually less threatened by economic exploitation. In savanna zones there may be pressure for grazing land or other agricultural lands but nowwhere -- except in the case of mineral exploitation -- is there as strong an economic incentive for the ruthless exploitation of natural resources as in tropical forests with their valuable hardwoods. In fact many savanna conservation areas are economically marginal for agriculture due to unfavourable soil or water conditions or the presence of tsetse fly, which make it impracticable to keep livestock. Moreover, savanna areas lend themselves more easily to tourism development than do rain forests and can thereby contribute significantly to the local economy. As a result, some of the world's finest and best-managed protected areas are found in savanna zones, while protected areas in tropical rain forest are often under threat.

There are important ecological differences between primary rain forests and savanna which needed to be taken into account when considering their conservation. Given appropriate protection and correct management, savanna areas, and the wildlife they contain, can recover in a relatively short space of time -- even from levels of severe degradation -- and reassume most of their original biotic features. Although rain forests are initially much more stable than savanna ecosystems, once forests have been destroyed they will never recover in the same form or structure as the original forest, nor contain the same plant and animal species.

The great diversity of plant and animal species in tropical lowland rain forest is associated with low density of species. This renders them particularly vulnerable to local extinction. To maintain the diversity of rain forest reserves, large areas must be protected and, as logging continues apace throughout the humid tropics, they must be protected soon.

Given the above facts, there is a strong case for preferential conservation efforts in the humid forest zones and a need for more and larger conservation areas in these habitats. However, if one examines the conservation situation on a worldwide scale it soon becomes obvious that tropical forests are still poorly protected. Of a total of approximately 935 million ha of moist forest, only about 39 million ha, i.e. 4.2 per cent, have been designated as national parks or equivalent reserves.

Given the rate at which tropical forests are vanishing, felled for timber or to open up agricultural lands, it is a matter of urgency to conserve as much as possible now. In general, savanna ecosystems are both less threatened and better represented within national systems.

The management of national parks and protected areas in rain forest zones is also quite different from that in savanna areas. From a physical point of view, protection and control, as well as routine observation of game populations, are more different in rain forests than open savannas, due to inaccessibility and limited visibility. Ecologically, as little human interference as possible is desirable in rain forests. This implies that utilisation of rain forest parks is more critical than for protected areas savanna, and the two ecosystems sometimes require quite different management prescriptions.

1.4 Problems and Challenges of Establishing Permanent Reserves in Tropical Contries

Right across the (African) continent there are still vivid examples of military coups, border disputes, civil confrontations and internal political tensions. All these have affected the atmosphere in which most conservationists work and changed national priorities to favour heavy investments into military expenditure. National budgets have consequently shown only small allocations to conservation...

"Because of political uncertainty in some countries it has been difficult to make plans in the long term and as one director of wildlife conservation puts it, 'you just never know what will happen tomorrow'. Under the circumstances, it is quite possible -- and this has happened on a few occasions -- that assistance or support earmarked for conservation finds its way into other unrelated activities" (Lusigi, 1984).

The above quotation illustrates some of the challenges involved in operating a secure system of protected areas in the tropics. These include severe limitations of funds, resources, public support and trained expertise. High rates of illiteracy, low levels of institutional development, and complex land ownership systems are other obstacles. In addition, habitat modification due to economic forces and population growth in these countries is happening so fast that the reserve planner is usually working against severe time constraints. Often the manager must make bold decisions and recommendations on few facts and with little interest or support from a poorly - informed public. Together these limitations necessitate a different approach to protected area management to that accepted as the norm in temperate regions.

Political instability is another worrying factor in some tropical countries. Revolts, coups, guerrilla warfare and the presence of refugees can wreak havoc in protected areas. Political upheavals in Uganda and their well-documented and disastrous effects on wildlife populations and facilities in the parks are only too well-known (Kayanja and Douglas-Hamilton, 1984). Unfortunately, there is no foolproof management prescription to protect parks under such circumstances.

With a growing number of mouths to feed, it is only natural that politicians and government planners will be more oriented to agricultural and production development than to establishing natural reserves. Park managers must generate public support and persuade politicians of the long-term benefits of protected areas. It is a sad fact that protected areas are still generally undervalued, even when the economic return alone is comparable to, or better than, that from other patterns of land use. Too frequently there is a lack of understanding of environmental problems on the part of decision makers and priority is often given to short-term financial gain from logging or other forms of exploitation even where this conflicts with long-term environmental considerations.

The theme of integrating conservation into the development process, stressing the multiple functions of protected areas was central to the formulation of the Bali Action Plan developed at the Third World Congress on National Parks, held in Bali, Indonesia, in 1982. The linkage between protected areas and development is seen as the approach most likely to bring long term success in protected area management.

Acknowledgement

This paper is based on a much longer treatment of this topic contained in MacKinnon, Child and Thorsell, "Managing Protected Areas in the Tropics", IUCN/UNEP, 1987. 300 p.

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ANNEX I: Protected Area Coverage of Biomaes in Tropical Realms

Biome and Realm	Number of areas	Total area (hectares)
Tropical humid forests		
Afrotropical	44	8,905,733
Indomalayan	122	5,092,774
Australian	53	7,776,347
Neotropical	61	17,277,197
	280	39,052,051
Tropical dry forests/woodlands		
Afrotropical	240	48,673,552
Indomalayan	238	10,420,406
Australian	10	934,272
Neotropical	93	5,501,447
	581	65,529,677
Evergreen sclerophyllous forests		
Afrotropical	41	1,620,967
Neotropical	5	38,795
	46	1,659,762
Warm deserts/semi-deserts		
Afrotropical	57	23,783,085
Indomalayan	35	1,628,854
Neotropical	7	1,446,751
	99	26,858,690
Tropical grasslands/savannas		
Australian	12	2,041,393
Neotropical	18	7,011,403
	30	9,052,796
Mixed mountain systems		
Afrotropical	38	5,104,626
Neotropical	86	11,037,282
	124	16,141,908
Mixed island systems		
Afrotropical	4	23,033
Indomalayan	177	10,426,372
Oceanian	51	4,108,584
Neotropical	26	1,190,599
	258	15,748,588
Lake systems		
Afrotropical	2	55,100
	2	55,100
TOTAL:	1,420	174,098,572

Source: IUCN, 1985 (IUCN Management Categories I-V)

Summary of discussion following presentation

Philippines - Mr G. Parades: How could specific proposals related to research and education in protected areas be developed and supported?

Dr Jim Thorsell: There are several possibilities for obtaining international support for such activities. Educational activities in particular are very important. WWF, ICC in UK and the World Heritage Fund are some sources for requesting support.

Thailand - Mr Choob Khemnark: How much benefit to local people from protected areas is 'sufficient'?

Dr Jim Thorsell: It is difficult to generalise on this matter. Several countries provide different types of benefits. In Khao Yai National Park of Thailand local people get employment opportunities; India has spent large sums of money in the development of areas surrounding protected areas; in Royal Chitwan National Park of Nepal people are allowed into the park for two weeds every year for collecting thatching grass.

Mr N. Nanthakumar: How do international agencies know which projected areas they should support?

Dr Jim Thorsell: International agencies do not establish protected areas. This is the responsibility of national governments. However, with the support of international agencies vast improvements could be made in the resources available for the protection of any reserve.

Mr N. Nanthakumar: The Indomalayan realm probably has the largest concentration of human populations. What are the implications of this fact towards establishing protected areas in the realm.

Dr Jim Thorsell: Indomalayan realm does have high population density which brings up concerns regarding the protection of its diversity. But there cases such as Jaya, where despite high population densities, an efficient protected area system has been developed.

Dr N. Ishwaran: Could you comment on IUCN proposal for twinning of parks and equivalent reserves.

Dr Jim Thorsell: It is an attempt to link the management and administration of protected areas, as well as botanical gardens, in different parts of the world but have ecological similarities. Twinning a national park from a developed country with an ecologically similar protected area of a developing country could lead to a variety of exchanges which can benefit both parks.

Dr(Mrs.) D. Nugegoda: What about threats to protected areas due to political unrest? The Wilpattu National Park of Sri Lanka, at the moment, is almost completely inaccessible!

Dr Jim Thorsell: There are sites of much concern such as in Chad. IUCN had recommended the setting up of an International Anti-poaching Force to patrol such trouble spots. The Sri Lankan situation you mentioned however, is generally not considered that grave.

TROPICAL HUMID FORESTS AS A RESOURCE FOR LOCAL PEOPLE FOR SHIFTING CULTIVATION, TIMBER, FUELWOOD & NON-TIMBER RESOURCES

I.A.U.N. GUNATILLEKE

According to Whitmore (1984), man's march forward to increasing domination of the forests of the Far East which is equally valid for those of Indo-Malayan Realm can be conveniently, although crudely, divided into 3 stages: the Primeval, traditional and modern phases of civilisation.

Primeval Cultures

In the earliest stage, man lived in the rainforest as a nomad hunting animals and gathering food plants making use of limestone caves (as at Niah in Sarawak and in east Java) for shelter and cemeteries. He made no attempt at cultivation. Even today a few tribes of negroid pygmies still live this way eg. the Andaman Islanders, the Agta of the Philippines and the Veddas of Sri Lanka. Among the nomadic tribes are the Kubu of Sumatra, the Tola of Celebes, and the Panan of Northern Borneo.

Many of these tribes have now changed their nomadic life style into more settled agricultural life. The primeval, nomadic man had no more effect on the forest ecosystems than other animals.

Traditional Cultures

Slowly man mastered the problems of agriculture. In alluvial plains settled societies evolved, mostly based on irrigated rice fields, established on former swamp and seasonal swamp forest land. Elsewhere the art of shifting agriculture was evolved.

The impact of man on the forests of the New Guinea mountains has been dated to about 5000 years ago (Walker 1970). It is widely believed that species - poor monsoon forests of east Java have been derived from regrowth on ancient fields abandoned several centuries ago (van Steenis 1961). In the dry zone of Sri Lanka a civilization practised agriculture from 300 BC to 1200 AD and left behind it a complex network of reservoirs and canals; the area then reverted to climax forest. It was re-invaded by shifting agriculturists and now is being redeveloped by a more modern form of settled agriculture based on newer version of reservoir-canal system. The shifting agriculturists progressively destroyed vast tracts of rainforests and the forest itself was culled for materials to construct houses and household goods thereby becoming depleted of useful plants near the centres of population. Jungle produce for trading was widely collected. Rattans, resins, edible birds nests from caves, latex, poison and medicines and part of animals - Rhinoceros horns, pelts, hornbill casques, ivory, bezoar stones (Burkill, 1935, 1966) all found their way out of the forst, and were traded down to the coasts. These early peoples brought many plants into cultivation. The most important world food plants originating from the South-east Asian rain forest region are sugar cane, the banana, and from its continental margin, rice. Within the Sunda-Shelf rain forests, there is a host of kinds of fruit tree. Some are not cultivated-their fruits are gathered from the forest, viz. Dialium, Elateriospermum tapos, Eugenia, Lansium, Mango Sandoricum, Durian, Mangosteen, Rambutan.

Modern Cultures

The arrival of the western man in the Far-East heralded the change to the modern period. Western man introduced plantation agriculture initially to grow spices (cinnamon by Dutch), later to grow other cash crops, with coffee, tea, rubber and oil palm predominating. The introduction of western medicine has led to the increase in human population in our region, largely by depressing the death rate. The larger populations have increased man's impact on primary tropical lowland rain forest by increasing locally the demand for land on which to grow food or cash crops.

Until the Second World War timber extraction made little impact on the rain forests of Indo-Malayan Region in relation to their vast extent. The picture changed dramatically from the 1950s onwards. Light hardwoods gained favour and for the first time extraction began over large areas.

The Tropical Humid Forest Resource

Tropical humid forests (THF) are ecologically speaking, the most complex and diverse ecosystems on earth. Biotically, this biome is much richer than any other, containing within its compass of less than 10% of the planet's land surface, some 40 - 50% of earth's 5-10 million species. Regrettably, Tropical Humid Forests are being disrupted and depleted more rapidly than any other biome. According to Norman Myres (1981), so far as can be ascertained, on the basis of limited surveys and with an extremely meagre data base of highly variable validity, TMFS appear to be declining at a significant rate; at somewhere in the region of 245,000 km^2 per year - though the actual rate could turn out to be a good deal different. The FAO estimates are lower in the region of 120,000 - 170,000 km^2/year which are cautiously minimal estimates and in many instances from trends documented in the early 1970's if not before - since which time, exploitation patterns have accelerated markedly. According to Norman Myres (1981) until more information is available, it is not unreasonable to suppose that the earth is losing around 670 sq. km of TMF a day or 46 ha a minute to be compared with 20 ha/minute by Sommer's 1976 report or Lanly and Clements (1979) figure of 10 ha per minute. At the rate predicted by Norman Myres, 9 million sq.km of Tropical Moist Forests will be converted from marginal modification to fundamental transformation in a matter of 37 years. Conversion rates in some areas are likely to accelerate beyond present levels in the years ahead.

The main agents responsible for this accelerated conversion are the timber harvester, forest farmer, fuelwood gatherer and the cattle rancher.

Table 1

Tropical hardwood production of the world

			Major producers	
Asian region	67%	- major producers	Indonesia, Malaysia, Philippines, PNG, Burma, Thailand	1-5 Million M^3/y by each of these countries.
West Africa	15%			
Latin America	18%			
	100 (100 million^3)			

This is estimated to be increased to 160-180 million M^3 by 1990.

Table 2

Areas of Tropical Closed Forests in Australasia

(Source: Report to the President by a US I.T.F. on Tropical Forests 1980)

Indonesia	80 million ha.
PNG	40 million ha.
Burma	30 million ha.
Other nations	150 million ha.

This accounts for 30% of the global total.

According to Wheeler (1981) 80% of the tropical humid forest destruction is caused by shifting agriculture and fuelwood harvesting whereas only 20% by timber harvesting. However, often the commercial logger plays a catalytic role in opening up forests that would otherwise remain closed to the forest farmer (Myres,1981). These latter areas are categorised as shifting cultivation sites, although the root cause for this practice was commercial logging for timber. Sommer, 1976 report says that shifting agricuture is practised in about 1/5th of tropical moist forests. About 250 million people are supported by this practice worldwide, and the area covered is 3.6 billion ha.

Shifting cultivation is not the only agricultural practice that leads to decrease in tropical humid forest reserve. The processing of agricultural products, such as grain drying, food processing, tobacco curing, rubber and tea manufacturing processes also require large amount of fuel wood. A staggering sum of 40% of wood energy in Malawi is used for tobacco curing. In gloomier terms I ha of tobacco needs 42 ha. of forests in that country to cure it.

Shifting Cultivation

Slash and burn agriculture or shifting cultivation is an age-old traditional peasant farming practice in the humid tropics, and the biological and ecological consequences of this land use pattern have received considerable attention. (Nye and Greenland, 1960 Sanchez 1973, 1976, Ewel 1976, Toky and Ramakrishnan 1984). Considerable extend of land in the humid tropics have been converted to unproductive grass or fernland consequent to abandoning such cultivated lands because of their low productivity resulting from low fertility levels in the soil. When a tropical forest is cleared and burned, the following changes in soil properties generally occur within the first year (Sanchaz, 1980): (i) Large volatilization losses of biomass nitrogen and sulphur occur upon burning, and soil organic matter decreases with time until a new equilibrium is reached. (ii) the pH of acid soils increases, aluminium saturation values decrease, and exchangeable bases and available phosphorus increase, all because of the nutrient content of the ash. These changes are gradually reversed with time, (iii) soil temperature increase and moisture regimes fluctuate more because more solar radiation reaches the soil surface. However, these soil properties change gradually with the fallow growth of successional species in the absence of repeated burning and nutrient build-up could result.

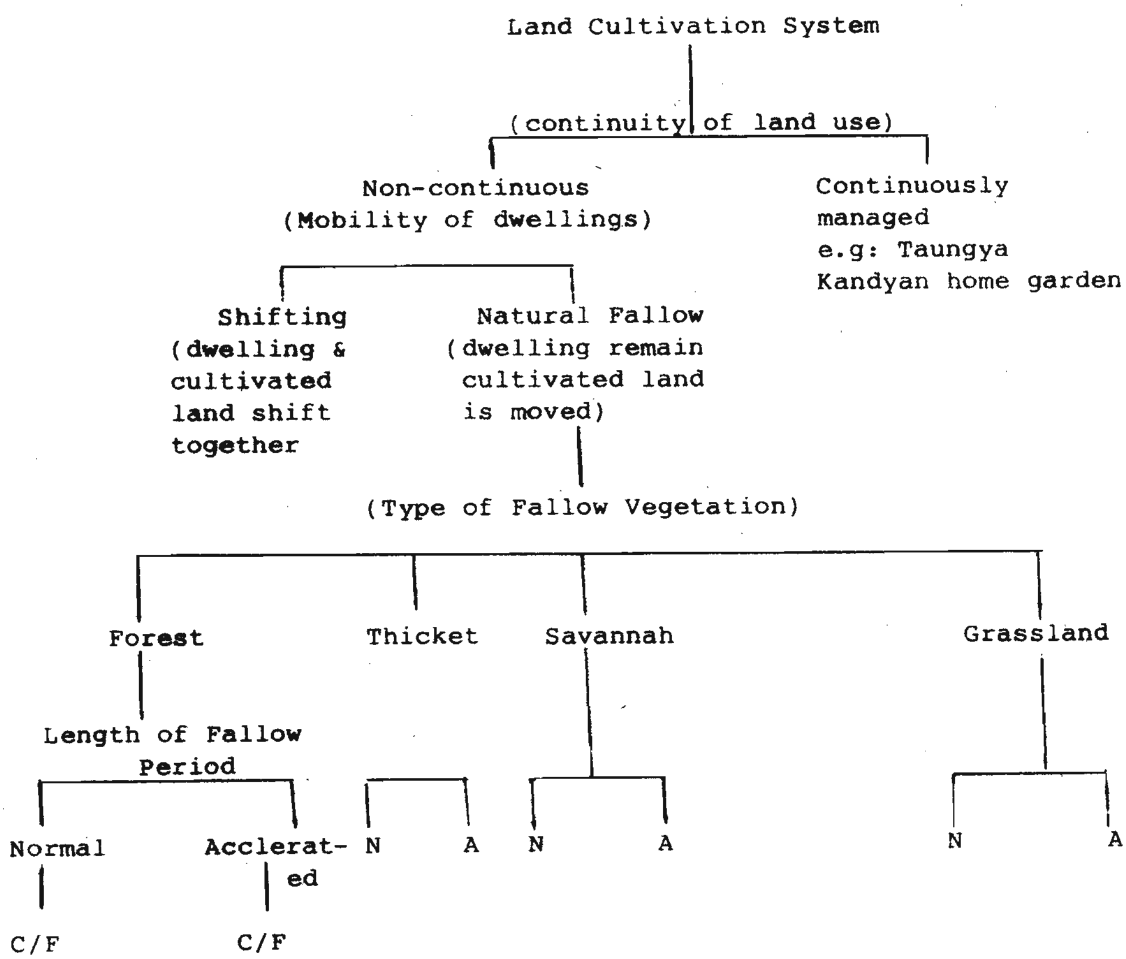
In shifting cultivation, there is a rotation of fields rather than the crops and therefore, is a system of extensive rather than intensive land use, characterised by a low carrying capacity and utilised mainly at the subsistance level.

The essential characteristics of shifting cultivation are that an area of forest is cleared, usually rather incompletely, the debris is burnt, and the land is cultivated for a few years. Usually less than five years and then allowed to revert to forest or other secondary vegetation before being cleared and used again. The system varies from place to place. Consequently many names are used for it. Nye and Greenland (1960) and many others use the term 'shifting cultivation' as a general term embracing many variations of natural fallow cultivation systems. Conklin (1957) discusses the revived term Swidden farming, and proposes its use for the more general descriptions of shifting cultivation.

Different types of land cultivation systems by rural inhabitants have been classified in FAO/SIDA (1974) Symposium on Shifting Cultivation and Soil Conservation in Africa.

Table 3

Classification of Land Cultivation Systems



Natural fallow systems shall thus be described in the following terms:

Normal or Accelerated	forest or thicket or Savannah or grassland	fallow system	$\frac{\text{Cultivation period (C)}}{\text{Fallow Period (F)}}$

e.g. an accelerated forest Fallow system 2/5

Greenland (1974) reviewing the evolution of shifting cultivation recognized a 4-phase development, based on intensity of land use and mobility of the dwellings of the cultivators.

Phase I →	Phase II →	Phase III →	Phase IV
Simple shifting cultivation, dwellings & cultivated land area shift together	Recurrent cultivation, cultivated area shifts more frequently than dwellings	recurrent cultivation with continuously cultivated plots	Continuous cultivation, may involve alternate husbandry with planted & cultivated pastures or Fallow crops

Phase II and III can be subdivided according to the intensity of land use, given by Allen's land - use factor, which is expressed as

$$L = \frac{C + F}{C}$$

L = land use factor
C = length of cropping period
F = length of Fallow period

The science behind the practice of natural fallow system of agriculture as it applies to traditional tribal farming systems (known as Jhum) in North-eastern hill region of India has been studied in great detail by Ramakrishnan and colleagues (Toky & Ramakrishnan, 1981). This is a more advanced form of shifting cultivation approaching phase III of Greenland's land cultivation classification (1974).

As many as 30 crops are grown together in Jhum plots in April and there is a sequential harvested pattern from mid July - December every year. The multiple cropping insures against soil nutrient loss and provides all purpose diet to the farmer. The Jhum cycle would vary from a more frequent 4-5 yr to 10-30 yr in remote areas and each plot vary from 1-25 ha in size and each cropped by a family of 5-7 members.
A characteristic feature of the Jhum-agro ecosystem is the high rate of biomass accumulation under 5 yr and 30 yr cycles. High biomass under the 5 yr. cycle chiefly due to shift in emphasis toward tubers and vegetable crops.

One of the important conclusions derived from the studies by Toky and Ramakrishnan (1981) on yield pattern and socio-economics is that the returns to the farmer is higher under a 10 yr or longer cycle of Jhum compared to that of more settled farming in terraced hill slopes or in valley bottoms.

Fuelwood

Tropical forests deliver fuel wood to some 1.5 - 2.5 billion people (Smith 1981, Goodman, 1986). The greatest value of fuel wood of tropical forests for the people of those countries is the evident valuelessness of this commodity in the world market; for that is what protects these traditional fuel supplies against the price manipulations and reductions that have together characterised the fortunes of tropical primary products on a world market dominated by industrial metropolitan states. Therefore, the supply of fuel wood may be of far greater value to the local people than anything they could produce for export on their land, given market fluctuature and current prices of alternative fuel such as kerosene oil and hydro-electric power.

World Bank annual report for 1978 estimated that non-commercial energy sources still supply about ½ of total energy in developing countries and more than 85% of energy used by the 2,200 million people in the rural areas in these countries. At world market prices of alternative sources of fuel, the value of the firewood consumed in this way is very substantial both to the individuals and to the countries concerned.

Therefore, it does not behove foresters to devalue tropical forests because they 'merely' supply fuel wood for the peoples of those countries. Such an argument depends on a minor premise in the thesis that tropical forests should be developed and exploited for world market, which is of course dominated by metropolitan industrial and commercial interests. Moreover, the techniques of development and exploitation proposed for tropical forests in order that their products should be 'competitive' on the world market, derive from metropolitan sources. Accordingly, wherever such programmes are pursued in tropical countries, these become very heavily dependent on metropolitan countries for technical guidance, equipment, spare parts marketing and 'quasi-expert' management services. Under such circumstances, more often that not the final state of the countries affairs is worse than at the beginningto anyone other than the metropolitan interests who have stage-managed this so called development and derive the principal benefits from it (Smith, 1981).

Large scale conversions of tropical rain forests for timber and pulpwood exports by countries in our region like Indonesia and Philippines have already witnessed these shortcomings but the seriousness of it has not been felt as they still have significant proportion of their land under forest cover.

More than 1 billion cubic metres of wood are harvested each year in the tropics, and the rate is increasing. How much of this is dead wood, how much is cut in closed forests, how much is from open forests and how much is from brush are not known. At least 4/5 of all wood annually harvested in the tropical countries (some 825 million cubic metres) is used for firewood charcoal, the rest for building materials and export.

Industrial wood (i.e. wood for construction materials, fibre and manufactured products) account for 1/5 of the total volume removed from tropical forests. Of this fraction, 1/4 (6%) is exported each year.

Table 4

Share (%) of Primary Energy World Wide (by Fuel Type) in 1984

	Energy Source -						
Country	Oil	Gas	Hydro	Nuclear	Coal	Biomass	Total
DCS	7	2	2	(o.5)	8	15	34
ICS	26	15	4	3	18	(20.5)	66
Total	33	17	6	3	26	15	100

Ref. G.T. Goodman (1986) recalculated from BP Statistical Review 1985).
(D.CS - Developing countries; I.CS - Industrial countries)

It is seen from the above table that out of all the sources of energy only the biomass fuels (wood charcoal, leafly shoots, crop wastes and animal dung) are used more by the DCS than the ICS. In the per capita terms of energy for the basic needs of people, however, biomass is still the prevailing fuel. It constitutes about 45% of all primary energy use in developing countries and approximately 2-2.5 billion people in DCS, almost half the world's current population, still relies overwhelmingly on it for its basic needs such as cooking, space-heating and even lighting.

Although the available figures for the worldwide consumption of wood fuels (wood and charcoal) are still rather unreliable, Table 5 gives an indication that globally, the use of wood as a fuel remains greater even today than its industrial uses (for sawn timber; pulp-wood etc.). This is particularly true in DC's where despite overall harvesting being only a little greater than in ICS, about 80% of it is consumed as fuel, as against 20% for industrial uses, whereas in ICS, the converse is true.

Table 5

Average Annual Removal (%) of Wood 1981-83

Countries	Fuelwood[1] & Charcoal		Industrial[2] Wood		Total Wood Removal
DCS	44	+	11	=	55
ICS	10	+	35	=	45
	54		46		100 2.9 billion (10^9) cubic meters

Notes: 1. Fuelwood & charcoal = all wood used for cooking, space & process heating; power & charcoal production

2. Industrial wood = Saw-timber, sleepers, pitprops, veneer pulpwood

Source Recalculated by Goodman (1986) from FAO (1985)

Table 6

Annual Availability and Demand for Fuelwood in Sri Lanka (Forestry Master Plan for Sri Lanka September 1986 p.50)

	Period	
Available Source:	1984/85	2001-10
	(x 1000 tons/annum)	(Estimated)
Non Forest Wood		
(Rubber, Coconut, homestead)	7100	9062
Natural Forests	1770	1035
Forest Industry residues	250	435
Existing forest Plantations	50	335
Total annual availability	9170	10,867
Total annual demand	9170	11,435
Balance	Nil	- 568

Conversion factor : $1m^3$ solid/fuelwood equivalent = 0.7 ton fuelwood/biomass (18% moisture) (or 700 kg)

Fuelwood situation in Sri Lanka is predicted to reach a critical level by the year 2001 and thereafter.

Forestry Implication of Wood Fuels

These simple facts highlight what may turn out to be one of the most important policy messages for forest scientists for the next few decades or so. Up to the present time, foresters have been almost exclusively preoccupied with the supply of industrial wood. This is mainly because well established commercial markets exist for wood products internationally. But during the last decade, the increasingly serious problem of the critical shortages of woodfuel in developing countries (the so called 'other energy crises') has become widely recognised. It may well be that in future, forest science will have to confront the fuelwood problem, whose dimensions are now thought to be much larger than the problem traditionaly posed by the supply of industrial wood (Smith, 1981).

As the rural communities are not traditionally fuelwood purchasers but gatherers, their dependency on natural forests in humid tropics will be greater to the extent of total obliteration of such forests including protected reserves in some regions.

Non-timber resources

Tropical humid forest is a great storehouse of plants and animals of potential economic importance to both village and metropolitan inhabitants. However, only a fraction of it are at present utilised by man. In addition, there are other minor forest products of non-biological origin such as gem-stones and quality water supply (health,water,mineral water etc.).

Among the minor plant products gathered by villagers living in the vicinity of rain forests are food material, spices, medicinal plants, poison (eg, fish poison),resins and utility material like rattan and sedges for basket and mat weaving. Within the Malayan region there is a host of kinds of fruit trees eg. East Malayan mountain village at Kampong Melor has recorded a number of wild fruit trees cultivated in home gardens (Whitmore, 1984).

In Sri Lankan rainforests tapping of Caryota palm is one of the major cottage industries, the techniques of which are traditionally handed down over generations in the peripheral villages. The inflorescence of this palm is tapped and the phloem sap collected is concentrated and used as sugar substitute in traditional sweet-making. Traditionally the trees in the forest are tapped and its cultivation in village home gardens is rare. According to the villagers the quantity and quality of the sap varies from tree to tree and also from inflorescence to inflorescence. Both hereditary and environmental factors seem to play an equally important role in determining these qualities. A 'good' tree may yield 30 litres of phloem sap per day and concentration of this volume may yield about 3 kg of jaggery (sugar candy). Such 'good' inflorescences, if the correct tapping technique is adhered to, could be tapped over 2 months and therefore a monthly income of Rs. 25x3x30 = Rs. 2250 (US $ 75) could be obtained from a single inflorescence. There is a great potential in developing this cottage industry in the peripheral villages in the lowland wet zone of Sri Lanka. Similarly tapping of Nypa fruiticans in Malaysia is also a village level industry with potental for improvement. Wild cardomom, medicinal vines, rattan and resins are other marketable products which are at present harvested directly from the wild but could be domesticated in village home gardens or in mixed plantations and in turn could generate a steady income to these villagers. A survey of forest plants and their parts used by villagers around Sinharaja for various purposes revealed that out of a total of 211 tree species recorded from Sinharaja MAB Reserve in Sri Lanka, 53 (25%) have some form of utility value to man (Gunatilleke, 1987).

Among the animal products, ivory tusks of elephants, horns of rhinoceros, skins of leopards, bushmeat, fish and bees honey are the common ones.

As the tropical humid forests are disappearing at a rapid rate due to large scale logging, farming and shifting cultivation, the traditional uses of forests by the villagers for their subsistence and source of income are also becoming more and more restricted. As a result, an array of traditional cultures and their wisdom of rational forest utilisation are being lost from our midst. Therefore, documentation of this wealth of traditional knowledge of forest utilisation and at the same time taking measures to revive and sustain them by incorporating them in peripheral or buffer zone development plans around protected forest reserves are needed urgently.

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Tables

Summary of Discussion following Presentation:

Philippines - Mr. Jose O. Sargento: We have all talked quite a lot about local people. What does it mean when you say local people?

Dr. N. Gunatillake: In my presentation it refers to people living around the Sinharaja Biosphere Reserve.

Dr. A.H. Perera: You talked about 'tangya' as a continuous agricultural system. Is not it a highly envolved shifting agricultural system?

Dr. N. Gunatillake: I think it is more of settled type of agriculture.

Prof. B.A. Abeywickrema: In 'tangya' there are tree crops as well as food crops. The tree crop is more or less permanent but it is the food crop which shifts. I think it is more of a permanent system.

Dr. A.H. Perera: I think 'tangya' was evolved to prevent the shifting cultivators becoming nuisance to government rather than provide benefits to the people.

Prof. B.A. Abeywickrema: Although I agree with the fact that local people should benefit from conservation, benefits to human populations at the rural and national levels must not be forgotten.

Thailand - Mr. Choob Khemnark: We must keep in mind, when planning for local people, that the forest if cut down is nearly impossible to bring back. Futhermore, shifting cultivation is not widely known as an efficient system: yields could fall below 50% of the first-year levels during the third year.

Prof. R.N. de Fonseka: What are the educational levels and needs of local people in Sinharaja?

Dr. N. Gunatillake: As for levels of education they are quite low. Opportunities for school education above fifth grade are nearly non-existent; lot of the youngesters move out but others stay and utilise local products.

Prof. R.N. de Fonseka: Have you attempted any treatments for the Caryota seeds?

Dr. N. Gunatillake: We have tried a few treatments but keeping in the sun appears to be the best for the moment.

Dr.(Mrs.) W.G.A. Nissanka: Being someone who had my early education near the Sinharaja Reserve I can vouch for the fact that long distances must be covered to reach schools. Those who leave the village to go to urban areas very rarely go back to the village.

Dr.(Mrs.) S. Gunatillake: Lot of the youth from the area who work as tree-climbers in our research studies and have had some form of school education wish to go to urban areas.

Dr. N. Gunatillake: Several traditional cultures are threatened by urban migration!

Dr. V.R. Nanayakkara: But is'nt urban migration a good thing for protected area management?

Dr. N. Gunatillake: May be! But in itself urban migration might not be desirable.

Indonesia - Mr. Achmad Abdullah: While governments want to increase levels of education among people others want to preserve traditional cultures.

Philippines - Mr. Jose O. Sargento: As village industries grow with increasing support from the authorities to them increasing migration towards such village areas might threaten protected areas. How will you control such developments?

Dr. N. Gunatillake: This is true! But protection of the area could continue.

Prof. B.A. Abeywickrema: Traditional life styles would be difficult to maintain if traditional attitudes are changed.

AGRO-FORESTRY AND SOCIAL FORESTRY CONCEPTS AND THEIR ROLE IN SERVING THE NEEDS OF LOCAL PEOPLE

V. R. NANAYAKKARA

General

Some might wonder what connection the subject of my presentation has with the subject of this Training Workshop - "The Ecology and Conservation of Tropical Humid Forests of the Indo-Malayan Realm". To Foresters who understand and need to tackle the problems of the two adverse effects of forest degradation and forest denudation quickly and who understand the need for forest conservation and the need for ecological studies of the Tropical Humid Forest in the face of these adverse effects and in the face of population pressure on the balance forest, the connection is clear.

Classical forestry as practised in the past was on lands permanently dedicated to forestry. It was forestry practised by the individual forester at the behest of Government far removed from the humdrum of human interference with complete freedom and enough time to manipulate, regenerate and manage the forest according to his thinking. That such a classical forestry approach by itself cannot be considered today to conserve and develop Tropical Humid Forests in the face of rapidly increasing tropical populations has been realized by most foresters over the last decade, the reasons for this being the growing rural populations and the reduction of soil productivity and groundspace consequent to ensuing adverse environmental effects. Foresters have therefore over the last decade or so evolved what can be referred to as non classical forestry practises namely Agro-forestry and Social Forestry. Some authorities include both these concepts of agro-forestry and social forestry under one banner as it were and refer to it as Social Forestry as opposed to classical forestry while some others like the FAO call them Community Forestry. I know that there are a plethora of descriptive terms to define agro and social forestry and that these sorts of differentiations in terminology are debatable ones, and as such I shall try not to dwell on these distinctions and their merits and demerits and on the institutions and individuals who advocate the use of these different terminologies. In this paper therefore, I shall refer to these different terminologies whenever appropriate without argumentation because trying to define and describe each term will tend to confuse rather than explain. Examples of terms currently used include Agroforestry, Social Forestry, Farm Forestry Rural Forestry, Urban Forestry, Door-step Forestry, Homestead Forestry, Agri-silviculture, Agro-silvo-pastoral, Sylvo-pastoral, Mini-forestry, people's forestry, Community forestry, Extension forestry, Family forestry, Private forestry, Community forestry, Landscape forestry and Semi forestry.

The thinking behind these agroforestry and social forestry concepts is based on the fact that Agriculture Forestry and Pasture could be practised on the same piece of land outside natural forests thereby minimizing or preventing human intrusions into the natural forest thus conserving and maintaining the ecological stability and status of the natural forest ecosystem enabling this fragile but vital self-supporting and life supporting ecosystem to exist in perpetuity. Hence, no training workshop on the Ecology and Conservation of Tropical Humid Forest will be complete without consideration of this philosophy of alternate forestry in whatever language, you may call it, Social Forestry, Agro-forestry, Community forestry or just non classifical forestry.

Of course, this does not mean that such alternate forestry practices had not been practiced in the past. For instance, shifting cultivation, called 'Chena' cultivation in Sri Lanka is an ancient form of Agro-forestry where agricultural crops and fallow forest alternated at reasonable intervals of time. Also, the 100 year old "Taungya" system of Burma responsible for raising valuable Teak plantations in Sri Lanka, is a system of Agro-forestry where Agriculture and Forestry are practised on the same piece of land,the agricultural crops for up to about 3 years, the agricultural crops being inter-cultivated between rows of forest plants e.g. Teak and Eucalyptus.

I shall classify these new alternate forestry practices in this paper as currently generally adopted in the tropics, but it must be realized that the art of Agro-forestry and Social forestry practices is very old and that it is only the science of these practices that is new. One has only to look at the Kandyan Home Gardens (Ge - Watta) systems of Sri Lanka to realize that the art of Agro-forestry is very old. Other examples are found in Central American countries, in Thailand - the "forest village" system, and the "Coltura promiscua" in Tuscany Italy a multi species multi-tiered Forest garden an example from the Meditteranean. Such practices are now being utilized by foresters scientifically to wean away people from the tropical humid forests of the world especially in the Indo-Malayan Realm. Foresters, Ecologists and Sociologists throughout the tropics are therefore desperately adopting a variety of such forestry practices and researching for new, in order to meet the needs of local peoples, thereby preventing them from degrading and denuding balance natural forests.

Agro-forestry and Social Forestry concepts currently in vogue and benefits acruing to rural people from them are stated in this paper. The Sri Lanka scenario is also presented, and examples from several other countries also mentioned to provide a broader spectrum of the activities of Agro and Social Forestry and their role in serving the needs of local people.

Over the last decade many persons and authorities have advocated, written and repeatedly propagated these concepts and there has been some criticism of this new trend to evolve a "fashion concept" to preach Agro-forestry and Social forestry and other related forestry practices. Such criticism of this new trend or "fashion concept" has arisen mainly because of insufficient outputs of value in these fields, outputs that are not commensurate with the massive volumes of verbage preceding them. It appears fashionable nowadays to talk on Social forestry, Environment, the need for people's participation, socio-economic upliftment, quality of life of rural people, poverty lines so on and so forth. Hence I trust that this presentation will not be heard similarly as a sermon but heard as a statement of present thinking and present state of the "art" in the respective fields with hopes for the future. Sermonization and the fashion fad will not help the cause of rural people and meet their needs quickly. Furthermore, any practices of agro-forestry or agricultural use of forest lands have to be naturally and socially acceptable, ecologically durable and economically beneficial to people, to communities, and to nations as a whole despite how much they have been advocated.

In this connection it is worth noting the philosophy behind the current global Dutch project "TROPENBOS" (Tropical Forest) which aims at conservation and development of the world's Tropical Humid Forests by research networking and propaganda. Accroding to TROPENBOS philosophy deforestation of the tropical humid forests is a global problem and should be everyone's concern. One important topical step of the programme encompasses studies concerned with human activities, people's cultures, their economic circumstances and how these people use technologies now available to them, the objective being to pinpoint conditions under which alternate forms of land use would be locally and nationally welcome[2]. Such studies would naturally encompass the concepts of Agro-forestry and Social forestry. Hence the global importance of these concepts especially their roles in serving the needs of local people.

Agro-forestry and Social forestry concepts

ICRAF the International Council for Research in Agro-forestry based in Nairobi Kenya has classified prominent Agro-forestry systems and practices in tropical countries by different geographic regions. As this Workshop deals with the Indo-Malayan Realm I shall tabulate those Agro-forestry systems identified by ICRAF in the geographic regions of SE Asia and South Asia. It appears that ICRAF for convenience sake and for making definitions less complicated less theoretical and more practical have not created distinctions between Agro-forestry and Social forestry concepts. However, as stated earlier, this is a debatable issue.

Nevertheless, I would like to refer to the following two definitions of Agro-forestry and Social forestry before listing the ICRAF classification. Agro-forestry has been defined as a "sustainable land arrangement system which increases the yield of land, combines the production of crops (including tree crops) and forest plants and/or animals simultaneously or sequentionally on the same unit of land, and applies management practices that are compatible with the cultural practices of the local population".[6] " Social forestry is a small scale land use operation ranging from pure forestry to integrated agro-forestry, and planned and implemented by individual farmers or communities to yield products and services for their primary use and benefits.The land used for social forestry projects could be sole-owned, community or clan owned, or government controlled but made accessible to farmers".7

ICRAF Classification of prominent Agro-forestry systems[3]

Prominent Agroforestry Systems	Systems & Practices in 2 Geographic Regions	
	SE Asia	S.Asia
1. Agro-silviculture (FAO uses the term Agri-silviculture at times)	1. Commercial trees among crops	1. Taungya
	2. Fruit/shade trees	2. Plantation crops & arable crops
	3. Live fences	3. Commercial trees & fruit trees with crops
	4. Shelter belts	4. Live fences & shelter belts
	5. Taungya	5. Various trees on farmlands for productive functions
	6. Shifting cultivation systems	6. Various forms of shifting cultivation
	7. Intercropping in plantation crops (rubber, oil palm, coconut).	7. Medicinal plants and agricultural species.
II. Silvo-Pastoral	1. Pasture in forest plantations	1. Pasture under trees
	2. Pasture in secondary forests	2. Plantation crops & cattle grazing
	3. Commercial trees in pasture	3. Fodder trees and shrubs

Prominent Agroforestry Systems	Systems & Practices in 2 Geographic Regions	
	SE Asia	S.Asia
	4. Fruit/shade trees in pasture	4. Fruit trees & commercial trees in pasture
	5. Fodder trees	
	6. Coconut & pasture	
III. Agro-Silvo Pastoral	1. Crops and grazing in plantations	1. Plantation crops and arable crops and livestock
	2. Agricultural tree crops and grazing in forest plantations	2. Agricultural tree crops and grazing in forest
	3. Multipurpose trees MPTS with crops/ animals	
	4. Integrated farming systems with agricultural plantation crops (rubber, coconut, oil palm).	
IV. Home Gardens	1. Various forms of multispecies combination	1. Multi-storey plant canopies in humid regions
		2. Arid/semi arid systems
V. Others	1. Silviculture in mangrove forests	1. Mixed perennial cropping
	2. Agri-silvi-fishery	2. Irrigation systems
	3. Trees on bunds of fish breeding ponds	3. Various site-specific systems

Prominent Agroforestry Systems	Systems & Practices in 2 Geographic Regions	
	SE Asia	S.Asia
	4. Swidden farming	4. Fuelwood systems
	5. Fuelwood agro-forestry	

Examples of some such alternate forestry practices mentioned later in this paper are taken from different parts of the world, not only from these two regions.

Benefits to local people

The benefits of Agro and Social forestry to local people mostly to the rural poor are many. With expanding populations and difficulty in finding landspace for classical forestry practice and landspace for permanent agriculture, rural people find it more and more difficult to obtain their needs of fuelwood, domestic wood, fodder and most importantly of all their food. Agro-forestry and social forestry as alternate forestry practices solves to some extent this problem faced by rural people.

Broadly speaking, benefits could be categorized as follows: 1. Jobs & Income 2. Household consumption and 3. Environmental effects. The first increases incomes and job opportunities. The second provides materials for consumption at household level or on the farm, and the third improves the environment.

The FAO has given some examples of benefits under these categories as follows:

I. Jobs & Income	II. Household Consumption	III. Environmental effects
- fuelwood and charcoal production	- fuelwood & charcoal	- erosion control
- poles and logs	- building poles	- floods and land slides prevention
- gums, resins and oils	- fodder and forage	- water availability
- saw milling, carpentry and handicrafts	- fruits, nuts and honey	- shade, protection from wind and rain

I. Jobs & Income	II. Household Consumption	III. Environmental effects
- medicines	- agricultural uses	
- mushrooms	- thatch	
- wild life, leaves, tasar silk	- weaving	
- tourism	- medicines	

Such increases in incomes needless to emphasize will result in increase of a country's GNP by a sizeable amount and broadbased rural Agro-forestry and Social forestry will thereby serve the needs of rural folk more than any other development process in rural areas.

Indirect benefits

Certain indirect benefits also accrue to local populations and their environments by agro-forestry and social forestry programmes. These are:

- Improvement of aesthetic values.
- prevention of pollution of environments.
- control of floods by storing excess rainfall.
- increasing productivity of existing agricultural lands.
- maintaining soil fertility.
- creation and improvement of habitats for bird and other forms of wild life.
- improvement of ground water resources.
- reduction of silt loads.
- more water to rivers enabling inland navigation the year round.
- improved O_2/CO_2 balances in the atmosphere. It has been estimated that about 3.7 tonnes of CO_2 are absorbed by 1 ha. of woodlot per year, emphasizing the disastrous consequences of deforestation to life and the need to accelerate tree planting by both classical, and alternate forestry practices like Agro and Social forestry, wherever possible.

Thus it is clear that appropriate Agro-forestry and Social forestry practices will alleviate the acute socio-economic problems of rural people living in tropical countries especially the poorest of the poor. Such practices to succeed have to be acceptable to the rural poor who are basically poor farmers, they should be ecologically and socio-economically satisfying, and they should be people oriented. These poor people need to reap all the benefits for themselves and government have to play their part in assisting the people to do so by providing guidance, technical and financial assistance. Both approaches, top to bottom and bottom upwards have therefore to go hand in hand if overall success is to be achieved and Agro and Social forestry practices made to meet the needs of local people. Furthermore, it is the poor hardworking woman folk who usually have to collect firewood and cook food who will benefit most and their drudgery reduced thereby.

Examples from countries

The classic example of Social forestry or Community forestry connected with political ideology is of course from China where after the revolution wave upon wave of China's masses marched forward to plant trees inspired by the now historical Mao Tse Tung thought "Plant the countryside with trees". This gave rise to what was technically know as the "4 around" or "4 sides" planting forestry system. In this system, 1. roadsides, 2. canal sides, 3. boundaries of villages, and 4. boundaries of homesteads were planted with trees quite successfully. Mao stressed the interdependance of forestry with agriculture and animal husbandry. FAO field inspections and reports have described in detail this system of social tree planting which one hundred percent benefitted China's rural masses. The main roles of these plantings were to improve environmental conditions, provide shelter belts and windbreaks, provide domestic wood for poles, fence-posts and handles of domestic implements, and fuelwood for cooking and heating. Such tree plantings were later extended to the high mountains of the Tibetan region.

The two Koreas have also achieved spectacular results from Agro and social forestry. The results from the Republic of Korea are well documented, and the FAO's Regional Office for the Asia and the Pacific has studied the work in the Democratic People's Republic of Korea. In the Republic of Korea, the VFAS (Village Forestry Associations) have planted or enriched 1 million ha. of land. The success was because of the collective or cooperative spirit of the rural farmers of the VFAS and the Government's decision to legislate to provide the VFAS with title to the lands planted or enriched by them. Here too, it was the needy rural farmers that benefitted.

In VANUATU (New Hebrides), the Government has thought it necessary to incude the Agro-forestry approach in the country's NDP (National Development Plan) for a more rational and optimum use of a limited land area. Thus in Vanuatu Agro-forestry is now being used as an aid to national rural development.[4] I believe that most tropical countries with large rural populations should follow Vanuatu's example. Species being planted in Vanuatu are *Pinus caribaea* and *Cordia alliodora*. Agro-forestry pastoral is being practiced. Subsistence crops cultivated are yams, manioc, sweet potato, cabbage, sugar cane, maize, banana, papaya, pineapple, pumpkin, melons and coconut.

The example from Indonesia is the PP "Perum Perhutani" or State Forest Corporation set up in Jaya with the objective of enhancing social and economic standards of the local people. Here, efforts are made to conserve the living environment especially forest vegetation through a preventive measure called the "prosperity approach. The approach which is a multi-disciplinary approach creates projects designed to improve the standard of living of local people living near forests. These projects include mass intensification of inter-cropping, honey bee rearing, creating fuelwood supplies, planting elephant grass Pennisetum purpureum building check dams and supplying clean water. The local Forest Guard and the Village Headman work jointly and guide and educate local people. This is the grass roots connection which is essential if Agro and Social Forestry is to give maximum benefit to local people. This personal relationship between officials of the PP and village leaders has developed a sense of mutual responsibility between them promoting self help that fits local needs and cultures. Such psychological benefits could be forerunners to actual physical benefits of Agro and Social forestry in the field. This multi-disciplinary holistic approach has worked successfully in Indonesia and calls for application in Sri Lanka.

Thailand provides the example of a somewhat unique "forest village" system introduced by FIO (Forest Industries Organisation) of Thailand. Here, the beneficiaries are village people depending on the forest for most or all of their needs. Permanent and continuous inputs by government are required to maintain forest villages of this nature in a stable condition and enable local people living in them to improve their quality of life. Markets for produce of forest villages have to be ensured. Thailand also aims at integrating forestry with agirculture and this has been done successfully by small farmers in Choengsaeo Province who grow Eucalypt wood amidst rice fields for charcoal production. Another success story from Thailand is the inter-cultivation of Acacia mangium plantations with food crops.

From the Philippines comes the example of the "Family approach" where 5 ha. plots are planted by families. The tree species is mainly Pinus insularis. The State either provides the seedlings or the families raise their own. However, there is a firm guarantee of land tenure for the family. This is the crucial point for success-firm land tenure. Sri Lanka too will also have to give firm undertakings to Community forestry and Agro-forestry farmers, other individuals, and societies that the land they plant will be theirs if they plant both trees and agricultural crops successfully according to scientific principles laid down by supervisory technical agencies.

From Central America come the examples of farmers cultivating tree species simulating as far as possible the structure and species diversity of tropical forests by planting a variety of crops with different growth habits, 1/10th ha. at times having 24 species. One of the answers to the utilization of fragile eco-systems may thus be agricultural systems of mixed cropping which brings benefits to both the eco-system and to man himself. A similar example is the "Cultura promiscua" of Tuscany, Italy.

Classic examples from Sri Lanka are the self sustaining multitiered home gardens or "Ge Watta" in the Kandyan hills with storied canopies of 3 to 4 tiers at times terraced, yielding fuelwood, timber, fodder food and medicine as well as providing habitats for bird life. This system of Agro-forestry or "family home garden agri-silviculture" is "as old" as the hills, and needs to be extended wherever suitable to meet the needs of the rural people of Sri Lanka in the face of an ever expanding population and decreasing groundspace.

In Tanzania, the Masai practice sylvo-pastoral systems providing food for its extensive herds of livestock. Sahelian countries have to face the increasing problem of competition not only between humans but also between humans and animals for crops, biomass, and groundspace. Much has to be done in the region if agro-forestry and social forestry practices are to serve the needs of local people.

Burma of course has provided an Agro-forestry system, the "Taungya" system, which has enabled many countries including Sri Lanka to raise very valuable man-made forests mainly Teak and produce large quantities of food. The main drawback of this system is that benefits to the local cultivators are only over the first three or so years and confined to food crops.

India boasts of many agro-forestry systems, and so does Nepal. In India farm forestry has arisen out of Gandhian philosophy and much earlier Social forestry through Buddhist philosophy, this latter philosophy also influencing the home garden system of Social forestry in South and South East Asia including Sri Lanka. India's forestry problems are large and some of its Community forestry projects have not achieved desired results. The Gujarat success story has eventually benefitted the richer farmers and not the rural poor of India who are subject to what has been described by Indian Forest Researcher Tiwari as "grinding poverty".[5] Survival rates have been more on lands planted by richer farmers and not on lands planted by local rural people. With only 11% forest cover, India needs to step up its tree planting and social forestation programmes adopting new strategies on lands occupied by the rural poor if social forestry is to serve the needs of local people in that country better. In the mountains of Nepal the situation is still more critical.

In Peru and Colombia Forestry Extension Schemes have been designed. Rural people are taught the essentials of tree planting and how they will benefit from the final products, an improved environment and new employment. This is also being done in Sri Lanka by the Forest Department's extension service.

Other countries with Social and Community Forestry systems combining tree planting with agricutlure and/or pasture are Guatemala, Honduras, Bhutan and Papua New Guinea, all of which have the clear objective of trying to serve the needs of local people in an integrated manner and this is being done with support from the FAO.

With the arrival of Scientific Agro-forestry Social Forestry and Community Forestry, Forestry Institutions are changing their concepts e.g. by including forestry extension work. Forestry curricula are being changed in teaching institutions, and Foresters are working jointly with Agronomists, Soil Conservationists, Hydrologists, Zoologists and Sociologists with whom they had little contact earlier. The art of Agro and Social Forestry is being fashioned and made scientific to bring more benefits to local people and to increase productivity from forest lands.

The Sri Lankan Experience

Apart from the traditional multitiered multispecies home garden concept, shifting or chena agriculture, and "Taungya" agriculture, Sri Lanka also has a new Forestry Extension Programme to generate social forestry and tree planting activities throughout the country. The Sri Lanka Forest Department heralded this change by introducing this concept of social forestry in 1979. The change was meant to develop and use forest resources for the betterment of people specially the rural people at Community level. Both the need for Social forestry and Agro-forestry were emphasized and advocated by the Conservator of Forests in the Sri Lanka Forest Department Administration Reports of 1979 and 1980. It has also been incorporated in Sri Lanka's National Forest Policy in 1980.[8] This change in policy will also substantially increase the country's total forest vegetation cover which is now 37.5% of the total area of the country.[9]

A Community Forestry Project with aid from the ADB has also been launched. Individual family home gardens forestry concepts are ingrained in the people and selfsustaining home gardens or "door step" forestry practices established for a long time. Hence it should not be too difficult to enlist the support of local people in Sri Lanka to start community forestry projects to yield benefits in a collective sense as well to more people than earlier in groups when the need arises or when the time comes making it imperative to do so. Home gardens with closed canopy, cover large extents of land in Sri Lanka in the South Western and Central parts of the country and the majority of species grown under this home garden system are indigenous species.

The Community Forestry Project covers the 5 near-fuelwood-deficient districts of Nuwara Eliya, Matale, Kandy, Badulla and Batticoloa. Started up in 1982, it has components of Block fuelwood, Farmer's woodlots, Community woodlots, Demonstration woodlots, Technical assistance, Training, and Agro-forestry research. Problems faced in this project were the ever increasing problem of land tenure for beneficiary farmers and communities, selection of suitable lands and beneficiary farmers by bureaucrats and the setting up of Community Participatory Societies. As I said earlier when the need arises or when the fuelwood pinch is felt more it may be easier to solve those problems of society formation and society action, but more governmental and political will to release land permanently to beneficiary farmers and communities will solve the land tenure problem as has been done in Philippines. Also, the Forest Department should be given the task of selecting suitable beneficiary farmers and suitable lands for woodlots in order to achieve success. After all, it is only a technical person who will be able to judge whether a farmer knows how to do the job correctly and also whether a particular land is suitable. Bureaucrats cannot do this.

Agro-forestry research is an important component of this project which when in full swing will certainly bring sustained benefits to rural people in the 5 districts in the matter of providing domestic wood and fuelwood, agricultural crops for food including fruit and fodder, which will improve the socio-economic conditions of the farmers and the community participatory societies. Tree species to be introduced will also include a variety of traditional indigenous species.

The Research Programme has the following activities:-

I. Agricultural crops and trees

- Home garden models.
- MPTS over food and other crops.
- Fruit trees and fuelwood/timber production.

II. Sylvo-pastorals

- Spacing trials of Eucalyptus over grazed existing pasture.
- Biomass production of Gliricidia over existing pasture.
- Spacing and biomass production of Eucalyptus, Gliricidia and Leucaena over improved pasture for cattle.
- Cattle stocking rates and production in these systems.
- Cut-and-carry systems for stall fed cattle.
- Use of improved pasture for weed control.

III. Applied silviculture.

IV. Species and provenance trials.

V. Nursery management.

VI. Demonstration and Communication of research results.

Bulk of the work is in the principal distict covered by the Project, Badulla district, and at the end of the project period of 6 years the project is expected to make a sizeable contribution to alleviating the biomass energy and small wood problems of the local people and also make available more food in the project areas of the 5 districts. It is also expected to act as a catalyst to generate more agro-forestry and social forestry activities in other regions of the country by creating a community, family and individual awareness of the value of community forestry agro-forestry and social forestry. It will also help to improve environmental conditions and demonstrate to people the sustainability and life supporting nature of Agro Social and Community Forestry systems. The ultimate aim of Community Forestry Projects such as this is to create techniques in which trees, livestock, agricultural crops, and groups of people interact in an almost closed enviornmental system but with increasing socio-economic benefits. Even though the Sri Lanka project falls short of these goals, if it succeeds in introducing trees into the agricultural and pastoral landscape in an integrated manner in which people livestock trees and crops interact in a balanced and environmentally benign system then it could be concluded that success has been achieved. This Agro and Social forestry strategy will be the main forestry scenario beyond the year 2000 when Sri Lanka's population is expected to be 22 million. This will in fact be the real "Master Plan" for increasing the vegetative cover in Sri Lanka.

Comparison with negative effects

Vergara (1985) has listed some negative effects of agro and social forestry. These negative effects include N uptake, evapotranspiration losses, reduction of groundspace for food, more labour inputs, costs, and reduction of time for leisure and recreation. These negative effects of course pale into insignificance when all positive effects both micro and macro are considered. These include, site protection maintenance and rehabilitation, improvement of soil tilth and porosity, increase in water retentive capacity ensuring productivity and sustainability, production of litter and mulch, tree crowns for shade to minimize evaporation, all these enabling farmers to aim at higher crops and biomass productivity, and macro-environmental benefits as well as increase in site quality as a result of conversion of grassland or forest fallow into agro and social forestry.

Social Forestry Philosophy and Political Thought

I feel that before I conclude this presentation it is only fitting that I refer to the approach of certain ethical philosophies to forestry practice specially social tree planting and social forestry. Eastern philosophies like Buddhism inculcates in man the love for trees, environment, landscape, wild life and forests. Gautama Buddha himself advocated the planting of trees about 2500 years ago. Buddhist teaching encourages every good Buddhist to plant and establish at least one tree every 5 years. The Buddha is also quoted as saying "The forest is a peculiar organism of unlimited kindness and benevolence that makes no demands for its sustanance and extends generously the products of its life's activity; it affords protection to all beings offering shade even to the axeman who destroys it". the Buddha himself achieved enlightenment under a "Bo" tree <u>Ficus religiosa</u> in a forest grove.

Mahatma Gandhi is quoted as saying "Every villager should be able to get his needs of fuelwood, fodder, bamboos, timber for agricultural implements and for housing and thatching grass, within a radius of 5 miles from his village" which conceptually is what Social forestry is all about.

Indira Gandhi, former Prime Minister of India is quoted as saying "trees are amongst man's most reliable friends and a country which cares for its future must take good care of its forests". As Agro and Social forestry helps to alleviate living conditions of rural people and improve their earning capacities there is also bound to arise a close linkage between these alternate forestry practices and political ideologies.

The indigenous ancient peoples of North America the "Red" Indians were also great lovers of the forest environment and they depended much on the forest for wood fodder, food and medicines. They advocated forest conservation and tree planting long before European people set foot on their land. Quotations from Indian chiefs of North America on the social importance of the forest environment and tree planting are many, a well known one being from Chief Seattle in 1854. Recently too, only last year in September 1986, at the 18th IUFRO, International Union of Forest Research Organisations World Congress held in Ljubljana, Yugoslavia, one of the specially invited speakers an indigenous North American Russel Jim a member of the Yakima tribe of Washington State re-echoed the words of Chief Seattle. Some quotations from Chief Seattle's speach of 1854 made in response to the demand from his white rulers that he sells Indian forest lands to the white man are worth quoting here. He said "The Earth does not belong to man, man belongs to Earth. Earth is our mother, for what befalls the Earth, befalls the children of Earth. Man did not weave the web of life, he is merely a strand in it. Whatever he does to the web, he does to himself", and "every part of this land is sacred to my people. Every shining pine needle, every sandy shore, every mist in the dark woods, every hearing and every humming insect is holy in the memory and experience of my people. The sap which courses through the trees carries the memories of the Red man".

After China and the 2 Koreas, recently too, many other countries have experienced a new upsurge of socio political will towards expanding agro and social forestry systems thus tending to link these systems with political ideologies and socio political thought prevailing in those countries. "Green" environment bound political parties and social organisations in Europe, tree protection or tree hugging "Chipko" movements in the Indian Himalayas and the "Rukrakaganno" or tree protection society in Sri Lanka are some results of such generated socio-political will. There has been a great emphasis on Forestry and the emergence of new ideas on the subject in Sri Lanka too recently to further extend the arms of Agro-forestry and Social forestry throughout the entire country thereby improving socio economic conditions and raising the quality of life of the country's rural poor. The Forest Department with support from NGOS has been in the forefront in accepting the challenge that has arisen as a result and is adopting new strategies to develop and expand agro-forestry and social forestry in the country.

Forest scientists in the tropics therefore, have to be mindful of ethical philosophies as well as of political ideologies and new thinking, when implementing their alternate forestry plans, enlisting support from NGOS and rural people themselves who will ultimately stand to benefit,keeping in mind always that two of the goals of Agro and social forestry are to save balance natural forests in the region and improve living conditions of the rural poor, goals which should therefore start in rural areas with the rural poor and also end with them. Thus, Agro and Social forestry may be the last hopes for conservation of Tropical Humid Forests in the World.

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Summary of discussion following presentation

Thailand - Mr Choob Khemnark: In choosing trees for agro-forestry programmes we have to more or less rely on woody perennials, bamboos, shrubs and palms. Among these however, there are few which are good timber species. Is there any conflicts between agriculturists and foresters in this regard?

Mr V.R. Nanayakkara: I don't see any conflicts as long as foresters and agriculturists are prepared to work together.

Bangladesh - Mr M. Kalimuddin Bhuiyan: What are the cropping and rotation systems used?

Mr V.R. Nanayakkara: Our studies in this aspect are still experimental. Although they are encouraging I think still it is not time to generalise about results. Normally we have been combining tree and shrub species with vegetables.

Dr A.H.Perera: In the dry zone of Sri Lanka, conversion of natural dry forest to teak forest has been practiced for long; why is it not successful any more.

Mr V.R. Nanayakkara: Teak plantations have been given up due to pressure from environmental groups.

Dr Mathew George: Social forestry is a joint venture between people and government agencies. Do you have any data on anticipated demands of villagers. In your reference to forest cover in India, natural forest cover was 11%, but in India if you include man-made forests we have about 19% forest cover.

Mr V.R. Nanayakkara: We consult villagers in selecting species and try not to impose our choice on them. I referred to 11% as India's natural forest cover.

Dr Mathew George: Have you worked out anticipated demands and increases?

Mr V.R. Nanayakkara: This has been done in the master-plan.

Thailand - Mr Choob Khemnark: In Thailand we have problems about determining criteria for agroforestry schemes. Such schemes are practiced in state-owned as well as private lands. Management in private lands is facilitated since there everything belong to farmers; in state-owned lands only the crops belong to the farmers but the trees to the government.

Mr V.R. Nanayakkara: I do not think the schemes will be successful unless ownership was completely with the farmers.

Philippines - Mr Jose O. Sargento: Agroforestry products should have a market values; it is essential for governments to develop a strategy in this regard. If products of natural forests continue to have a greater demand than that of agroforestry schemes then threats to natural forests could increase.

Bangladesh - Mr M. Kalimuddin Bhuiyan: Most agroforestry concepts have been practiced in the past; we are only putting science into it.

INTEGRATING LOCAL PEOPLE AND PROTECTED AREAS IN THE HUMID TROPICS

JIM THORSELL

Introduction

The challenge facing today's protected area manager in tropical countries relies very much on the degree of support and respect awarded to the protected area by neighbouring communities. Where protected areas are seen as a burden, local people can make protection impossible. When the protected area is seen as a positive benefit, the local people will themselves become allied with the manager in protecting the area from threatening developments.

There are many ways in which local people can benefit from protected areas, including utilisation of some resources from certain protected areas and buffer zones, the preservation of traditional rights and cultural practices, and special preference for local residents in employment or social services. Nevertheless, there are limits that must be placed on exploitative uses if reserve areas are to fulfil their primary protective functions. Managers must know where to draw the line.

This paper will review a range of human-related and social policy issues involved in ensuring closer integration between people and protected areas. It is based on a longer treatment of the subject in MacKinnon, Child and Thorsell (1987).

2. Protected Areas and Indigenous People

Some protected areas, particularly Protected Landscapes (Category V), Anthropological Reserves (Category VII) and Biosphere Reserves (Category IX), may be inhabited by indigenous people (IUCN, 1985). In other categories of protected areas, the presence of indigenous peoples may sometimes be acceptable where these people are living in close and balanced harmony with their environment and can be said to have become a part of the natural ecosystem. In other cases, where no people live in a reserve, traditional harvesting of various resources may be permitted on a seasonal basis and the use of traditional cultural sites for religious or spiritual purposes may continue.

The whole question of protection of indigenous cultures is highly sensitive. Where planners have forbidden the continued practice of traditional rights in national parks or other protected areas, they have been strongly criticised. On the other hand, those who seek to preserve "primitive" cultures are often accused of preventing indigenous people from pursuing the advantages of modern development and of trying to establish "human zoos as scientific curios or tourist objects".

There are many areas in which native populations, following their traditional cultures on their own land, protect large areas of essentially natural ecosystems and harvest the renewable resources of their environment on a sustained yield basis (see McNeely and Pitt, 1985 for case studies). These people and protected area managers can be appropriate allies and the need to reach a mutual understanding is urgent. Managers can learn much about resource conservation and use, while the conservation of natural areas can provide the opportunity for traditional cultures to survive. The social and behavioural patterns of these allegedly "primitive" people have become so integrated with their natural environment thay they often achieve ecologically sound long-term use of an area. Both are easily disturbed by insensitive forces from outside.

Where a protected area is designated to correspond with the territory of a particular native ethnic group, the traditional residents should be given the authority to oversee the activities of their own group and to expel any unauthorised invaders. The national conservation agency may remain the official administrator of the area, but managers should work closely with the resident native population. The following guidelines should be kept in mind.

-- When establishing protected areas, resettlement of native peoples should be avoided whenever possible. A native culture will remain intact only in its home territory, where the productive capacity of the environment is intimately understood.

-- The protected area should be sufficiently large to accommodate its dual functions, a reserve for nature with a reserve for native populations. The creation of reduced reserves serves only a symbolic end and begins a process of cultural devolution and ecological degradation if the native population does not have access to the resources they require.

-- Protected areas planning must also anticipate population increases and culture change. It is unrealistic to to expect a group to atrophy, or wosse, to "return" to some traditional technology long ago discarded in favour of a more modern alternative.

-- Official park guards should be drawn from the traditional residents. The threat to the integrity of a protected area originates largely from the outside. If reserve administrators expend their expectably meagre resources controlling the native residents, they will have neither sufficient force nor the peoples' good will to expel outsiders.

These guidelines all require the participation of the native population in the planning and implementation of the reserve. This requires good communications between reserve planners and the native peoples.

3. Human Enclaves within Protected Areas

Wherever possible, reserve boundaries should be selected or adjusted so as to exclude human settlements. Resettlement of small numbers of people is sometimes desirable if alternative and acceptable sites can be found for their villages. Where this is impossible, it may be necessary to declare an enclave inside a reserve.

The danger of enclave settlements is that they tend to expand at the expense of the reserve and that they invariably have access routes that cut through the reserve. Ultimately these will split the reserve unless firm controls are applied. The following regulations are suggested:

-- As a check on growth, immigration of outsiders into the enclaves is prohibited, i.e. no land may be purchased or cleared, or houses erected, by non-residents or new immigrants to the enclave.

-- The limit of agricultural spread that is tolerable must be clearly defined in the field and an appropriate buffer zone established. No expansion beyond these limits will be permitted.

-- Road access to and from the enclave must be limited to traditional routes (i.e. no new trails or roads) and no clearing allowed along the sides of the roads.

With restrictions on the spread of agriculture and prohibition of further immigration, population growth within the enclave should be minimal or even drop as young people move away to find employment. In an expanding population there will be economic pressure for emigration both as a result of the lack of growth potential within the enclave and the settlement's general remoteness. As enclaves are abandoned the land can be absorbed into the reserves.

4. Protection of Cultural Sites

Many cultural sites are located within natural protected areas and nature conservation often benefits from the protection of important cultural features. Examples include the Tikal National Park of Guatemala, Tassili National Park in Algeria and Angkor Wat National Monument in Kampuchea. Some such sites may be spectacular and well publicised while others may be less conspicuous and kept secret by the people for whom they have a special significance. The former often attract visitors and it is usually a relatively simple matter for the park manager to provide for their appropriate use. This is more difficult in the case of the more secret sites as the manager may not know of their existence or of their importance and may unwittingly prevent their use or permit their desecration. A sensitive manager will try to establish the location of these sites (or other cultural features such as traditional pilgrimage routes) and provide adequate protection without becoming too intrusive in his enquiries about their cultural significance.

In any case, the proper use of cultural sites calls for close liasion with a range of interested parties from professional scientists to informed and influential members of local communities.

5. Harvesting in Protected Area Buffer Zones

Development of buffer zones can be a useful way of providing some compensation to rural communities in cases where they have lost traditional harvesting rights or privileges through the establishment of the reserve. These zones can provide essential products (e.g. firewood, timber, building poles, thatch, meat, fish) which could otherwise be obtained only by illegal collection from the protected area itself.

The buffer zones should benefit the whole community and not just a few privileged individuals, otherwise the "have-nots" will still exploit the protected area. It is, therefore, recommended that buffer zones should be established for use only by specified villages and that exploitation is controlled by a village cooperative in which every household has a share. The cooperatives must ensure fair harvesting rights and organise profit-sharing from cash crops. In areas where there already exist traditional laws concerning community rights, these would form an excellent basis for determining sharing of buffer zone produce. Elsewhere, the park management authority could help in drawing up regulations for use and distribution of benefits.

Some categories of protected areas (V, VIII) may contain products that are useful to local communities and which may be harvested without detriment to the area itself. Naturally this will depend on the nature of the product, how it is to be harvested, and the particular protective status and management objectives of the area. Clearly, situations vary and there is a need to lay down very clear policy guidelines so that the protected area manager can act with consistency within a framework that is understood, if not always warmly accepted, by neighbouring communities.

Examples of useful products that may sometimes be harvested from a protected area by people from surrounding areas include firewood, thatching grass, surplus animals, traditional medicinal herbs, honey, fruits and seeds, and clay for traditional pottery. Where such harvesting is permitted, it should be viewed by those who benefit as a privilege rather than a right and in this regard some form of payment in cash or kind may have advantages.

Mishra (1984) describes a system in the Chitwan National Park in Nepal where the controlled harvesting of grass and reeds for thatch helps to compensate the local people for the loss of potentially rich agricultural land and for the inconveniences they suffer due to the proximity of the park. Similarly, native Indians are permitted to harvest wild nuts in the Grand Canyon National Park in the USA.

These examples represent the way in which products from a protected area can be harvested by local people under appropriate controls, to the benefit of both the park and its neighbours, without affecting natural values to any significant extent. Such interchanges build up good public relations at little or no cost and remove the need for local populations to engage in activities which may be more damaging to the protected area.

6. Protected Areas and Employment

Directly and indirectly, a protected area can enhance employment opportunities in the region. A certain number of local people may be employed directly by the management authority, or in catering for visitors to the area or providing ancillary services. In some cases a park or reserve can stimulate the whole local economy, especially if the monies deriving from the reserve and its visitors are used and cirulated within the region. Paid employment may be less easily recognised as a benefit by the local communities, however, because payment for labour is not always clearly related to the protected status of employment and other benefits through the protected area extension and information programme. Whenever possible, local people should be employed as reserve staff or as concessionaires in preference to outsiders from more distant towns. This keeps locally generated wealth within the communities immediately adjacent to the protected area.

7. Provision of Social Service -- Roads, Health, Assistance Grants

Expanded social services should be provided to local people as a benefit of their proximity to a protected area and to reduce their dependence on the adjacent protected area for harvestable products.

Many of the threats and abuses to reserves result because people simply have no alternative but to steal wood or poach. Since these activities are often hard work, uncomfortable, risky or even dangerous, and are often only marginally profitable, many offenders can be persuaded to halt their illegal activities if they are provided with other ways of earning a living. The management authority of a reserve may solve the problem more effectively by investing in development of social services and alternative employment than by increasing law enforcement.

Government can provide many forms of special assistance to rural people including:

- -- Agricultural and grazing improvement schemes
- -- Road improvement schemes
- -- Water, sewage and electricity services
- -- Schools, clinics and dispensaries
- -- Director grants for land improvement
- -- Loans or credit facilities for individual farmers
- -- Alternative land rights
- -- Establishing plantations on village lands or in buffer zones
- -- Creating local employment by stimulating local industry

Since protected areas which are developed for tourism become showpiece areas of a country, local government may be willing to promote development in surrounding areas. It pays to make clear to the local people the fact that they are getting preferential treatment, and that this is due to their privileged location close to the protected area. These benefits should be emphasised by the extension and information programme of the reserve. The examples of Amboseli National Park in Kenya and India's rural community policy show how successful this approach can be.

8. The Need for Communication and Public Relations Programme

In theory, the manager of a protected area could "go it alone" and protect his "closed area" from all unnatural disturbances and threats. Although such a policy might be one way to protect an ecosystem, it is unlikely to win public support and without public support no reserve is secure in the long term. Ultimately, the management of resources is <u>for</u> people and must be undertaken in a social framework. The survival of a protected area depends heavily on the attitudes of the local people, and public support at both the local and national level is a critical component of management. A vital part of any manager's job is to justify to higher authorities, and to the wider public to which they in turn are responsible, the existence of the protected area, the management policies chosen, and the expenditure incurred in applying such management.

In the short term, it may well be enough to convince the leader of a country or local governor that the establishment of a protected area would be a good thing. He simply orders it and it is so. But what about his successor? And what about the general public? How long will they accept the status quo? As pressures for land increase, protected areas will not survive intact unless the real benefits they confer are appreciated by the whole community.

India, with its large and expanding human population putting increasing pressure on land and natural resources, has realized the need to elicit public support for wildlife conservation and protected areas. First, the Task Force of the Indian Board for Wildlife (Government of India, 1983) assessed the levels of awareness and apathy towards wildlife conservation among different sections of the public and endeavoured to determine the causes. Their findings, outlined below, apply to many countries in the tropics.

-- Urban people, upon whom the influences of a depleted or an optimum wilderness are subtle and indirect, are often indifferent to wildlife conservation. Since most decision makers and professionals emerge from this group, lack of concern cripples the support needed for wildlife conservation and protected areas.

-- The outlook of rural people is determined by the degree of their dependence upon forests for pasture, firewood, timber and other products. Many communities in the neighbourhood of reserves sustain themselves by eroding marginal land and depleting forest pastures. Their precarious existence may be threatened by enforcement of restrictions in wildlife reserves and this can trigger antagonism towards protected areas.

-- The younger generation -- both urban and rural -- must be viewed as a separate group. Their concern for wildlife will remain largely undeveloped unless they are exposed to conservation education and interpretation at an impressionable age and made aware of its values and significance.

To achieve long-term support for a protected area programme and to encourage real appreciation of individual reserves, it is, therefore, vital to gain widespread support at all levels of public and institutional sectors.

The language, degree of detail, focus and the channel of communication will vary according to the target audience. For instance, it is quite meaningless to quote the scientific names of rare species to land-hungry farmers, counterproductive to bore busy ministers with inessential details, and an ineffective use of time to talk about biological diversity to the army commander who wants to use the reserve for military exercises.

The message must thus be tailored to fit the audience. This is an important job, requiring professional communicators. At ground level, the manager of any reserve cannot escape involvement in the communications field and must develop his capacities in this direction, even though he was probably selected for quite different abilities. It is the manager who selects the information to be presented and it is he and his staff who have the immediate contact with visitors to the reserve and with neighbouring communities.

9. Schools and Education Services

The sooner the reserve manager communicates the conservation message to his potential supporters the sooner it will begin to bear fruit. Moreover, the attitudes of the local people (those most affected by the restrictions of the reserve) will mellow as they begin to appreciate the reserve and its benefits. Using the reserve for teaching purposes is of benefit to both the reserve and the local community and through schools and youth groups the management can extend its message to the younger generation.

Protected area managers should contact local schools directly or through the local education offices to offer facilities for field excursions or classroom lessons about the reserve. Ideally, each reserve should have at least one education officer who is respposible for all arrangements to ensure that school parties arrive in a well-planned manner within the capacity of the reserve, generally avoiding weekends, holidays and other busy periods. Sometimes school visits may be day trips, in other cases, parties may need to stay in dormitories or tents for a longer trip. This may involve the reserve establishing special facilities where organized groups of young people and others can attend appropriate educational courses under the supervision of park staff. These can be simple and quite inexpensive. Sometimes the schools's own biology teacher will act as guide and instructor for the visit, but more probably some reserve staff will be involved and will need to be adequately trained. Obviously, the programme arranged will depend on the age and previous experience of the children but extension work with children is most important and worthwhile and may have a powerful effect on their attitudes towards nature and conservation.

10. Local Village Extension Service

Usually the nearest neighbours of the reserve are the greatest potential threat to its integrity but can also be the greatest asset for its protection. Local villagers can make the manager's job difficult, impossible or easy depending on how well or otherwise they accept the principles of the park and are brought to understand how it brings them benefits, not hardships.

Winning the support of the local people at grassroots level and the speed with which this occurs will depend very much on whether local communities do indeed benefit from the park and not just lose access to resources that would otherwise be available to them. Where the benefits accruing to local people are clear and readily-felt, there will be little difficulty in getting local communities to support the park. Where the benefits are not so obvious and the local people still see the park as a restriction on land needs, the manager will have greater difficulty in gaining their cooperation. He will need considerable patience and persuasion, an effective guard force and a major public relations programme.

The manager must take the job of winning friends outside his own protected area boundaries by carrying his message to the surrounding villages. This process of extension work may include posting notices and posters, holding slide shows or film shows in villages, holding discussions with neighbouring land-users or farmers' committees, and giving talks in local schools and to other concerned groups. Nor must the environmental education have to be wrapped in a conservation package. It can be integrated into other types of extension materials. The message to be carried to these villages must achieve various aims:

-- explain why it is important to establish protected areas,
-- show why this particular area has been selected,
-- indicate what benefits derive to the local community and local economy,
-- identify alternative sources of land, forest, etc., which villagers may exploit (if applicable), or, in some cases, explain entitlement to compensation payments,
-- develop a local sense of pride in the richness of local nature,
-- emphasise the Government's determination of make the reserve a success,
-- point out that law-breaking for selfish ends is a community offence not just an offence against the government

Mobile education units are particularly suitable for this sort of extension work. The mobile education unit can consist of no more than a man on foot with posters and colouring books. More generally, however, it implies a vehicle, equipped with a portable generator, slide and film equipment and a staff capable of setting up mobile and impromptu performances in villages and/or schools to show conservation education materials. Such material must be relevant to the country and the particular reserve. It is useful for the park authority to have someone on the staff capable of producing audio-visual material. This sort of training may be given _in situ_ by instructors from agencies such as the International Centre for Conservation Education (ICCE) or park staff may be sponsored for extra training at ICCE or elsewhere by international agencies.

11. Committees and Dialogue

Another way to help develop better local relations is to establish special committees, to help advise the management authority and/or share decision making responsibilities. Any or all of the following committees may be useful to help in the management of a given protected area.

-- Committees with local residents set up specifically to review reserve/village relations and in particular the management of buffer zones discuss infringements of park regulations or village grievances, e.g. channel through which the reserve management may complain about continuing abuses of reserve regulations by local villagers.

-- Inter-departmental committees set up to handle coordination of reserve management activities and requirements with ongoing developments that may affect the reserve, e.g. building of local roads. Such committees generally have members from the local planning authority, tourism, and public works, and may also have non-aligned members to provide technical expertise on certain subjects.

-- Advisory committees set up to advise the management authority on technical or scientific matters. In some cases these are set up independently by a particular group of interested parties who wish to have a forum for comment and a representative of the management authority is invited to attend meetings. Alternatively, the authority may only be sent the Minutes and Recommendations of the self-designated committee. In this latter instance, the advice can often be counter-productive, especially if the management authority feels resentful at the outside committee involving itself in the authoriy's business. Sometimes advisory committees are constituted at the express request of the management authority to give special advice in a field where it feels its own expertise to be weak and in such circumstances these committees can be very useful. Depending on the issues under discussion, they may be rendered more effective when the members are free agents expressing their own views and not representatives of different interest groups, nor government servants.

Good communication within and from a protected area management authority is an essential component of overall management. It facilitates cooperation, understanding, and appreciation and helps to minimise conflicts and problems. Unfortunately, public relations and other communication skills do not always "come naturally" and staff may require some training in putting across the conservation message. Effort devoted to conservation education and communication with local communities usually pays off handsomely, even if the immediate dividends are difficult to quantify.

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Summary of discussion following presentation

Dr(Mrs.) C.V.S. Gunatillake: Park or protected area managers need to be aware of the multi-disciplinary needs essential for satisfactorily carrying out their responsibilities.

Indonesia - Mr Achmad Abdullah: Despite the good intentions behind the idea giving the conservation message to traditional cultures is not an easy task.

Dr Jim Thorsell: In this regard it is good policy to work with the local leaders.

Nepal - Mr K. Kaphle: In Nepal about 1,023,000 ha of land is protected. One of the frequent problem to local people due to these protected areas is crop-damage by wildlife. Compensation for loss incurred is rarely paid. But even if one animal is killed heavy fines are imposed.

Dr Jim Thorsell: It is a problem. Elephant depredations often cause crop damage and sometimes even loss of human life. Protected area managers could win support by helping minimise damage.

Malaysia - Mr Fong Foo Woon: WWF-Malaysia has an extension service which spreads the conservation message quite effectively. They have produced a number of films and other audio-visuals illustraing the importance of conservation.

Dr Jim Thorsell: Growth of Wildlife and conservation clubs, particularly near protected areas, is most welcome. The wildlife clubs of Kenya and the Greens Foundation of Indonesia have also been very active in promoting conservation.

Philippines - Mr Jose O. Sargento: Economic and political issues related to conservation are also important. Over-emphasis on the needs of local people around conservation area could endanger the resources of the protected area. Those who are educated on availability, location etc., of local resources could use the same information for extraction of resources at times of economic hardships.

Dr R.P. Jayewardene: I am very much in agreement with the comment of the participant form Philippines. There are several ways in which local people could threaten the availabilitY of resources in protected areas.

Indonesia - Mr Achmad Abdullah: Given the limited resources available and the variety of threats facing them how can we ensure the long-term survival of protected areas.

Dr Jim Thorsell: There is no easy answer to that question. They should not become mere objects of international charity but should have benefits at the national and local levels. Such benefits along with an increase in the awareness of their need can ensure the survival of protected areas.

Mr N. Nanthakumar: In Sri Lanka, March for Conservation has stimulated several youth organisations around protected areas to become active in conservation. Such groups have, spread the conservation message through sport and religious events.

Prof.B.A. Abeywickrema: Even in 1977 when the threat of logging Sinharaja Biosphere Reserve was still present it was a buddhist priest from a temple just outside the southern parts of the reserve who led a delegation to the President of the country and initiated its declaration as a protected area.

Dr Jim Thorsell: The alliance between conservation and religion has been recognised and was recently demonstrated in connection with the 25th anniversary celebrations of the WWF-International.

Session IV

International mechanisms for Consolidating Local Conservation

Chairman: Prof. R.N. de Fonseka

RESEARCH AND TRAINING UNDER THE INTERNATIONAL MAN AND THE BIOSPHERE PROGRAMME

N. ISHWARAN

Abstract

The three continuums of Di Castri & Hadley (1984) which provide the framework for interdisciplinary research and training in the International Man and the Biosphere (MAB) programme are described. Four new orientations for the future of MAB research, recommended by a General Advisory Panel, and endorsed by the International Coordinating Council of the MAB programme are also elaborated. The increasing importance of biosphere reserves as centres of MAB activities is highlighted.

Introduction

The International Man and the Biosphere programme (hereafter referred to as MAB), of UNESCO was launched in 1971. It is a programme of research and training, aimed at understanding the structure and functioning of the biosphere and its ecological divisions, in relation to the changes brought upon them by man as well as to the effects of these changes on the human species, in order to develop, within the natural and social sciences, a basis for rational use and conservation of the resources of the biosphere (UNESCO/MAB, 1972; Spooner, 1986). Since 1971 the activities under the Man and the Biosphere programme have promoted the gathering of scientific information on practical solutions to problems of resource use and conservation and facilitated the dissemination and exchange of the information thus gathered. After a period of 15 years of growth, those responsible and interested in the programme are seeking for new directions which while maintaining continuity with the research/training themes of the past could also accommodate recent developments in ecology and related fields.

This paper provides a brief outline of the rationale behind the organisation of research and training under MAB. It also describes some of the emergent themes which are likely to form the focus of future MAB research and training. The increasing importance of biosphere reserves as foci for MAB research and training is emphasised.

Research and Training in MAB

In research and training encouraged under the MAB banner there has always been a significant emphasis on interdisciplinarity. Di Castri & Hadley (1984) recognise three continuums within the organisational framework of MAB, which perhaps facilitates specialists of different discipline to work together.

The three continuums are:

1. Geographic: The MAB programme deals with a whole range of global situations, from equatorial to polar zones and from littoral to high mountain areas. This continuum, is in reality, biogeographical in character, since it also identifies the programmes coverage of terrestrial, freshwater and coastal ecosystems.

2. Human action: Research and training does not confine to natural areas in pristine conditions but address questions in systems sparsely or densely populated by humans. In natural areas protected for the purposes of resource conservation this dimension extends MAB research and training interests beyond the core zones into buffer zones and adjacent human settlements.

3. Programme activities: This component relates to the diversity of actions, e.g. basic and applied research, demonstration and training, popularisation and education, and provide ample opportunities for introducing interdisciplinarity.

The fourteen projects (Table 1) of the MAB programme have a scientific structure dependant upon subject matter and are designed to incorporate multidisciplinary approaches to the study of ecological problems apparent in particular ecosystems or arising out of certain types of human actions (Spooner, 1986). Projects 1 - 7 relate to human impacts on and/or rational use of ecosystems e.g. tropical forests, savannahs and grasslands, mountains and tundra etc. Project 8 revolves around the general theme of conservation of natural areas and of the genetic material they contain therein and hence, in its application, is relevant to nearly all the other projects as well. Projects 9-14 study ecological problems arising out of specific categories of human actions, e.g. pest management and fertiliser use, construction of major engineering works and energy utilisation,, as well as deal with questions related to environmental perception.

Pilot Projects and Comparative Studies

In each MAB project, a variety of approaches are used in respect of the research and training strategy. The pilot project is a particularly important approach that has characterised several MAB research and training efforts. The pilot projects involve basic and applied research studies on ecological aspects of a given land-use problem, utilisation of the findings of the research to demonstrate practical solutions to that problem and training of national specialists in relevant subject areas necessary for sustaining the research ad land-use management efforts on a long-term basis. The Integrated Project on Arid Lands of Kenya, is a well known example of this approach. Others are known from east Kalimantan (Indonesia), Sakaerat (Thailand), Tai forest (Ivory Coast) and Makoku (Gabon).

Table 1

The major project areas of the Man and the Biosphere programme

1. Ecological effects of increasing human activities on tropical and sub-tropical forest ecosystems.

2. Ecological effects of different land uses and management practices on temperate and meditterenean forest landscapes.

3. Impact of human activities and land use practices on grazing lands: savanna and grassland (from temperate to arid areas)

4. Impact of human activities on the dynamics of arid and semi-arid zone ecosystems, with particular attention to the effects of irrigation.

5. Ecological effects of human activities on the value and resources of lakes, marshes, rivers, deltas, estuaries and coastal zones.

6. Impact of human activities on mountain and tundra ecosystems.

7. Ecology and rational use of island ecosystems.

8. Conservation of natural areas and of the genetic material they contain.

9. Ecological assessment of pest management and fertilizer use on terrestrial and aquatic ecosystems.

10. Effects of man and his environment of major irrigation network.

11. Ecological aspects of urban systems with·particular emphasis on energy utilisation.

12. Interactions between environmental transformations and the adaptive, demographic and genetic structure of human populations.

13. Perception of environmental quality

14. Research on environmental pollution and its effect on the biosphere

Another approach, namely comparative studies, in certain selected themes of interdisciplinary character, seems to be becoming an important element of MAB research and training efforts in recent times. The joint programme between UNESCO-MAB and IUBS (International Union of Biological Sciences) on Tropical Soil Biology and Fertility is a good example where this approach has been adopted. Under this programme two research planning workshops were held where the issues and questions to be addressed by the projects as well as the hypotheses to be tested were identified. The workshops also evolved methods of field data collection and study of biological processes of tropical soils which will be carried out in different parts of the world. Data thus collected is expected to be comparable for the purposes of analysis and several measures for improving intercalibration and comparison between research sites are now in progress. A similar joint effort is being developed in relation to a study of the Responses of Savannas to Stress and Disturbance as well.

Future Orientations for MAB Research and Training

The International Coordinating Council of the MAB programme, at its eighth session in December 1984, empowered its chairman to set up a General Scientific Advisory Panel for reviewing the MAB programme and making recommendations for introducing new criteria, concepts, techniques and methods throughout MAB activities. This Advisory Panel met twice in 1985 and 1986, respectively, and identified four new orientations, which while maintaining continuity with MAB's past research and training activities would also enable the introduction of several new dimensions (UNESCO-MAB, 1986). The four new orientations recommended are:

1. Ecosystem functioning under different intensities of human impact.
2. Management and restoration of human impacted resources.
3. Human investment and resource use.
4. Human response to environmental stress.

It is evident that the four new orientations have been defined broadly so that several of MAB's past research efforts could, either in a modified or unchanged manner, continue. The maintenance of continuity was essential in respect of several countries where MAB has provided the forum to initiate basic ecological research and training and which perhaps either did not have sufficient data-base or necessary infrastructure to adopt modern research techniques. On the other hand, the recommended orientations could provide the basis for other countries to synthesise data accumulated under a variety of MAB projects using a many modern techniques and at the same time test their utility in attempts to model natural ecosystems. The new research orientations have thus taken into account the needs of countries which are at different stages of development in their research and training capabilities but collaborate together as part of the international MAB programme.

The pilot project and comparative studies approach which have catered to the needs of an international research programme such as MAB are likely to continue to be important in designing research projects in relation to the four new orientations mentioned above. All the four orientations emphasise human-environment interactions, unavoidable at a time when areas which are totally devoid of human influence on the physical and biological environment are rare to find. Investigations on several topics related to these four new orientations are essential for improving the productivity as well as biological diversity of degraded ecosystems. Under the theme "human investment and resource use" the natural and social scientists would be required to interact to a greater extent than ever before since this theme could address an understanding of socio-economic and political factors which affect resource use patterns and precipitate ecological/environmental problems. Human response to environmental stress, another of the four new MAB orientations, demands greater attention from scientists in light of the increasing incidence of environmental pollutants affecting health conditions of humans. The four new themes appear to have effectively laid down the thematic basis for the introduction of a variety of new dimensions in research and training under MAB.

The International Coordinating Council of the MAB programme which met for its ninth session during October 1986 endorsed the four new orientations for the future but requested that their scope and potential applications, in relation to past research efforts of MAB and otherwise, be further reviewed and refined. The Council also suggested that such review and refinement be guided by the triple needs of maintaining continuity, of adapting to new issues and opportunities, and of being in line with the resources likely to be made available for the servicing and implementation of the programme (UNESCO-MAB, 1986).

MAB Research and Training and Biosphere Reserves

A biosphere reserve is a special kind of protected area established, to be part of an international network, in connection with the implementation of MAB Project 8-conservation of natural areas and the genetic resources they contain therein. While the project title itself summarises one of the primary functions of a biosphere reserve these protected areas are also expected to play an important role in a) scientific research and training b) monitoring of ecological/environmental parameters c) environmental education and d) demonstrating the connection between conservation and development.

In the past, biosphere reserves have been the focus of several MAB research and training activities. The fact that a biosphere reserve could be found in any part and in any of the biogeographical provinces (Udavardy, 1975) of the world made it relevant to the geographic continuum of the MAB research and training framework. The characteristic zonation of an ideal biosphere reserve, in relation to different extents of "human-nature" interactions (Di Castri & Robertson, 1982; von Droste & Gregg, 1985; Batisse, 1986) gave relevance of the human action continuum of the MAB research and training efforts to this protected area. Thirdly, the programme activities continuum of MAB had frequently focused on biosphere reserves since they have been sites of basic and applied research, environmental education campaigns, and demonstration projects for illustrating the link between conservation and development.

Given the fact that the new orientations recommended for MAB's future research and training have been defined more broadly than the previous ecosystem/human action directed projects, the biosphere reserves likely to become more important in research, training/ education and demonstration projects in the coming years. There are now 261 biosphere reserves distributed over 70 countries and several of these are ideally suited for the application of either the pilot project or the comparative studies approach. Furthermore, decreasing resources available for the programme demands greater efficiency in their use and the emphasis of biosphere reserves as centres of future MAB research and training could be one way of attaining this objective. Presently, about 21 biosphere reserves are also World Heritage Sites, which are another category of internationally recognised protected areas suported by the World Heritage Convention of UNESCO and a World Heritage Fund established under that Convention. Hence, at least in some cases, the biosphere reserves have the support from additional resources available within the administrative framework of UNESCO. Several international organisations such as UNEP, FAO and the IUCN are committed to promote the implementation of the Action Plan for Biosphere Reserves and hence, actively collaborate with UNESCO in this regard.

Summary

The International Man and the Biosphere (MAB) programme promotes research and training aimed at demonstrating practical solutions to modern problems of land-use management and resource conservation. In the past MAB research and training activities have been organised around geographic, human action and programme activity continuums, in fourteen major projects. The four new orientations recommended by General Advisory Panel and endorsed by an International Coordinating Council of the MAB programme are a) ecosystem functioning under different intensities of human impact b) management and restoration of human impacted resources c) human investment and resources use and d) human response to environmental stress. Protected areas that are part of the international network of biosphere reserves established for the conservation of natural areas and the genetic resources they contain would continue to be important sites for MAB research, training/education and demonstration projects.

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Summary of discussion following presentation

Dr N. Gunatillake: I like to mention a few things about the TSBF programme since I have been involved in several of the planning workshops. I think this programme is likely to make valuable contributions to the understanding of processes affecting fertility of tropical soils using the comparative study approach. It is also hoped that the programme will also, in the future, attract sufficient funds for its successful implementation.

Dr K. Swarupanandan: How could we regularly obtain the publications of UNESCO on subjects related to ecology?

Dr N. Ishwaran: Whatever the publication you would be interested in and is available for free circulation could be obtained by writing to the Division of Ecological Sciences.

Dr E.F.W. Fernando: Is there some way of finding out the important MAB-sponsored workshops well ahead of schedule?

Dr N. Ishwaran: The best way to achieve this will be through the MAB newsletter INFOMAB which is sent to the MAB National Committees in sufficient numbers of copies.

Prof. R.N. de Fonseka: All the publications the MAB National Committee receives through their links with UNESCO-MAB is available for those interested in the NARESA library.

INTERNATIONAL MECHANISMS FOR CONSOLIDATING NATIONAL EFFORTS IN NATURE CONSERVATION

by

N. ISHWARAN

Abstract

Two international mechanisms for consolidating national efforts in nature conservation, namely the Action Plan for Biosphere Reserves and the World Heritage Convention, respectively, of UNESCO, are considered. Their conceptual basis, and important administrative and procedural factors related to their implementation are described. The status of implementation of both mechanisms, from an overall perspective as well as specifically in the Indomalayan realm, are reviewed. Some of the links in the implementation of the two mechanisms are outlined.

Introduction

Biological and ecological units, such as species, ecosystems and biomes, are always defined globally than locally; a given species or an ecosystem could be distributed worldwide or within defined regions of the world. Political and social action which aim to conserve such units, and originating locally and nationally, therefore needs frequent coordination at the regional and international levels. This is particularly so during modern times when even the remotest parts of the world comprising habitats of rare species or unique ecosystems could be adversely impacted upon by technology and 'development'. Furthermore the imbalance between the resources spent on 'development' as against 'conservation' in several developing countries frequently necessitates inputs from external sources in favour of national conservation efforts.

Two international mechanisms which consolidate national efforts to conserve natural areas and the resources they contain therein are described in this paper. The conceptual and administrative basis of the two mechanisms, namely the Action Plan for Biosphere Reserves and the World Heritage Convention, respectively, of UNESCO, are briefly outlined. The extent of participation by countries of the Indomalayan realm in the implementation of these two mechanisms are briefly reviewed.

Action Plan for Biosphere Reserves

The Biosphere Reserve Concept (Di Castri & Robertson, 1982; Batisse, 1982; von Droste & Gregg, 1985; Batisse, 1986) originated in connection with the implementation of Project 8 of the

Man and the Biosphere Programme-conservation of natural areas and the genetic material they contain. The concept envisaged the establishment of an international network of protected areas, referred to as biosphere reserves, which would demonstrate the link between conservation and development (UNESCO, 1984). The concept has evolved since its origin in 1971 and the establishment of the first biosphere reserve in 1976. Today the international network comprises 261 biosphere reserves in 70 countries.

The identity of a biosphere reserve revolves around the functions it serves in society of which the following are considered most important:

1) Conservation of ecosystems, representative of the major biogeographical provinces of the world (Udvardy, 1975), and the genetic resources contained in those ecosystems.
2) A field site and centre for scientific research on a variety of subject areas in the natural as well as the social sciences; the international network of biosphere reserves is therefore a mechanism enabling exchange of information and experience among scientists, technicians and managers.
3) Together with other reserves of the international network is a field centre for long-term monitoring of parameters useful in understanding changes in the regional and global environment.
4) A field laboratory for nature and environmental education to a variety of audiences for increasing the overall awareness of conservation needs in society.
5) A field centre for genetic resources of potential and real economic value to people where scientific research on the sustainable use of such resources and its benefits to the socio-economic upliftment of local people could be demonstrated.

It would be idealistic to assume that all 261 biosphere reserves which are now part of the international network fulfill these five essential functions. However, there are quite a few which have achieved considerable success with respect to some functions. Research and monitoring have become central to the management of several biosphere reserves in the USSR (Sokolov, 1985). In the Mapimi (Halfter, 1981) and other biosphere reserves of Mexico (Halfter, 1985) environmental education as well as linking conservation and socio-economic development of local people have received emphasis and have been met with a fair measure of success.

Nominating any reserve to the international network of biosphere reserves is primarily the respondibility of the national authorities. MAB national committees may take the leadership in this regard since they communicate frequently with the MAB secretariat in UNESCO and are familiar with the administrative details concerning the procedure for nomination. Nomination forms could be obtained from the MAB secretariat at the Division of Ecological Sciences, UNESCO. The nominations are evaluated by a small panel of experts and submitted to the review of the Bureau of the International Coordinating Council (ICC) of the Man and the Biosphere Programme (MAB). This Bureau which meets at least once a year decides whether or not a nominated site is to become part of the international network of biosphere reserves (UNESCO, 1987).

A survey of the 261 biosphere reserves which are part of the international network (appendix 1) would show a wide variety of protected area and reserve categories known worldwide e.g. Yellowstone (USA), Serengeti (Tanzania) etc., as well as those dedicated primarily to scientific research such as the Hubbard Brook Experimental Forest of the United States.

The benefits to countries participating in the implementation of the Action Plan for Biosphere Reserves are several. In many countries the realisation of the Biosphere Reserve Concept has helped to expand the constituency for conservation to include new interest groups such as the social scientists and anthropologists as well as voluntary agencies working for the benefit of native people. The increase in the information content available to scientists, technicians and managers through mechanisms of exchange made possible through the international network is often substantial. The present regional training workshop entitled "ecology and conservation of tropical humid forests in the Indomalayan realm" which has brought together specialists from 10 different countries and with field exercises in the Sinharaja Biosphere Reserve of Sri Lanka is an example of what could be achieved as part of implementation of the Action Plan. Futhermore UNESCO has the full support of various international agencies such as UNEP, FAO and IUCN in its efforts to implement the Action Plan for Biosphere Reserves and frequently invites consultants from such agencies to participate in these workshops. The Action Plan therefore provides a useful focal point of international action on conservation of genetic resources as well as for demonstrating the link between conservation and development.

The World Heritage Convention

The conceptual basis for the World Heritage Convention stems from the fact that throughout the world there are properties, both natural and cultural, whcih have certain outstanding universal values whose conservation is not only the responsibility of the country within which the property is found but of the international community as a whole. The Convention was adopted by UNESCO's General Conference in 1972. Today the convention has been ratified/accepted or acceded to by 95 States Parties (appendix 2). There are 247 sites inscribed on the World Heritage List of which 179 are cultural, 60 natural

and 8 mixed (appendix 3).
Article 2 of the World Heritage Convention defines natural heritage as follows:
-- natural features consisting of physical and biological formations or groups of such formations, which are of outstanding universal value from the aesthetic or scientific point of view
-- geological or physiographical formations and precisely delineated areas which constitute the habitat of threatened species of animals and plants of outstanding universal value from the point of view of science and conservation.
-- natural sites or precisely delineated areas of outstanding universal value from the point of view of science, conservation or natural beauty.
Any state Party to the Convention could nominate a natural heritage site, as defined above, for inscription on the World Heritage List. The World Heritage Committee comprising 21 State Parties is elected when the UNESCO General Conference meets every two years. The Committee itself meets annually to decide upon the inscription of sites, nominated by States Parties, on the World Heritage List, as well as to approve suitable requests for assistance submitted by States Parties for implementing the Convention. The "Operational Guidelines for the Implementation of the World Heritage Convention" defines, under paragraph 33, the following criteria, at least one of which should be met for the Committee to consider inscription of the site ont he World Heritage List; sites nominated should therefore
i) be outstanding examples representing the major stage of earth's evolutionary history; or
ii) be outstanding examples representing significantly ongoing geological processes, biological evolution and man's interaction with his natural environment; as distinct from the periods of the earth's development; this focuses upon ongoing processes in the development of communities of plants and animals, landforms and marine areas and freshwater bodies; or
iii) contain superlative natural phenomena, formations or features for instance, outstanding examples of the most important ecosystems, areas of exceptional natural beauty or exceptional combinations of natural and cultural elements; or
iv) contain the most important and significant natural habitats where threatened species of animals or plants of outstanding universal value from the point of view of science or conservation still survive.
The applications of these criteria are further elaborated in the "Operational Guidelines for the Implementation of the World Heritage Convention".

The Committee's task in evaluating nominated natural sites is facilitated by the work of IUCN (International Union for the Conservation of Nature and Natural Resources) which undertakes field visits and prepares a summary of the nomination submitted by the State Party and a technical evaluation of the nomination. The summary and evaluation for each nominated site is reviewed by the Bureau of the World Heritage Committee. The Committee takes its decision with respect to each site during its annual sessions, taking into consideration recommendations made by the Bureau and IUCN.

While most legal mechanisms for conservation are restrictive in one way or the other the World Heritage Convention is unique in contributing towards the conservation actions of its States Parties through the resources of the World Heritage Fund established under article 15 of the Convention. The fund is made up of a) compulsory (1% of the contribution made to the regular programme of UNESCO) and voluntary contributions from States Parties to the Convention b) contributions from other states not party to the Convention, UNESCO or other organisations of the UN system and public or private bodies or individuals c) interests due on the resources of the Fund d) funds raised by collections and receipts from events organised for the benefit of the Fund and e) all other resources authorised by the Fund's regulations, as drawn up by the World Heritage Committee.

The resources of the fund are available to States Parties under the following types of international assistance:

a) Preparatory assistance: This form of assistance is available to countries which are party to the Convention and wish to 1) conduct a systematic review of their national protected area network so as to prepare an indicative list of natural properties of potential World Heritage quality 2) prepare dossiers for one or more ptential sites nominating them for inscription on the World Heritage List and 3) prepare, for sites already inscribed on the World Heritage List, requests for other forms of international assistance available under the World Heritage Fund. The budgetary ceiling on individual requests for preparatory assistance is US $ 15,000.

b) Technical Cooperation: Certain types of projects in which the work foreseen is considered important for the conservation of a natural property inscribed on the World Heritage List could receive support from the allocations available for technical cooperation under the World Heritage Fund. Such projects may involve construction of guard-posts, visitor centres, purchase of field and laboratory equipment as well as in-situ training of local officers, volunteers etc. Large scale technical cooperation requests above US $ 30,000 require longer processing time and for consideration during the same year in which they are submitted they should preferably reach the World Heritage Secretariat before the 31st August.

c) Training: Assistance could also be sought for training of individuals (fellowships) or organizing national/regional/ international training centres. In general group training is preferred.

Training of individual specialists, when approved, is normally for attending specialised seminars/workshops/courses of short duration. Only those requests where training is the only activity envisaged is considered for funding under training. Others where training is only part of the project activities foreseen are normally funded under technical cooperation.

d) Emergency Assistance: Natural properties inscribed on the World Heritage List but where serious threats to their universal values are recognised are considered for inclusion on a list of World Heritage in Danger. Procedures for State Parties nominating one of their World Heritage Sites in the 'Danger' list are outlined in paragraphs 54-67 of the "Operational Guidelines for the Implementation of the World Heritage Convention". These sites receive special consideration for funding under emergency assistance if the activities foreseen, in the opinion of the World Heritage Committee, reduces the actual and potential threats facing the site. This type of assistance could also be requested to repair damage caused to World Heritage Sites due to unexpected causes such as earthquakes, fire or floods.

Requests for all categories of assistance outlined above must be made in specific application forms obtainable at the World Heritage Secretariat, UNESCO. They must be submitted to the consideration of the World Heritage Committee through the UNESCO National Commission and the Permanent Delegation in UNESCO of the State Party requesting assistance.

All requests for assistance which are less than US $ 20,000 could be approved by theChairperson of the World Heritage Committee as long as the request is not made by that State Party of which the he/she is a citizen. If a request is above this amount but less than US $ 30,000 it could be approved by the Bureau of the World Heritage Committee which meets at least twice a year. Any request amounting to more than US $ 30,000 could only be approved by the World Heritage Committee which meets annually, towards the end of the year.

The World Heritage Committee, while deciding upon the annual allocations for the different types of assistance mentioned above also sets aside some financial resources for the promotion of the Convention. The establishment of national organization(s) for the promotion of the Convention, is encouraged. Some assistance for the activities of such national organisation in relation to increasing the general awareness of the Convention could be made available upon request by States Parties.

Relationships between the Action Plan for Biosphere Reserves and the World Heritage Convention

Some of the relationships between the two international mechanisms supporting national conservation efforts discussed here are clearly apparent. Both mechanisms despite the differences in administrative and other procedural aspects of implementation are guided in their enaction by the same international agency. Furthermore the conceptual basis behind the two mechanisms have common elements. It is possible that an area comprising one or more ecosystems representative of the biogeographical units as defined by Udvardy (1975) may at the same time have outstanding natural values of universal importance as well. At present there are 21 sites distributed over 17 countries which are part of the international network of biosphere reserves and at the same time World Heritage Sites as well (appendix 4). These 21 sites are particularly important since they are recognised, internationally, for their role in promoting conservation as well as scientific research.

Both biosphere reserves and World Heritage Sites require strict legislative bases for the protection of the specific values for which they have been recognised internationally. It may be possible that there are protected areas in several countries which clearly possess the natural values for consideration as biosphere reserve and/or World Heritage site but are yet to receive such international status. While this could be attributable to several reasons a site nominated for consideration for a particular international status by a State Party could be recognised for the values it possesses but not given the specific status requested due to inadequate legal protection at the national level. In this manner the two mechanisms encourage and support countries in their efforts to ensure the highest levels of legal protection to such reserves.

Participation of countries within the Indomalayan Realm in the Implementation of the two mechanisms

In respect of the implementation of the Action Plan for Biosphere Reserves, 11 of the 27 biogeographical provinces identified with the realm (Udvardy, 1975), are represented in the international network so far. There are a total of 14 biosphere reserves in the realm covering a total area of 1,699,976 ha. Seven of the fourteen biosphere reserves are distributed in the mainland and Sri Lanka while the other seven are in the mixed island systems of south and southeast Asia. In the mainland of the seven types of biogeographical provinces categoriesed for the tropical humid forest biome only two are represented (Ceylonese rainforest and the South Chinese rainforest) in the biosphere reserves of the international network (MAB-IUCN, 1986).

Among the member states of UNESCO ratification of the World Heritage Convention has been lowest in the Asia-Pacific region. However, it is encouraging to note that knowledge about the Convention among countries of the Indomalayan realm is increasing and more countries are likely to become party to the Convention in the near future.So far only India has natural sites which are inscribed on the World Heritage list (Nepal which has sent participants for this workshop also has two natural sites inscribed on the World Heritage List). Sites nominated by the People's Republic of China and Sri Lanka are being evaluated this year and the final decision regarding their inscription will be taken by the World Heritage Committee in December 1987. It is quite obvious that there are several more natural sites within the realm which have values of potential World Heritage quality; the Sundarbans of the People's Republic of Bangladesh and the several ASEAN Heritage Sites are examples which comes to one's mind immediately. The countries under consideration need to take the initiative in ratifying/accepting the Convention and/or nominating such sites for inscription on the World Heritage List.

Summary

The Action Plan for Biosphere Reserves and the World Heritage Convention are two international mechanisms implemented by participating countries with the guidance of UNESCO. Biosphere reserves are areas comprising ecosystems representing the world's biogeographical units (Udvardy, 1975). They are managed with the objectives of conserving genetic resources, providing opportunities for research, environmental education and ecological monitoring and demonstrating the link between conservation and development. There are at present 261 biosphere reserves in the international network which are distributed over 70 countries. The World Heritage Convention aims to protect natural and cultural properties of outstanding universal value. Presently 95 states parties have adhered to the Convention. There are 247 sites which are now inscribed on the World Heritage List of which 179 are cultural, 60 natural and 8 mixed. States Parties could request support for preparatory assistance, technical cooperation, training, emergency assistance and activities promoting the convention from the resources available under the World Heritage Fund. 23 natural sites in 17 countries are biosphere reserves as well as World Heritage Sites. Implementation of both mechanisms require adequate national legal structures for protecting the natural sites under consideration. Countries in the Indomalayan realm could greatly benefit by increasing their participation in the implementation of these two international mechanisms which consolidate national conservation efforts.

Appendix 1
List of Biosphere Reserves
Liste Des Reserves De La Biosphere

March/mars 1987

(266 in 70 countries) (266 dans 70 pays)	Biogeographic province/ Province bio-biogeographique	Area/ Superficie (ha)	Date of approval/ Date d'approbation
ALLEMAGNE, REPUBLIQUE FEDERALE D'			
Voir paragraphe Germany, Federal Republic of			
ALGERIA/ALGERIE			
Parc national du Tassili	2.18.07	7,200,000	1986
ARGENTINA/ARGENTINE			
Reserva de la Biosfera "San Guillermo"	8.37.12	981,460	1980
Reserva Natural de Vida Silvetre "Laguna Blanca"	8.25.07	981,620	1982
Parque Costero del Sur	8.31.11	30,000	1984
Reserva Ecologica de Nacunan	8.25.07	11,900	1986
AUSTRALIA/AUSTRALIE			
Croajingolong	6.06.06	101,000	1977
Danggali Conservation Park	6.10.07	253,230	1977
Kosciusko National Park	6.06.06	625,525	1977
Macquarie Island Nature Reserve	7.04.09	12,785	1977
Prince Regent River Nature Reserve	6.03.04	633,825	1977
Southwest National Park	6.02.02	403,240	1977
The Unnamed Conservation Park	6.09.07	2,132,600	1977
Uluru(Ayers Rock-Mount Olga) National Park	6.09.07	132,550	1977
Yathong Nature Reserve	6.13.11	107,241	1977
Fitzgerald River National Park	6.04.06	242,727	1978
Hattah-Kulkyne NP & Murray-Kulkyne Park	6.05.06	49,500	1981
Wilson's Promontory National Park	6.06.06	49,000	1981
AUSTRIA/AUTRICHE			
Gossenkollesee	2.32.12	100	1977
Gurgler Kamm	2.32.12	1,500	1977
Lobau Reserve	2.32.12	1,000	1977
Neusiedler See-Osterrichischer Teil	2.12.05	25,000	1977
BIELORUSSIE REPUBLIQUE SOCIALISTE SOVIETTQUE			
Voir paragraphe Byelorussian Soviet Socialist Republic			

List of Appendices:

1) List of Biosphere Reserves, by country, giving details of biogeographic province (by code number devised by Udvardy, 1975), total area and date of declaration as a biosphere reserve.

2) List of States Parties to the World Heritage convention.

3) List of natural and cultural properties, by country, that are inscribed on the World Heritage List, giving date of inscription and natural/cultural criteria for inscription

4) List of sites that are Biosphere Reserves as well as World Heritage Sites

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BENIN			
Reserva de la biosphere de la Pendjari	3.04.04	880,000	1986
BOLIVIA/BOLIVIE			
Parque Nacional Pilon-Lajas	8.06.01	100,000	1977
Reserva Nacional de Fauna "Ulla Ulla"	8.36.12	200,000	1977
Estacion Biologica Beni	8.35.12	135,000	1986
BULGARIA/BULGARIE			
Parc national Steneto	2.33.12	2,889	1977
Reserve Alibotouch	2.33.12	1,628	1977
Reserve Bistrichko Branichte	2.33.12	1,177	1977
Reserve Boatine	2.33.12	1,281	1977
Reserve Djendema	2.33.12	1,775	1977
Reserve Doupki-Djindjiritza	2.33.12	2,873	1977
Reserve Kamtchia	2.33.12	842	1977
Reserve Koupena	2.33.12	1,084	1977
Reserve Mantaritza	2.33.12	576	1977
Reserve Maritchini ezera	2.33.12	1,510	1977
Reserve Ouzounboudjak	2.33.12	2,575	1977
Reserve Parangalitza	2.33.12	1,509	1977
Reserve Srebarna	2.11.05	600	1977
Reserve Tchervenata stena	2.33.12	812	1977
Reserve Tchouprene	2.33.12	1,440	1977
Reserve Tsaritchina	2.33.12	1,420	1977
BURKINA FASO			
Foret classee de la mare aux hippopotomes	3.04.04	16,300	1986
BYELORUSSIAN SOVIET SOCIALIST REPUBLIC			
Berezinskiy Zapovednik	2.10.05	76,201	1978
CAMEROON, UNITED REPUBLIC OF			
Parc national de Waza	3.04.04	170,000	1979
Parc national de la Benoue	3.04.04	180,000	1981
Reserve forestiere et de fauna du Dja	3.02.01	500,000	1981
CANADA			
Mont St Hilaire	1.05.05	5,550	1978
Waterton Lakes National Park	1.19.12	52,597	1979
Long Point Biosphere Reserve	1.22.14	27,000	1986
Riding Mountain Biosphere Reserve	1.04.03	297,591	1986
CENTRAL AFRICAN REPUBLIC			
Basse-Lobaye Forest	3.02.01	18,200	1977
Bamingui-Bangoran Conservation Area	3.04.04	1,622,000	1979
CHILE/CHILI			
Parque Nacional Fray Jorge	8.23.06	14,074	1977
Parque Nacional Juan Fernandez	5.04.13	9,290	1977
Parque Nacional Torres del Paine	8.37.12	184,414	1978
Parque nacional Laguna San Rafael	8.11.02	1,742,448	1979
Parque nacional Lauca	8.36.12	358,312	1981

Parque nacional Lauca	8.36.12	358,312	1981
Reserva de la Biosfera 'Araucarias'	8.22.05	81,000	1983
Reserva de la Biosfera La Campana-Penuelas	8.23.06	17,095	1984
CHINA/CHINE			
Changbai Mountain Nature Reserve	2.14.05	217,235	1979
Dinghu Nature Reserve	4.06.01	1,200	1979
Wolong Nature Reserve	2.39.12	207,210	1979
Fanjingshan Mountain Biosphere reserve	2.15.05	41,533	1986
Xilin Gol Natural Steppe Protected Area	2.30.11	1,078,600	1987
Fujian Wuyishan Nature Reserve	2.01.02	56,527	1987
COLOMBIA/COLOMBIE			
Cinturon Andino Cluster Biosphere Reserve	8.33.12	855,000	1979
El Tuparro Nature Reserve	8.27.10	928,125	1979
Sierra Nevada de Santa Marta (incl. Tayrona NP)	8.17.04	731,250	1979
CONGO			
Parc national d'Odzala	3.02.01	110,000	1977
COSTA RICA			
Reserva de la Biosfera de la Amistad	8.16.04	500,000	1982
COTE D'IVOIRE			
Parc national de Tai	3.01.01	330,000	1977
Parc national de la Comoe	3.04.04	1,150,000	1983
CUBA			
Sierra del Rosario	8.39.13	10,000	1984
Cuchillas del Toa	8.39.13	127,500	1987
Peninsula de Guanahacabies	8.39.13	101,500	1987
Baconao	8.39.13	84,600	1987
CZECHOSLOVAKIA			
Krivoklatsko Protected Landscape Area	2.11.05	62,792	1977
Slovensky Kras Protected landscape Area	2.11.05	36,165	1977
Trebon Basin Protected Landscape Area	2.11.05	70,000	1977
Palava Protected Landscape Area	2.11.05	8,017	1986
DENMARK/DANEMARK			
Northeast Greenland National Park	1.17.09	70,000,000	1977

ECUADOR			
Archipielago de Colon (Galapagos)	8.44.13	766,514	1984
EGYPT/EGYPTE			
Omayed Experimental Research Area	2.18.07	1,000	1981
EQUATEUR			
Voir paragraphe Ecuador			
ESPAGNE			
Voir paragraphe Spain			
ETATS-UNIS D'AMERIQUE			
Voir paragraphe United States of America			
FRANCE			
Atoll de Taiaro	5.04.13	2,000	1977
Foret domaniale du Fango	2.17.06	6,410	1977
Reserve nationale de Camargue BR	2.17.06	13,117	1977
Reserve de la biosphere du PN des Cevennes	2.09.05	323,000	1984
GABON			
Reserve naturelle integrale d'Ipassa-Makokou	3.02.01	15,000	1983
ITALY/ITALIE			
Collemeluccio-Montedimezzo	2.32.12	478	1977
Foret Domaniale du Circeo	2.17.06	3,260	1977
Miramare Marine Park	2.17.06	60	1979
JAPAN/JAPON			
Mount Hakusan	2.02.02	48,000	1980
Mount Odaigahara & Mount Omine	2.02.02	36,000	1980
Shiga Highland	2.15.05	13,000	1980
Yakushima Island	2.02.02	19,000	1980
KENYA			
Mount Kenya Biosphere Reserve	3.21.12	71,759	1978
Mount Kulal Biosphere Reserve	3.14.07	700,000	1978
Malindi-Watamu Biosphere Reserve	3.14.07	19,600	1979
Kiunga Marine National Reserve	3.14.07	60,000	1980
KOREA, REPUBLIC OF			
Mount Sorak Biosphere Reserve	2.15.05	37,430	1982
MALI			
Parc national de la Boucle du Baoule (etc)	3.04.05	771,000	1982

MAURITIUS			
Macchabee/Bel Ombre Nature Reserve	3.25.13	3,594	1977
MEXICO/MEXIQUE			
Reserva de Mapimi	1.09.07	100,000	1977
Reserva de la Michilia	1.21.12	42,000	1977
Montes Azules	8.01.01	331,200	1979
Reserva de la Biosfera "El Cielo"	1.10.07	144,530	1986
Reserva de la Biosfera de Sian Ka'an	8.16.04	528,147	1986
NETHERLANDS			
Waddensea Area	2.09.05	260,000	1986
NIGERIA			
Omo Strict Natural Reserve	3.01.01	460	1977
NORWAY/NORVEGE			
Northeast Svalbard Nature Reserve	2.25.09	1,555,000	1976
OUGANDA			
Voir paragraphe Uganda			
PAKISTAN			
lal Suhanra National Park	4.15.07	31,355	1977
PANAMA			
Parque Nacional Fronterizo Darien	8.02.01	597,000	1983
PAYS-BAS			
Voir paragraphe Netherlands			
PERU/PERPU			
Reserva de Huascaran	8.37.12	399,239	1977
Reserva del Manu	8.05.01	1,881,200	1977
Reserva del Noroeste	8.19.04	226,300	1977
PHILIPPINES			
Puerto Galera Biosphere Reserve	4.26.13	23,545	1977
POLAND/POLOGNE			
Babia Gora National Park	2.11.05	1,741	1976
Bialowieza national park	2.10.05	5,316	1976
Lukajno Lake Reserve	2.10.05	710	1976
Slowinski National Park	2.11.05	18,069	1976
PORTUGAL			
Paul do Boquilobo Biosphere Reserve	2.17.06	395	1981
REPUBLIQUE CENTRAFRICAINE			
Voir paragraphe Central African Republic			

REPUBLIQUE DE COREE
Voir paragraphe Korea, Republic of

REPUBLIQUE DEMOCRATIQUE D'ALLEMAGNE
Voir paragraphe German Democratic Republic

REPUBLIQUE-UNIE DU CAMEROUN
Voir paragraphe Cameroon

REPUBLIQUE-UNIE DU TANZANIE
Voir paragraphe Tanzania, United Republic of

ROMANIA/ROUMANIE			
Pietrosul Mare Nature Reserve	2.11.05	3,068	1979
Retezat national Park	2.11.05	20,000	1979
Rosca-Letea Reserve	2.29.11	18,145	1979

ROYAUME-UNI
Voir paragraphe United Kingdom

RWANDA			
Parc national des Volcans	3.20.12	15,065	1983
SENEGAL			
FForet classee de Samba Dia	3.04.04	756	1979
Delta du Saloum	3.04.04	180,000	1980
Parc national du Niokolo-Koba	3.04.04	913,000	1981
SPAIN			
Reserva de Grazalema	2.17.06	32,210	1977
Reserva de Ordesa-Vinamala	2.16.06	51,396	1977
Parque Natural del Montseny	2.17.06	17,372	1978
Reserva de la Biosfera de Donana	2.17.06	77,260	1980
Reserva de la Biosfera de la Mancha Humeda	2.17.06	25,000	1980
Las Sierras de Cazorla y Segura BR	2.17.06	190,000	1983
Reserva de la Biosfera de las Marismas del Odeiel	2.17.06	8,728	1983
Reserva de la Biosfera del Canal y los Tiles	2.40.13	511	1983
Reserva de la Biosfera del Urdaibai	2.16.06	22,500	1984
Reserva de la Biosfera "Sierra Nevada"	2.17.06	190,000	1986
SR LANKA			
Hurulu Forest Reserve	4.13.04	512	1977
Sinharaja Forest Reserve	4.02.01	8,864	1978
SUDAN/SOUDAN			
Dinder National Park	3.13.07	650,000	1979
Radom National Park	3.05.04	1,250,970	1979

SUEDE
Voir paragraphe Sweden

SWEDEN			
Lake Torne Area	2.06.05	96,500	1986
SWITZERLAND/SUISSE			
Parc national Suisse	2.32.12	16,870	1979
TANZANIA, UNITED REPUBLIC OF			
Lake manyara National Park	3.05.04	32,500	1981
Serengeti National Park	3.05.04	2,305,100	1981
TCHECOSLOVAKIA			
Voir paragraphe Czechoslovakia			
THAILAND/THAILANDE			
Sakaerat Environmental Research Station	4.10.04	7,200	1976
Hauy Tak Teak Reserve	4.10.04	4,700	1977
Mae Sa-Kog Ma Reserve	4.10.04	14,200	1977
TUNISIA/TUNISIE			
Parc national de Diebel Bou-Hedma	2.28.11	11,625	1977
Parc national de Djebel Chambi	2.28.11	6,000	1977
Parc national de l'ichkeul	2.17.06	10,770	1977
Parc national des Iles Zembra et Zembretta	2.17.06	4,030	1977
UGANDA			
Queen Elizabeth(Rwenzori) National Park	3.05.04	220,000	1979
UKRAINIAN SOVIET SOCIALIST REPUBLIC/UKRAINE			
Chernomorskiy Zapovednik	2.29.11	87,348	1984
Askaniya-Nova Zapovednik	2.29.11	33,307	1985
UNION OF SOVIET SOCIALIST REPUBLICS/ UNION DES REPUBLIQUES SOCIALISTES SOVIETIQUES			
Chatkal Mountains Biosphere Reserve	2.36.12	71,400	1978
Kavkazskiy Zapovednik	2.34.12	263,477	1978
Oka River Valley Biosphere Reserve	2.10.05	45,845	1978
Repetek Zapovednik	2.21.08	34,600	1978
Sikhote-Alin Zapovednik	2.14.05	340,200	1978
Tsentral'nochernozem Zapovednik	2.10.05	4,795	1978
Astrakhanskiy Zapovednik	2.21.08	63,400	1984
Kronotskiy Zapovednik	2.07.05	1,099,000	1984
Laplandskiy Zapovednik	2.03.03	278,400	1984
Pechoro-Ilychskiy Zapovednik	2.03.03	721,322	1984
Sayano-Shushenskiy Zapovednik	2.35.12	389,570	1984
Sokhondinskiy Zapovednik	2.30.11	211,000	1984

Voronezhskiy Zapovednik	2.11.05	31,053	1984
Tsentral'nolesnoy Zapovednik	2.10.05	21,348	1985
Lake baikal Region Biophere Reserve	2.04.03	559,100	1986
Tzentralnosibirskii biosphere Reserve	2.03/04.03	5,000,000	1986
UNITED KINGDOM			
Beinn Eighe National Nature Reserve	2.31.12	4,800	1976
Braunton Burrows national Nature Reserve	2.08.05	596	1976
Caerlaverock national Nature Reserve	2.08.05	5,501	1976
Cairnsmore of Fleet National Nature Reserve	2.08.05	1,922	1976
Dyfi National Nature Reserve	2.08.05	1,589	1976
Isle of Rhum National Nature Reserve	2.31.12	10,560	1976
Loch Druidibeg National Nature Reserve	2.31.12	1,658	1976
Moor House-Upper Teesdale Biosphere Reserve	2.08.05	7,3999	1976
North Norfolk Coast Biosphere Reserve	2.08.05	5,497	1976
Silver Flowe-Merrick Kells Biosphere Reserve	2.08.05	3,088	1976
St Kilda National Nature Reserve	2.08.05	842	1976
Claish Moss National Nature Reserve	2.31.12	480	1977
Taynish national Nature Reserve	2.31.12	326	1977
UNITED STATES OF AMERICA			
Aleutian islands National Wildlife Refuge	1.12.09	1,100,943	1976
Big Bend National Park	1.09.07	283,247	1976
Cascade Head Expt. Forest & Scenic Research Area	1.02.02	7,051	1976
Central Plains Experimental Range (CPER)	1.18.11	6,210	1976
Channel Islands Biosphere Reserve	1.07.06	479,652	1976
Coram Experimental Forest(incl. Coram NA)	1.19.12	3,019	1976
Coweeta Hydrologic Laboratory	1.05.05	2,185	1976
Denali National Park and Biosphere Reserve	1.03.03	2,441,295	1976
Desert Experimental Range	1.11.08	22,513	1976
Everglades national park (incl. Ft. Jefferson NM)	8.12.04	585,867	1976
Fraser Experimental Forest	1.19.12	9,328	1976
Glacier National Park	1.19.12	410,202	1976
Great Smoky Mountains National Park	1.05.05	209,000	1976
H.J. Andrews Experimental Forest	1.20.12	6,100	1976

Habbard Brook Experimental Forest	1.05.05	3,076	1976
Jornada Experimental Range	1.09.07	78,297	1976
Luquillo Experimental Forest (Caribbean NF)	8.40.13	11,340	1976
Noatak National Arctic Range	1.13.09	3,035,200	1976
Olympic National Park	1.02.02	363,379	1976
Organ Pipe Cactus National Monument	1.08.07	133,278	1976
Rocky Mountain National Park	1.19.12	106,710	1976
San Dimas Experimental Forest	1.07.06	6,947	1976
San Joaquin Experimental Range	1.07.06	1,832	1976
Sequoia-Kings Canyon Nationa Park	1.20.12	343,000	1976
Stanislaus-Tuolumne Experimental Forest	1.20.12	607	1976
Three Sisters Wilderness	1.20.12	80,900	1976
Virgin Islands National Park & Biosphere Reserve	8.41.13	1,127	1976
Yellowstone National Park	1.19.12	898,349	1976
Beaver Creek Experimental Water-shed	1.08.07	111,300	1978
Konza Prairie Research Natural Area	1.18.11	3,487	1979
Niwot Ridge Biosphere Reserve	1.19.12	1,200	1979
The University of Michigan Biolo-gical Station	1.18.11	4,048	1979
The Virginia Coast Reserve	1.05.05	13,511	1979
Hawaii Islands Biosphere Reserve	5.03.13	99,545	1980
Isle Royale National Park	1.22.14	215,740	1980
Big Thicket National Preserve	1.06.05	34,217	1981
Guanica Commonwealth Forest Reserve	8.40.13	4,006	1981
California Coast Ranges Bios-phere Reserve	1.02.02	62,098	1983
Central Gulf Coastal Plain Bios-phere Reserve	1.06.05	72,964	1983
South Atlantic Coastal Plain BR	1.5/6.05	444,335	1983
Mojave and Colorado Deserts Bios-phere Reserve	1.08.07	1,297,264	1984
Carolinian-South Atlantic Bios-phere Reserve	1.06.05	1,515,015	1986
URUGUAY			
Banados del Este	8.32.11	100,000	1976
YOGOSLAVIA/YUGOSLAVIE			
Reserve Ecologique du Bassin de la Riviere Tara	2.33.12	200,000	1976
The Velebit Mountain	2.17.06	150,000	1977
ZAIRE			
Reserve Floristique de Yangambi	3.02.01	250,000	1976
Forest Reserve of Luki	3.02.01	33,000	1979
Vallee de la Lufira	3.06.04	14,700	1982

Prepared by the
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Appendix 2

United Nationals Educational, Scientific and Cultural Organization

Convention Concerning the Protection of the World Cultural and Natural Heritage (1972)

List of States having deposited an instrument of ratification, acceptance or accession as at 2 April 1987

States	Date of deposit of ratification(R) acceptance(Ac) or accession(A)
Afghanistan	20.3.79 R
Algeria	24.6.74 R
Antigua and Barbuda	1.11.83 Ac
Argentina	23.8.78 Ac
Australia	22.8.74 R
Bangladesh	3.8.83 Ac
Benin	14.6.82 R
Bolivia	4.10.76 R
Brazil	1.9.77 Ac
Bulgaria	7.3.74 Ac
Burkina Fasa	2.4.87 R
Burundi	19.5.82 R
Cameroon	7.12.82 R
Canada	23.7.76 Ac
Central African Republic	22.12.80 R
Chile	20.2.80 R
China (People's Rep. of)	12.12.85 R
Colombia	24.5.83 Ac
Costa Rica	23.8.77 R
Cote D'ivoire	9.1.81 R
Cuba	24.3.81 R
Cyprus	14.8.75 Ac
Democratic Yemen	7.10.80 Ac
Denmark	25.7.79 R
Dominican Republic	12.2.85 R
Ecuador	16.6.75 Ac
Egypt	7.2.74 R
Ethiopia	6.7.77 R
Finland	4.3.87 R
France	27.6.75 Ac
Gabon	30.12.86 R
Germany (Fed. Rep. of)	23.8.76 R
Ghana	4.7.75 R
Greece	17.7.81 R
Guatemala	16.1.79 R
Guinea	18.3.79 R

Guyana	20.6.77 Ac
Haiti	18.1.80 R
Holy See	7.10.82 A
Honduras	8.6.79 R
Hungary	15.7.85 Ac
India	14.11.77 R
Iran (Islamic Rep. of)	26.2.75 Ac
Iraq	5.3.74 Ac
Italy	23.6.78 R
Jamaica	14.6.83 Ac
Jordan	5.5.75 R
Lao People's Democratic Republic	20.3.87 R
Lebanon	3.2.83 R
Libyan Arab Jamahiriya	13.10.78 R
Luxembourg	28.9.83 R
Madagascar	19.7.83 R
Malawi	5.1.82 R
Maldives	22.5.86 Ac
Mali	5.4.77 Ac
Malta	14.11.78 Ac
Mauritania	2.3.81 R
Mexico	23.2.84 Ac
Monaco	7.11.78 R
Morocco	28.10.75 R
Mozambique	27.11.82 R
Nepal	20.6.78 Ac
New Zealand	22.11.84 R
Nicaragua	17.12.79 Ac
Niger	23.12.74 Ac
Nigeria	23.10.74 R
Norway	12.5.77 R
Oman	6.10.81 Ac
Pakistan	23.7.76 R
Panama	3.3.78 R
Peru	24.2.82 R
Philippines	19.9.86 R
Poland	29.6.76 R
Portugal	30.9.80 R
Qatar	12.9.84 Ac
Saint Christopher and Nevis	10.7.86 Ac
Saudi Arabia	7.8.78 Ac
Senegal	13.2.76 R
Seychelles	9.4.80 Ac
Spain	4.5.82 Ac
Sri Lanka	6.6.80 Ac
Sudan	6.6.74 R
Sweden	22.1.85 R
Switzerland	17.9.75 R
Syrian Arab Republic	13.8.75 Ac
Tunisia	10.3.75 Ac
Turkey	16.3.83 R
United Kingdom of Great Britain and Northern Ireland	29.5.84 R
United Republic of Tanzania	2.8.77 R

United States of America	7.12.73 R
Yemen	25.1.84 R
Yugoslavia	26.5.75 R
Zaire	23.9.74 R
Zambia	4.6.84 R
Zimbabwe	16.8.82 R

Appendix 3

L I S T E D E S B I E N S I N S C R I T S S U R L A L I S T E D U P A T R I M O I N E M O N D I A L

L I S T O F P R O P E R T I E S I N C L U D E D I N T H E W O R L D H E R I T A G E L I S T

CONVENTION CONCERNANT
LA PROTECTION DU PATRIMOINE MONDIAL, CULTUREL ET NATUREL

CONVENTION CONCERNING
THE PROTECTION OF THE WORLD CULTURAL AND NATURAL HERITAGE

UNESCO - 1972

Centre de Documentation UNESCO-ICOMOS Documentation Centre
Decembre - 1986 - December

Etat partie ayant soumis la proposition d'inscription du bien conformement a la Convention / Contracting State having submitted the nomination of the property in accordance with the Convention

N : Bien naturel/Natural Property et/ou // and/or
C : Bien culturel/Cultural Property

Etat partie / Contracting State		No.Id.	Nom du bien / Name of Property / Date d'inscription / Date of inclusion *	Criteres / Criteria
Algerie / Algeria	C	102	La Kalaa des Beni Hammad / Al Qal'a of Beni Hammad 5/9/80	(iii)
	N/C	179	Tassili n'Ajjer 17/12/82	N (ii)(iii) C (i)(iii)
	C	188	Vallee du M'Zab / M'Zab Valley 17/12/82	(ii)(iii)(v)
	C	191	Djemila 17/12/82	(iii)(iv)
	C	193	Tipasa 17/12/82	(iii)(iv)
	C	194	Timgad 17/12/82	(ii)(iii)(iv)
Rep. fed. d'Allemagne / Federal Rep. of Germany	C	3	Cathedrale d'Aix-la-Chapelle / Aachen Cathedral 8/9/78	(i)(ii) (iv)(vi)
	C	168	Cathedrale de Spire / Speyer Cathedral 30/10/81	(ii)
	C	169	La Residence de Wurtzbourg avec les jardins de la Cour et la place de la Residence / Wurzburg Residence with the Court Gardens and Residence Square 30/10/81	(i)(iv)
	C	271	Eglise de pelerinage de Wies / Pilgrimage Church of Wies 9/12/83	(i)(iii)
	C	288	Chateaux d'Augustusburg et	

			de Falkenlust a Bruhl / The Castles of Augustusburg and Falkenlust at Bruhl 2/11/84	(ii)(iv)
	C	187 rev.	Cathedrale Sainte-Marie et Eglise Saint-Michel d'Hildesheim / St. Mary's Cathedral and St. Michael's Church at Hildesheim 6/12/85	(i)(ii)(iii)
	C	367	Monuments de Treves / Monuments of Trier 28/11/86	(i)(iii) (iv)(vi)
Argentine / Argentina	N	145	Los Glaciares 30/10/81	(ii)(iii)
	N	303	Parc national de l'Iguazu / Iguazu National Park 2/11/84	(iii)(iv)
Argentine et Bresil / Argentina and Brazil	C	291-275	Missions jesuites des Guaranis : San Ignacio Mini, Santa Ana, Nuestra Senora de Loreto et Santa Maria Mayor (Argentine), Ruines de Sao Miguel das Missoes (Bresil) / Jesuit Missions of the Guaranis : San Ignacio Mini, Santa Ana, Nuestra Senora de Loreto and Santa Maria Mayor (Argentina), Ruins of Sao Miguel das Missoes (Brazil) 2/11/84 - 9/12/83	(iv)
Australie / Australia	N/C	147	Parc national du Kakadu / Kakadu National Park 30/10/81	N (iii)(iv) C (i)(iii)(iv)
	N	154	La Grande Barriere / Great Barrier Reef 30/10/81	(i)(ii) (iii)(iv)
	N/C	167	La Region des Lacs Willandra / Willandra Lakes Region 30/10/81	N (i) C (iii)
	N/C	181	Parcs nationaux des etendues sauvages de Tasmanie occiden- tale / Western Tasmania Wilderness National Parks	N (i)(ii) (iii)(iv) C (iii)(iv)

			17/12/82	(vi)
	N	186	Les Iles Lord Howe / Lord Howe Island Group 17/12/82	(iii)(iv)
	N	368	Parc des forets pluviales temperees subtropicales de la cote est de l'Australie / Australian East Coast Temperate and Sub-Tropical Rainforests Park 28/11/86	(i)(ii)(iii)
Bangladesh	C	321	La ville-mosquee historique de Bagerhat / The historic mosque city of Bagerhat 6/12/85	(iv)
	C	322	Ruines du Vihara Bouddhique de Paharpur / Ruins of the Buddhist Vihara at Paharpur 6/12/85	(i)(ii)(vi)
Benin	C	323	Palais royaux d'Abomey / Royal Palaces of Abomey 6/12/85	(iii)(iv)
Bresil / Brazil	C	124	Ville historique d'Ouro Preto / Historic town of Ouro Preto 5/9/80	(i)(iii)
	C	189	Centre historique de la ville d'Olinda / Historic Centre of the town of Olinda 17/12/82	(ii)(iv)
	C	309	Centre historique de Salvador de Bahia / Historic Centre of Salvador de Bahia 6/12/85	(iv)(vi)
	C	334	Sanctuaire du Bon Jesus a Congonhas / Sanctuary of Bom Jesus do Congonhas 6/12/85	(i)(iv)
	N	355	Parc national d'Iguacu / Iguacu National Park 28/11/86	(iii)(iv)
Bulgarie /	C	42	Eglise de Boyana / Boyana	

Bulgaria			Church 26/10/79	(ii)(iii)
	C	43	Cavalier de Madara / Madara Rider 26/10/79	(i)(iii)
	C	44	Tombe thrace de Kazanlak / Thracian tomb of Kazanlak 26/10/79	(i)(iii)(iv)
	C	45	Eglises rupestres d'Ivanovo / Rock-hewn churches of Ivanovo 26/10/79	(ii)(iii)
	C	217	Ancienne cite de Nessebar / Ancient City of Nessebar 9/12/83	(iii)(iv)
	C	216	Monastere de Rila / Rila Monastery 9/12/83	(vi)
	N	219	Reserve naturelle de Srebarna / Srebarna Nature Reserve 9/12/83	(iv)
	N	225	Parc national de Pirin / Pirin National Park 9/12/83	(i)(ii)(iii)
	C	359	Tombeau thrace de Svechtari / Thracian tomb of Sveshtari 6/12/85	(i)(iii)

Canada	C	4	Parc national historique de l'Anse aux Meadows / L'Anse aux Meadows National Historic Park 8/9/78	(vi)
	N	24	Parc national Nahanni / Nahanni National Park 8/9/78	(ii)(iii)
	N	71	Parc provincial des Dinosaures / Dinosaur Provincial Park 26/10/79	(i)(iii)
	C	157	Ile Anthony / Anthony Island 30/10/81	(iii)
	C	158	Le Secteur du precipice a bisons "Head-Smashed-In Bison Jump Complex" / Head-Smashed-	

			In Bison Jump Complex 30/10/81	(vi)
	N	256	Parc national de Wood Buffalo / Wood Buffalo National Park 9/12/83	(ii)(iii) (iv)
	N	304	*Parcs des Rocheuses canadiennes / Canadian Rocky Mountain Parks 2/11/84	(i)(ii) (iii)
	C	300	Arrondissement historique de Quebec / Quebec (Historic area) 6/12/85	(iv)(vi)
Canada et Etats-Unis d'Amerique / Canada and United States of America	N	72	Parc national de Kluane et Monument national de Wrangell- St. Elias / Kluane National Park/Wrangell-St. Elias National Monument 26/10/79	(ii)(iii)(iv)
Chypre / Cyprus	C	79	Paphos 5/9/80	(iii)(vi)
	C	351	Eglises peintes de la region de Troodos / Painted churches in the Troodos region 6/12/85	(ii)(iii)(iv)
Colombie / Colombia	C	285	Port, forteresses et ensemble monumental de Carthagene / Port, Fortresses and Group of Monuments, Carthagena 2/11/84	(iv)(vi)
Costa Rica	N	205	Reserves de la Cordillere de Talamanca-La Amistad / Talamanca Range-La Amistad Reserves 9/12/83	(i)(ii) (iii)(iv)
Cote d'Ivoire / Ivory Coast	N	195	Parc national de Tai / Tai National Park 17/12/82	(iii)(iv)
	N	227	Parc national de la Comoe / Comoe National Park 9/12/83	(ii)(iv)
Cuba	C	204	Vieille ville de la Havane et son systeme de fortifications /	

			Old Havana and its Fortifications 17/12/82	(iv)(v)
Egypte / Egypt	C	86	Memphis et sa necropole - les zones des Pyramides de Guizeh a Dahchour / Memphis and its Necropolis - the Pyramid fields from Giza to Dahshur 26/10/79	(i)(iii)(vi)
	C	87	La Thebe antique et sa necropole / Ancient Thebes with its Necropolis 26/10/79	(i)(iii)(vi)
	C	88	Les Monuments de Nubie d'Abou Simbel a Philae / Nubian monuments from Abu Simbel to Philae 26/10/79	(i)(iii)(vi)
	C	89	Le Caire islamique / Islamic Cairo 26/10/79	(i)(v)(vi)
	C	90	Abou Mena / Abu Mena 26/10/79	(iv)
Equateur / Ecuador	N	1	Iles Galapagos / Galapagos Islands 8/9/78	(i)(ii)(iii)(iv)
	C	2	Ville de Quito / City of Quito 8/9/78	(ii)(iv)
	N	260	Parc national Sangay / Sangay National Park 9/12/83	(ii)(iii)(iv)
Espagne / Spain	C	313	La Mosquee de Cordoue / Mosque of Cordoba 2/11/84	(i)(ii)(iii)(iv)
	C	314	L'Alhambra et le Generalife a Grenade / The Alhambra and the Generalife, Granada 2/11/84	(i)(iii)(iv)
	C	316	Cathedrale de Burgos / Burgos Cathedral 2/11/84	(ii)(iv)(vi)
	C	318	Monastere et site de l'Escurial (Madrid) / Monastery and site	

			of the Escurial, Madrid 2/11/84	(i)(ii)(vi)
	C	320	Parc Guell, Palais Guell, Casa Mila a Barcelone / Parque Guell, Palacio Guell and Casa Mila, in Barcelona 2/11/84	(i)(ii)(iv)
	C	310	Grotte d'Altamira / Altamira Cave 6/12/85	(i)(iii)
	C	311 rev.	La vieille ville de Segovie et son aqueduc / Old town of Segovia and its aqueduct 6/12/85	(i)(iii)(iv)
	C	312	Eglises du royaume des Asturies / Churches of the Kingdom of the Asturias 6/12/85	(i)(ii)(iv)
	C	347	La vieille ville de Saint-Jacques-de-Compostelle / Santiago de Compostela (Old town) 6/12/85	(i)(ii)(vi)
	C	348 rev.	La vieille ville d'Avila avec ses eglises extra-muros / Old town of Avila with its extra-muros churches 6/12/85	(iii)(iv)
	C	378	Architecture mudejare de Teruel / Mudejar Architecture of Teruel 28/11/86	(iv)
	C	379	Ville historique de Tolede / Historic City of Toledo 28/11/86	(i)(ii)(iii)(iv)
	N	380	Parc national de Garajonay / Garajonay National Park 28/11/86	(ii)(iii)
	C	384	Vieille ville de Caceres / Old Town of Caceres 28/11/86	(iii)(iv)
Etats-Unis d'Amerique / United States of America	N	134	Parc national Redwood / Redwood National Park 5/9/80	(ii)(iii)
	C	27	Mesa Verde	(iii)

			8/9/78	
	N	28	Yellowstone 8/9/78	(i)(ii) (iii)(iv)
	N	75	Parc national du Grand Canyon / Grand Canyon National Park 26/10/79	(i)(ii) (iii)(iv)
	N	76	Parc national des Everglades / Everglades National Park 26/10/79	(i)(ii)(iv)
	C	78	Independence Hall 26/10/79	(vi)
	N	150	Parc national de Mammoth Cave / Mammoth Cave National Park 30/10/81	(i)(iii)(iv)
	N	151	Parc national Olympique / Olympic National Park 30/10/81	(ii)(iii)
	C	198	Site historique d'Etat des Cahokia Mounds / Cahokia Mounds State Historic Site 17/12/82	(iii)(iv)
	N	259	Parc national des Great Smoky Mountains / Great Smoky Mountains National Park 9/12/83	(i)(ii) (iii)(iv)
	C	266	Forteresse et site historique de San Juan a Porto Rico / La Fortaleza and San Juan Historic Site in Puerto Rico 9/12/83	(vi)
	C	307	Statue de la Liberte / The Statue of Liberty 2/11/84	(i)(vi)
	N	308	Parc national de Yosemite / Yosemite National Park 2/11/84	(i)(ii)(iii)

Ethiopie / Ethiopia	N	9	Parc national du Simen / Simen National Park 8/9/78	(iii)(iv)
	C	18	Eglises creusees dans le roc de Lalibela / Rock-hewn Churches, Lalibela 8/9/78	(i)(ii)(iii)

	C	19	Fasil Ghebi / Fasil Ghebbi, Gondar Region 26/10/79	(ii)(iii)
	C	10	Basse vallee de l'Aouache / Lower Valley of the Awash 5/9/80	(ii)(iii)(iv)
	C	12	Tiya 5/9/80	(i)(iv)
	C	15	Axoum / Aksum 5/9/80	(i)(iv)
	C	17	Basse vallee de l'Omo / Lower Valley of the Omo 5/9/80	(iii)(iv)
France	C	80	Mont St. Michel et sa baie / Mont St. Michel and its Bay 26/10/79	(i)(iii)(vi)
	C	81	Cathedrale de Chartres / Chartres Cathedral 26/10/79	(i)(ii)(iv)
	C	83	Palais et parc de Versailles / Palace and Park of Versailles 26/10/79	(i)(ii)(vi)
	C	84	Basilique et colline de Vezelay / Vezelay, Church and Hill 26/10/79	(i)(vi)
	C	85	Grottes ornees de la Vallee de la Vezere / Decorated Grottoes of the Vezere Valley 26/10/79	(i)(iii)
	C	160	Palais et parc de Fontainebleau / Palace and Park of Fontainebleau 30/10/81	(ii)(vi)
	C	161	Chateau et domaine de Chambord / Chateau and Estate of Chambord 30/10/81	(i)
	C	162	Cathedrale d'Amiens / Amiens Cathedral 30/10/81	(i)(ii)
	C	163	Theatre antique et ses abords et "Arc de Triomphe" d'Orange / The Roman Theater and its	

			surroundings and the "Triumphal Arch" of Orange 30/10/81	(iii)(vi)
	C	164	Monuments romains et romans d'Arles / Roman and Romanesque Monuments of Arles 30/10/81	(ii)(iv)
	C	165	Abbaye cistercienne de Fontenay / Cistercian Abbey of Fontenay 30/10/81	(iv)
	C	203	Saline royale d'Arc et Senans / Royal Saltworks of Arc et Senans 17/12/82	(i)(ii)(iv)
	C	229	Places Stanislas, de la Carriere et d'Alliance a Nancy / Place Stanislas, Place de la Carriere and Place d'Alliance in Nancy 9/12/83	(i)(iv)
	C	230	Eglise de Saint-Savin-sur-Gartempe / Church of St-Savin-sur-Gartempe 9/12/83	(i)(iii)
	N	258	Caps de Girolata et de Porto et Reserve naturelle de Scandola en Corse / Cape Girolata, Cape Porto and Scandola Nature Reserve in Corsica 9/12/83	(ii)(iii)(iv)
	C	344	Le pont du Gard / Pont du Gard (Roman aqueduct) 6/12/85	(i)(iii)(iv)
Ghana	C	34	Forts et Chateaux de Volta, d'Accra et ses environs et des regions centrale et ouest / Forts and castles, Volta Greater Accra, Central and Western Regions 26/10/79	(vi)
	C	35	Batiments traditionnels Asante / Ashante Traditional Buildings 5/9/80	(v)
Grece / Greece	C	392	Temple d'Apollon Epikourios a Bassae / Temple of Apollo	

			Epicurius at Bassae 28/11/86	(i)(ii)(iii)
Guatemala	N/C	64	Parc national de Tikal / Tikal National Park 26/10/79	N (ii)(iv) C (i)(iii)(iv)
	C	65	Antigua Guatemala 26/10/79	(ii)(iii)(iv)
	C	149	Parc archeologique et ruines de Quirigua / Archaeological Park and Ruins of Quirigua 30/10/81	(i)(ii)(iv)
Guinee et Cote d'Ivoire/ Guinea and Ivory Coast	N	155	Reserve naturelle integrale du Mont Nimba / Mount Nimba Strict Nature Reserve 30/10/81	(ii)(iv)
Haiti	C	180	Parc national historique - Citadelle, Sans Souci, Ramiers / National History Park - Citadel, Sans Souci, Ramiers 17/12/82	(iv)(vi)
Honduras	C	129	Site maya de Copan / Maya Site of Copan 5/9/80	(iv)(vi)
	N	196	Reserve de la biosphere Rio Platano / Rio Platano Biosphere Reserve 17/12/82	(i)(ii) (iii)(iv)
Inde / India	C	242	Grottes d'Ajanta / Ajanta Caves 9/12/83	(i)(ii) (iii)(vi)
	C	243	Grottes d'Ellora / Ellora Caves 9/12/83	(i)(iii)(vi)
	C	251	Fort d'Agra / Agra Fort 9/12/83	(iii)
	C	252	Le Taj Mahal / Taj Mahal 9/12/83	(i)
	C	246	Le temple du soleil a Konarak / The Sun Temple, Konarak	(i)(iii)(vi)

			2/11/84	
	C	249	Ensemble de monuments de Mahabalipuram / Group of Monuments at Mahabalipuram 2/11/84	(i)(ii) (iii)(vi)
	N	337	Parc national de Kaziranga / Kaziranga National Park 6/12/85	(ii)(iv)
	N	338	Sanctuaire de faune de Manas / Manas Wildlife Sanctuary 6/12/85	(ii)(iii)(iv)
	N	340	Parc national de Keoladeo / Keoladeo National Park 6/12/85	(iv)
	C	234	Eglises et Monasteres de Goa / Churches and convents of Goa 28/11/86	(ii)(iv)(vi)
	C	240	Ensemble monumental de Khajuraho / Khajuraho group of monuments 28/11/86	(i)(iii)
	C	241	Ensemble monumental de Hampi / Group of monuments at Hampi 28/11/86	(i)(iii)(iv)
	C	255	Fatehpur Sikri 28/11/86	(ii)(iii)(iv)
Irak / Iraq	C	277 rev.	Hatra 6/12/85	(ii)(iii) (iv)(vi)
Iran	C	113	Tchogha Zanbil 26/10/79	(iii)(iv)
	C	114	Persepolis 26/10/79	(i)(iii)(vi)
	C	115	Meidan-e Shah, Ispahan / Meidan-e Shah, Esfahan 26/10/79	(i)(v)(vi)
Italie / Italy	C	94	Art rupestre du Valcamonica / Rock drawings in Valcamonica 26/10/79	(iii)(vi)
	C	91	Centre historique de Rome / Historic Centre of Rome 5/9/80	(i)(ii) (iii)(iv)

	C	93	L'eglise et le couvent dominicain de Santa Maria delle Grazie avec "La Cene" de Leonard de Vinci / The Church and Dominican Convent of Santa Maria delle Grazie with "The Last Supper" by Leonardo da Vinci 5/9/80	(i)(ii)
	C	174	Centre historique de Florence/ Historic Centre of Florence 17/12/82	(i)(ii) (iii)(iv)(vi)
Jamahiriya arabe libyenne/ Libyan Arab Jamahiriya	C	183	Site archeologique de Leptis Magna / Archaeological Site of Leptis Magna 17/12/82	(i)(ii)(iii)
	C	184	Site archeologique de Sabratha / Archaeological Site of Sabratha 17/12/82	(iii)
	C	190	Site archeologique de Cyrene / Archaeological Site of Cyrene 17/12/82	(ii)(iii) (vi)
	C	287	Sites rupestres du Tadrart Acacus / Rock-art sites of Tadrart Acacus 6/12/85	(iii)
	C	362	Ancienne ville de Ghadames / Old Town of Ghadames 28/11/86	(v)
Jordanie / Jordan	C	148	La vieille ville de Jerusalem et ses remparts / Old City of Jerusalem and its Walls 30/10/81	(ii)(iii)(vi)
	C	326	Petra 6/12/85	(i)(iii)(iv)
	C	327	Qusair Amra / Quseir Amra 6/12/85	(i)(iii)(iv)
Liban / Lebanon	C	293	Anjar 2/11/84	(iii)(iv)
	C	294	Baalbek 2/11/84	(i)(iv)
	C	295	Byblos	(iii)(iv)(vi)

			2/11/84	
	C	299	Tyr 2/11/84	(iii)(vi)
Malawi	N	289	Parc national du Lac Malawi / Lake Malawi National Park 2/11/84	(ii)(iii)(iv)
Malte / Malta	C	130	Hypogee de Hal Saflieni / Hal Saflieni Hypogeum 5/9/80	(iii)
	C	131	Ville de La Valette / City of Valetta 5/9/80	(i)(vi)
	C	132	Temples de Ggantija / Ggantija Temples 5/9/80	(iv)
Maroc / Morocco	C	170	Medina de Fes / Medina of Fez 30/10/81	(ii)(v)
	C	331	Medina de Marrakech / Medina of Marrakesh 6/12/85	(i)(ii) (iv)(v)
Nepal	N	120	Parc national de Sagarmatha / Sagarmatha National Park 26/10/79	(iii)
	C	121	Vallee de Kathmandu / Kathmandu Valley 26/10/79	(iii)(iv)(vi)
	N	284	Parc national de Royal Chitwan / Royal Chitwan National Park 2/11/84	(ii)(iii)(iv)
Norvege / Norway	C	58	"Stavkirke" d'Urnes / Urnes Stave Church 26/10/79	(i)(ii)(iii)
	C	59	Quartier de "Bryggen" dans la ville de Bergen / Bryggen 26/10/79	(iii)
	C	55	Roros 5/9/80	(iii)(iv)(v)
	C	352	Sites d'Art rupestre d'Alta /	

			Rock drawings of Alta 6/12/85	(iii)
Nouvelle-Zelande / New Zealand	N	375	Parc national de Westland et du Mont Cook / Westland and Mount Cook National Park 28/11/86	(i)(ii)(iii)
	N	376	Parc national de Fiordland / Fiordland National Park 28/11/86	(i)(ii) (iii)(iv)
Pakistan	C	138	Ruines archeologiques de Mohenjo Daro / Archaeological ruins at Moenjodaro 5/9/80	(ii)(iii)
	C	139	Taxila 5/9/80	(iii)(vi)
	C	140	Ruines bouddhistes de Takht-i-Bahi et vestiges de Sahr-i-Bahlol / Buddhist ruins of Takht-i-Bahi and neighbouring city remains at Sahr-i-Bahlol 5/9/80	(iv)
	C	143	Monuments historiques de Thatta / Historical Monuments of Thatta 30/10/81	(iii)
	C	171-172	Fort et Jardins de Shalimar a Lahore / Fort and Shalamar Gardens in Lahore 30/10/81	(i)(ii)(iii)
Panama	C	135	Les fortifications de la cote caraibe du Panama : Portobelo, San Lorenzo / The fortifications on the Caribbean side of Portobelo-San Lorenzo 5/9/80	(i)(iv)
	N	159	Parc national du Darien / Darien National Park 30/10/81	(ii)(iii)(iv)
Perou / Peru	C	273	Ville de Cuzco / City of Cuzco 9/12/83	(iii)(iv)
	N/C	274	Sanctuaire historique de Machupicchu / Historic	

			Sanctuary of Machu Picchu 9/12/83	N (ii)(iii) C (i)(iii)
	C	330	Site archeologique de Chavin / Chavin (Archaeological site) 6/12/85	(iii)
	N	333	Parc national de Huascaran / Huascaran National Park 6/12/85	(ii)(iii)
	C	366	Zone archeologique de Chan Chan / Chan Chan archaeological zone 28/11/86	(i)(iii)
Pologne / Poland	C	29	Centre historique de Cracovie / Cracow's Historic Centre 8/9/78	(iv)
	C	32	Mines de sel de Wieliczka / Wieliczka Salt Mine 8/9/78	(iv)
	C	31	Camp de concentration d'Auschwitz / Auschwitz Concentration Camp 26/10/79	(vi)
	N	33	Parc national de Bialowieza / Bialowieza National Park 26/10/79	(ii)(iv)
	C	30	Centre historique de Varsovie / Historic Centre of Warsaw 5/9/80	(ii)(vi)
Portugal	C	206	Centre d'Angra do Heroismo aux Acores / Central Zone of the Town of Angra do Heroismo in the Azores 9/12/83	(iv)(vi)
	C	263	Monastere des Hieronymites et Tour de Belem a Lisbonne / Monastery of the Hieronymites and Tower of Belem in Lisbon 9/12/83	(iii)(vi)
	C	264	Monastere de Batalha / Monastery of Batalha 9/12/83	(i)(ii)
	C	265	Couvent du Christ a Tomar / Convent of Christ in Tomar 9/12/83	(i)(vi)

	C	361	Centre historique d'Evora / Historic Centre of Evora 28/11/86	(ii)(iv)
Republique arabe syrienne/ Syrian Arab Republic	C	20	Ancienne ville de Damas / Ancient City of Damascus 26/10/79	(i)(ii) (iii)(iv)(vi)
	C	22	Ancienne ville de Bosra / Ancient City of Bosra 5/9/80	(i)(iii)(vi)
	C	23	Site de Palmyre / Site of Palmyra 5/9/80	(i)(ii)(iv)
	C	21	Ville ancienne d'Alep / Ancient City of Aleppo 28/11/86	(iii)(iv)
Republique-Unie de Tanzanie / United Republic of Tanzania	N	39	Zone de conservation de Ngorongoro / Ngorongoro Conservation Area 26/10/79	(ii)(iii)(iv)
	C	144	Ruines de Kilwa Kisiwani et de Songo Mnara / Ruins of Kilwa Kisiwani and Ruins of Songo Mnara 30/10/81	(iii)
	N	156	Parc national de Serengeti / Serengeti National Park 30/10/81	(iii)(iv)
	N	199	Reserve de gibier de Selous / Selous Game Reserve 17/12/82	(ii)(iv)
Royaume-Uni / United Kingdom	N	369	La Chaussee des Geants et sa cote / The Giant's Causeway and causeway coast 28/11/86	(i)(iii)
	C	370	Cathedrale et chateau de Durham / Durham Castle and Cathedral 28/11/86	(ii)(iv)(vi)
	C	371	Gorge d'Ironbridge / Ironbridge Gorge 28/11/86	(i)(ii) (iv)(vi)
	C	372	Parc de Studley Royal avec les ruines de l'abbaye de Fountains /	

			Studley Royal Park including the ruins of Fountains Abbey 28/11/86	(i)(iv)
	C	373	Stonehenge, Avebury et sites associes / Stonehenge, Avebury and associated sites 28/11/86	(i)(ii)(iii)
	C	374	Chateaux-forts et enceintes du Roi Edouard Ier dans l'ancienne principaute de Gwynedd / The Castles and Town Walls of King Edward in Gwynedd 28/11/86	(i)(iii)(iv)
	N	387	Ile de St. Kilda / St. Kilda 28/11/86	(iii)(iv)
Saint-Siege / Holy See	C	286	La Cite du Vatican / Vatican City 2/11/84	(i)(ii) (iv)(vi)
Senegal	C	26	Ile de Goree / Island of Goree 8/9/78	(vi)
	N	153	Parc national du Niokolo-Koba / Niokolo-Koba National Park 30/10/81	(iv)
	N	25	Parc national des oiseaux du Djoudj / Djoudj National Park 30/10/81	(iii)(iv)
Seychelles	N	185	Atoll d'Aldabra / Aldabra Atoll 17/12/82	(ii)(iii) (iv)
	N	261	Reserve naturelle de la Vallee de Mai / Vallee de Mai Nature Reserve 9/12/83	(i)(ii) (iii)(iv)
Sri Lanka	C	200	Ville sainte d'Anuradhapura / Sacred City of Anuradhapura 17/12/82	(ii)(iii)(vi)
	C	201	Cite historique de Polonnaruva / Ancient City of Polonnaruva 17/12/82	(i)(iii)(vi)
	C	202	Ville ancienne de Sigiriya / Ancient City of Sigiriya	(ii)(iii)(iv)

17/12/82

Suisse / Switzerland	C	268	Couvent de Saint-Gall / Convent of St. Gall 9/12/83	(ii)(iv)
	C	269	Couvent benedictin Saint-Jean-des-Soeurs a Mustair / Benedictine Convent of St. John at Mustair 9/12/83	(iii)
	C	267	Vieille ville de Berne / Old City of Berne 9/12/83	(iii)
Tunisie / Tunisia	C	36	Medina de Tunis / Medina of Tunis 26/10/79	(ii)(iii)(v)
	C	37	Site archeologique de Carthage / Site of Carthage 26/10/79	(ii)(iii)(vi)
	C	38	Amphitheatre d'El Jem / Amphitheatre of El Jem 26/10/79	(iv)(vi)
	N	8	Parc national d'Ichkeul / Ichkeul National Park 5/9/80	(iv)
	C	332	Cite punique de Kerkouane et sa necropole / Punic Town of Kerkwan and its Necropolis 6/12/85 - 28/11/86	(iii)
Turquie / Turkey	C	356	Zones historiques d'Istanbul / Historic areas of Istanbul 6/12/85	(i)(ii) (iii)(iv)
	N/C	357	Le parc national de Goreme et les sites rupestres de Cappadoce / Goreme National Park and the rock sites of Cappadocia 6/12/85	N (iii) C (i)(iii)(v)
	C	358	Grande Mosquee et Hopital de Divrigi / Great Mosque and Hospital of Divrigi 6/12/85	(i)(iv)
	C	377	Hattousa / Hattusha 28/11/86	(i)(ii) (iii)(iv)

Yemen	C	385	Vieille ville de Sana'a / Old City of Sana'a 28/11/86	(iv)(v)(vi)
Yemen democratique / Democratic Yemen	C	192	Ancienne ville de Shibam et son mur d'enceinte / Old walled City of Shibam 17/12/82	(iii)(iv)(v)
Yougoslavie / Yugoslavia	C	95	Vieille ville de Dubrovnik / Old City of Dubrovnik 26/10/79	(i)(iii)(iv)
	C	96	Le vieux Ras avec Sopocani / Stari Ras and Sopocani 26/10/79	(i)(iii)
	C	97	Noyau historique de Split avec le Palais de Diocletien / Historical complex of Split with the Palace of Diocletian 26/10/79	(ii)(iii)(iv)
	N	98	Parc national Plitvicka / Plitvice Lakes National Park 26/10/79	(ii)(iii)
	N/C	99	Contree naturelle et culturo-historique d'Ohrid / Ohrid region with its cultural and historical aspect and its natural environment 5/9/80	N (iii) C (i)(iii)(iv)
	C	125	Contree naturelle et culturo-historique de Kotor / Natural and Cultural-Historical Region of Kotor 26/10/79	(i)(ii)(iii)(iv)
	N	100	Parc national Durmitor / Durmitor National Park 5/9/80	(ii)(iii)(iv)
	C	389	Monastere de Studenica / Studenica Monastery 28/11/86	(i)(ii)(iv)(vi)
	N	390	Grottes de Skocjan / Skocjan Caves 28/11/86	(ii)(iii)
Zaire	N	63	Parc national des Virunga /	

			Virunga National Park 26/10/79	(ii)(iii)(iv)
	N	136	Parc national de la Garamba / Garamba National Park 5/9/80	(iii)(iv)
	N	137	Parc national du Kahuzi-Biega / Kahuzi-Biega National Park 5/9/80	(iv)
	N	280	Parc national de la Salonga / Salonga National Park 2/11/84	(ii)(iii)
Zimbabwe	N	302	Parc national de Mana Pools, Aires de Safari Sapi et Chewore / Mana Pools National Park, Sapi and Chewore Safari Areas 2/11/84	(ii)(iii)(iv)
	C	364	Monument national du Grand Zimbabwe / Great Zimbabwe National Monument 28/11/86	(i)(iii)(vi)
	C	365	Ruines de Khami / Khami Ruins National Monument 28/11/86	(iii)(iv)

* Le site de Burgess Shale, precedemment inscrit sur la Liste du Patrimoine mondial, fait partie des Parcs des Rocheuses canadiennes / The Burgess Shale Site, which was previously inscribed on the World Heritage List, is part of the Canadian Rocky Mountain Parks.

Date d'inscription / Date of inclusion *
2e session du C.P.M./2nd session of W.H.C.:Washington, 5-8/9/1978
3e session du C.P.M./3rd session of W.H.C.:Louxor, 22-26/10/1979
4e session du C.P.M./4th session of W.H.C.:Paris, 1-5/9/1980
5e session du C.P.M./5th session of W.H.C.:Sydney,26-30/10/1981
6e session du C.P.M./6th session of W.H.C.:Paris, 13-17/12/1982
7e session du C.P.M./7th session of W.H.C.:Florence, 5-9/12/1983

8e session du C.P.M./8th session of W.H.C.:Buenos Aires,
29/10-2/11/1984
9e session du C.P.M./9th session of W.H.C.:Paris, 2-6/12/1985
10e session du C.P.M./10th session of W.H.C.:Paris, 24-28/11/1986

Appendix 4

List of Natural World Heritage Properties which are also Biosphere Reserve

Liste des Sites Naturels du Patrimoine Mondial qui sont Egalement des Reserves de la Biosphere

Country/Pays	World Heritage site/ Site du Patrimoine Mordial	Biosphere Reserve/ Reserve de/la Biosphere
Algeria/Algerie	Tassili n'Ajjer	Parc national du Tassili
Bulgarie	Srebarna Nature Reserve/ Reserve naturelle de Srebarna	Reserve Srebarna
Costa Rica	Talamanca Range-La Amistad Reserves/Reserves de la Cordillere de Talamanca-La Amistad	Reserva de la Biosfera de la Amistad
Cote d'Ivoire	Tai National Park/Parc national de Tai	Parc national de Tai
Ecuador/Equateur	Galapagos Islands/Iles Galapagos	Archipielago de Colon (Galapagas
France	Cape Girolata, Cape Porto and Scandola Nature Reserve in Corsica/Caps de Girolata et de Porto et Reserve naturelle de Scandola en Corse	Foret domaniale du Fango (seulement l'extreme nord du site du site du patrimonie mondial).
Guinea and Cote d'Ivoire/Guinee et Cote-d'Ivoire	Mount Nimba Strict Nature Reserve/Reserve naturelle integrale du Mont Nimba	Reserve de la biosphere des Monts Nimba
Honduras	Rio Platano Biosphere Reserve/Reserve de la biosphere Rio Platano	Rio Platano Biosphere Reserve
Panama	Darien National Park/ Parc national du Darien	Parque Nacional Fronterizo Darien
Peru/Perou	Huascaran National Park/ Parc national de Huascaran	Reserva de Huascaran
Poland/Pologne	Bialowieza national Park/ Parc national de Bialowieza	Bialowieza National Park
Senegal	Niokolo-Koba National Park/ Parc national du Niokolo-Koba	Parc national du Niokolo-Koba
Tanzania(United Republic of)/Tanzanie(Republique-Unie de)	Ngorongoro Conservation Area/Zone de conservation de Ngorongoro Serengeti National Park/ Parc national de Serengeti	Ngorongoro Conservation Area/ Serengeti National Park(One biosphere reserve)

Tunisia/Tunisie	Ichkeul National Park/ Parc national d'Ichkeul	Parc national de l'Ichkeul
United Kingdom/ Royaume-Uni	St. Kilda/Ile de St. Kilda	St Kilda National Reserve
United States of America/Etats-Unis d'Amerique	Redwood National Park/ Parc national Redwood	California Coast Ranges Biosphere Reserve (only one part)
	Yellowstone	Yellowstone National Park
	Everglades National Park/Parc national des Everglades	Everglades National Park (incl. Ft. Jefferson NM)
	Olympic National Park/ Parc national Olympique	Olympic National Park
	Great Smoky Mountains National Park/Parc national des Great Smoky Mountains	Great Smoky Mountains National Park
Yugoslavia/ Yougoslavie	Durmitor National Park/ Park national Durmitor	Reserve Ecologique du Bassin de la Riviere Tara

Summary of discussion following presentation

NA-91-433

India - Dr Mathew George: Do you encourage and provide support for research studies in World Heritage Sites and Biosphere Reserves.

Dr N. Ishwaran: Research is encouraged in both areas; in Biosphere Reserves it is one of the essential functions by definition. In World Heritage Sites if the research is important for the conservation and management of features which give the site its World Heritage character then it might receive support.

Thailand - Mr Choob Khemnark: The Biosphere Reserve Concept has been very useful in the management of the Sakerat Reserve of Thailand.

Mr V.R. Nanayakkara: Why are most of the World Heritage Sites shown in the map you have circulated concentrated in Europe?

DR N.Ishwaran: This might be a result of the fact that there are more cultural than natural sites on the list; presently the ratio is about 2:1. Furthermore several European nations were also the first to ratify/accept the Convention and the observation you make may only be a temporary feature.

Philippines - Mr Jose O. Sargento: Are there any special efforts made to make the Convention better known in Asia and the Pacific.

Dr N. Ishwaran: Yes. The promotional Plan endorsed by the World Heritage Committee had stressed the importance in utilising national agencies for this particular task. We anticipate that UNESCO National Commissions and MAB National Committees would be willing to carry out promotional activities.

Session V

Presentation of case studies by participants

Sixteen case studies were presented by the participants during the workshop. They are listed below.

1. The Ecology of Sundarban Mangrove Forest
   A.K.M. Nazrul-Islam - Bangladesh

2. Forestry Resource Situation in Pakistan
   Mirza M.Ashraf - Pakistan

3. The Sakaerat Biosphere Reserve (SERS)
   Choob Khemnark - Thailand

4. Forestry Practices and Conservation in Malaysia
   F.W. Fong - Malaysia

5. Conservation and Management G.Gede - Pangrango National Park
   Achmad Abdullah - Indonesia

6. Conservation of Endangered Plants in Makiling Forest
   Jose O. Sargento - Philippines

7. Problems in the Natural Regeneration of the Wet Evergreen Forests in Kerala (India)
   K. Swarupanandan - India

8. Mathematical Treatment of Vegetation Data for Ecological Studies
   M. George - India

9. Biomass Production of Eucalyptus Camaldulensis Dehn. in combination with tree legumes
   M.D. Kalimuddin Bhuiyan - Bangladesh

10. A Phytosociological study of Margalla Hills National Park
    Tahira Ahmad - Pakistan

11. Reservoir sedimentation in Magat Watershed
    Roland I. Medina - Philippines

12. The conservation and management of the Dipterocarp forest in the Angat Watershed
    Gregory Parades - Philippines

13. Forest reserve management
    OB Preeyagrysorn - Thailand

Due to limitation of space only a few case studies selected at random are included in this publication.

CONSERVATION OF ENDANGERED PLANTS IN MAKILING FOREST

JOSE O. SARGENTO*

Importance of the Makiling Forest

The Makiling Forest is one of the most well-known forests in the Philippines. Its high accessibility to Manila made it popular not only to tourists and excursionists but also to scientists and researchers, especially local and foreign botanists.

The usefulness of the Makiling Forest is known in Philippine literature because of its rich legends and beauty spots and varied plant and animal life. In fact, it is known internationally as the home of more species of woody plants than in the entire United States (Fairchild, 1948; Dasmann, et al., 1973; Earthlife Foundation, 1986).

It is the site of the world famous 10th World Boy Scout Jamboree held in 1959 and many other national and international jamborees since then. It is also the site of an elaborate National Arts Center, botanical gardens, forest recreation areas and numerous other resorts.

Most foresters in the Philippines learned the basics of forestry in the Makiling Forest which for the last seven decades has served as the most valuable teaching and research laboratory of the College of Forestry, University of the Philippines at Los Banos (UPLB).

The Makiling Forest serves as a watershed for the agricultural lands and communities surrounding it, including the UPLB complex, numerous resorts, and geothermal power plants established within and near its boundaries. It contains rich clay deposits and geothermal power which has been harnessed to contribute electricity to the Luzon Power grid in the country.

General Description of the Makiling Forest

Location and Area - The Makiling Forest is 65 kilometers southeast of Manila (Fig. 1). The summit is located at longitude $121^{o}11'$ East and latitude $14^{o}08'$ North. A relatively small mountain,

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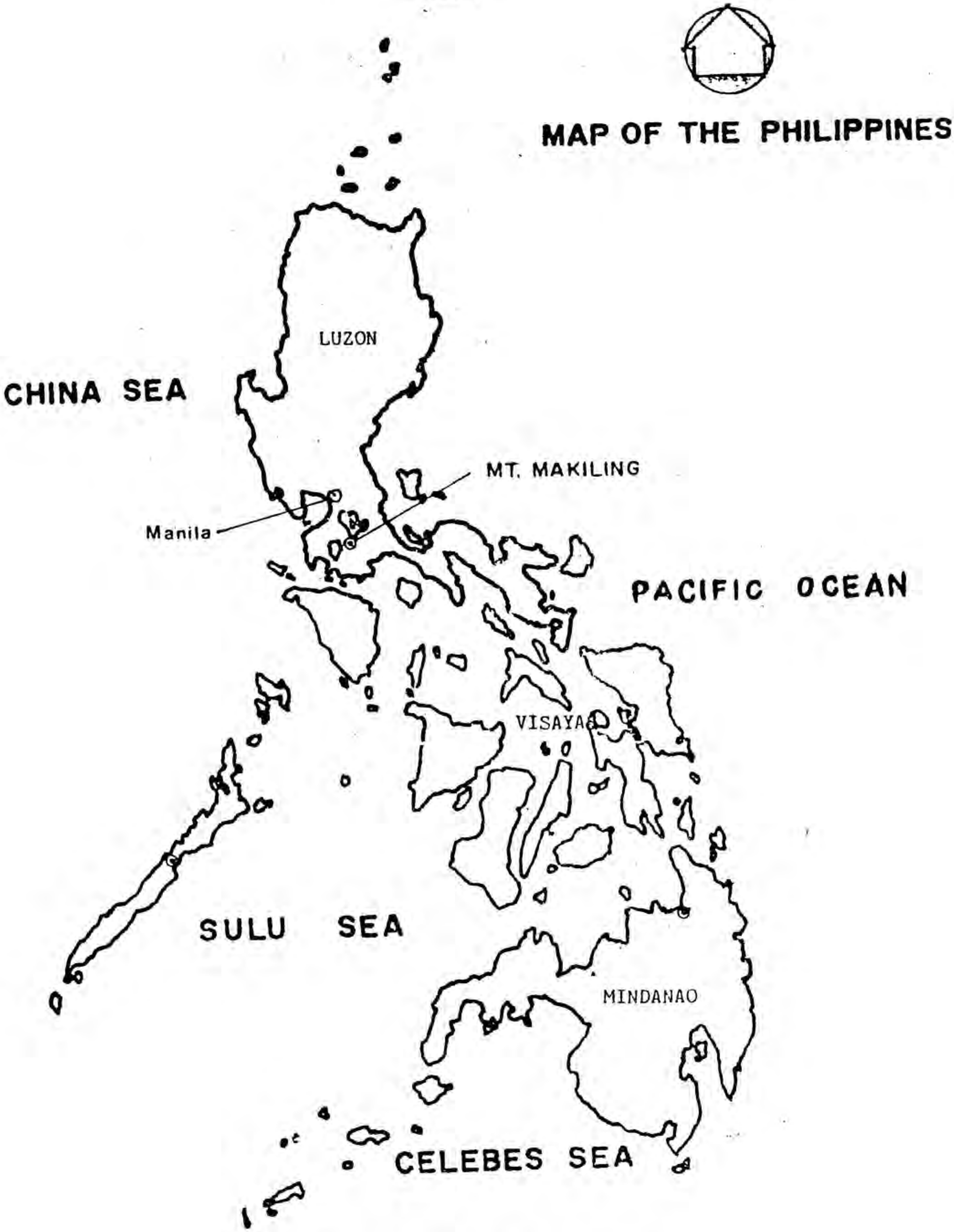

FIG. 1 MAP OF THE PHILIPPINES

the Makiling Forest has an area of 4,244.37 hectares, but it includes portions of four municipalities and two provinces in the island of Luzon, namely: Los Banos, Calamba and Bay in Laguna province and Sto. Tomas in Batangas province (Fig. 2)

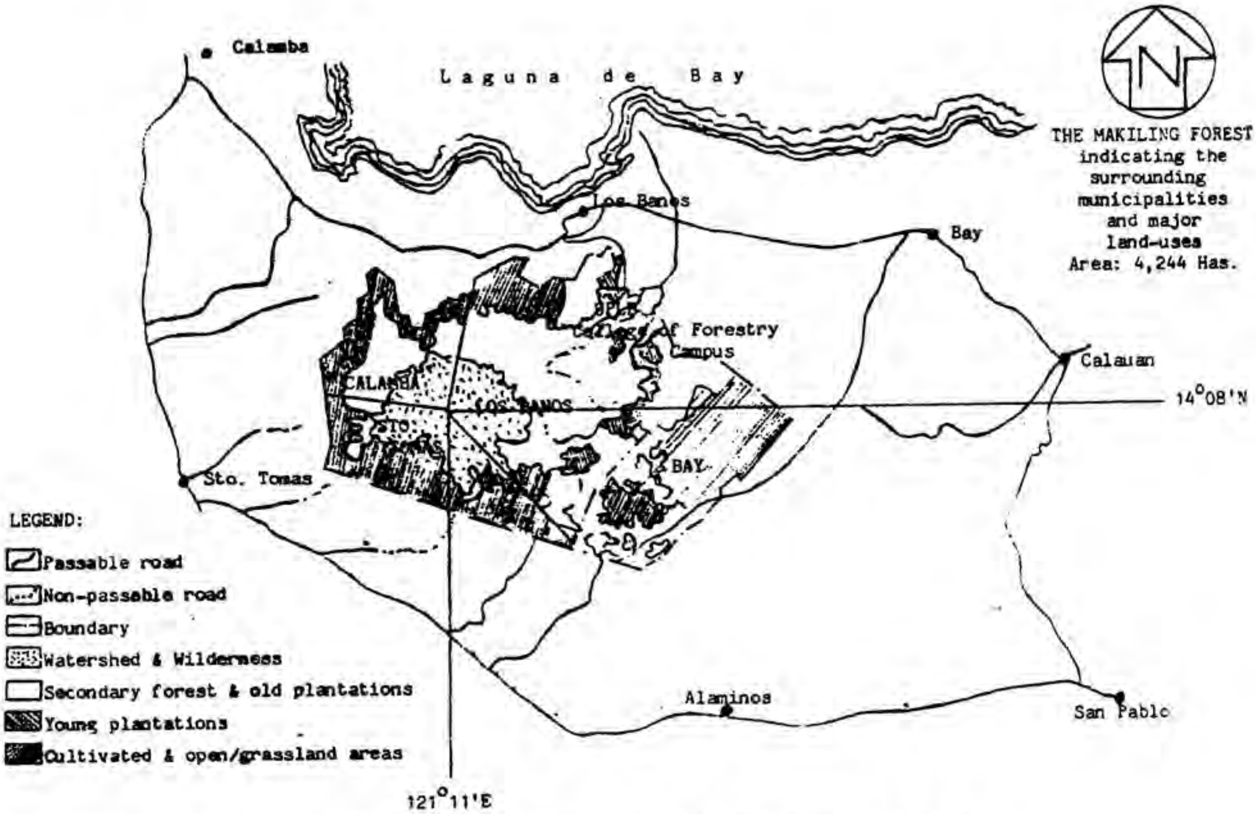

FIG. 2 MAP OF THE MAKILING FOREST

Physical Features - The Makiling Forest occupies the major and central portions of Mount Makiling, a dormant, almost extinct volcano. The volcanic past of this mountain is manifested by numerous hot springs around its base. Now, hot spring resorts have proliferated in the area. A mudspring at 350 m altitude in the Los Banos area is also a much-visited site.

There are three peaks in the Makiling Forest. These peaks rise rather steeply from about 500 m to the summits. But below this elevation the mountain gradually merges with surrounding plains at 200 m in the South and at less than 100 m in the North. The highest peak is 1109 m tall while the other two are 1090 m and 1985 m high, respectively.

Climate - The Makiling Forest falls under the Philippines' Climatic Type I which has two pronounced seasons. Generally, it is dry from January to April and wet (rainy) from May to December. The mean annual rainfall is 220 cm. Rainfall is considerably greater at higher elevations and the soil is relatively moist at all times above 800 m altitude.

The average annual temperature is 27°C, a mean annual maximum of 30.4°C and a mean annual minimum of 23.8°C. Near the summit, the night temperature falls regularly below 15°C.

Soil - The Makiling soils are classified as clay-loam type and are derived from volcanic tuff and ash. A notable exception is the white-clay, a deposit that marks the sites of recent sulfateras. The pH ranges from 4.3 to 6.5.

Fauna - Major mammals native to the Makiling Forest are wild boar (*Sus celebensis philippinensis* Nehring), a deer (*Cervus philippinensis* Smith), a monkey (*Macaca philippinensis* Jourdan). Other mammals are various species of bats and rodents.

About 200 species of birds have been recorded from the mountain. Lizards are plentiful, but snakes are rather few, although two poisonous species occur in the area. Toads and frogs represent the amphibians.

Land leeches are considered the most troublesome of the fauna. They are found on elevation about 350 meters to the summit, and for some reason are phenomenally abundant in Makiling especially during the rainy season.

Flora - Makiling Forest contains large number of families, genera and species of plants. Pancho (1983) reported 949 genera, 2038 species, 19 subspecies, 167 varieties, and several forms and cultivars of flowering plants and ferns representing 225 families. Of these, there are 28 families, 97 genera and 29 species, 4 varieties and hybrids of ferns (Price,1975).

Approximately 60% of the known Philippine fungi, several described as new, originate in the Makiling area. There are also 211 species of mosses (Tan, 1982) and 42 species of liverworts (Tixier, 1972).

The vegetation of Makiling may be divided roughly into three zones (Brown, 1919). The first zone covers elevations from 100 to 500 m. This zone is called the High Forest or Dipterocarp Forest because the dominant plants are very tall and belong principally to the family Dipterocarpaceae.

Above this zone up to about 900 m is called the Midmountain Forest or Rainforest. Here the dipterocarps are no longer dominant and their place is taken by species belonging to various other families. The trees are farther apart. The heights of the different components of this forest are not as variable as those at lower altitudes. Two stories of vegetation are distinguisable; height of trees in the upper storey ranges from 20 to 25 meters while trees and shrubs in the lower storey is about 10 meters .

The third zone, which reaches up to the summit of the mountain, is called the Mossy Forest. This vegetation is characterized by abundant epiphytic mosses and liverworts which form dense growth on the trunks of trees. The largest tree specimens are about 12 m tall; tree ferns are also common.

Recent floristic survey of the vegetation of Mt. Makiling however shows different forest types based on elevations. These include: Parang vegetation at 0-200 meters, Dipterocarp forest at 201m - 600 meter, Mid-mountain forest at 601m - 900 meters, and mossy forest at 901 - 1060 meters above sea level (Quimbo, et.al., 1980). Parang vegetation consists mainly of grasses dominated by cogon (Imperata cylindrica) and talahib (Saccharum spontaneum) and some scattered trees.

Development History of the Makiling Forest

In 1910, the Philippine Commission by Act 1989 proclaimed the Makiling Forest, consisting of approximately 3,910 hectares (now 4,244 hectares), a forest reserve for the purpose of conducting silvicultural experiments and the establishment of a forest school. From that time up to 1950, the Bureau of Forestry (now Bureau of Forest Development) did intensive protection of the natural forest and establishment of plantations of both endemic and exotic trees of economic importance in the lower and mid-elevations of Makiling. Palms, medicinal trees and ornamental plants were also introduced and were planted in scattered areas in and around the main campus of the College of Forestry.

From 1950 to 1960, the Makiling Forest was under the administration of the Parks and Wildlife Commission (now integrated to the Bureau of Forest Development). In 1960, Presidential Proclamation 629 turned over the "Park" to the University of the Philippines (UP) [now the University of the Philippines System (UPS)] for administrative purposes and the use of the College of Forestry. In 1961, the U.P. gained ownership of the area.

Republic Act 3523, approved on June 20, 1963, authorized the College of Forestry, University of the Philippines "to carry out a nationwide program of public education and information in forestry for the purpose of providing for the dissemination of research findings on forestry and to bring about general public appreciation of forest values." (UPLB College of Forestry, 1979). This Act also provided the necessary land resources, i.e., the parcel of public domain known as Mt. Makiling for the establishment of the Central Forest Experiment Station and Botanical Garden and for other related purposes.

The Central Forest Experiment Station now integrated in the Makiling Experimental and Demonstration Forest MEDF was established to carry out research in protection and multiple-use management of forest land and demonstration of applied forestry. On the other hand, the Botanical Garden now called the Makiling Botanic Gardens (MBG) of not less than 200 hectares, was established for the purpose of supporting professional instruction and research relating to forestry and plant sciences and also serving as recreational areas. Both offices, which are now under the supervision of the newly-created Institute of Forest Conservation of the College of Forestry, are actively involved in the protection and conservation of plants, animals and other natural resources of the Makiling Forest, the establishment of plantations of indigenous and exotic species and the promotion of forest values and services.

Along with the change in the administration of Mt. Makiling there was also a change in its name. From 1910 to 1933, the area was renamed Makiling National Botanic Gardens; from 1933 to 1960, Makiling National Park and from 1960 to date, Makiling Forest.

Floristic Studies in the Makiling Forest

The Makiling Forest has been the object of biological studies, spanning centuries, from the scientific exploration and collection of the 18th and 19th centuries to the present intensive investigations conducted by the institutions at the University of the Philippines at Los Banos (Price, 1975b). The Makiling flora received more attention than its fauna from scientists. Some major floristic studies undertaken in the Makiling Forest are shown in Table 1.

Conservation of Endangered Plants in the Makiling Forest

Classification and Determination of Endangered Plants

Endangered plants in the Makiling Forest may be classified or categorized following the IUCN Red Data Book Guide of 1980 which Tan, Fernando and Rojo (1986) adopted in the preparation of "An Updated List of Endangered Philippine Plants." Thus, the endangered plants in the Makiling Forest may be categorized as follows:

"Category A, Immediately endagered species. These are species with only a small population struggling to survive in an embattled habitat. Their number of individuals is so critically low that a breeding collapse may become a possibility whether or not they are threatened by man."

Category B. Vulnerable and potentially threatened species. These are species whose populations are decreasing because of continued destruction of habitats or heavy depletion of wild stocks for commercial purposes."

Table 1

Some major floristic studies in the Makiling Forests*

Period Covered	Institution/Persons Involved	Significant events/accomplishments
1789 - 1794	Malaspina Expedition Haenke (Czech), botanist Nee (Frenchman), botanist Juan de Cuellas (Spanish), naturalist	The name of Makiling first appeared in botanical literature in the account of Malaspina Expedition of Spain in the Philippines.
1840	Hugh Cuming (Englishman),naturalist	The first collector who botanized extensively the Makiling Forest and vicinity. Most of the 130,000 plant specimens he brought to England came from the Philippines.
1842	U.S. Exploring Expedition Led by Captain Charles Wilkes	Did first collections of Jade vine (*Strongylodon macrobotrys* A. Gray) and Kapa-kapa (*Medinilla magnifica* Lindl.), both now highly prized as ornamental and tagged as endangered.
1890-1916	A. Lahor	Did significant botanical work especially ferns and orchids
	During American Administration in the Philippines	
1909	a) E.B. Copeland (American), systematic botanist	Engaged in extensive field work, started an herbarium, and encouraged his better students since the founding of U.P. College of Agriculture to do work in Botany.

Table 1 continued:

Period Covered	Institution/Persons Involved	Significant events/accomplishments
1917	b) Elmer, A.D.E., botanist	Botanical collections comprised his 17,350 to 18,000 field numbers which were used as basis for his planned book entitled "Forest flora of Mt. Makiling" which was never published.
1919	c) Brown, W.H. (American)	Published the classic accounts of Makiling Forest in his book entitled "Vegetation of Philippine Mountains".
1966	Lantican C.B. (Filipino), taxonomist	Prepared a manual entitled "The Seed Plants of Mount Makiling and Vicinity."
1972	Tixies, P.	Studied and identified 34 species of mosses and 42 species of liverworts.
1975	Price, M. (American) taxonomist, botanist	Did thorough studies on pteridophytes and discovered 3 fern species which are found exclusively in Makiling Forest, namely: Schellolepis terrestis, Diplazium egenolfioides, and Chingia urens.
1980	Quimbo, L.L. (taxonomist), Fernando E.S. (Taxonomist), Alcachupas, P. (forester) and Pabuayon, C. (forester), All Filipinos	Studied the floristic composition of Mt. Makiling based on exposures and elevations.

Table 1 continued:

Period Covered	Institution/Persons Involved	Significant events/accomplishments
1982	Tan, B.C. (Filipino), botanist	Studied and identified 211 species of mosses including Chaetomitrium leptopoma which is new to the Philippines.
1983	Pancho, J. (Filipino), botanist	His 15 years of botanical field studies now appears in his book entitled "vascular Flora of Mount Makiling and vicinity (Luzon: Philippines). Part I."

* Mainly based on scientific and historical accounts made by Panchi (1983)

Table 2

Partial list of endangered plants being conserved in the Makiling forest.*

1. Category A. Immediately Endangered Species
   1. Rafflesia manillana Teschem. ("Malaboo")** - Rafflesiaceae
2. Category B. Vulnerable or Potentally Threatened Species
   1. Agathis dammara (Lambert) Richard ("Almaciga") *** Araucariaceae
   2. Albizzia acle (blanco) Merr. ("Akle")** - Leguminosae
   3. Alocasia zebrina Koch & Veitch. ("Gabing tigre")** -Araceae
   4. Areca ipot Becc. ("Bunga ipot") *** - Palmae
   5. Calamus merrillii Beec. ("Palasan"_** - Palmae
   6. Cinnamomum mindanense Elmer ("Mindanao cinnamon")*** Lauraceae
   7. Diospyros blancoi DC. ("Kamagong", "Mabolo") ** - Ebenaceae
   8. Dracontomelon dao (Blanco) Merr. & Rolfe ("Dao")** - Anacardiaceae
   9. D. edule (Blanco) Skeels ("Lamio") - Anacardiaceae
   10, Glenniea philippinensis (Radlk.) Leenh. ("Mamoko") ** - Sapindaceae
   11. Medinilla magnifica Lindl. ("Kapa-kapa")** - Melastomataceae
   12. Phoenix hanceana Naud. var. philippinensis Becc. ("Voiavoi")*** - Palmae
   13. Strongylodon macrobotrys A. Gray ("Jade vine")** - Leguminosae
   14. Toona calantas Merr. ("Kalantas")*** - Meliaceae
   15. Vanda sanderiana Reichb. f.)"Waling- waling")*** -Orchidaceae
   16, Wrightia pubescens R. Br. Subsp. laniti (Blanco) Ngan ("Lanete")** - Apocynaceae
3. Category C. Rare Species
   1. Chingia urens Holtt.** - Thelypteridaceae

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* Mainly after Tan, Fernando and Rojo (1986), Lantican (1966), Enalbes (1977), Price (1975a), Steiner (1960) and Carandang (Pers. comm.).

** Indigenous to the Makiling Forest.

*** Native to the Philippines but not indigenous to the Makiling Forest.

"Category C. Rare species. These are known to have a limited geographical range such as a single locality or a highly specialized habitat that may or may not be threatened at the moment."

Based on the works of Tan, Fernando and Rojo (1986), Lantican (1966), Price (1975a), Enalbes (1977), Steiner (1960), personal communication with Forester W. Carandang of MBG and the field observations of the author, a partial list of endangered plants being conserved in the Makiling Forest has been determined (Table 2).

Conservation Measures Adopted

a. Legal and Administrative Measures

Serious conservation strategies for Makiling Forest was formally started in 1910 when Act 1989 proclaimed Makiling as a National Forest Reserve under the Bureau of Forestry. The conduct of commercial logging activities and agricultural pursuits in the area was prohibited. Forest protection was intensified.

World War II, however left the area with numerous squatters who cut timber and converted portions of Makiling to agricultural land by slash-and-burn or shifting cultivation (kaingin). Thus, serious squatting problem was inherited by the U.P. College of Forestry when its ownership and administration was transferred from the Bureau of Forestry by virtue of RA 3523. About 41% of the Makiling area was under shifting cultivation and the natural forests and plantations were subjected to occasional poaching, illicit cutting of timber and illegal gathering of forest products.

To solve such a problem, legal action and preventive measures were accelerated. Foot-patrols and strict enforcement of rules and regulations for the protection and conservation of the Makiling Forest were intensified. Preventive measures conducted include the increase of forest guards and the initiation of accentuated information campaign.

Supplementary moves were made to delineate the true boundaries on the ground and at the same time gather benchmark information about the squatter and his family. Several families of squatters/ kaingineros were resettled at Caldong, Sampalok, Quezon in 1976 by virtue of Proclamation No. 1540 issued by President Ferdinand Marcos to ease Makiling Forest of its problems. Collection/ gathering of forest products and conduct of activities in the Makiling Forest particularly in the natural forest areas are strictly regulated. Collection of rare and endangered plants was strictly prohibited. Persons caught violating the regulations are dealt with accordingly. There is a case for Calamus merrilli a highly prized rattan species but now an endangered species. Many people are aware of the consequences if caught illegally gathering this species. However, only 3 apprehensions were made by MEDF between 1985 and January 1987 and cases were filed in court against apprehended illegal gatherers. Two persons were convicted and have served their jail sentence while others await decision of the trial court. Higher penalty is charged against illegal gatherers of premium and rare timber species. Such legal measures have somehow significantly reduced the incidence and amount of destruction of Makiling Forest.

b. Education and Information dissemination

Education - Forest conservation is taught from the elementary up to the collegiate levels of education. In July 1971, the UPLB College of Forestry and the Bureau of Public Schools formally agreed to implement the Makiling Conservation Education Program (MACONEP).

This is a project involving extension and information activities geared towards elementary school children in community schools surrounding the Makiling Forest. This is a task-oriented program designed to generate understanding, cooperation and participation of people living within and around the Makiling Forest towards its conservation. It is premised on the notion that only by mutual understanding and cooperation between the UPLB College of Forestry and the people can problems about Makiling be resolved with diginity.

The Program involves the gathering of basic information about the people living within the area to serve as guideline in formulating action programs and engaging in massive public information campaign to create awareness among the people the benefits derived from the conservation of Makiling Forest to their well-being. It includes initiation of training programs designed to develop manipulative and social skills and functional leadership favourable towards forest conservation. Examples of which include (1) forestry vocational skills training for out-of-school youth, and (2) reforestation training for community leaders, 4-H club members and other groups.

During summer vacation an Outdoor Recreation Education (ORE) for elementary and high school children are being regularly conducted by the Forestry Extension Office (now Public Education and Information Office of the Institute of Forest Conservation). Part of this program is the teaching of conservation of forest resources which include valuable and endangered plants.

Collegiate students particularly those in biological sciences have their field laboratory in the Makiling Forest in order to have a better understanding and appreciation of forest values and its conservation. Aiterary/essay writing contest was conducted during the 1974 UPLB Arbor Week Celebration on the theme "Mt. Makiling: An Ecological Prerogative." Several students, faculty and researchers actively participated in this contest. In fact, the best entry entitled "Mt. Makiling: The Green is Gold" by Mike Price (1975b) has been very informative and has also challenged many people towards the conservation of Makiling Forest.

After about a decade since those educational activities were implemented, some significant results can be observed. Foremost is the observation that unlike before, violations of forest laws in the Makiling Forest particularly on clearing of new area (Kaingin-'making) and illegal cutting of trees are now reported by local officials and concerned citizens to the UPLB college of Forestry. There was also a noted increase in the number of request of planting materials for reforestation purposes either for their school campuses, home back-yards, or in open or unproductive portions of Makiling Forest.

Information Dissemination - Side by side with educational approach is information dissemination to concerned public. Print and broadcast media are the major means of disseminating conservation vlaues and strategies for the protection of Makiling Forest. The UPLB College of Forestry publishes Conservation Circular, Forestry Digest and Makiling News while the Department of Forest Biological Sciences publishes Makilingia. These publications bring about public appreciation of the forests as well as challenge them towards its protection and conservation.

For instance, the maiden issue of Makilingia (1982) has stressed the destructive effects to plants, animals and water values of Makiling if the geothermal drilling operations inside a 7,000 square meter natural forest area near the base of its mossy forest is continued. Valuable plants in the area and vicinity including endangered species such as *Rafflesia manillana*, *Medinilla magnifica* and *Calamus merrillii* will undoubtedly be adversely affected by the geothermal operations. Such information has been very enlightening to many and become useful in the holding of dialogue of concerned parties which eventually led to the cessation of the geothermal activity in the heart of Makiling. Now, the area is abandoned and natural succession has almost covered the cleared area with secondary vegetation.

Information on conservation has also been dessiminated through U.P. Los Banos radio DZLB. This radio program enabled the listening public to learn and appreciate the ABC of forest conservation particularly with respect to Makiling Forest.

c. Phenology and Propagation Work

Phenology - Flowering and fruiting periods of important plants were carefully observed and monitored in order to determine the appropriate time of fruit/seed collection. Enalbes (1977) has gathered phenological data of the following endangered plants in the Makiling Forest:

Species	Flowering	Fruiting
1. Albizzia acle	-	May
2. Dracontomelon dao	-	January
3. D. edule	November	June
4. Diospyros blancoi	March	-
5. Agathis dammara	-	May
6. Strongylodon macrobotrys	March	June
	November	

Propagation - Valuable forest species are propagated in two nurseries of the UPLB College of Forestry. The MEDF Nursery raises mainly timber, reforestation and other commercially important forest species. Among the endangered plants it has raised successfully include about 300 Diospyros blancoi, 85 Agathis damara and 35 Medinilla magnifica in containers. These are ready for outplanting this coming rainy season. MBG nursery, on the other hand, raises almost all forest species, particularly those endangered plants, for planting in its arboreta. Some of the endangered plants it has raised include several potted seedlings of Phoenix hanceana var philippinensis and Diospyros blancoi in 1977 (Enalbes, 1977) and 20 Albizzia acle, 30 Toona calantas and 120 Areca ipot from 1984 to 1986. These plants are now growing well at MBG arboretum (Carandang, pers, comm.)

d. Reforestation and Plantation Development

Reforestation as a conservation measure started in Makiling as early as 1910 during the establishment of Forest School (now UPLB College of Forestry) in an area covered with cogon (Imperata cylindrica) grass and small trees in Makiling. Students cleared the area and planted different tree species as requirements in the silviculture class. After six years about 600 native and exotic forest tree species were planted and found growing well in Makiling.

Before World War II, about 700 hectares of forest plantations were already established. However, during the war most of these plantations and valuable natural timber and other plants species of Makiling were destroyed by illegal logging and shifting cultivation. Remnants of these plantings are few scattered large trees found in the UPLB College of Forestry campus. Of these are some endangered species which include Dracontomelon dao, D. edule, Albizzia acle, Toona calantas, Agathis dammara, Diospyros blancoi, and Wrightia pubescens subsp. laniti.

Massive reforestation program was again conducted in the Makiling Forest when its ownership and administration was transferred to the U.P. College of Forestry in 1960, through its Central Forest Experiment Station (now integrated in the Makiling Experimental and Demonstration Forest). Grassland and other open areas in Makiling are planted to tree species during Arbor Day Celebrations through joint efforts of the university constituents, civic organizations, school children and teachers, municipal employees and officials, barangay officials and officers of other government and private institutions in Makiling Forest and vicinity. Establishment of experimental and demonstration tree plantations of valuable species in the Makiling Forest was also accelerated. Kaingin areas were also planted to reforestation species in collaboration with upland farmers/kaingineros. Now, only small portion of Makiling is grassland, open, or unproductive land.

e. Botanical Gardens Development

The development of no less than 200 hectares of the Makiling Forest into botanical gardens is a major step towards its conservation. The gardens is being developed to support professional instruction and research related to forestry and plant sciences generally and for serving the needs of tourism as well as the educational and recreational needs of the general public.

One of the major accomplishments of the gardens is the development of arboreta of important native trees with emphasis on those facing the danger of vanishment or disappearance due to population pressure and exploitation (de Guzman, 1974; Enalbes, 1977).

Several species of endangered trees native to Makiling and those indigenous in the Philippines are now successfully grown in the gardens. These include Diospyros blancoi, Albizzia acle, Toona calantas and Glenniea philippinensis among others. Important palms, fruit trees, medicinal, ornamental (especially orchids), and other economically important plants are also collected and grown in the gardens.

Examples of the endangered ornamental plant species found in the gardens are Strongylodon macrobotrys, Medinilla magnifica, Phoenix lanceana var philippinensis, Areca ipot and Alocasia zebrina. The plants in the gardens (mostly labelled) have been very useful to students, researchers and nature and plant lovers. The beauty of the gardens has also created a sense of awareness and appreciation of Makiling and the importance of its conservation. In fact, only a insignificant number of violations (mostly minor) have been observed in the gardens and even in its adjacent areas in the Makiling Forest.

Present Conservation Problems

a. Continued presence of squatters - The continuing presence and increasing number of illegal occupants/squatters in some portions of the forest reserve poses dangers to the security of the remaining forest, particularly the endangered plant species. Some of these squatters come from nearby provinces and towns that have worsening economic and peace and order situation. Other squatters are temporary returnees to Makiling from the resettlement area. Others are additional family members by birth and marriage. The need to have a land area for agricultural cultivation for survival has somehow forced them to clear and cultivate inch-by-inch plantation or natural forest inspite of heavy penalties if apprehended.

b. Indifference of some people towards conservation

Many people particularly those on a hand-to-mouth existence are still indifferent towards conservation inspite of the conservation programs conducted by the UPLB College of Forestry. For example, some people even risk being apprehended for gathering highly prized but difficult to gather endangered rattan species, *Calamus merrillii.* Surprisingly, some rich people, politicians and even government employees are involved in perpetrating the despoilation of valuable endangered plants.

c. Inadequate resources for protection and conservation work

The effectiveness of extension and protection strategies to conserve the Makiling Forest is greatly hampered by the inadequacy of resources such as communication and transport systems, personnel safety gears and firearms among others.

Conservation Prospects

Bright rays of hope are seen inspite of the problems earlier presented. Such optimism is based on the programs and current developments for the Makiling Forest. These include:

a. A closer and critical look on the existing policies, rules and regulations governing the protection and conservation of the Makiling Forest particularly on the squatting problem by concerned parties of the UPLB College of Forestry is underway. Social Forestry is seen as a potential solution to the squatting problem.

b. A continuing dialogue/consultation between the university officials and users/ leasees of portions of Makiling Forest for its more effective utility and protection is getting positive results.

c. A growing conservation consciousness and high sense of concern and cooperation from among some sectors of the community in planning and implementing conservation activities for the Makiling Forest.

Conclusion

Makiling Forest is a small forest which was endowed with rich natural resources. The existence and continued usefulness of these resources, however, was threatened by man's abusive interventions during the past decades. Plants which could only be found in Makiling has been endangered of being extinct. Many people are still unmindful of the consequences of disappearance of forest resources because of the pressing socio-economic conditions prevailing in Makiling and the vicinity. A holistic approach to forest conservation particularly those concerning endangered plants is imperative. Cooperation and assitance of all sectors of the community however are necessary in order to effect a genuine conservation program and thereby ensure continued usefulness of Makiling. It must always be remembered that man is the main recipient of benefits from the Makiling Forest.

ACKNOWLEDGEMENT

The author is grateful to several individuals in the preparation of this case study. Foremost of whom are Dr Felix M. Eslava, Jr., Director of the Institute of Forest Conservation, UPLB College of Forestry for providing moral support and encouragement, and Mr. Edwino S. Fernando, Instructor at the Department of Forest Biological Sciences, UPLB College of Forestry for lending reference materials and providing technical assistance.

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Summary of discussions following presentation

Dr N. Ishwaran: What kind of penalties are imposed upon squattes?

Mr Jose O. Sargento: Both fine and imprisonment on the basis of a municipal court order.

Dr T. Jayasingham: What percentage of plants in the area are endemics?

Mr Jose O. Sargento: I cannot give an exact percentage; but there are lots of references which you could get if you want to get an idea about this estimate;

Prof. B.A. Abeywickrema: The genus Strongulodon was found in Sri Lanka as part of its westernmost range in the realm. It may, however, be becoming extinct here.

Mr M. Kalimuddin Bhuiyan: How can people be stopped from encroaching into the forest and over-utilising its resources.

Mr Jose O. Sargento: This kind of actions relate to people trying to obtain their basic requirements and necessities. Whatever you may do it is unlikely that legislation could be avoided.

MATHEMATICAL TREATMENT OF VEGETATION DATA FOR ECOLOGICAL STUDIES

M. GEORGE

Introduction

Forest vegetation is studied by various methods. A quadrat is found to be the most convenient unit of sampling by many ecologists, but the size and shape of the quadrat depends on the purpose as well as the limitations of the investigator. However, the quadrat size as well as the intensity of sampling is standardised (Sharma et al, 1983) to get a representative account of the study area. The basic data thus obtained is processed through several ways. Irrespective of the criteria used for interpretation like physiography etc. every system has its own advantages as well as disadvantages and therefore selection of criteria again depends on the purpose of investigation. However, communities recognised by one or more dominant species are used as basic unit of vegetation study.

Vegetation Communities and Tabular Comparison

Mueller and Ellenberg (1974) have illustrated the tabular comparison of floristics to isolate groups of species that show similar distribution. In this method, the quadrat data is compared through a series of tables namely row table, frequency table, intermediate frequency table, partial table, ordinated partial table and the differentiated table. In the differentiated table three groups of vegetation with distinct character species are separated. Further each group is named with reference to dominant species as per importance value index (IVI). Quadrat data collected from a dry deciduous forest were processed through this procedure and the three groups in the differentiated table is shown in table I. Here the quadrats of group I are characterised by the presence of Commiphora caudata and its associates, group III by Anogeissus latifolia and its associates and group II a combination of both C.caudata and A. latifolia. Further treatment is with reference to IVI.

Generally the vegetation communities are differentiated by a close observation of the forest type. But such differentiation is always biased as it involves personal judgement. This is overcome by tabulation method as the number of quadrats in each group are arrived at through the presence or absence of a leader and thereby avoids any suppositions. It also facilitates to identify the character species of the community.

TABLE 1. DIFFERENTIATED TABLE IN WHICH THE QUADRATS WERE REARRANGED TO ARRIVE AT THE THREE DIFFERENTIATED GROUPS.

Quadrat Nos	4	8	11	25	23	7	1	14	13	24	18	27	12	26	6	22	20	9	2	19	17	21	16	5	3	15	10
Commiphora caudata	3	6	5	4	9	3	4	5	7	8	3	5	·	·	·	11	2	2	2								
Euphorbia antiquorum	7	4	9	9	6	5	5	6	7	6	7	7	5	8	·	2											
Diospyros montana	1	1	3	4	·	2	3	5	3	2	4	3	1	3	2												
Wrightia tinctorea	2	5	4	1	3	1	2	5	5	·	2	·	1	2													
Commiphora berryi	2	3	·	3	2	2	3	2	6	1	·	2	·	2		·	·	·	·	1							
Capparis grandis	1	2	1	2	1	·	·	2	2	2	3	·	2	·	-	2											
Canthium dicoccum	2	1	3	2	2	·	4	·	·	5	·	-	3	4	·	5											
Tamarindus indica	·	1	2	·	1	·	-	1	2	·	1	1	1	·	·	·	·	·	·	2							
Cordia dichotoma	3	2	3	-	3	7	7	·	·	·	·	·	·	·	3	·	-	3									
Premna tomentosa	2	1	·	2	·	1	3	·	·	·	·	·	·	·	1	·	3										
Atalantia monophylla	5	·	3	-	·	·	-	1	·	1	·	·	·	3	2												
Gyrocarpus jacquini	3	1	·	2	·	1	·	·	-	·	1	·	1														
Anogeissus latifolia																9	11	12	12	5	12	10	11	12	12	5	5
Emblica officinalis																4	5	4	4	2	3	13	2	5	8	2	2
Pterocarpus marsupium																1	4	3	3	2	5	·	4	3	6	2	2
Careya arborea																7	6	·	·	3	2	6	9	·	·	3	5
Bridelia crenulata																·	·	3	3	2	·	4	·	3	3	2	2
							GROUP I									GROUP II					GROUP III						

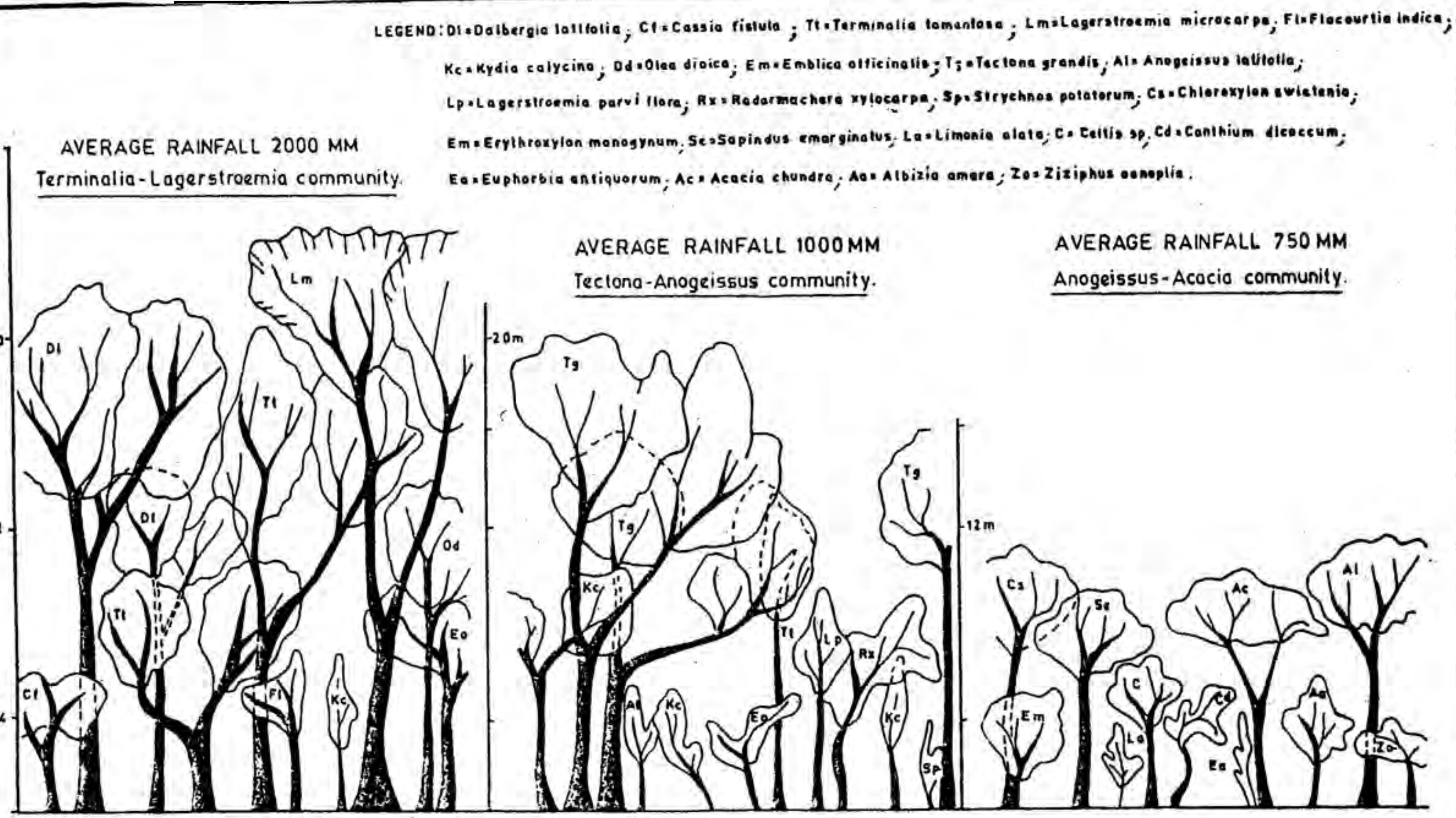


FIGURE I. PROFILE DIAGRAM OF DIFFERENT FOREST TYPES.

Vegetation Communities and Profile Diagrams

Vegetation communities are also studied by drawing profile diagrams wherein the structure of the community is dealt in detail. Figure.1 shows an abstract of profile diagram of three vegetation communities where the profile was studied in a rectangular plot of size 61m x 5m. The figure gives a clear understanding of the communities with reference to their composition, spatial distribution and canopy nature - like crown depth, shape, opening etc. (George and Varghese, 1985). This also facilitates to explain the community characters with reference to parameters like rainfall and its distribution, temperature, topography, altitude etc.

Vegetation Communities and Plexus Diagram

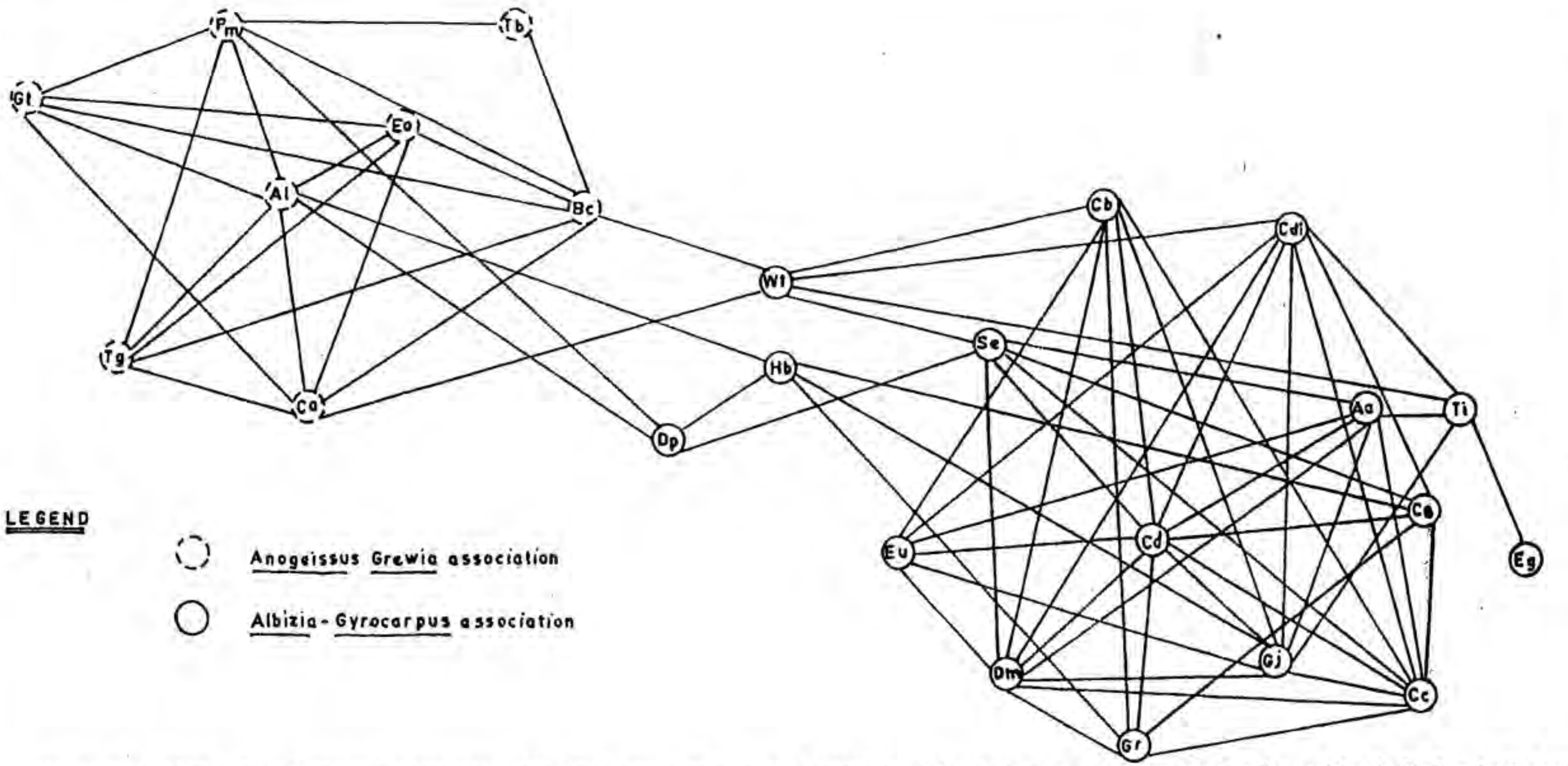
Those species which have the same requirements for their growth establish themselves forming associations. Plexus diagrams can be used to identify groups of associated species as it reveals those species which have strong ecological ties among themselves as well as to a common environment. Fig.11 shows the constellation and species association in a deciduous forest ecosystem. The quadrat data were processed in 2 x 2 contingency tables and chi-square test was employed. The plexus diagram was drawn using coefficient of association and Cole's index. (Kershaw, 1973). The figure shows that the whole vegetation forms two groups where Anogeissus latifolia and Cordia dichotoma are the two characteristic species. In each group the members are associated among themselves and the two groups are linked together through intermediate species. The dominant species was arrived at through IVI and associations were named after the dominant species. Plexus diagrams explain the affinity between and among species with reference to various ecological factors. (George and Varghese, 1985). The diagram is also used to interpret vegetation mapping with reference to topography, biotic factors climatic as well as edaphic conditions.

Species Variation and Similarity Index

Similarity relations among vegetation communities can be expressed mathematically and these are known as community coefficients or indices of similarity. This is generally estimated with reference to the presence or absence of species between stands in the form:

$$IS = \frac{C \times 100}{A + B + C}$$

Where IS is the index of similarity, A is the number of species unique to stand 'A', B is the number of species unique to stand 'B', and C is the number of common species in stand A and B.



Gt = <u>Grewia</u> <u>tilitolia</u>, Pm = <u>Pterocarpus</u> <u>marsupium</u>, Al = <u>Anogeissus</u> <u>latifolia</u>, Tg = <u>Tectona</u> <u>grandis</u>, Ca = <u>Careya</u> <u>arborea</u>, Eo = <u>Emblica</u> <u>officinalis</u>, Tb = <u>Terminalia</u> <u>bellirica</u>, Bc = <u>Bridelia</u> <u>crenulata</u>, Wl = <u>Wrightia</u> <u>tinctorea</u>, Hb = <u>Hardwickia</u> <u>binata</u>, Dp = <u>Dalbergia</u> <u>paniculata</u>, Se = <u>Sapindus</u> <u>emarginatus</u>, Eu = <u>Euphorbia</u> <u>sp</u>, Dm = <u>Disopyros</u> <u>montana</u>, Gr = <u>Givotia</u> <u>rottleriformis</u>, Cd = <u>Cordia</u> <u>dichotoma</u>, Gj = <u>Gyrocarpus</u> <u>jacquini</u>, Cdi = <u>Canthium</u> <u>dicoccum</u>, Aa = <u>Albizia</u> <u>amara</u>, Ti = <u>Tamarindus</u> <u>indica</u>, Cs = <u>Chloroxylon</u> <u>swietenia</u>, Cc = <u>Commiphora</u> <u>caudata</u>, Eg = <u>Elaeodendron</u> <u>glaucum</u>, Cb = <u>Commiphora</u> <u>berryi</u>

FIGURE II. PLEXUS DIAGRAM OF SPECIES IN A DECIDUOUS FOREST VEGETATION BASED ON POSITIVE ASSOCIATION.

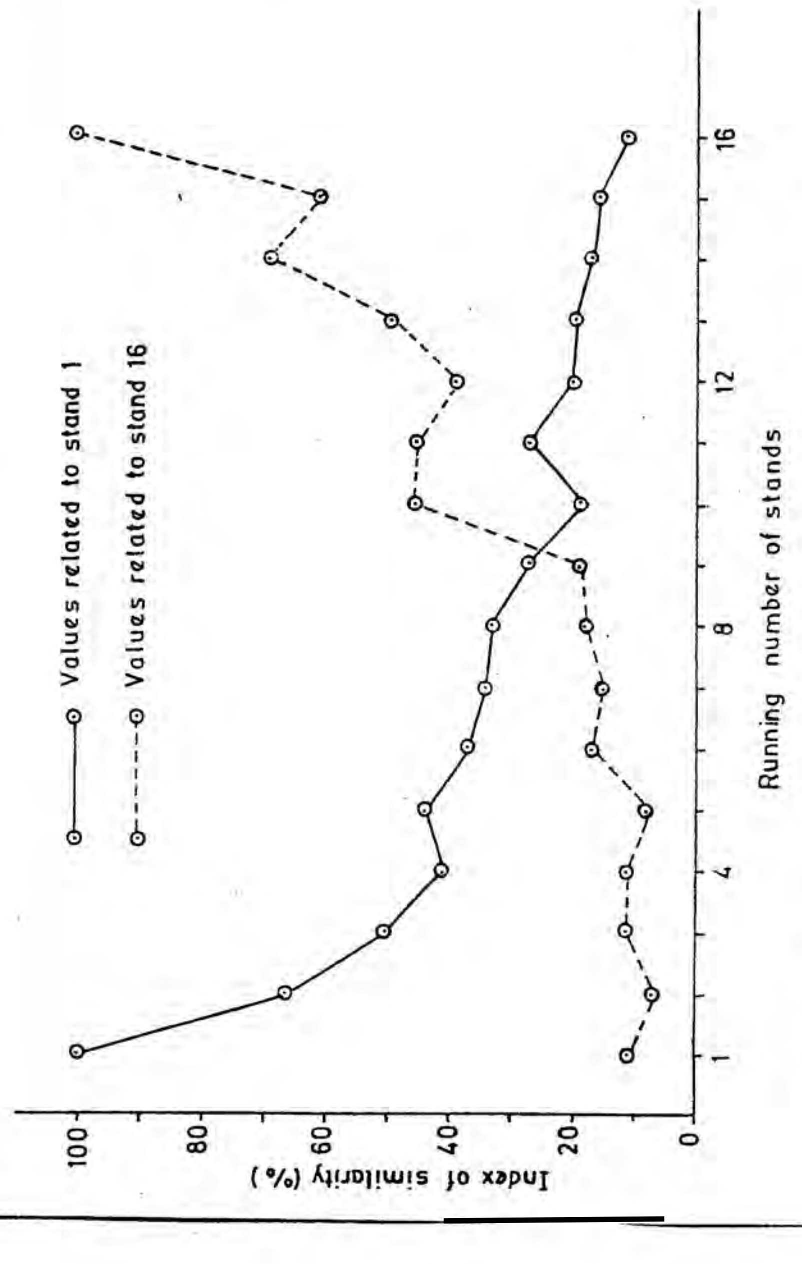


FIGURE III. SIMILARITY INDEX IN FOREST VEGETATION COMMUNITIES.

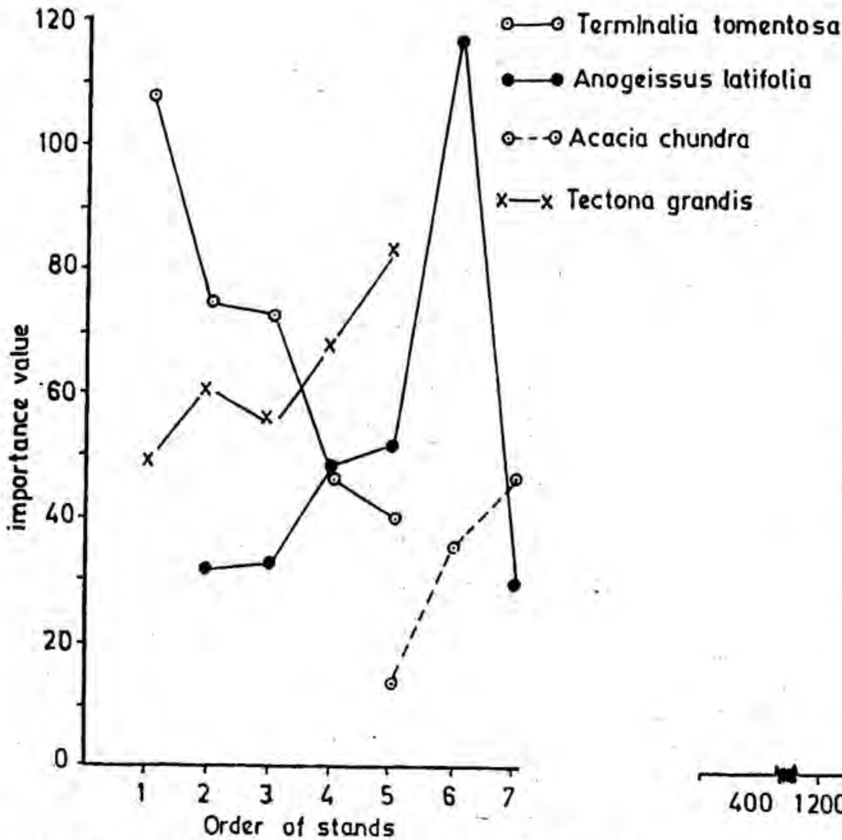
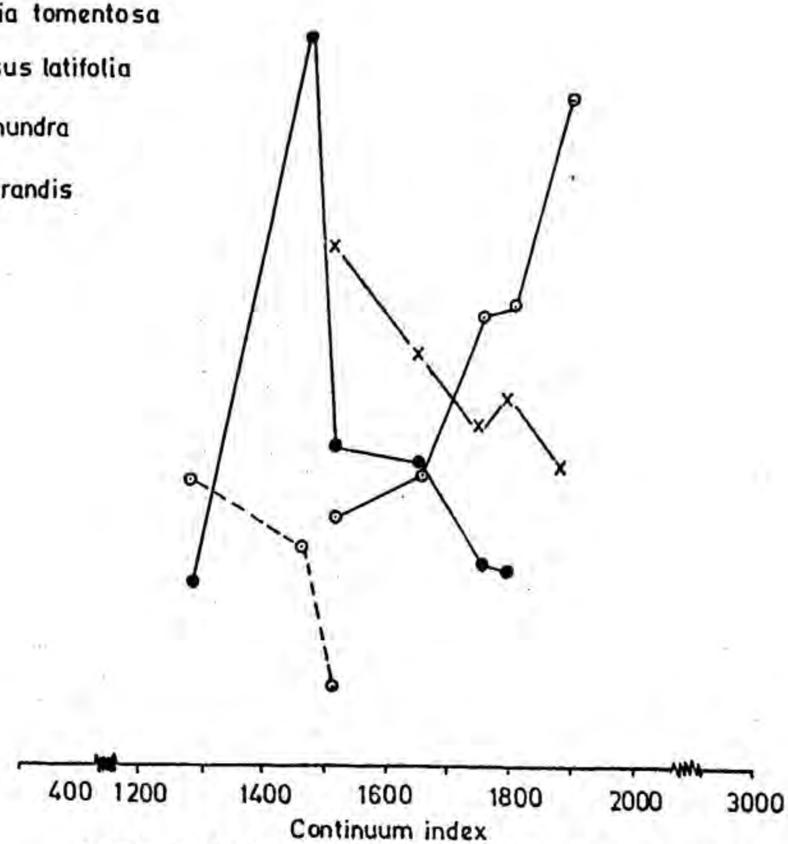


FIGURE IV. IMPORTANCE VALUE OF FOUR MAJOR SPECIES ARRANGED IN AN ORDER OF STANDS.



IMPORTANCE VALUE OF FOUR MAJOR SPECIES ARRANGED IN AN ORDER OF CONTINUUM INDEX.

Fig. III is the similarity index among forest stands which was calculated using relative frequency as the criteria. Here, the floristics at one end of the ordination is compared with the other stands and the variation in species performance is interpreted with reference to any of the independent parameters like moisture gradient, degree of disturbances etc. In addition to this, similarity index of stands is also employed as a tool to explain the better performance of a species in a stand as well as the poor performance of the same species in another stand.

Vegetation Continuum Index

Generally the species are distributed along a gradient either environmental or geographical. In either case the floristic pattern of a site goes on changing with reference to difference in gradient which paves way for the continuum concept. For instance, environmental variation is known at the start and the floristic variation is then correlated to see the rate of floristic variation with reference to that envirionemt. Figure IV depicts the importance value of four species arranged in an order of continuum index (George and Varghese, 1986). The estimated continuum varies from 1279 (stand I) to 1890 (stand 7). Here, at one end of the continuum where the index value is the highest, *Terminalia tomentosa* performs the best. At the same time, in the other extreme end of the continuum where the index value is the lowest *T. tomentosa* is almost absent and *A.chundra* performs the best. This confirms that the requirements of these two species are entirely different. In between these two extreme values the other stands dominated by *Tectona grandis* and *Anogeissus latifolia* are spread. The continuum analysis is a quantitative expression of plant growth and is interpreted with reference to a dominant factor (uni dimensional) like moisture availability or soil parameters.

Since an association is the basic unit of community description, all the above procedures gave satisfactory results in forest vegetation analysis. In most of the ecological studies a base map or a community map is quite essential for various reasons like periodical observation, maintenance of the experiemtal plot to record the statistics of flora and fauna, monitor various dependent and independent parameters etc. In such circumstances also the mathematical treatment counter checks the process of vegetation mapping.

Summary

Though forest vegetation is studied by employing different methodologies a quadrat of standard size is the most convenient unit for sampling. Vegetation communities arrived at through importance value index provides satisfactory results for discussion. Tabular comparison, profile diagram, plexus diagram, similarity index and vegetation map is used at definite context for interpretation of vegetation communities with reference to various ecological parameters.

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Summary of discussions following presentation

Dr A.H. Perera: In your classification of three community types what criteri did you use?

Dr Mathew George: Community values and similarity indices were obtained through presence/absence estimates.

Dr A.H. Perera: What about the plexus diagrams?

Dr Mathew George: These were constructed using X>> estimates.

FORESTRY PRACTICES AND CONSERVATION IN MALAYSIA

F.W. FONG

Introduction

There has been much international concern lately over the importance of saving the world's tropical forests which are being destroyed at an unprecedentedly rapid rate as a result of expanding swidden agriculture, logging and other development activities. Destruction has brought about tremendous adverse ecological effects such as loss of top soil, disruption to the water balance, silting and pollution of rivers and long term climatic changes.

An FAO study in 1980 indicates that based on current rates of forest destruction almost one fifth of the world's remaining tropical forests will be devastated or seriously degraded. It is predicted that countries like Indonesia would lose 10% of its remaining forests in 1981 by the year 2000 Philippines will lose 20%, Malaysia 24% and Thailand 60% (Caufield, 1984). Another pertinent point is that whilst swidden agriculaturists have contributed to deforestation in recent years the role of timber industry has also been major and possibly much greater. FAO statistics show that timber industry with its modern techniques of logging has a rapacious capacity to destroy forests in a short period which swidden agriculture could not do in generations.

Rate of forest depletion

Forest Loss

Malaysia is the world's biggest exporter of tropical hardwood. Ten years ago the then Deputy Prime Minister and presently the Prime Minister, Dato Seri Dr Mahathir warned that uncontrolled exploitation of forest would deplete the nation's timber resources within twelve years citing data for Peninsular Malaysia. The distressing facts were (a) about 5.5 million ha of forests had been logged in the 20 year period to 1976 (b) most of this loss occurred in the later part of the two decades i.e. 2.23 million ha were cleared in the last six years (1971 to 1976) and 0.4 million ha in 1976itself, and (c) compared to the average of 275,000 ha of forests logged annually, only 219,000 ha of forest reserves had been reafforested in the period from 1957 to 1976. The call then was for the reduction of the average forest clearing rate from 275,000 ha a year to 57,000 ha annually in order to extend the life of the forests to 35 years (New Straits Times, 1977).

The warning came as part of an address before the National Forestry Council which later approved a National Forestry Policy whose objectives were "to conserve forest resources, to meet ecological requirement for the protection of the environment, to sustain the yield of the productive forests known as permanent forest reserves, to reduce resources wastage through an efficient mills, and to introduce into the market the under utilised species in 1978" (see appendix).

Under the policy the National Forestry Council agreed to set up about 5.1 million hectares of permanent forest reserves in Peninsular Malaysia and to gradually reduce annual cutting rate from about 400,000 ha in 1979 to 220,000 ha in 1983 and 145,000 ha by 1986 and there after (Anon1, 1986). Unfortunately the state governments did not fully accept this policy, and not only the rate of logging continued at a pace which would deplete the forests within 12 years but an additional 280,000 ha of permanent forest reserve had been opened for agriculatural development since 1977. Realising the seriousness of the situation, the Federal Government at the urging of the National Forestry Council had stepped in and in 1981 declared that the annual logging rate be reduced from 75,000 ha to 42,000 ha and the reafforestation rate doubled from 40,500 ha To 81,000 ha. In a recent Bank Negara Annual Report (Anon[2], 1986) the area logged in 1985 was estimated at 180,000 ha which was in line with the projected figures which the National Forestry Council first proposed in 1978.

Timber yields

However, whilst logging has been cut down in Peninsular Malaysia, the reverse seems to have happened in Sabah and Sarawak which do not come under the National Forestry Policy. Log production for Malaysia as a whole rose from 17.8 million cu metres in 1970 to 27.9 million cu metres in 1980. The production figures for the early part of this decade are shown in table 1. Timber output in Peninsular Malaysia dropped from 10.5 million cu metres in 1980 (37% of the total output) to 8.3 million cu metres in 1985 (27%) while the share of both the East Malaysian States rose from 63% to 73% of the overall output, these figures indicate that whilst logging has indeed slowed down in Peninsula Malaysia (output fell by 20% between 1980 to 1985), it has increased in Sabah (19% rise in the same period) and especially in Sarawak (which experienced a tremendous 45% jump in log output).

Davidson (1982) estimated that based on the then prevailing annual logging rate by the end of 1980 the area of remaining virgin forest was about 2.8 million ha (21% of the area of the peninsula) and remaining logged forest 2.6 million ha (19.4%). Of the 2.8 million ha of virgin forest left at the end of 1980, 486,000 ha lie above the 914.4 m (3000 ft.) contour, leaving about 2.3 million ha of lowland virgin forest (this figure would be much less if one takes an altitudinal limit of 760 m instead).

Bearing in mind that there are also parts of the lowland forest which could never be logged because of steepness, boulders or swamps along the coasts, the estimated total area which therefore could provide economic loggable forests was slightly more than 4 million ha. This estimate indicates that the forests at prevailing logging rates could last perhaps another 10-15 years only.

Development of forest resources

The options for the development of forest resources range from management of natural forests for harvest of selected species to establishment of plantations of one or a few species to service the needs of raw materials for timber-based industries.

Management of natural forests

Management and silvicultural practices in Malaysia are variations of the shelterwood system. The wellknown Malayan Uniform System (MUS) had been developed primarily for lowland forests having several dominant species of the single family of Dipterocarpaceae. The MUS relied on the presence of adequate number of well distributed seedlings of desired species to form the next crop. Relic trees left behind after logging are often poison girdled to release cohorts of desired seedlings from canopy suppression (Wyatt-Smith, 1963). In recent years MUS has undergone transformations due to a number of factors:-

(a) High intensity logging often create large sized gaps which undermine the capacity of the stand to recover particularly with adequate stocking of commercial species the bulk of which are small gap specialists (Sensu Denslow, 1981)

(b) The rapid loss of productive lowland forests due to expansion of agricultural development programes particularly in Peninsular Malaysia has necessitated the shift of major forestry activities in the permanent forest estates to the hill forests which form the bulk of the current and future productive hardwood forest areas. The field conditions assumed for the MUS are often not always present in the hill forests which differ from the lowland forests in terms of species composition, variability of stockings, terrain, site productivity and environmental conditions.

(c) An expanding world market demand for tropical hardwoods has made a number of species, which were once poison-girdled if they were left behind after logging, become marketable in recent years. This has led to the questioning of the basis for poison-girdling operations of 'unwanted' species.

Before the onset of the eighties, forest management had always been undertaken by the Forest Department whilst forest utilisation was, and still is, in the general interest of the private sector. This situation has now changed. Some state governments have allocated sizeable areas of forest concessions to private enterprises which also carry out the responsibility of managing the forests on sustained yield basis. According to Mohd Dahan (1979) about one-seventh of the total forest area had been parcelled out in this manner. One of the changes brought about by the participation of the private sector in forest management was the alteration of the management system in their concession forests.Initially, the management of this concession was based on a bicyclic felling system which involves a variable cutting limit, a rotation of 50 years and a cutting cycle of 25 years (Sallah et al 1979). Subsequently, the bicyclic system (in contrast to the monocyclic MUS) was modified to give it greater flexibility and applicability, to the present Selective Management System (SMS) which is also practised in public forests by the State Forestry departments. Under this system a mandatory pre-logging inventory provides information on the stand characteristics and various diameter cutting limits are simulated to determine the optimum cutting limit. Management practices include complete removal of the stand to be followed by artificial regeneration to highly selective logging where forest development is dependent on intermediate sized trees present in the residual stands.

Plantation forests

In recent years many tropical countries have turned away from natural forests management to plantation forest management since the economic advantage gained from the vastly superior rate of useful wood production of the latter over that of the former is high. In Malaysia, however, plantations sited generally in areas covered with secondary indigenous forests of low timber yielding potentials play a supplementary or complementary role to the natural forests. The establishment of large scale plantations with coniferous species in Peninsular Malaysia was only started in 1974, initially for the sole purpose of supplying long fibred wood for pulp and paper. However, the plantation programmes have since been accelerated with emphasis of producing multipurpose logs using broad-leaved species mainly to overcome the anticipated timber shortage around 1990's. Plantation forestry in East Malaysia (Sabah and Sarawak) has also been recognised as making significant contributions to forest resources development. It provides a means of rehabilitating degraded forest stands resulting from swidden agriculture and it also serves as a vehicle for rural development with participation of the rural population in the projects.

Conservation of Forest Resources

Conservation update

In the early years when forestry activities started there were no definitive forest policies on the conservation of forests, but efforts towards conservation were spear-headed by the Forest Department itself naturally, In Peninsular Malaysia the Forest Enactment 1934 laid down the rule for the formation of reserved forests. The general understanding was that about 25% of the country should be forest reserves (Wyatt-Smith, 1961). Within this permanent forest estate the Forestry Department, had by departmental agreement, throughout the states set aside areas of undisturbed forests called Virgin Jungle Reserves (VJR), the size of these varying from a few hectares to 16,000 ha, in an effort to retain representative samples of the many forest types in the country. Whilst this programme is itself laudable and very important, it does not by itself constitute a complete forest conservation programme. A census in 1976 indicate that there were about 18,000 ha of VJR which barely make up 0.3% of the permanent forest estate (Putz,1976). In recent years some VJR have been lost because the Forest Reserves in which they were located were alienated for agriculature. This probably stems from the fact that there is still no comprehensive land policy in Malaysia. Land is said to be strictly a state matter i.e. responsibilities and jurisdiction of land matters rest with the state governments which depend on the land for a major part of their revenue.

However, the Federal Constitution of Malaysia does take the conservation of the country's natural resources as an item in the National Development Plan (Article 92). The Federal Constitution also allows for the acquisition of state land for federal purposes (Article 83). This means that despite the states having the control of land, the Federal Government can acquire state land for conservation purposes. The policies of the Federal Government in this respect has been spelt out in the Third Malaysian Plan (1976 - 1980) in which the government recognises" the need to balance the goals for economic development on the one hand against those for maintaining sound environmental conditions".

There is no official blue-print for conservation in Malaysia. What is available is an environmental policy included in the 5 year development plan for the country for 1976 to 1980. A non-government organisation (NGO), the Malayan Nature Society published in 1974 a 'Blue Print for Conservation in Peninsular Malaysia" (Anon, 1974). The main objective of the document was "to recommend an overall plan whereby representative examples of all the major biological communities will be preserved and at the same time characteristic landscapes, outstanding features and all species of wildlife will be saved for posterity'. Some 64 sites (70 if those areas already gazetted are included) meriting protection for perpetuity in their original state were identified for the Peninsular Malaysia. The types and designations of the conservation areas that were proposed reflected the utilisation they were put to. (see appendix). Acting on this cue, the government included a list of conservation areas and a list of proposed areas intended for gazettement as conservation areas in the Third Malaysia Plan (Anon. 1975). The number of national parks proposed was modest, namely the Endau Rompin National Park and the Gunung Blumut National Park.

No national parks, however, were created within the said five year period. The lack of progress in creating national parks and other conservation areas on the part of the government was the absence of appropriate legislation. The Wild Life Protection Act of 1972 had provisions for the creation of Wild Life Reserves and Sanctuaries but not National Parks. When the National Parks Act of 1979 was finally passed after years of deliberation it was thought as the most significant development towards conservation of natural areas in Malaysia. It was an official expression of the concern for the rapidly decreasing acreage of natural forests in the past twenty years prior to 1979. The main objective of that act was "the establishment of national parks is the preservation and protection of wildlife, plant life and objects of geological, archaeological historical and ethnological and other scientific and scenic interest and through their conservation and utilisation to promote the education, health, aesthetic values and recreation of the people". Yet the country has a long way to go to achieve these targets as planned - a wide and glaring gap exists between intent and implementation in relation to actual conservation measures (Sallah and Tang, 1980). Evidence for this is evinced in the absence of any move by the state governments of the Peninsula to implement any of the provisions of the Act.

Another example of lack of commitment to conservation is seen in the implementation of conservation strategies drawn up for some of the states in the country. Recognising that economic development is far exceeding environmental safeguards, the World Wildlife Fund Malaysia in conjunction with the World Conservation Strategy of the IUCN along with UNEP produced 'conservation strategies' for the state of Negeri Sembilan, Melaka, Trengganu and Kodah in 1981. Among other things proposed, these state conservation strategies recommended that forestry plantations be established on degraded or marginal agricultural lands in the lowlands rather than on hill slopes, where natural forest is better for preventing erosion and providing wildlife habitat, that rehabilitation of abandoned farmland be stressed rather than the conversion of protection forest, and that varied rather than monocultural landscapes for conservation purposes be created. To date little progress has been achieved with certain state authorities, as there appear to have been no follow-up subsequent to the submission of the strategies reports prepared (IUCN Bulletin Supplement 3/1983).

Conservation efforts by NGO's

The dispute over Endau Rompin is a milestone in the history of conservation and the environment in Malaysia, since for the first time the general public had become actively involved in a matter concerning the continued existence of this country's rich and invaluable natural history. The facts:

* Endau - Rampin was an area ear-marked for the establishment of a national park under the Third Malaysia Plan (1976 - 1980), as it was known to have abundant wildlife (home of the largest remaining population of sumatran rhinocerous in the country) and one of the few remaining extensive areas of lowland forest left in Peninsular Malaysia.

*Both the states, Pahang and Johore which the Endau Rompin Forest area straddles agreed in principle to the formation of the Endau Rompin National Park. The proposal called for a two zoned area a core area which would be an inviolate sanctuary and a buffer zone surrounding this core area. The buffer zone could be logged but on a controlled basis which would allow for (i) polycyclic logging and (ii) sufficient tall forest to provide habitat for a significant percentage of the wildlife that could inhabit the total area.

*In 1976, the Bukit Selanchar FELDA scheme encroached into the buffer zone surrounding the inviolate sanctuary of Endau Rompin, and the forest was clear felled for oil palm.

*Between April 1977 and August 1978, the Pahang Government started logging east of the FELDA scheme into the proposed core area.

*By 1980, the proposed area had shrunk from 200,000 ha to 84,000 ha (48,000 ha in Johore and 36,000 ha in Pahang).

Conservationists realised very quickly that if this core area was destroyed by logging the whole concept of the Endau Rompin National Park would also be destroyed. And realising that private appeals were of no avail, and also as the matter was of public and national importance, several NGOs (viz Malayan Nature Society, World Wildlife Fund Malaysia, Malaysian Zooligical Society, National Geographical Association of Malaysia, Malaysian Society of Marine Sciences and the Malaysian Foresty Society) began a public campaign to stop the exploitation starting with an advertisement (7 May 1977) in the local press carrying the caption 'Save the Endau Rompin National Park'. This action unleashed an unprecedented flood of protests which over the next few months was well documented by the national press who were also not slow to add their own protest (Chambers 1978). The Pahang State Government attempted initially to justify its position but its arguments were very quickly countered by interested bodies through the Press. In reaction the state authorities remained more or less silent and meanwhile extraction of timber continued and the pace of operations increased, possibly as a result of the public out cry resulting in a fear that the operation would be stopped.

Despite the failure of the "Save the Endau-Rompin" campaign to prevent logging some success were achieved. The Pahang State Government agreed to stop issuing any further logging licence in the area. Malaysians in all walks of life were begining to be concerned about the well being of their environment - such public feeling cannot be ignored. Lastly, the campaign served notice that any future plans for irrational exploitation of Malaya's forests would be met with fierce and determined opposition. From that date, conservation efforts by NGOs continued fervently and culminated recently in the launching of the Malaysian Heritage and Scientific Expedition - Endau Rompin 1985 with the objectives" to document all species of plants and animals encountered - with special attention being focussed on those that were rare and endemic and to provide reports on the expedition which would have lasting value and be in a form that would be readily available to the government, students and all". The latter objective had utmost relevance because there has yet to be available any socio-economic analysis, resource management plan or administration and operational details which would allow the state government to assess the cost-benefit and also the administrative implications of the national park project. The reluctance of the state governments to commit themselves is perhaps understandable. As it is the matter is still stalling presently.

Conclusion

The reduction of forest resources, the shift from lowland to hill forests, changing market trends and increased mechanisation in logging and processing technologies point to the seriousness of the problem of conservation of natural areas. In line with the World Conservation Strategy (WCS), it is stressed that the maintenance of essential ecological processes and life support systems (viz soil protection and regeneration, nutrient cycling and the cleansing of waters) requires national planning and allocation of uses and high quality management of those uses. The objectives of the WCS need more than national action - it need international action, because not withstanding the principles of national jurisdiction, the effects of ecosystem destruction transcend national boundaries.

Perhaps the most important form of international action is the development of international conservation law and the means to implement it. Strong international conventions or agreements provide a legally binding means of ensuring the conservations of those natural resources, particularly our tropical humid forests that cannot be conserved by national legislation alone.

APPENDIX 1

Objectives of the National policy on the use of forest resources:

Among these are:

To set up as Permanent Forest Estates sufficient areas of land strategically located throughout the country as an effective measure to safeguard climatic conditions, water sources, soil fertility, environmental quality and to prevent floods and erosion;

To ensure perpetual supply of all forms of forest produce which can be economically produced within the country and which are required for agricultural, domestic and industrial purposes as well as for export;

To conserve adequate forest areas for recreation, education, research and the protection of the country's unique flora and fauna;

To pursue a sound programme of forest development through approved silvicultural practices to achieve maximum productivity from the Permanent Forest Estates;

To ensure thorough an efficient utilisation of the forest resources on land not included in the Permanent Forest Estates through co-ordinated planning by land development agencies;

To promote efficient harvesting and utilisation of all forms of forest produce;

To stimulate the development of appropriate wood-based industries, thus creating more employment opportunities and generating foreign exchange;

To promote the export of forest products by ensuring the sound development of trade and commerce;

To promote effective bumiputra participation in forest and wood-based industries consistent with government policy;

To undertake and support an intensive research programme in forest development;

To undertake and support a comprehensive programme of forestry training at all levels in the public sector to ensure an adequate supply of trained man power to meet the requirements of forestry and wood-based industries;

To encourage private sector involvement in forestry research and training at all levels with a view to accelerating industrial development and to enhance the quality of professinalism in forestry and forest industrial practices;

To foster, by education and publicity, a better understanding among the community of the multiple value of the forests to them and their descendants; and

To foster close co-operation among all to achieve optimum utilisation of the valuable natural resources of the country.

APPENDIX I1

A Blue Print for Conservation:

THE TYPES OF RESERVES

A. **National Park:** An area of great extent and very high quality established for the multiple-purposes of conserving scenery, flora and fauna, and for human recreation, education and inspiration, in perpetuity. Access and commercial development should be subject to the strictest control.

B. **National Scenic and Nature Reserve:** An area of smaller extent than a National Park established mainly for the conservation of scenery and for recreation. Plant and animal life must be protected. Access to the public should not be limited. Commercial development is permitted to cater for tourist needs e.g. hotels, restaurants, shops, playgrounds.

C. **National Nature Monument:** An outstanding geological or botancial feature. Free access should normally be permitted. (Examples: limestone and quartzite formations of outstanding beauty, stands of very old giant trees).

D. **Wildlife Sanctuaries and Reserves:**

a. Wild Life Sanctuaries - Areas where indigenous wild life exists in good number and where it may be given full protection. Such santuaries may be established for one or a few species, but generally they will be intented to protect all species. Such areas approach the status of strict nature reserves and entry is restricted to authorized persons undertaking activities compatible with the purpose of the area. These santuaries may be inside wildlife reserves or by themselves.

b. Wild Life Reserves- Areas established for the conservation and utilization of the natural resources. Protection will be given to wild life consistent with other uses of the reserve, such as for forest protection, water catchment and recreation. The establishment of such reserves will recognize wild life as one of the uses of the land, and the long-term plans for the particular area will consider the needs of the wild life and its habitat in the context of total land-use planning.

E. **Marine Reserve:** Area set aside for protection of coral reefs, particularly spawning grounds etc. Access should be controlled.

F. **Field Research Sites/Stations:** Areas set aside principally for biological and environmental research. Such research may be conducted by the Universities. Forest Department, Game Department, Institute for Medical Research and other organizations. Access would only be permitted to the scientists carrying out the research, and to approved visitors and students. Where more than one organization is involved in using the research area a steering committee and a research co-ordinator should be appointed to manage the area. A Field Research Station normally has buildings and personnel on the site. A Field Research Site does not have buildings nor permanent staff on site and are subject only to periodic data-collecting visits by research personnel.

G. **Catchment Reserve:** Area set aside for protection of a water catchment. Access should be controlled and logging normally not allowed.

H. **Protective Forest Reserve:** Steepland area in which logging and clearing of vegetation is strictly prohibited.

I. **Productive Forest Reserves:** Areas set aside for the growing and periodic harvesting of timber. They constitute one of the most important examples of multiple use. Forest Reserves, because of their large area and long rotation of harvesting, have an effective role to play in providing sanctuary for animal and plant life and in conservation of soil and water.

The designations of the above reserves are not mutually exclusive. Smaller designated reserves may be located within larger ones, for example a Field Research Site may be located within a Forest Reserve.

Table 1

Log production for the last five years

	Total for the country	Peninsular Malaysia		East Malaysia			
				Sarawak		Sabah	
	$x10^3$ cu metres	$x10^3$ cu metres	%	$x10^3$ cu metres	%	$x10^3$ cu metres	%
1980	27,916	10,453	37	8,399	30	9,064	33
1981	30,655	10,226	33	8,697	28	11,732	38
1982	32,724	9,842	30	11,243	34	11,639	36
1983	32,794	10,238	31	10,565	32	11,991	37
1984	31,088	9,183	30	11,401	37	10,504	34
1985	31,300	8,300	27	12,200	39	10,800	34

Sources: 1. Statistics on Commodities, April 1986
Ministry of Primary Industries, Malaysia

2. Annual Report 1985
Bank Negara Malaysia

Table 2

The Identified Conservation Areas from the Blueprint for Conservation Document

Type of reserves	Number
National Parks	2
National Science and Nature Reserves	25
National Nature Monument	7
Wildlife Sanctuaries	13
Wildlife Reserves	10
Marine Reserves	5
Field Research Stations/Sites	7
Catchment Reserves	1
Total	70

Source: Anon, 1974

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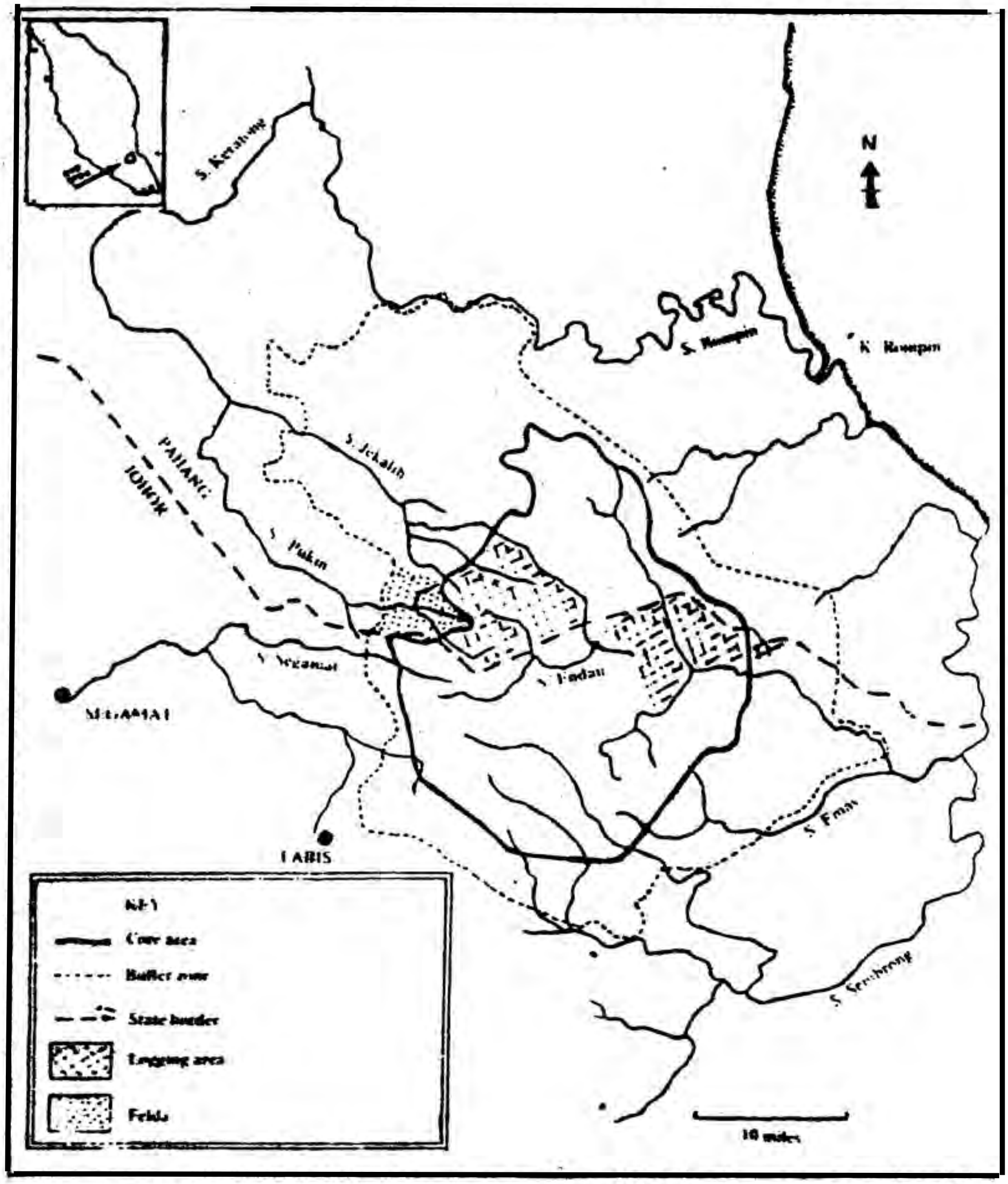

Proposed Endau – Rompin National Park.

Table 3

Conservation Areas existing and proposed in the Third Malaysian Plan (1976-1980)

	Existing in 1976	Proposed for 1976 - 1980
Game Reserves	3	-
National Parks	1	2
Bird Sanctuaries	4	2
Wildlife Reserves	7	8
Wildlife Sanctuaries	-	1
Forest Reserves	1	-
Nature Reserves	1	4
Game Sanctuaries	1	-
Turtle Sanctuaries	-	1
Nature Monument	-	5
Research Reserves	-	1

Source Anon 1975

Summary of discussions following presentation

Prof. R.N. de Fonseka: I am a little disturbed by privatisation of forest lands. Private companies are commercially oriented. Their role is perhaps important only in taking over degraded land and recovering it!

Mr Fong Foo Woon: Recovering ecosystem could ensure only long-term returns and could be possible only for strongly financed companies.

Dr(Mrs.) K. Abeynayake: Do these companies have ownership for a specified period of time and have the right to exploit resources?

Mr Fong Foo Woon: Yes.

Dr N. Ishwaran: Why is there a lot of incongruities between the priorities of state and federal government's conservation policies? What do NGOs do about reconciling differences or where do they fit into the whole picture?

Mr Fong Foo Woon: NGOs attempt to work at various levels and encourage the government both at the national and federal levels towards conservation. But in western Malaysia in some states the forest ordinances have very little relationship with national ordinance and there are a variety of historical and other reasons behind it. NGOs have very little influence on changing this scene!

CONSERVATION AND MANAGEMENT G.GEDE - PANGRANGO NATIONAL PARK

ACHMAD ABDULLAH

Introduction

The Gunung Gede and Pangrango area has a very special place in the history of both conservation and botanical research in Indonesia. It includes the Cibodas Nature Reserve which has been the scene of numerous botanical and other studies over a period of well over a hundred years by a series of scientists and naturalists, including such eminent figures as Reinwardt, Junghuhn and Wallace. The Cibodas Botanical Gardens at the foot of the mountains was established as early as 1830 and played an important role in the introduction to Indonesia of cinchona, so vital for control of malaria, and also of other exotic plants. In 1889 an area of natural forest adjoining the Botanical Gardens was established as Indonesia's first Nature Reserve, which in 1924, was further extended to the summits of G. Gede and Pangrango, with a total area of 1040 ha.

In former times G. Gede-Pangrango was a wild place little frequented by visitors apart from occasional naturalists. Junghuhn writes of an encounter with rhinoceros. There were also probably tigers - at least in the lower elevations and also leopard the presence of which no doubt discouraged local people other than hunters from wandering too far into the forest. Today the situation is very different. The rhinoceros and tigers have disappeared, though other interesting wildlife still exists, including the rare Javan gibbon. But the greatest difference is in the large numbers of visitors to the National Park area, now probably totalling over 20,000 a year, while those visiting the Cibodas Botanical Gardens exceed 150,000.

In the Indonesia of today, with its rapidly expanding urban population centres, there is a real need for wilderness areas where the city dwellers - and especially the young people - can go for recreational enjoyment and relaxation amid natural unspoilt surroundings.

A Number of National Parks are planned, of which Gunung Gede-Pangrango is one of the first, together with Ujung Kulon (another equally famous area in west Java). Not only will they provide much needed recreational opportunities, but will also serve to safeguard examples of the fast disappearing flora and fauna of these islands, as important part of the Indonesian natural heritage which would otherwise soon be lost forever.

For nearly one and a half centuries G. Gede-Pangrango and especially Cibodas has been well known to scientist and naturalists and has been the scene of much valuable botanical and other research. Van Steenis in his magnificient book on The Mountain Flora of Java (1972) wrote: "It is precisely this Reserve which has been subject to many scientific studies, that makes Cibodas a tressure for international science". While the future National Park will be of great value as a recreational area, it must be remembered that its most important function will be to safeguard for the future the unique communities of plants and animals which it contains. It is therefore vital that in its management, conservation should always take precedence over tourism or other interests.

Description in Brief

The National Park is roughly circular in shape but the cultivated valley bottoms which are not included within the boundaries alternate with long forested ridges which reach down into the lowlands like fingers, resulting in a very irregular deeply indented boundary. Its radius is about 6 km with the summit of G. Pangrango at the centre.

There are two major volcanoes, G. Gede and G. Pangrango, in the National Park connected with each other by a high saddle at Kandang Badak at an altitude of more than 2400 m. The G. Pangrango complex, consists of the remaining walls of the former G. Pangrango crater with G. Mandalawangi and G. Masigit which extend to the southwest from the summit of Pangrango in a horse-shoe shaped ridge for a distance of about 4 km, and G. Gegerbentang which is situated to the northeast of Pangrango, the summit of which is an old basaltic crater-rim. The G. Gede outer wall of the crater has an older crater rim, G. Gumuruh, reaching an altitude of 2929 m. parallel to it at a distance of about one kilometer to the east. The crater wall of G. Gede itself has a broken character and is open to the northwest with G. Sela (2709) as an isolated part of the original crater wall.

The slopes of these mountains are strongly fissured into deep gullies by the many small rivers flowing down. The slopes are forested with dense submontane and montane forest but on the southern slopes below about 1000 m some lowland forest can still be found although it has been logged and parts changed into plantation forest. The high mountain tops above approx. 2500 m have a sub alpine moss forest. The crater of G. Gede has a typical crater flora with between the rocks a few pioneer plants whereas the "alun-alun" (=plains) of G. Gede and G. Pangrango have a typically alpine flora including grasses, everlasting flowers and low shrubs.

Some parts of the National Park and an area adjoining the boundaries proposed as buffer zones are covered with plantation forest. A small swamp Rawa Gayonggong and a small colourful lake, Danau Biru, can be found near the waterfalls of Cibeureum in the present Cibodas Nature Reserve and a large lake, Situ Gunung, on the southern slopes with some swampy area along the shores. Hot water springs Air Panas are found at an altitude of 2150 m. somewhat below Kandang Badak.

Climate

Climatically Java can be divided into a western part a tropical maritime climate and an eastern part with a typical monsoon climate. Here the strong southeastern trades from Australia cause a pronounced dry season during the period from April to September. G. Gede-Pangrango is situated in the wettest part of Java with a mean annual rainfall between 3000 and 4200 mm, Even the four driest consecutive months of the year, had more than 40 rainy days. Meteorological data has been collected in the area since 1879. There are now meteorological stations at some of the surrounding tea estates, though the former stations at Kandang Badak and on the summit of G. Pangrango no longer exist. The wettest season extends from October to May, coinciding with the NW monsoon, with more than 200 mm of rain every month and over 400 mm per month between December and March.

Geology and Soils

Gunung Gede and Pangrango are a part of the great belt of volcanoes which extends in an arc through Sumatra, Java and the lesser Sundas. They follow a major anticline or fold-belt in the earth's crust (marked in Sumatra by the Barisan Mountains), and have been formed as a result of continuing movements in the earth's crustalong this very unstable and geologically active arc. Soils on the higher slopes of the mountains are andosols derived from the underlying igneous rocks and ash. Characteristics of these soils are their dark colour, high porosity, low bulk density and their high capacity for water retention. On the lower slopes the soils become more weathered with a mixture of andosols and latosols. The latter have a clay content but are not sticky. The sub-soil is friable and easily penetrated by roots. Lower down deeply weathered and highly fertile latosols are the dominant soil type. In the crater of Gede with its comparatively recent volcanic activity only unweathered lithosols are found while on the steep south-eastern slopes of G. Gumuruh washing away of the surface soil has left only the sandy regosols. Soils in the upper mountain forest have a high moisture content resulting from the heavy precipitation, which retards biological activity and chemical weathering and producing a characteristically peaty soil (Burnham in Whitmore, 1975).

Vegetation

G. Gede-Pangrango is covered with splendid mountain forest and at present it is one of the last mountains of west Java where the forest is till relatively undisturbed. The Cibodas - G. Gede reserve was established especially for the conservation of this forest as a research area and still has the best forest of the G. Gede - Pangrango complex. Best known are the vegetation descriptions of Junghuhn (1835), Docters van Leewen (1933) and van Steenis (1972) and van Steenis, Schipper and Lammertse, (1965) together with their personal observation form the basis of this paper on vegetation description. With increasing elevation the temperature decreases. This has a major effect on the plant community in which five altitudinal zones are distinguished. The National Park is situated between approximately 1000 m and 3019 m, and it includes submontane (1000-1500 m), montane (1500-2400 m) and subalpine (above 2400 m) vegetation. Many mountain plants dispersed from the nothern temperate regions southwards through Sumatra to Java and the Lesser Sundas, probably in the Pliocene or Upper Miocene. The G. Gede-Pangrango National Park with the most splendid mountain forest of Java is an important step of this migration pathway.

Most of the rare plants of the National Park are strictly forestbound and with the disappearance of the forest these plants will vanish too. The mountain forest is very susceptible to destruction as was shown by Kramer (1933) who found in the course of research on the southern G. Gede slopes that in cleared plots larger than 0.3 ha regeneration of the forest became nearly impossible. The extinct Pangrango volcano summit bears a different flora to the active G. Gede. The parental material was longer decomposed and so the soils are deeper and more developed, and the climax plant association on the Pangrango summit is more diverse whereas on the summit of G. Gede with its still active one finds species that are typical pioneers and can withstand the volcanic gases. The luxuriant vegetation of the Gede-Pangrango mountains is dependent upon an everwet climate with abundant moss growth, filmy ferns (Hymenophyllaceae) growing in the shade of the primary forest, the "resam" thisket-forming ferns (Dicranopteris and Gleichenia) in more open places and also the pitcher plants (Nepenthes) and many other everwet forest undergrowth plants. Beardmosses (Usnea) are abundant and also indicative of the everwet climate.

High Forest of the Submontane and Montane Zone

The high forest between 1400 and 2400 m has a very mixed composition. The canopy is about 30-40 m high with an abundant development of laurels (Litsea spp), oaks (Lithocarpus and Quercus spp.) and chesnut (Castanopsis spp.).Junghuhs for that reason named it the Fago-Laureaceous zone. The puspa, Schima wallichii (Theaceae) is common in West Java's rainforest and often conspicuous by its reddish flush that at times colours the whole forest canopy, also by its large white flowers with yellow stamens. Leptospermum flavescens (Myrtaceae), a tree that occurs at low altitudes outside Java in poor soils, is here found above 1750 m and becomes dominant at higher altitudes. The forest has a very mixed character with a luxuriant undergrowth of shrubs, herbs and ferns like the Begonia spp; of which especially B. robusta catches the eye with the beautiful red young leaves, the climbing pandan Freycinetia Javanica with the probably bat-pollinated spikes with large yolk-yellow appendages. Strobilanthes cernua (Acanthaceae) seems the dominant in the undergrowth. This plant has a common rhythm in its flowering which recurs once in nine years so that the forest then appears as if in a bridal dress.

Epiphytes are abundant with the large nest ferns (Asplenium nidus) growing on the tree stems and branches overloaded with mosses, ferns and orchids. From the 592 known indigenous orchid species of west Java, 200 species (35%) occur in Cibodas. The majority have tiny flowers and are epiphytic, but there are also terrestrial ones like the Paphiopedilum Javanicum and the large yellow Phaius flavus (Koorders, 1918).

Emergents of this forest include the grand rasamala Altingia excelsa which reaches 60 m in height with a bole up to 1.5 m diameter. Its upper limit is just up to the Cibeureum waterfalls (1800 m). Rasamala is a valuable timber tree which has now almost disappeared from the lower parts of G. Gede-Pangrango as a result of past logging activities. The conifers Podocarpus imbricatus and P. neriifolius with a height of 40-50 m occur up to 2500 m. In the upper part of the forest between Cibeureum and Kandang Badak, Podocarpus imbricatus is the dominant canopy tree colouring the forest top layer greyish green. Outside the Cibodas-G. Gede Reserve this tree is often felled by the local people and in the protection forest above G. Mas tea Estate we still find. P. imbricatus at about 2500 m but with many fresh signs of felled trees lower down.

Just below the Cibeureum waterfalls there is a small swamp 'Rawa Gayonggong' probably a former subsidiary crater. The vegetation consists largely of the red Phragmites karka and the large-leafed Gunnera macrophylla (Haloragaceae). It is the westernmost place in Java where the rush Juncus effusus and Xyris capensis (Xyridaceae) are found, and there is small real Sphagnum peat bog in the eastern part. The open surroundings of the Cibeureum waterfalls are covered with an association which usually occurs at higher altitudes., with the Ericaceae Gaultheria leucocarpa and Rhododendron Javanicum, the Javanese edelweiss Anbaphalis Javanica and the buttercup Raninculus diffusus. There are many Zingiberaceae too, such as Phaeomeria solaris and Hornstedtia paludosa. The rocky walls near the waterfalls, where the water is dripping down, are overgrown with Sphagnum moss and the Utticaceae Pilea Peploides and Elatosteme strigosum. In open places the pitcher plant Nepenthes gymnamphora, a low climber, can be found.

Subalpine Forest

At the altitude of about Kandang Badak, the saddle at 2400 m between G. Gede and G. Pangrango, one enters the subalpine or elfin forest. This forest has only one stratum of smallish trees and a ground layer. It is poorer in species and Ericaceae form an important component of the forest with Vaccinium varingiaefolium as the predominant tree species. Other subdominants are Leptospermum flavescens (Myrtaceae), Eurya acuminata (Theaceae), Symplocos cochinchinesis (Symplocaceae), and Myrica Javanica (Myricaceae). There is an abundance of moss growth, not only epiphytic but also on the ground, especially on G. Pangrango where all stems,rocks and fallen logs are overgrown with mosses and the higher twigs with long hanging strings of Usnea, the greyish green beardmoss (lichens).

Owing to the volcanic activity of G. Gede, its forest is, in comparison with the extinct G.Pangrango, thin-stemmed and sparse with less undergrowth but abundant lichens, due to their better resistance against crater gases.

Vaccinium varingiaefolium,Rhododendron retusum and Myrsine avenis are more common close to the crater, and in the crater even a pure Vaccinium varingiaefolium forest has developed. Ardisia javanica is very common in the undergrowth.

On these high mountains, particularly in the open places where herbs are more abundant, one is surprised by the great number of herbs which reflect affinity with the flora of the northern termperate zone. The botanist from these regions immediately recognizes the genera ; the species are mostly different and confined to the high mountain tops in Sumatra, Java and sometimes lesser Sundas islands (Jacob, 1978). Two species of Ranunculus, R. blumei and R. javanicus occur up to the summits in open places; Viola pilosa (Violaceae) and Sanicula europaea (Umbelliferae) are forest plants and found enerywhere. The majestic Primula prolifera, in Java only found on G. Pangrango, Papandayan, Sumbing and Yang, but only really protected on G. Pangrango where it grows in Lebak Saat, along the trail and in the open forest on the summit, forms a large flowering stem up to 1½ m with beautiful yellow flowers. All four Javanese populations are distinguishable from each other (van Steenis, 1972). On the open places one also finds Thalictrun javanicum (Ranunculaceae), Solanum nigrum (Solanaceae), Plantago major (Plantaginaceae), Pimpinella pruattjan (Umbelliferae) and Valeriana hardwickii (Valerianaceae).

Crater Vegetation

The vegetation in the crater of G. Gede is strongly influenced by sterile and acid rocks and poisonous gases. The most prolific plants are the crater fern Selliguea feei, the ericaceous Vaccinium Varingiaefolium and Rhododendron retusum. Somewhat more distant from the solftaras one finds Anaphalis javanica, Myrica javanica, Dianella javanica, Rhododendron javanicum, Gaultheria spp. and Lycopodium clavatum. More in the open spots of the elfin forest but also to the crater the leguminose Albizia lophantha occurs. This tree grows very fast and after a couple of years dies. It is promoted by fire and acids from the solfataras which break down the hard seed-shells so that germination quickly follows. The parasite Balanophora elongata, with its main hosts Vaccinium and Albizia, is common. In former times the Sundanese extracted the wax of this Balanophora and used this for making candles.

Alun-alun Vegetation

There are two alun-alun or grassy plains in the National Park, a large cresent -shaped one on G. Gede and a smaller one near the summit of G. Pangrango, both of which are drained by small streams. A combination of the poor soils, frost which may accur in these depressions and fires could have been the reason that no forest developed here.

The vegetation, especially along the edges, is dominated by the Javanese "edelweiss" (Anaphalis javanica). On the barren places the tiny grass Isachne pangerangensis is found with tussocks of mosses.

Between them grow the gentian, Gentiana quadrifaria, the terrestrial orchid Thelymitra javanica, the grasses Agrostis infirma and Calamagrostis australia and the sedge Carax hypscphyta. Near the camping sites on the alun-alun G. Gede the strawbery Fragaria vesca and bramble Rubus lineatus are common. Along the edges of the alun-alun Anaphalis javanica grows higher, up to 4-5 metres, their stems often being overgrown by lichens. On the humid places, especially along the Cikuripan on G. Pangrango a richly varied vegetation grows with the striking yellow-flowered Hypericum leschenaultii, Viola pilosa, Thalictrum javanicum, Pimpinella pruatjan and others.

Rare or Endemic Plants

In the National Park several rare or endemic plants accur. The sedge Carex graeffeana is, found only near the Cibeureum waterfalls (but also in New Guinea, northern Borneo and the Philippines); Corybas mucronatus (G. Gegerbentang), Liparis bilaburlata, Malaxis sagittata snd Pachycentria varingiaefolia are all orchids andemie to G. Gede, thus occuring only in the National Park and nowhere else in the world. On the northern spurs of G. Gede (G. Gegerbentang, G. Telaga) the large parasite on chestnuts (Castanopsis acuminatissima) Dendrophthoe magna (Loranthaceae) grows, which besides this restricted region is found only on G. Kinabalu (Sabah). Other rare plants of Java found only in the National Park are the tree Ormosia penangensis (papilionaceae) and the orchid Platanthera blumii.

Introduced Plants

Several plants have been introduced into the National Park, either as a result of acclimatization experiments, as weeds or as plantation crops. Very conspicuous are the large Cupressus sempervirens near Kandang Badak, as well as Fragaria vesca, Rumex alpinus and Rubus fruticosus, planted by Teysmann. Other plants like Rosa rubiginosa, Pirus malus (pear) and the beech Fagus sylvatica which were also introduced have already disappeared. Docter van Leeuwen planted Dendrobium jacobsoni and Anemone sumatrana, which can still be found on the summit of G. Pangrango along the Cikuripan stream. Exotic plantation trees include Agathis lograntifolia (Maluku) Pinus merkusii (Sumatra) and Maesopsis eminii (Africa). Weeds commonly found are amongst others, Eupatorium pallescens and E. riparium, Bidens pilosa, Erigeron linifolius, Galinosa parviflora and the grasses Poa annua and P. trivialis. Fortunately these plants play but a very insignificant rôle among the native species that must have become established here thousands and thousands of years ago.

Fauna

In general, the fauna of the montane forest is rather poor. On the tops of the higher mountains one hardly hears any sound of birds. The forest in the lower part is so dense that here also observation of animals is very difficult. But on a bright morning it seems the forest becomes alive. One hears everywhere birds. Several animals of G. Gede-Pangrango commonest during earlier times are now extinct. When the early travellers visited these mountains they reported of many rhinoceros tracks they found and they used these tracks for climbing the mountains. Junghuhn even saw two rhinoceroses.

But as everywhere on Java during the second half of the nineteenth century rhinoceros hunting was popular, and most of the rhinoceros populations disappeared. At the present day the last Javan rhinoceros (Rhinoceros sondaicus) are in the Ujung Kulon Nature Reserve, on the westernmost tip of Java. The name Kandang Badak, which means rhinoceros cage still reflects their former occurrence. The Javan tiger (Panthera tigris sondaica), (now extinct) banteng (Bos javanicus) and rusa deer (Cervus timorensis russa) also probably occured in the lower parts or in the vicinity of the National Park. Monkeys, gibbons, pigs and leopards still occur in these mountain forests. The avifauna of the G. Gede-Pangrango National Park was studied in detail at Cisodas-G. Gede by Hoogerwerf (1950), and at Cimungkat by Bartels (1917). 245 species or about 53 percent of the ± 460 bird species known from Java (this number 245 however also includes birds from the surrounding tea and vegetable gardens) were found there. Doctors van Leeuwen (1933) made an intensive study of the biology of plants and animals in the higher parts of G. Gede-Pangrango. The insect fauna is rather poor on these high tops. On rainy days insects except bumble bees (Bombus rufipes) were rarely seen but on sunny days several insect species were present. There were relatively few species of insects, chiefly Diptera, which sometimes occur in large numbers. Leeches (Haemadipsa zeylanica) were numerous in the humid forest, at lower altitudes especially in the rainy season, but were not very common on the main paths.

Primates

Four species of primates occur on G. Gede-Pangrango. The endemic Javan gibbon (Holyobates moloch) only found in western Java, east to G. Slamet (Kappeler, 1978), is found in the lower parts of the mountains. It lives in family groups with 2-4 individuals and is strictly territorial. It appeared to be rare in Gibodas except on the southwestern slopes (near Cibadak) where it is still common. Docters van Leeuwen (1933) reported it from Kandang Badak at 2400 m, an exceptional altitude for this gibbon.

Perhaps these were solitary animals, expelled from their groups. The Javan gibbon, an animal listed in the IUCN Red Data Book as endangered is extremely rare. There was unlimited trapping of these animals as pets a few years ago and in 1976 they were still being openly sold along the roads near Ciawi and Bogor. It is still possible to buy gibbons although this is illegal (gibbons have been protected by law since 1931). Loss of habitat by clearing the forest for agricultural purposes and by changing the forest cover into monotypes Agathis and pine plantations have also been major factors in the disappearance of the gibbons.

The other endemic Javan primate, the Javan leaf monkey (Presbytis aygula) is endangered too. The Javan leaf monkey is confined to the forests of the lower zones. One can observe these monkeys, which live in relatively large groups (6-9 per group) in Cibodas below the waterfalls. They are rather shy and difficult to see, because unlike the other primates they feed quietly in the forest canopy.

Two other primates are rather common and distributed all over the Greater Sundas. The long-tailed macaque (Macaca fascicularis) occurs in the lower parts of the forest, mainly along the edges. They live in large groups in the forest but often they raid vegetable plantations causing economic loss to local people.

The silvered leaf monkey (Presbytis cristata) is common in the coastal forest of Java and also occurs in the lower montane forest. In G.Gede-Pangrango it is not abundant and is most probably confined to the dense forest of the lower slopes.

Leopards

Leopard (Panthera pardus melas) is still the only large predator of West Java, besides the extremely rare wild dog. Accurate data on its distribution is hard to get. People claim that leopards regularly kill domestic animals in the surroundings of G.Gede-Pangrango. Docters van Leeuwen (1933) found droppings and tracks on the top of G. Pangrango, and Hoogerwerf (1947) mentions the crater rim of the G. Gede as an often used path. Foot prints have been found near Cibeureum (1976). Its main prey consists of wild pig and monkeys. Recently an observation of a leopard with cubs was reported by Cisarua Selatan (1978).

Pigs

Wild pigs are very common and are found throughout the mountain forest and also from the surrounding tea gardens. While two pig species Sus scrofa and Sus verrocosus occur in Java, only the former is definitely known from Cibodas,

Wild dog

The wild dog (Cuon alpinus) is very rare and should be considered as endangered on Java. In the past they were reported frequently from the Puncak Pass and the Sukabumi area. No recent reports are available about its occurrance in this region.

Smaller Mammals

The Javanese skunk or stink badger (Mydaus javanensis) is said to be common. Dammerman (1929) reported them from the lower elevation up to the summits. They dig up large patches of ground, like pigs, in search of their food which consists of insects and worms. Small predators include the leopard cat (Felis bengalensis), the yellow threatened martin (Mustela flavigula) the flying lemur (Galeopterus variegatus), the shrew (Crocidura fuliginosa orientalis) and several bat species.

Birds

Hoogerwerf (1950) lists some 200 bird species for the Cibodas Reserve, Botanical Gardens and environs. He observed 140 species, including 110 which were restricted to forest habitats. All the 12 endemic birds of Java are listed for Cibodas and the following are mentioned as common : brown-throated barbet (Megalaema corvina), laughing thrush (Garrulax rufifrons), brown-cheeked fulvetta (Alcippe pyrrhoptera), redtailed fantail (Rhipidura phoenicura), Kuhl's sunbird (Aethopygia aximia), Javan grey throated white-eye (Lophozosterops javanica) and pygmy tit (Psaltria exilis), the last species is known only from West Java mountains and the sole representative of an endemic genus.

The most obvious bird of the higher parts is the mountain thrush Turdus poliocepahlus. It usually occurs near open places in the mountain forest, where they feed mainly on Vaccinium and Rubus berries. Its song is like that of the European blackbird. The peregrine falcon (Falco peregrinus) can be observed near the crate walls of G. Gede, where this bird of prey finds one of its last strongholds for breeding in Java. Fruit pigeons are common especially the wedge-tailed pigeon Treron sphenura, and the barred cuckoo dove Macropygia unchall. Barbets, laughing thrushes and the lesser racket-tailed drongo Dicrurus remifer regularly give their calls and songs at the lower altitudes.

Effects of Visitor Impact of the Reserve

The Cibodas Gunung Gede Reserve is relatively close to Jakarta and many people, especially students from secondary schools and Universities, climb the mountains. During a long weekend or on a holiday, the numbers of people can run into hundreds and even thousands. Without any control as at present such numbers would inevitably result in serious damage to the Reserve.

Plastic, empty tins and bottles, paper and other garbage are scattered everywhere. There is scarcely a rock of any size at Cibeureum, Kandang Batu, on the crater of G. Gede or elsewhere which is not painted with names and dates of visitors. More and more trees have names carved into the bark or painted on them, and some have painted pieces of tin nailed or hung on them.

Paths. The original paths up to the steeper slopes such as the one from Kandang Batu to Kandang Badak and the one to the summit of G. Pangrango were laid out in a zig-zag pattern, to maintain an easy gradient and minimizing erosion. In many places these old carefully graded paths have been abandoned and new ones opened straight up and down the steep slopes, resulting in the formation of deep erosion gullies.

Flowers. Many visitors who climb the mountains pick flowers of the Javanese edelweiss (Anaphalis Javanica). For them and for their friends in Jakarta this plant is the proof of having reached the summit. Also many other plants such as orchids and ferns are being collected, and taken to Jakarta where in the completely different and unsuitable climate they will soon die.

Formerly the majority of visitors came without any equipment and relied for shelter on the forest, which often turned out to be much colder than they could have expected, so that they had to make large fires to keep warm. But good camping equipment like tents, stoves, and clothing suitable for the mountains is now becoming readily available and is more commonly used.

Aims of Management

The Gunung Gede-Pangrango National Park consists of the active volcano G. Gede and the extinct G. Pangrango. There are a number of different ecosystems, varying from the montane and elfin forest to the pioneer crater vegetation. The montane and elfin forest is the least disturbed and most splendid forest of that type in Java. The National Park includes the Cibodas G. Gede Reserve, the first established Nature Reserve in Indonesia.

Formerly connected with the Cibodas Botanical Gardens the Reserve has been and still is a well-known centre for botanical research. Although the diversity of the larger mammals is rather poor, the National Park is the type locality of many plant and other animal species.

The Cibodas Nature Reserve fills already an important role in providing recreational facilities. Despite its status of Strict Nature Reserve large numbers of visitors, the majority of which are students of secondary schools and universities, climb the mountains and camp in the forest. The G. Gede--Pangrango National Park is easily accessible from the major population centres such as Jakarta, Bandung and Bogor. Besides the main conservation values the Park has also great recreational and educational values and through interpretation their interest in nature and understanding of environmental problems could be encouraged.

The forested mountains enclosed within the boundaries of the National Park are of importance as the water shed areas of the lower tea Gardens, vegetable and ricefields and the main rivers like Ciliwung and others. But at present, many of the surrounding people are still dependent on the forest of the National Park for their fuelwood and timber, the removal of which causes serious damage to the forest. The future National Park has a high value as an area for scientific research,field study and as a demonstration area for the Training School for Nature Conservation in Ciawi.

On the basis of the foregoing premises the main objectives of management may therefore be stated as follows:

Conservation

1) Conservation of the montane forest and other ecosystems found within the National Park, subject only to such minimum interference as may be necessary for the perpetuation of endangered species of plants and animals.

Research

1) Encouragement of all research consistent with the objectives of the National Park.Research related to practical management problem should be given special emphasis.

2) Establishing maximal cooperation with the Lembaga Biologi Nasional, administering, the staff of the Cibodas Botanical Gardens and the Cibodas Field Laboratory, and providing optimal support for all research undertaken by the staff of LBN or scientists from elsewhere, as far as it is not contrary to the conservation aims.

Tourism

1) Establishment of G. Gede-Pangrango National Park and its development for recreational tourism in so far as this is compatible with conservation objectives.

2) Discourage recreational and other activities likely to cause environmental damage or which would otherwise not be in keeping with the objectives of the National Park.

Education and Interpretation

1) Explain the history, purpose and scientific and other values of the National Park to visitors in the context of Indonesia's overall conservation programme.

2) Help visitors to see the maximum possible diversity of flora and fauna and help them to understand what they observe.

3) Provide special facilities for visits by students and similar educational groups.

4) Develop extension activities to encourage understanding by local people living in the vicinity of the National Park of its value and enlist their cooperation.

Buffer Zones

The establishment of effective buffer zones around the National Park is very desirable and has been taken into consideration in realizing boundaries.

If people from the surrounding villages are to be prohibited from taking firewood, charcol, building poles and other forest produce from the National Park, they should be provided with alternative sources of supply.

The major function of the buffer zones is the absorption of the population pressure from the surrounding rural areas, serving as a physical barrier insulating the Park from external influences. They should at the same time be used for production of fuelwood and building timber to supply the needs of the local people so that they are no longer tempted to take it from within the Park itself. The proposed forest plantations to be established within the buffer zones will also have an important function in maintenance of forest cover and prevention of soil erosion.

Hardly any experience is available on establishment of firewood plantations on relatively high altitudes and it is therefore proposed to start with one or more small scale pilot projects to gain experience and to provide an alternative source of fuelwood for those communities which are at present most dependant on the Reserve. The Directorate General of Reafforestation and Rehabilitation in implementing the reafforestation programme should take into account management objectives of the Park. World Bank funding could be sought, since such a project would be in line with its proclaimed policy of supporting projects concerned with environmental and protection forestry, and especially reafforestation and fuelwood plantations in rural areas (Spears, 1978).

Prescriptions for a Pilot Project 'Buffer Zone Management and Firewood Plantations'

Forestry Department estimates that depending upon altitude and species the annual yield of firewood per ha may be estimated on 10-20 m^3 and WWF education project estimated the total fuelwood need in G.Putri/Cibodas as 1000-1500 m^3 per year, in Maleber/Sarongge as 1000 m^3 per year and G.Mas/Cisarus as 500 m^3 per year. It is therefore proposed initially, as a pilot project to establish small plantations of respectively 150 ha, 100 ha 50 ha at G. Putri, Sarongge and Cisarua Selatan. In G. Putri and Sarongge the firewood need is highest so it is proposed to start here with a mixed plantation of much yielding species Acasia decurrens, Albizia lophanta, Albizia falcataria and Caliandra haematocophala. In Cisarua Selatan, indigenous species such as Casuarina junghuhniana, Dillenia spp, Schina wallichii and Fagaceae such as Quercus, Castanopsis and Lithocarpus can be planted, on experimental basis to provide charcoal.

Zonation

The National Park has been divided into the following management zones is addition to the external buffer zones and Intensive Use Area mentioned above.

1) Wilderness Zone

i. The present path from the main entrance to Cibeureum and Kandang Badak, and from here the path through the crater of G. Gede and down along G. Sela to Cibodas; the path from Kandang Badak to G. Gede and down to the Alun-alun and to both G. Putri and Salabintana; the path from Kandang Badak to G. Pangrango but not continuing to the Alun-alun of G. Pangrango; the trail through Cimungkat.

ii. To open a path from Danau Biru/Rawa Gayonggong to the East, the Cibodas river and from the new entrance to the East to connect the trail to G. Sela.

iii. Limited areas are available in Cibeureum, Kandang Badak, Kandang batu, Alun-alun of G. Gede and the banks of Situ Gunung. Very limited low intensity development would be permissible within these zones, such as construction of guardpost, shelters, visitor camps, and maintenance of footpaths and construction of foot bridges.

iv. The area from the Puncak southwards to Cibeureum waterfalls (Gegerbentang) for future development of wilderness trails.

2) Sanctuary Zone

The whole of the National Park except those areas designated as wilderness Zone. Sanctuary zones receives a degree of protection equivalent to a Strict Nature Reserve (Cagar Alam), with no access except by Park staff or authorized research workers when necessary for purposes of management. No development would be permitted other than minimum construction of guardposts and foot tracks required for patrolling and law enforcement.

Habitat Management

There should be as little disturbance as possible apart from such minimum clearing of paths, measures to rehabilitate areas damaged by present overuse at Cibeureum, Kandang Badak and Alun-alun of G. Gede, and for erosion control, especially along trails.

The montane and elfin forest habitat does not need any management at all, except for maximal protection.

Wildlife Management

Wildlife includes several endangered species such as Javan gibbon and Javan leaf monkey, both animals of the primary forest and therefore not in need of any management other than protection from undue disturbance. This holds for the majority of flora and fauna, which is strictly forest-bound. Strict protection against poaching is, however, essential.

Law Enforcement

The most important law enforcement tasks are to prevent the taking of firewood,timber and other forest produce by local villagers; also illegal entry and damage by visitors, including collection of plants and animals, cutting and carving of names on trees, littering, painting of stones and other forms of vandalism, wandering off trails and opening of new trails, and poaching by both local hunters and visitors.

Most of the local people are well aware of the illegality of collecting forest produce and similar activities within the Reserve, but they are largely dependent upon it for fuelwood and certain other resources. With the establishment of fuel plantations in the buffer zones, which will also provide some employment, combined with frequent patrolling these harmful effects could be minimised. Most of the visitors who do damage to the Reserve do so out of ignorance rather than intention. Development of an effective interpretive programme is therefore of the highest priority, including appropriate displays in an Education Centre. An information room at the entrance and in the Park itself, providing information on the Park and appealing for the visitors cooperation in keeping it clean and avoiding damage to the national environment, would be useful. Only after repeated warnings by the Park staff should measures such as prosecution be taken against offenders. Such problems are however common to most Reserves and National Parks and there should be serious difficulty in dealing with them given good interpretive possibilities and an adequate guard force under effective direction and with the proper equipment.

It is essential that appropriate arrangements are made for dealing with offenders, including appointment of several of the Park staff (e.g. Warden and Rayon Chiefs) as authorised Prosecuting officers, and that they should be trained in court procedures and presentation of cases. In the budget sufficient money should be allocated in the case of serious crime, joint patrols and raids with the police might be needed.

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NA-91-501

Summary of discussions following presentation

Dr Kaldhar Kaphle: What are the most threatened endangered species in the area?

Mr Achmad Abdulla: I would consider the Javan tiger and one of the *Hylobatus* sp. (gibbons) in this category.

Mr M. Kalimuddin Bhuiyan: Of the educational, ecological and economic value of the park which do you consider most important?

Mr Achmad Abdulla: Educational value is most important with the ecological values being second.

Dr Mathew George: Do the hot springs have any medicinal value and if so has there been any attempt to use it?

Mr Achmad Abdulla: Yes, the springs do have medicinal values; however, rehabilitation work in the area had been hampered by volcanic action.

PROBLEMS IN THE NATURAL REGENERATION OF THE WET EVERGREEN FORESTS IN KERALA (INDIA)

K. SWARUPANANDAN

Abstract

The problems of natural regeneration in the evergreen forests of Kerala remain the same as that of any other region in the tropics. Fox has categorized the constraints in the natural regeneration of tropical moist forests into three, viz. ecological, anthropogenic and intrinsic. Bawa and Krugman have added a fourth to the list, viz. scientific constraints. The present paper details out the problems, with specific examples from Kerala.

Introduction

Conservation is essentially a management strategy (Bawa and Krugman, 1986; Odum, 1971). The application of the principle of conservation need not always be a preservational treatment (Odum, 1971). In the case of a renewable resource like forests, if the renewability could be improved it will be a better approach for conservation.

Trees in any given forest do not remain the same for a substantially long period of time. Some of the trees do die and vanish while other younger trees appear in their place. Thus,the forest 'organism' is in a process of dynamic equilibrium. The dynamic equilibrium compensating the death rates is achieved through a process called silvigenesis (of Halle et al., 1978). Silvigenesis is a continuous process and is effected through regular (periodic) regeneration of the tree species. In the present paper, a brief outline of the problems of regeneration in the Kerala forests will be discussed.

The wet evergreen forests in Kerala

Before discussing the problems of natural regeneration, it is desirable that I give a general introduction of the wet evergreen forests of Kerala.

Geography: The Kerala State forms the southwest geographical unit in India. Bordered by the Western Ghats along the east and by Arabian sea on the west it is an elongated north-south strip lying within the geographic grid 8o18' - 12o48' N latitudes and 74o52'- 77o22'E longitudes (Bureau of Statistics, 1968).

Distribution: The evergreen forests of the state covers approximately an area of 2,000 km^2 (Iyppu, 1960). This forest type is distributed along the entire length of the Western Ghats and is mostly confined up to an elevation of a little over than 1,200 m.

Climate: The mean annual temperature of the area is ca. 30 °C fluctuating between 24 °C and 38 °C. The vegetation receives south west and north east monsoon showers between June and November. The mean annual precipitation is well above 2,000 mm in most areas, the actual figures ranging between 1016 mm and 7620 mm. There is no prolonged draught and the relative humidity does not fall below 80% (Iyppu, 1960; Nair, 1961).

Geology and Soil: Geologically the soils provide the substratum for the evergreen forests is composed ot crystalline and medamorphic rocks of Archean ages with an extraordirary tendency for decomposition. The soil on the slopes and valleys are deep, dark and loamy while the crests have a shallow soil substratum.

Physiognomy: The forest cover is loafty, ranging upto a height of 45 m or more above the ground (Champion, 1936). Some of the top storey species have clear boles upto 30 m and a girth of 3 - 4 m. The canopy is extremely dense. Epiphytes are fairly common, climbers are occasional, ground vegetation is often poor or absent, trees with buttress are frequent and cauliflory is quite common. Approximately some 200 species of trees growing over 10 m height inhabit the forests.

Species Composition: The evergreen forests of the Kerala State fall under three main types, viz. Western Tropical Evergreen, West Coast Tropical Semievergreen and High Range Shola Evergreen (cf. Chandrasekharan, 1962; Iyppu, 1960). Majority of the forests fall under the first category. The typical genera found in these forests are Palaquium, Dipterocarpus, Vateria, Calophyllum, Mesua, Cullenia, Poeciloneuron, Elaeocarpus, Hopea, Diospyros, Polyalthia, Tetrameles, Myristica, Artocarpus etc.

Problems in the natural regeneration of the evergreen forests

A precise circumsurvey of the processes and problems of natural regeneration of the evergreen forests has been provided by Nair, (1961). Subsequently, Fox (1976) tried to explain the problems in natural regeneration in terms of specific constraints. He classified these constraints under three major heads, viz. environmental, anthropogenic and intrinsic. Climatic, edaphic and biotic factors provide environmental constraints. Constraints due to felling, logging, fire, illegal cuttings, management problems such as short rotations, lack of control of exploitation etc. constitute the anthropogenic constraints. Constraints of the population structure, socioecological aspects, phenology etc. constitute the intrinsic constriants (Fox, 1976). Bawa and Krugman (1986) describes a fourth constraint, viz. the scientific constraints, owing to the lack of information on the reproductive biology of tropical trees.

Nair (1961) has already covered the general problems involved in the natural renegeraton of the evergreen forests of Kerala. My present task is to resolve these problems with specific instances from the Kerala forests.

Environmental Constraints:

Environmental factors such as light, water and soil are known to act as specific constraints in the natural regeneration of some tree species (of. Fox, 1976). Of these factors mentioned, light alone is the more predominant in the evergreen forest environment. The most obvious result of insufficient light supply is an invasive population structure (for the term of Harper and White, 1974). A few examples from the Kerala forests can be illustrated.

Vateria indica Linn. and Vateria macrocarpa (Dipterocarpaceae) Gupta are two important soft wood species very much in demand for plywood manufacture. Of this, the former extends its distribution outside Kerala, being recorded from Mysore to Tinnelvelly. While, the distribution of V. macrocarpa is highly restricted to just 25 km2 within the Palghat Division in Kerala (cf. Ayyar, 1982; Muhammed, 1967). A comparison of the numerical estimate of trees of the latter species during the period of three working plans between 1932 and 1975 (ca. 40 yrs.) shows a sharp reduction from 60,000 trees of 1932 to just 20,000 trees in 1975 (cf. Basha, 1985). The species is also considered as endangered.

In both the species mentioned above seed production and germination of the seeds are fairly high. In this sense regeneration is fairly satisfactory for both the species. On the other hand, when the girth class representation is taken into consideration, in both the species, pole and sapling stages are almost completely absent. Precisely, the same situation exists with the species Dysoxylum malabaricum Bedd. ex Hiern. (Meliaceae) and Toona ciliata Roem (Meliaceae).

Most evergreen trees are shade tolerant and shade loving in the initial stages. However as the seedlings advance in growth, the dense upper stratum of the canopy limits the quality and quantity of light to the seedlings and saplings. As a result they gradually get eliminated, unless a gap of advantageous size is created by the death and decay of an older tree.

Anthropogenic constraints:

The most important of all the constraints in the regeneration of tropical wet evergreen forests is perhaps anthropogenic. The evergreen forests are very delicately balanced systems (Fox, 1976) in the sense that their return to the original state is almost impossible after any serious disturbance (Meher-Homji, 1979).

With the intensive cultivation of plantation crops, large areas of evergreen forests at Yunad, Munnar and other places were converted into Coffee, Tea and Cardamom plantations. After a period of yield many of these areas proved unproductive and were abandoned subsequently. These abandoned areas are now under heavy infestation of heliophilic weeds and have lost their regenerative capacity.

Since the colonial powers in India, most of the evergreen forests were managed under a selection system of silviculture, so that the evergreen character is retained. A rotation of approximately 30 years and a removal of 3-4 trees per hectare were prescribed in most working plans. However there are records, where the prescriptions, were forgotten and shorter rotations and greater intensity of extraction were practised (cf. Ayyar, 1932; Nair, 1961).

The constraints due to the lack of ample light can be eliminated through proper tending and cultural practices. In fact many working plans prescribe tending and cultural practices for improving natural regeneration, although these recomendations are not followed.

Apparently under the pressure of the great wars, many of the approacheable forest areas were heavily worked for selected species like Mesua, Calophyllum and Hopea. As a result mother trees were eliminated partially or completely that the composition of forests have changed completely. Precisely this was what happened in the Silent Valley National Park.

Working with the evergreen forests of the Palghat forest division, Ayyar (1932) distinguished eight distinct associations, viz.

1. Cullenia-Palaquium association
2. Palaquium-Mesua association
3. Poeciloneuron-Palaquium association
4. Mesua-Calophyllum association
5. Vateria-Cullenia association
6. Mesua-Cullenia association
7. Reed-Calophyllum association and
8. Reed-Poeciloneuron association

A team of Scientists from the Kerala Forest Research Institute, including the author, visited the National Park during the last November (1986). To their astonishment, at least some of these associations have been found modified significantly. A locality in the National Park is known as Punnamala commemorating the preponderance of Punna (the local name for Calophyllum) in the area. The area has been heavily worked, that, mother trees and all stages of regeneration of Calophyllum are extremely rare in the area, now. All the more, the area is very understocked, as the forests have undergone heavy degradation. Similar exploitation of selected species of softwoods were followed in recent times under the pressure of plywood, match wood and packing case industries. Because of the interference of the above factors, tending operations to improve natural regeneration are increasingly difficult.

Forest fire in the tropics is almost exclusively anthropogenic in origin (cf. Rollet, 1962). The distributed grasslands sandwitched between the sylvan evergreens are of general occurrence along the hill tops of the Western Ghats. Most authors regard them as secondary, being the result of periodic forest fire in the past. Colonisation and regeneration of evergreen species in these disturbed areas are not observed.

Intrinsic Constraints

Intrinsic constraints refers to the constraints involved in silvics (life history), phenology and the population structure of the species. Quantitative disharmonies between flower and fruit production, supra-annual periodicities in fruiting and seeding behaviour, genetic incompatibilities, absence of seed set and viable embryos, overpredation of seeds, maturation of seeds before the onset of congenial environment for germination, insufficient seed bank in the soil, poor adaptability of seedlings to establish, allelopathic and autotoxic relations, population structure, successional status of the vegetation etc. are some of the intrinsic constraints in the natural regeneration. There are a few examples from Kerala which are fairly interesting.

Cynometra travancorica Bedd. (Caesalpiniaceae) is a large tree of the evergreen forests of Kerala. The species is nowhere common, although distributed throughout the Western Ghats in Kerala. We were fortunate to locate a fairly good population of this species in the Pattikkad Hills (Machad Range) of the Trichur District. Flowering and fruiting specimens of the species could be collected in three subsequent years. But, interestingly enough, none of the fruits were fertile, owing to the absence of seed set. The single ovule inside the ovary fail to grow into the seed. And for this reason, the seed of the species is recorded as 'unknown' in many floras (for eg. Meenwen,1970). The exact reason for the absence of seed set could not be traced, as it requires intensive studies tracing the whole reproductive history of the species. In every possibility, absence of pollinator insects or some incomptibility mechanisms may be the reason. Perhaps the absence of seed set might be the reason why the frequency of occurrence of the species is too low.

However, in the above mentioned locality of the species, sapling and pole stage of the species are available. The saplings and poles indicate that the species had active regeneration in the same locality some 10-15 years ago. Two questions are quite obvious now. 1. Had there been enough seed set in the site some 10-15 years before? 2. Where the observed regeneration seed based or from the roots, as already known in the case of Blepharistemma membranifolia (Rhizophoraceae; unpublished observation) and Dalbergia latifolia Roxb. (Fabaceae)? These questions are yet to be answered, after indepth studies.

Another interesting example is that of a semievergreen species, Lagerstroemia microcarpa Wt. (Lythraceae). The timber of the species stands to teak in quality and is very much in demand in the market. The species inhabits both semievergreens and moist deciduous forests. Here again, seedlings and diameter classes below 30 cm are practically absent from most localities, in both semievergreens and moist deciduous forests. Interested by this observation we have been trying to find out the reason. We started examing from the seeds. Lots of seeds collected from various localities all proved to lack an embryo. However, the reason for the absence of an embryo could not be studied in detail.

The endemic species Vateria macrocarpa Gupta (Diptrocarpaceae) perhaps stands as an example for the allelopathic constriants in the evergreens. The species forms dominant association with Mesua nagassarium (Burm. f.) Kosterm. (Clusiaceae), Cullenia exarillata Roxb. (Bombacaceae) and Poeciloneuron indicum Bedd. (Clusiaceae). The sapotacean species Palaquium ellipticum (Dalz.) Baillon also forms dominant associations with the three species mentioned above. But, once Palaquium ellipticum is in the scene, Vateia macrocarpa is practically lacking (cf. Muhammed, 1967) or the percentage is very low, perhaps indicating an allelopathic relation.

Constraints due to the seed setting patterns are well exemplified by the mast seeding in Dipterocarps of South East Asia (Janzen, 1974, 1978). Whether similar patterns exist in the fruiting behaviour of trees along the Western Ghats (where the Dipterocarps sustain) are yet to be studied.

Scientific constraints

The scientific constraints are very pronounced in the natural regeneration of evergreen forests. Before the ecological significance of the tropical evergreens were properly understood they were valued primarily for the economically important species they composed. This economical interest promoted regeneration studies of some of the economically importnat species. However, the economically important species alone do not contribute the evergreen physiognomy for the forest. The evergreen ecosystem is a living homoeostatic 'organism' in which the economic and noneconomic species interact and keep a harmony. Therefore, regeneration of all the component species of the ecosystem are equally important.

In developing working models and sound management practices, a first hand knowledge of the system is a sine qua non. Most previous attempts have been aimed at inducing good regeneration of the economically important species but did not make any attempt to understand the patterns of regeneration presented by individual species and forest types. Perhaps the fault was due to the fact that plant demography - the technique of analysing the patterns of regeneration (cf. Harper, 1967, 1978; Harper & White, 1974) - and reproductive biology were only developing during this period. Furthermore, these subjects are still juvenile when the question pertains to the forest trees. As a result we know practically next to nothing on our indigenous trees.

Regeneration studies will be of applied value only if the constraints involved could be identified and optimum conditions for good natural regeneration could be found out. In many cases such detials can be obtained only through detailed autecological studies. Similarly, only prolonged studies will bring to light the supra annual periodic trends, if any, in regeneration.

Other serious constraints are of the methodology. For most ecological, demographic and regeneration studies, field identification of vegetative specimens is required. Even for a taxonomist with years of experience, this is a little difficult when generative organs are not available, flowering is irregular and seedling and sapling heteroblasty interfere. Diagnostic vegetative characters are yet to be identified and seedling floras are yet to come. Likewise, for seed banking studies identification of fruits and seeds is required, often in the dry, dehisced and degenerating state. Although palynological details are available for many tree species, a fruit and seed flora, giving hand lens descriptions of fruits and seeds is totally lacking for most geographic regions of the world and Kerala also falls in this category.

Serious difficulties exist in the information storage and retrival too (Andrew and Burley, 1976). The science of systematics and nomenclature although was originally intended as an administrative and information management science, it detracted from the objective significantly. Consequently, taxonomic treatments repeat the same field descriptions of the species year after year. There is no unified effort to bring all the taxonomic, morpologic, ecologic, physiologic, silvicultural and economic informations of individual species together in one place. These informations are scattered over the pages of various journals, books and working plans. For this reason, there exist some confusion in decision making in research as to what aspects are to be studied further. Having experienced with these difficulties, we are now planning to build up a computer database on some 100 important indigenous tree species, as an initial step, with the help of the 'd' base' program and a synoptic language as used by the taxonomists.

Conclusions

The problems encountered in the natural regeneration in the wet evergreen forests of Kerala as described above are of the same kind as generalised by Dr Fox, for the whole of tropics.

Of these, anthropic constraints alone is the most pronounced. Proper tending and cultural and gap regeneration methods were practised in the past, which were given up later. Scientific constriants are also second to nothing in developing suitable management practices. Intensive studies on the regeneration pattern of individual species and forest types and developing improvement strategies based on scientific studies both of the economically important and other species are urgent needs.

Acknowledgements

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Summary of discussions following presentation

Dr N. Ishwaran: What, in your opinion is the usefulness of taxonomic studies in selecting species for regeneration?

Dr K. Swarupanandan: Observations in respect of the absence of certain size-classes, fruiting and seeding behaviour could be useful in this regard.

Dr T. Jayasingham: Have you identified any definite cases of allelopathy,

Dr K. Swarupanandan: There some cases but in all such cases the hypothesis needs to be tested.

THE SAKAERAT BIOSPHERE RESERVE (SERS)

CHOOB KHEMNARK *

Historical and General

An examination of 1953 aerial photographs of the SERS area showed a good stand of extensive forest with very little disturbed by human intervention. Such a condition did not remain stable and was evident to all, when the SERS was established in September 1967 by the Applied Scientific Research Corporation of Thailand (presently the Thailand Institute of Scientific and Technological Research) upon cabinet approval. Forest land for the station was donated, on a long-term loan basis, as a forest reserve for scientific purposes by the Forestry Department, Ministry of Agriculture and Cooperatives.

Geographically, SERS is located on the eastern face of Khao Phu Laung hill which rims the Khgrat Plateau. Its coordinates are approximately 14° 30' N. and 101° 55' E. and lies along-side highway 304 which connects Changwat Nakorn Ratchasima with Changwat Chachoengsao. It is about 60 Kilometers south of Changwat Nakorn Ratchasima and some 300 kilometers from Bangkok, access being either by highway 304or by Route 2 (Friendship Highway), thus placing the SERS within the administrative jurisdiction of Tambon Sakaerat, Amphoe Pak Thong Chai, Changwat Nakorn Ratchasima.

The approximate area of 74.58 square kilometers (in 1979 a survey to establish permanent boundaries of the SERS caused the area to increase to 81.0470 square kilometers), in general, has mountainous morphology, from the cuesta-like highlands, a broad, flat, slightly to moderately dissected surface slopes gently northeastward into an alluviated valley.

Khao Khliat (elevation 762 meters) and Khao Khieo (elevation 729 meters) dominate the upper area. Slopes are common between 10 to 30 percent, with many upper slope areas between 30 to 45 percent or over. The steepest slopes are in the south-west region and a nearly vertical escarpment forms the boundary with highway 304. The small areas of nearly flat to gently rolling plains are in the northeast.

The climate of the SERS area is tropical with no occurrence of frost. The winters are cool and dry while the summers are hot and humid. Annual rainfall averages 1222 mm. and the wet seasons occur from mid May to September. Rainfall is rare in December and February and the dry season occurs from November to April.

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Annual mean relative humidity is 75 percent and annual mean air temperature is 26°C. with a monthly mean deviation of about 2°C. March is the warmest month; maximum high 37°C. and January is the coolest month, maximum low 8°C.

Streams are intermittent, but water persists locally throughout the dry seasons. The major streams draining the SERS area flows gently north-east from headwaters near or at the lip of the euesta to the south-west of Ban Pin Fon Meed.

In the 30 square kilometers area centered on the forest tower in the core area there are two major trunk stream systems, those of Huai Nam Khem and Huai Pae. Only Huai Nam Khem can be considered a perennially flowing stream. Huai Wanasart and Puai Nong Yang are spring-fed and flows year-round, with Puai Yang providing year-round water supply to the SERS living quarters.

Bedrock is exposed only along streams and at the escarpments bounding the SERS on the south-east, elsewhere there is heavy soil and vegetation cover. The entire area appears to be underlain with sandstone of the Phra Wihan formation of the Khorat group. Up to the present time, no mineral deposits of economic importance has been found, except lateritic soils suitable for foundations in road construction.

Legally the SEPS belongs to the Royal Forest Department, however, an official letter of agreement (dated 27 December, 1973) allowed the existence and continuation of the station as a dwelling for studies and ecological research under the joint guidance and management of the National Research Council and the Thailand Institute of Scientific and Technological Research (NRC and TISTP).

In the initial stages of undertaking,the SERS was supported by grant-in-aid form the United States of America's advance research institutes totalling some 30 million dollars. However, U.S. government assistance was discontinued in 1972 and the SEPS suffered from the lack of operational funds. It was on May 15, 1974 that the cabinet approved the continuation of funding and management of the SERS for ecological and environmental research, which culminated with the SERS being accepted as one of UNESCO's international network of biosphere reserves.

Natural Vegetation Types

Two major natural vegetation types, which once covered the whole area, are dry-evergreen forest and dry dipterocarp forest.

The majority of vegetation is dense dry-evergreenforest, except for the north and northeast sections of the SERS where an open dry-dipterocarp forest occurs.

The boundary between these two forest types is sharp and can be easily determined through interpretation of aerial photographs of the SERS. Narrow strips of mixed deciduous vegetation are found in the transitional band between the dry-evergreen and dry-dipterocarp forests, especially in the north-east section of the SERS area.

The Dry-Evergreen Forest: is considered an intermediate between tropical rain forest or moist evergreen forest and mixed deciduous forest. The dry-evergreen forest of the SERS has a dense, vine tangled, four-storey canopy. The forest profile is normally composed of trees of small to medium size with straight stems, divided as follows:

The Upper Storey, is 21-40 meters high and consists of dominant species, such as, takian hin (Hopea ferrea), takian hin (Hopea odorata), chan (Shorea sericeiflora), and kabok (Irvingia malayana).

The middle Storey, is 15 - 20 meters high and consits of dominant species, such as, kabao klak (Hydnocarpus ilicifolius), Phlong (Memecylon obatum) and kat lin (Walsura trichostemon)

The Lower Storey is 4 - 14 meters high and consists of dominant species, such as, ma fai (Baccaures sapida), mak fak dong (Apodytes dimidiata), and sanan (Olea salicifolia).

The undergrowth is less than 4 meters high and, mainly, consists of seedlings and leafy shrubs belonging to the genera Ardisia, Canthium, and Clausena.

This dry-evergreen forest occupies, extensively, the south-west section around Khao Khiet, Khao Khieo, and Khao Ma Kha stretching northeastward along the northern boundary to Khao Hin Kerng, also along the south-east section parallel to highway 304. Small areas are scattered in the nearly flat area from Khao Hin Fon Meed northeastward to Khao Hin Kerng surrounded by grassland.

Several pockets of bamboo are found in the dry-evergreen forest in the higher elevations of Khao Khieo and Khao Khiet where relative humidity is quite high. Mak pa (Areca spp.) are also found scattered throughout the area and, in addition, various lichens are also found on the rock out-crops.

The Dry-Dipterocarp Forest; of the SERS occupies the rolling hills of exposed nature, where sandstone boulders are predominant. The soil being similar to that subtending the mixed deciduous forest, but laterites is more predominant. This type of vegetation dominates the northeast section of the SERS area.

The dry dipterocarp forests are open, generally, consisting of uniformly spaced trees forming a three-storey canopy, with sparse foliage allowing the sun's rays to reach the ground.

The Upper Storey, is 21 - 35 meters high, the dominant species in this stratum includes teng (Shorea obtusa), rang (Pentacme suavis), Krat (Dipterocarpus intricatus), and phluang (Dipterocarpus tuberculatus)

The Middle Storey, is 11 - 20 meters high, the dominant species in this stratum includes ko phae (Quercus kerrii), kham mok luang (Gardenia sootepensis), kham mok noi (Gardenia obtusifolia), and nam thaeng (Randia tomentosa).

The Ground Cover is normally covered with seedlings and grass which frequently includes ya phek (Arundinaria pusilla) and ya kha (Imperata cylindrica).

During the primary stages of growth the trees are usually stunted because of ground fires which occurs annually. The average tree height is 7 meters, individual trees varying and boles, may be upright or twisted into irregular knotty masses. The bark is thick and deeply furrowed, with leaves leathery and large.

Disturbed Areas

Grassland; in the SERS area is the result of shifting cultivation. Typically, after one or two crops, the fields are left fallow for three to four years while new sites are cleared and utilized. These fallow areas subsequently develop into formidable grassland.

These grasslands of 1-2 meters height consists primarily of cogon or ya kha (Imperata cylindrica) and ya phong (Saccharum spontanaum). Once established, these species of grass destroy all possibilities for obtaining a reasonable crop yield from low technology and inputs of small farmers, because the grass would shoot up faster than poorly husbanded cash crops, thus choking out the crops such as maize.

Shifting Cultivation; was principally practiced on the upland areas of the broad rolling plains in the interior of the SERS area and continuing on to the alluviated valley in the north-east.

Under this discontinuous cropping system, forests of the SERS are cleared and burned during the dry seasons. Cultivation is carried out on this land for a few years or until soil fertility is low. Then, the land is supposedly allowed to fallow for a considerable period before the vegetation might again be cleared and burned, however, no evidence of this practice is available.

This shifting cultivation is restricted to the wet seasons, and comprised maize and cassava crops. Such rain-fed cultivation also includes subsistence-type agriculture for vegetables, rice, and fruit crops. Dry-season crops are restricted to the hardier crops, such as banana, castor bean, kapok and mango.

Forest Products Exploitation; the SERS area may be divided into three categories according to the most important uses, within them.

Firewood and Charcoal, principally in response to household energy demands in the immediate vicinity of the SERS and in the adjacent provincial communities. The charcoal is produced in permanent type kilns in the north-east section of the SERS, and smuggled out during the night, while firewood, as found in most of the dwellings, is selected from deteriorated wood.

Commercial demands generated in cities and towns by wide spread ferro-cement construction induced the illegal felling of salable trees in the SERS, with 70 logs of mai pla lai found in the north-west section adjacent to the Nakhon Ratchasima Timber Company's forest concession in 1972.

Dwellings, were scattered throughout the SERS and usually located near small springs or streams. Single dwellings and small clustors were scattered within the area. These dwellings were constructed of rough wooden frames with thatch or wooden walls and thatch roof. The living area being elevated on stilts to allow the use of the ground level as animal stalls and for storage. Local Housing, incorporates about five to ten timber posts, while sawn timber found in the SERS was destined to be smuggled out and sold in nearby villages.

The Administrative Orgnaization of the SERS

In 1972 the cabinet instituted the SERS as a sub-division of the National Research Council (NRC) with the NRC assigning the Applied Scientific Research Corporation of Thailand (ASRCT)... which in 1979 became the Thailand Institute of Scientific and Technological Research (TISTR) ...the task of day-to-day administration of the station.

TISTR, although administering the station with full legal authorization from the NRC actually relies upon NRC fiscal support and direction from two forms of hierachial authority, namely the Sakaerat Environmental Research Committee and the TISTR.

The Sakaerat Environmental Research Committee; consists of the representatives of the universities and governmental agencies related to forest protection and conservation, totalling a maximum of fifteen persons, with the NRC Secretary-General, a member of the committee, presiding. The Secretary of this committee is a Deputy Secretary-General for Natural Science attached to the NRC.

This committee has the following functions:

(a) controls the operational administration of the SERS along avenues designed to encourage ecological and environmental research;

(b) collects the information and data generated by research in the SERS as relates to the tropical forest environment and ecology;

(c) coordinates and cooperates with local, regional, and international organizations interested in the tropical forest environment and ecology;

(d) supplies the guidelines for the programmes to study and moniter data related to the environment and ecology of this tropical forest;

(e) carries out exchanges of and distributes the results of tropical forest environment and ecology studies and data with/to mutually interested local, regional and international official institutes, organizations, and agencies.

The NRC and TISTR, jointly, supply and maintain the personnel for the day-to-day administration of the SERS. The head of the station and assistants, totalling five persons, are financially sustained by the TISTR and are charged with administrative and control duties of the SERS, they are assisted by 40 patrol and general work employees who are financially sustained by the NRC, and together form the personnel of the SERS.

In addition to the committee and the personnel mentioned the NRC has refined the tasks of the SERS through the appointment of two sub-committees, namely;

(a) the sub-committee for research fund allocation, consisting of five experts in different fields of tropical forest environment and ecology research; and

(b) the sub-committee for monitoring, studying, defining and solving the problems of illegal deforestation in the area which is under the responsibility of the SERS, consisting of 15 persons within the immediate administrative divisions responsible for forest protection and preservation and presided over by the head of the SERS and assisted by a representative of the NRC acting as the Secretary.

Because the immediate personnel of the SERS are not empowered under the Criminal Procedure Code or the Forest Act or the Forest Reserve Act they, therefore, have no power of arrest. Thus, the SERS has been provided with two competent officials, empowered with the power of arrest, from the Forest Police Division, as Joining Officials.

Land Use : Land use within the SERS has changed over the years, even with changes to the exact boundaries of the Biosphere Reserve (due to actual Land Boundary demarkation). Thus, based upon the 1953, 1964 and 1975 surveys of 74.58 square kilometers being 100 percent, there was a dramatic change, due mostly to swidden agricultural expansion into the dry evergreen forest area, respectively 1.295 sq.km. (1.72 percent); 12.193 sq.k.m. (16.35 percent); and 34.6838 sq.km. (46.51 percent) ... with the 1978 boundaries giving the SERS a new total area of 81.0470 sq. km. (100 percent) the total swidden agricultural area increased to 37.8702 sq.km. (46.73 percent)

It should be noted that the dry evergreen forest area (DEF) was most susceptible to land use pressure and changes or was the most attractive to swidden farmers intent upon soils suitable for maize cultivation, thus, reducing the DEF area from 58.2021 sq.km. in 1953 to only 29.1746 sq.km. in 1975. At the same time the dry dipterocarp forest area (DDF) also became an attractive swidden area for farmers attracted to the simplicity of cultivation and good net returns of cassava, thus reducing the DDF area from 13.6544 sq.km. in 1953 to only 9.1556 sq.km. in 1975.

Due to changes inadvertantly allowed by the government in 1975 and the weak points inherent in the various legal powers applicable to the conservation and preservation of the SERS as a Biosphere Reserve the 1965 Land Use map of the site will yield the following figures, for the various land use categories: built-up land used for SERS housing and officers (0.0050 sq.km.); forest land (41.7600 sq.km.); bamboo forest (1.4168 sq.km.); and swidden agricultural area (37.8702 sq.km.) for a total of 81.0470 sq.km.

When the more heavily forested areas were denuded and put to the plough under maize, sorghum, soyabeans, cotton, and other cash-crops the immediate annual net direct economic returns appeared to be popular and politically acceptable.

However, as the immediate annual net direct economic returns gradually accelerated, the percentage of Thailand's natural timber forests decreased (as verified from aerial photographs, photo-interpretation of ERTS satellite transmissions, and on the spot surveys) to alarming proportions. But, the difficulaties related to the abatement programme of the Royal Forest Department had to be tempered and balanced by national socio-economic needs, a short-fall of alternatives the local and international political atmosphere, and the rising expectations for a materially better way of life.

Fully realizing that a nation-wide conservation programme was not a pragmatic approach, therefore, the development of pockets of strictly enforced forest preservation and conservation was undertaken with the SERS being the smallest pocket of natural forest.. and luckily as well as wisely... it contained two typical and valuable foprest types: the dry-evergreen and dry dipterocarp forests.

It is easy to under-estimate the real value or the attempt at a direct (and immediate economic evaluation of the SERS. However, the SERS provides a unique opportunity to learn of the natural flora association necessary for the establishment of timber species of direct and indirect value to the growth of dry evergreen and dry dipterocarp forests re-established as cultivated and husbanded tree farms for household construction materials, household heating and cooking fuel, control of water and wind erosion of top-soil, increase percolation of rain-water into the sub-surface reservoirs, enhance normalization of micro-climate patterns, and increase the esthetical value of the country-side.

The SERS also offers the opportunity to witness evolutionary changes in flora as different species develop hybrid variation which could be well adapted, genetically, to the new environmental and ecological conditions.

Thus, the compilation of a comprehensive view of the many facets of the SERS has been attempted, based upon the natural type of land use, namely as the two recognizable and dominant forest types: the dry evergreen and dry dipterocarp forests.

Both types of forest are viewed as separate models, in order to simplify understanding and transfer to developmental and economic planning at local, national, regional, and other levels. The first emphasis would, however, be upon comprehending the intricate network which forms the basis of the SERS, as a national and an international Biosphere Reserve. The second emphasis would seek to convert whatever comprehension available into supporting the experimentation with a Japanese assisted programme in mechanized reafforestation within the abandoned swidden areas of the SERS. The third and final emphasis, would be to monitor the SERS as the control area which would be compared with the pilot mechanical reafforestation programme and with other programmes initiated by the Royal Forest Department.

The Sakaerat Biosphere Reserve received highest interest and attention by the Thai Government and UNESCO/MAB including natural and social scientists from Thailand and abroad. Many research results in different disciplines are published and distributed. The most outstanding integrated pilot project is entitled "The Sakaerat Environmental Research Station". Its Role as a knowledge Base for the Determination of Forest Lands Conservation Policies for Establishing Maximum Sustained Yields on Forest Resources" received high interest. The results of this research project was also synthesized and edited into Thai version for ease of understanding by Thai students and lay persons with the new title "Forest Resources and Social Development : Lessons from Sakaerat".

The SERS also renders service as an ideal site for many seminars, workshops, training courses at a local and regional levels which can accommodate about 40 people.

The protection of this biosphere reserve received partial financial support from UNESCO/MAB at its beginning. The Thai Government arranges for administrative and supporting staff and financial support to make the conservation of the SERS possible. Research grants are regularly provided to promote the activities of the SERS until most of the important research aspects were carried out. However, without the catalytic money and moral support of UNESCO/MAB some of the projects would probably not have taken place because the Thai Government may not recognize the necessity and needs of some research projects.The striking advantage of the catalytic research grant from UNESCO/MAB or external assistance is to stimulate and enhance the Government to offer better cooperation and support to local scientists.

The SERS is also an ideal site for ecological study by students and scientists. Many students from schools, colleges, and universities have used SERS biosphere reserve as one of their field laboratories and for recreation as well. The Thai-Japanese Reafforestation Training Center selected SERS as its training site and help the SERS to establish forest plantation in the abandoned areas left over by shifting cultivation. This activity makes the SERS looks lively.

~~This activity makes the~~

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Summary of discussions following presentation:

Dr N. Ishwaran: What kind of benefits local people have through resources available in the reserve?

Mr Choob Khemnark: Chiefly through medicinal plants. Several chemical studies have identified substances such as alkaloids which would soon be used for preparing/manufacturing medicinal compounds locally. Several species of crustaceans in the streams of the reserve are foods to local people. In general using lateritic bricks for housing construction has minimised the reliance on timber.

Dr Mathew George: Because of the towers you have built within the reserve is the reserve well connected with the outside?

Mr Choob Khemnark: Towers are mainly used for data collection and monitoring though it could help in other purposes such as radio-communication and patrolling. Helicopters are sometimes used for patrolling the area.

Prof. R.N. de Fonseka: Do most workmen live within the reserve and is this arrangement satisfactory?

Mr Choob Khemnark: Yes. It helps in a variety of management and administrative functions.

Dr(Mrs.) K. Abeynayake: Do most of the disturbances in the reserve confined to the buffer zone?

Mr Choob Khemnark: Yes, they are.

FORESTRY RESOURCE SITUATION IN PAKISTAN

MIRZA M. ASHRAF*

Pakistan has been blessed with invaluable renewable natural resources including a rather limited forestry heritage. Forestry resource of the country is strongly influenced by its characteristic history which dates back over many centuries in the past as the country was situated on the route of migration and invasions of different races. The destruction of the forests remained unchecked as the resource had to bear inevitable pressure due to rapid increase of settlers and their livestock. Scientific management of of the forests was, however, started just over a century ago, laying greater emphasis on conservation, which again was upset during First and Second World Wars. At the time of independence in 1947, the forests were already exploited to the maximum.

Pakistan is a forest poor country. Only 4.29 million ha. or 4.8% of its land mass is covered with forests. Besides there are 1.5 million hectares of land under private forests called 'Guzara' or 'Community Forests'. This compares unfavourably with several other countries of the region; Malaysia 64.5%, Sri Lanka 42.4%, India 23.7%, China 17.7% and Bangladesh 15.3%. The per capita forest area is merely 0.05 ha. as compared with the world average of 1 ha. A break down of the forest area under different types in the country including Azad Kashmir is given as under:-

VEGETATION TYPE	AREA (IN MILLION HECTARE	PERCENT OF THE TOTAL
Conifers	1.78	41.4
Irrigated plantations	0.19	4.5
Riverian	0.29	6.8
Scrub	1.72	40.0
Coastal	0.28	6.6
Others	0.03	0.7
	4.29	100.0

The forests in Pakistan produce both the softwood and hardwood timber. The production of conifer timber is slightly more than half of the total production of timber in the country. About 5 thousand tons of crude resin is annually obtained by tapping the Chirpine Forests in the hilly areas which is further refined to produce rosin and terpentine. The production of timber and firewood in the country including Azad Kashmir is as under:-

* : Director, Forestry & Environment, Pakistan Agricultural Research Council, Islamabad.

SOURCE	TIMBER ($000\ m^3$)	FIREWOOD ($000\ m^3$)
State Forests	384	600
Farmlands	678	15000
TOTAL:	1062	15600

Because of low forest area and wood production, the per capita consumption of wood is low. It is estimated to be only 0.024 m^3 of timber and 0.2 m^3 of fuelwood per annum. Further, on the basis of the above estimates, 60 percent of timber requirements and 90 percent of fuelwood needs are met from tree growth on farmlands and wastelands. Due to shortage of indigenous wood resources, substitute materials are being increasingly used in place of wood in many sectors of economy, e.g., Construction industry. In addition, almost Rs. 1300 million is spent annually on import of wood and wood products.

There are a number of factors responsible for this state of affairs. Firstly, Pakistan inherited a very small forest area at the time of Independence. Secondly, most of the land area in Pakistan is arid and receives low precipitaion on which natural tree growth is not possible without artificial irrigation. Further, in view of importance of agriculture, forestry development was given low priority despite the fact that population has increased three-fold with simultaneous rise in living standard of the people during this period. The demand for wood and wood products enhanced as a result of these factors. Only sporadic efforts were made on a small level in selected areas to increase tree growth and wood production.

Lack of awareness for importance of forests in the agricultural economy has also been responsible for forest devastation and low priority given to the development of this resource. Allocation of funds and investment in forestry sub-sector have been minimal. Therefore, regeneration, afforestation, opening up, road building and harvesting operations could be carried out on a small area only. The utilization of available resource is highly unscientific and wasteful. In spite of the fact that wood is scarce and expensive most of the wood is used in solid form and its considerable quantity is wasted during various processing operations to manufacture different products. There are only few manufacturing units in the country for particle board, plywood, fibre-board, etc. and none for making pulp and paper from woody raw material. All newsprint and long-fibre pulp is imported. Most of the energy of about 18 million m^3 of wood, which is consumed annually as fuel by majority of people in urban and rural areas, is wasted as efficiency of cooking stoves is hardly 15 to 20 percent.

The major type of forests in Pakistan is the coniferous. These are dry or moist temperate forests occuring at an elevation of 1500-3000 m above sea level and mainly consisting of species such as fir, spruce, deodar, blue pine and chirpine together with broad

-leaved associates viz. maple, walnut, horse chestnut, bird cherry, oak, poplar etc. They cover 1.78 million ha and account for 41.4% of the total forest area. They are the main source of constructional timber in the country. However, their vital importance lies in their services towards conservation of soil and water resources of the country, control of floods, prevention of siltation of dams and water reservoirs, cleaning of air pollution and promoting of recreational facilities. More than 55% are maintained just for their protection services. According to ownership status, 61% are state owned and the rest 30% private.

Scrub forests are the broad-leaved evergreen type elevation 500-1500 m, mainly consisting of olive phulai and associates. They occupy about 1.72 million ha. They,supply some fuel to the local population and grazing to the animals. They are rendering invaluable services to control soil erosion and maintaining productivity of agricultual lands in the plains. More than 90% of the area of scrub forests consists of protection forests. About 47% of the scrub forests area is privately owned.

The desert vegetation comprises of the dry tropical arid and semi arid zones receiving an average annual precipitation of 150-200 mm. and cover 33.29 m. ha. The pre-dominant natural species are Prosopis specigera (Jand), Acacia nilotica, Acacia senegal, Tamarix articulata, (Farash), Salvadora eleoides (Peelu) Prosopis juliflora (Mesquite) and Tecoma undulata (Lahura). This vegetation has been and continues to provide vast grazing ground for livestock of the people who have a nomadic way of life. Traditionally this desert scrub has been the source of energy needs of the people through centuries and inevitably therefore, stands impoverished.

The riverain forests occur between protective embankments and the banks of the Indus and its tributaries. The pre-dominat species are: Acacia nilotica, Tamarix, Populus euphratica and Prosopis specigera. They cover about 0.29 million ha. and occur mainly in Sind and Pubjab. They are the source of mining timber and fuelwood. The area is entirely state owned and is mostly productive.

Another type is the state owned irrigated plantations. These are man made forests having been grown after clearing the vast tropical thorn forests in areas where canal water could be made available. The irrigated forest plantations are spread over the plains of Pakistan and cover an area of nearly 0.19 million ha. These plantations are being managed for timber, for furniture and sports goods industry. The main species grown in these plantations are Dalbergia sissoo (Shisham) and Morus alba (Mulberry) in the Punjab, and Acacia nilotica (Babul) and eucalypts, in Sind. Salmalia malabarica (Semal) and Melia azedrach(Bakain) are also planted. Recently, planting of fast growing species like hybrid poplar and eucalypts has been started to produce wood for the pulp and fibreboard industries. With improved management practices and proper inputs, these plantations are expected to become an important source of high quality timber supplies.

Mangrove forests in the Indus Delta on the coast of Arabian Sea are categorised as coastal forests and cover an area of 0.28 m. ha. The main species found here include Avicennia officinalis (95%), Ceripos tagal(4%) and Bruguiera conjugata(1%). These are mainly protective forests, which are a good source of fodder for the livestock and fuel for the people living around the coast, mostly dependent on fish industry. A combination of biotic factors such as grazing and removal of fuelwood have adversely affected the mangroves. Natural regeneration and growth of mangroves has been further adversely affected by the decreasing availability of sweet water from the river Indus, eversince a chain of barrages have been built upstream diverting the water to irrigation system. The economic value of these forests cannot be under estimated as they also provide an environment or habitat for fish and prawns, apart from providing shelter to a variety of acquatic fauna.

A variety of insect pests inflict a heavy damage on the forestry resource. Cockhafers and cutworms damage the nurseries while large trees of Dalbergia sissoo are defoliated by Plecoptera reflexa. Recently there was a heavy attack of defoliation on Pinus wallichiana by a newly discovered defoliator Biston regalis. Poplars have found many enemies in the form of a defoliator, and stem borers. Powderpost beetles cause damage to firewood and timber. Termites cause damage to timber used in building construction. Fruits of chalgoza (Pinus gerardiana) and walnut (Juglans regia) are destroyed by chalgoza cone borer and walnut weevil respectively. Cultural, biological and chemical control of most of these insect pests have been developed over a period of time and are being implemented for the protection of forests and forest produce all over the country.

Many diseases kill trees, reduce their growth rate and cause decay in standing timber or make it defective. Pythium spp. is generally serious in the coniferous nurseries. Ganoderma lucidum is a destructive root parasite of Dalbergia sissoo. Fomes pini cause red ring rot in Pinus wallichiana resulting in 15-20% loss in wood. Mistletoes has caused considerable damage to Juniperus excelsa and Pinus wallichiana in the dry and moist temperate forests.

The northern mountain areas of Pakistan constitute the major portion of the watershed of the important Indus and Jhelum river systems of the country. The quantity and quality of water coming from the watersheds is, of great importance to the national economy. Two major water reservoirs have been built - one at Tarbela on Indus and the other at Mangla on Jhelum. Sediment load coming from the watersheds threatens to shorten the useful life span of these reservoirs. The land in watershed is mainly in private ownership. Wooded areas are interspersed with agricultural fields and often very steep slopes are cultivated. The firewood demands on the natural vegetation are heavy. The grazing pressure on this vegetation is also heavy. Consequently, the vegetation has been disappearing resulting in barren hills. The denuded watersheds produce flash floods resulting in accelerated erosion and sedimentation. A large number of afforestation and reforestation projects have been taken in hand and the watersheds are being progressively rehabilitated with vegetative cover.

Out of 88 million ha. of the land mass of the country about 60 million ha. can be taken as range lands of which about 20 million ha. are used partially, being under cultivation. The range land distribution among various Provinces is given as under:-

PROVINCE	TOTAL AREA	RANGE LANDS	PERCENTAGE
	M. ha.	M. Ha	
Baluchistan	34.72	32.41	93
Sind	14.09	9.26	66
Punjab	20.63	9.70	47
N.W.F.P.	10.11	5.67	56
Azad Kashmir	1.16	0.20	17
Nothern Areas	7.04	2.10	30
TOTAL:	87.75	59.34	66

The range lands by and large are under private ownership except about 6 million ha. which are controlled by the Forestry Departments in the provinces. From time immemorial, the range lands are being used for uncontrolled and unrestricted grazing by the ever increasing number of livestock. The livestock population within the past 10 yrs. has gone up from 70 million heads to 87 million heads. The current productivity of range land varies from 10 to 50% of their potential. High potential rangelands are well represented in the north and north-western region of Pakistan and the extensive semi-desert/desert ranges are found in the provinces of Punjab, Sind and Baluchistan. Efforts are being made to improve and preserve the productivity of these range lands through proper scientific management techniques.

Pakistan Forest Institute at Peshawar is the only organization in the country responsible for research in the field of forestry and allied subjects and professional and technical education in these fields. Research programmes are drawn up by a Research Review Committee consisting of heads or executives of the Forest Departments in the Provinces and experts from allied fields. This is done after thorough identification of the problems in the field and the priorities they merit. The research programme covers a very vast field of problem-oriented studies ranging from nursery to field planting techniques and management in the disciplines of forestry, range management, watershed, wildlife and protection and preservation of wildland reserves.

Regular forest management has been practised for over one century in government lands only. Foresters thus do not have any scope of employment other than the government forest departments. Education in forestry has, therefore, remained confined to training of individuals selected by the provincial governments. Consequently, two courses meant to train Forest Rangers (technical level) and Forest Officers (Professional level) have been running eversince the establishment of the Institute.

In order to accommodate recent advances in the science, the curricula are periodically updated to keep those comparable with universities in foreign countries. Affiliation with the University of Peshawar for the purpose of examinations was secured in 1958. The two courses now lead to the award of degrees of B. Sc. and M. Sc in Forestry respectively. So far, the Insitute has trained 1009 forest officers out of which 45 came from countries such as Bangladesh, Ethiopia, Iraq, Nepal, Somalia, South Yemen, Sudan and the Syria.

In addition to regular courses, 2 year courses of Logging Engineering and Wood Utilization, Watershed Management and Research are also in progress. Short-term refresher courses on special subjects are also held at regular intervals for the serving foresters to acquaint them with the latest findings in forestry and allied disciplines.

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Summary of discussion following presentation

Dr A.K.M. Nazrul Islam: You mentioned at least two man-made reservoirs. Are there any problems in these reservoirs which could be attributed to poor land-use practices in the catchment?

Mr Mirza M. Ashraf: The main problem is sediments coming in from upper catchments which increase the threat of siltation.

THE ECOLOGY OF SUNDARBAN MANGROVE FOREST

A.K.M. NAZRUL-ISLAM

Introduction

The Sundarban is a tropical humid forest that stretches Raimangal river on the west and Baleswar river on the east. In addition it also extends upto the Hoogly river (India), and covers the southern part of the District 24 Parganas. In Bangladesh, this mangrove forest spreads in the southern parts of the Khulna District. This is a low lying delta and is the world's largest single tract tidal mangrove forest. The area lies approximately between 21.30' and 22.30' N latitudes and 89^{o} and 90^{o} E longitudes.

This forest extends over the Gangetic delta, which is low, flat and alluvial. The forest is intersected from north to south by several rivers (½ to 1 mile wide); and many creeks. The water in these rivers and creeks is saline. The humid forest which grows in such delta is known as "mangrove swamps'. the total area of this forest in Bangladesh is 14,5895 acres (including water ways) on the flat and muddy shores of the Bay of Bengal. Total forested land area consitutes 10,0606 acres; out of these only 3050 acres are classified as unexploitable immature stands (Choudhury 1962). The main reivers of this forest which fall into the estuaries are Passur, Sela, Sibsa, Arpangassia, Malancha and Jamuna. The topgraphy of this forest including rivers and the environment has been discussed elsewhere (Nazrul-Islam, 1982, 1983). All these rivers are tidal in nature and have in general north-south course towards the Bay of Bengal. The difference in the water levels between high and ebb tides varies from 1 foot to 16 feet depending upon the phase of the moon.

There are a number of estuarine lands from east to west and these are Katka, Dubla, Passur, Tinkona. Large number of islands in the estuaries are still under formation.

Some ecological conditions including edaphic features of this forest are described elsewhere (Nazrul-Islam, 1982, 1985, 1986). The soils of this forest are generally clay-loam in nature and grey to greyish brown in colour. Sandy soils are found on islands facing the Bay. The present paper describes in general the ecological conditions of water and soil of this forest including the dominant plants in the various zones.

The soil and water samples from selected sites in different seasons were collected and analysed for Na, K, Ca, Mg, salinity and pH. Exchangeable elements Na, K, Ca and Mg from soil were extracted (ammonium acetate) as described by Nazrul-Islam (1978). Na and K were analysed by flame photometer; Ca and Mg by atomic absorption spectrophotometer. Total alkalinity and chloride in water samples were analysed according to the standard methods of APHA (1977).

Results and Discussion

The rivers of Sundarban forest are subject to tidal influence from the Bay, as a result the forest floor is flooded. Therefore, it was necessary to study the water characteristics of the Bay (Table 1). The result shows that, pH and total alkalinity values ranged from 25,000 to 40,000 µs/cm.

Table 1: Analysis of water samples of the Bay of Bengal (Nazrul-Islam 1985). Collected in February, 1982

Location Latitude N	Location Longitude E	pH	EC micromhos/cm	Chloride (mg/l)	Total alkalinity (mg/l)	DO (mg/l)	COD	Turbidity JTU
Karnafuli river		7.9	2000	496.5	140	5.9	80	130
Estuary		8.0	24000	10980	190	6.4	45	355
21° 56'	91°40'	8.1	25000	10425	250	5.8	46	25
21° 12'	90°15'	8.1	36000	14592	260	5.8	41	25
21° 41'	91°37'	8.2	24000	9926	220	5.6	42	25
21° 13'	89°46'	8.0	40000	16478	210	6.0	40	25
21° 25'	91°15'	8.0	25500	11319	210	5.8	40	25
21° 32'	91°31'	8.1	28000	11210	160	6.0	40	25

Soil physical analysis shows that the soils of the forest are rich in silt followed by clay. (Table 2).

Table 2: Physical Analysis of Soil (Values are in %)

Location	pH	Organic matter	Carbonates	Coarse sand	Fine sand	Silt	Clay
Sharankhola	6.7	7.5	14.3	8.5	12.5	35.3	25.0
Chandpai	6.9	6.8	16.2	6.3	14.2	32.5	23.5
Nalianala	7.0	6.5	12.5	5.5	12.0	19.5	29.5
Satkhira	7.0	6.5	11.6	5.0	11.0	26.2	34.2

In the western part of the forest, ie in Satkhira Range, the percentage of clay is comparatively higher than the other Ranges. Carbonates and organic matter are usually high in the island soils. Accumulation of leaf litter of the plants falling on the forest floor may be the reason for high organic matter (Nazrul-Islam 1982).

Periodicity in conductivity and chloride (mg/L) particularly in late winter was also noted. In Rupsha river (in Khulna) conductivity (4800 µs/cm) and chloride (1800 mg/L) values were in the month of April. These values are 15 and 5 times higher than those of other months respectively. This is probably due to less discharge of fresh water from upstream. Heritiera fomes (Sundri) seedlings show vigorous regeneration even at the Bay side in the eastern part of the forest. The seedlings find difficult to establish as a dominant vegetation due to lack of soil moisture in winter periods. It should be mentioned that, Gorai river, a distributary of the mighty river Ganges, is the only source of fresh water supply in the eastern part of the forest. During late winter, as a result of diversion of water by the Farakka Barrage the soil remains dry and therefore, the sundri seedlings die. It was noted that the roots of sundri seedlings are shallow. In contrast, Excoecaria agallocha (Gewa) seedlings with their deep root system can withstand such drought condition.

Table 3: Seasonal Variation of Soil Moisture (in%)

Location	1984-1985			
	July	November	January	April
Sharankhola	30.3	24.6	23.1	25.6
Chandpai	24.7	23.2	25.9	24.2
Nalianala	26.4	23.2	23.4	24.0
Satkhira	26.4	19.5	23.1	22.4

Table 4: Variation of Soil Nutrients (ug/g) from Different Sites

Zone	Location	Range	Na	K	Ca	Mg
Oligohaline	Dangmari	Chandpai	1270	59.5	2675	850
Oligohaline	Sharankhola	Sharankhola	750	65.4	3050	930
Mesohaline	Nalianala	Nalianala	1825	45.0	2250	680
Polyaline	Satkhira	Satkhira	2050	41.0	2100	550

Variation of soil moisture in the various regions of the forest exists (Table 3). Lack of soil moisture coupled with physical properties ie high percentage of clay have a strong effect on the growth and distribution of the various tree species in the different zones of forest.

On the basis of salinity, the whole Sundarban forest is divided into three ecological zones. These are (1) Oligohaline zone (ii) Mesohaline zone and (iii) Polyhaline zone.

The results of soil analysis (Table 4) suggest that the Oligohaline zone is rich in calcium followed by sodium and magnesium. In contrast the polyhaline zone has not only less exchangeable calcium but also has exchangeable sodium.

Floristic Composition

The dominant plants of all the three zones are briefly given in Table 5.

Table 5: Dominant plants of the Various Zones

Oligohaline Zone
Heritiera fomnes
Avicennia alba
Oligohaline zone
Sonneratia apetala
Amoora cucullata
Cerbera manghar
Cynometra ramiflora
Hibiscus tiliaceous
Lumnitzera racemosa
Nipa fruticas
Pawadanas foetidus
Phargmites Karka
Sonneratia apetala
Polyhaline zone
Excoecaria agallocha
Aegiceras corniculatum
Bruguiera sexangula
Xylocarpus granatum
Xylocarpus mekongensis
Ceriops decandra
Phoenix paludosa
Acrostichum aureum

Mesohaline zone
Rhizophora mucronata
Kaudelia candel

Phoenix paludosa
Heritiera fomes
Excoecaria agallocha
Ceriops decandra
Nipa fruticans

However, the vegetation of Sundarbans are complex and may also be classified as (i) the sea face forest (ii) the flora of the island and (iii) the swamp forest.

Prain (1903) listed 334 species of plants in the Subdarban and mentioned that the different possible means of dispersal and distribution of plants such as by sea and rivers and by wind, bird and human agencies have been responsible for introducing an interesting and complex flora in the area.

(1) Sea Face Forest

The sea face or the beach forest is usually found on the **sea** face **islands. These islands face strong** north western storms from March to **September. The more common species are,** Derris scaudens, Fimbristylis sp.Oryza coarctata, Phragmites karka, Imperata cylindrica, Zoysia martella, Acrostichum aureum.

(ii) The Formative Island Flora

The flora on the bank of the rivers are mainly shrubs and herbs. The prominant ones are Oryza coarctata, Phragmites karka, Acanthus ilicifolius.

(iii) The swamp forest consists of the plants as mentioned in Table 5.

Adverse Effects to the Sundarban Ecosystem

Vegetation deterioration has already been recorded particularly seedling establishment/ and die back of Sundri. There is evidence that this is due to salinity increase which happens during winter periods as a result of upstream diversion of the Ganges water by the Farakka Barrage (International Engineering Company Ins. 1977, 1980).

Since distribution of plants in the various zones differ, the results of this paper may help for suitable establishments of selected seedlings in the particular area. It was shown that the growth and distribution of Rumex acetosa, a wide edaphic tolerant species are related to the availability of calcium (Nazrul-Islam and Rorison 1981). Chemical analysis of leaf nutrients of the various zones might bring the results to a sharper focus on the ecology of this species.

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Summary of Discussions following presentation:

Dr N. Ishwaran: What are the main species of animals?

Dr A.K.M. Nazrul Islam: Spotted deer, the wild pig and several species of monkeys.

Dr Mathew George: What was the sampling procedure used in soil-collect and water-sampling. Did you see any correlations between water-quality and vegetation types?

Dr A.K.M. Nazrul Islam: Soil samples were collected from depths of 6-10 cm and last year they were even collected from 30 cm depths. I would like to point out that the data I gave was on individual plants and not on vegetation. I was not trying to establish any correlations between water-quality and vegetation types.

Mr Fong Foo Woon: Did you find any relationship between the different zones you talked about and topography.

Dr A.K.M. Nazrul Islam: No, not in analysing the data I have collected so far.

Mr Hoang Van Thang: What kind of deer do you have in the area?

Dr A.K.M. Nazrul Islam: We have the spotted deer (Axis sp.) as well as the barking deer.

Session VI

Field exercises at the MAB reserve at Sinharaja

FIELD PROGRAMME I

Visit to Moulawela - a small hill in Sinharaja
Conducted by Dr Nimal Gunatilleke.

The roadside secondary vegetation of Sinharaja
Conducted by Dr(Mrs.) C.V.S. Gunatilleke.

During this programme you will observe soil, climate & vegetation in undisturbed and disturbed sites of Sinharaja, viz.,

i. Skid trails,
ii. Selectively logged sites. Natural forest on the slope and summit of this hill.

On the way up, the following will be examined

1. Topography
2. Soil
   a. Physical features
   b. Chemical features
3. Micro climate and its vertical and horizontal variations
   a. Temperature
   b. Sunlight/shade
   c. Humidity
4. Vegetation
   a. Structure

      Density, Size (Girth & Height) distribution and Spatial distribution.

   b. Floristic composition

      Species richness, Dominance, Endemics, Species of Potential use,(Medicine, Food, Domestic purposes,) Species of Biogeographic importance.

   c. Features of rainforest vegetation

      i. Drip tips
      ii. Buttresses
      iii. Pole trees
      iv. Large leaves
      v. Abscence of thorny species
      vi. Nodding branches
      vii. Cauliflory

On the way down, the following will be examined

1. Interaction between Plants, Animals and Environment

   a. Environment/Plants :- Stratification; Microhabitats; Dispersal

   b. Plants/Plants :- Epiphytes; Mycorhiza; Lianas; Epiphyllous Plants

   c. Plants/Animals :- Nepenthes; Fugivores; Herbivores; Food; Shelter

   d. Animal/Animal :- Compitition; Bird flocks

   e. Animals/Environment :- Nutrient cycling processes; Litter decomposition

   f. Environment/Environment:- Temperature; Rain fall; Wind

2. Forest is a closed system, an equillibrium system

   Compare a fernland and forest in relation to the following factors.

   a. Energy
   b. Nutrients
   c. Biomass

3. Role of the forest in the hydrology of the area.

   a. Non flowering and flowering plants
   b. Soil

4. Role of the forest in Genepool Conservation

   a. Plants
   b. Animals, both above and below ground

GUIDE
TO
MOULAWELA TRAIL
IN
SINHARAJA FOREST

GUIDE TO MOULAWELLA TRAIL IN SINHARAJA FOREST

by

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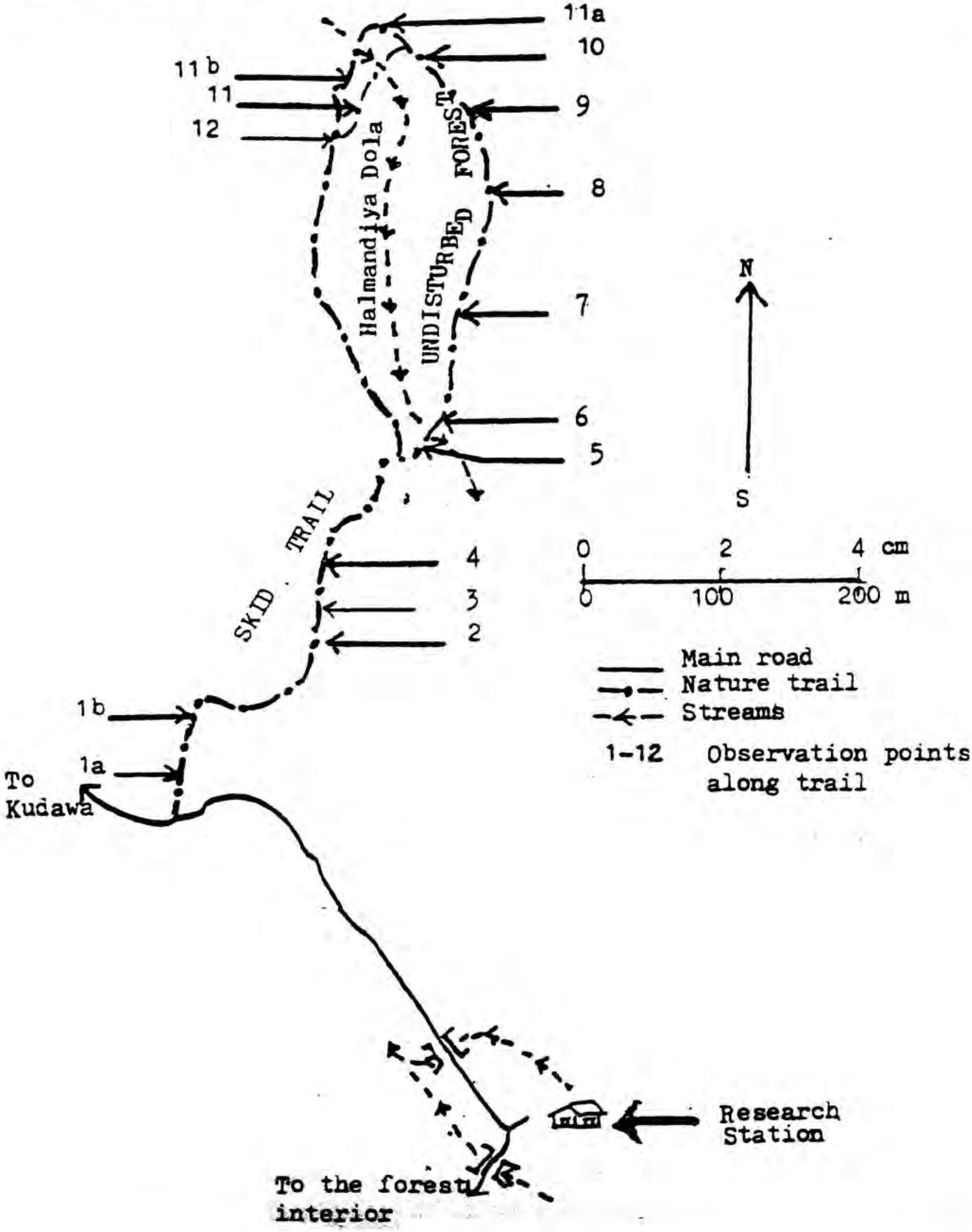
Department of Botany, University of Peradeniya

Prepared for the field exercises
at Sinharaja of the Regional
Training Workshop on
Ecology and Conservation of
Tropical Humid Forests of the
Indomalayan Realm

- 1st to 5th March 1987 -

- Sinharaja -

MOULAWELLA TRAIL



Moulawella Trail Observation Points

Introduction

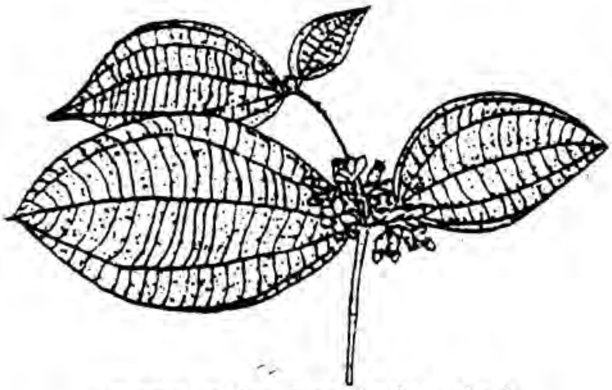
The first part of this trail follows a skidding road (road constructed for the movement of heavy mechines called skidders which drag logs from the interior of the forest to places on the main road where logs were stacked, i.e. a logging yard). The second part goes through a natural forest. Twelve observation points along the trail point out features of interest of the environment and/or vegetation at each point. It will take one and a half to two hours to go round the trail leisurely.

As you follow the trail you should be able to compare the microclimatic conditions, soil and vegetaion of the main logging road with the skid trail and the primary forest.

If you move about quietly, listen intently and keep looking with perception, you are bound to hear the symphony of the forest dwelling animals - monkeys, squirrels, birds, even frogs and at dusk or just before a downpour the Cicardas. You might see the movement of some of them on the aerial "walkways" of the branches or through the aerospace of the forest. Your silence through this trail will certainly be compensated by what you see,feel and hear in the forest.

Observation points 1a & 1b

Coleus sp.



Katakalu Bowitiya (S)

Cleidemia sp.

Schizostigma hirsuta

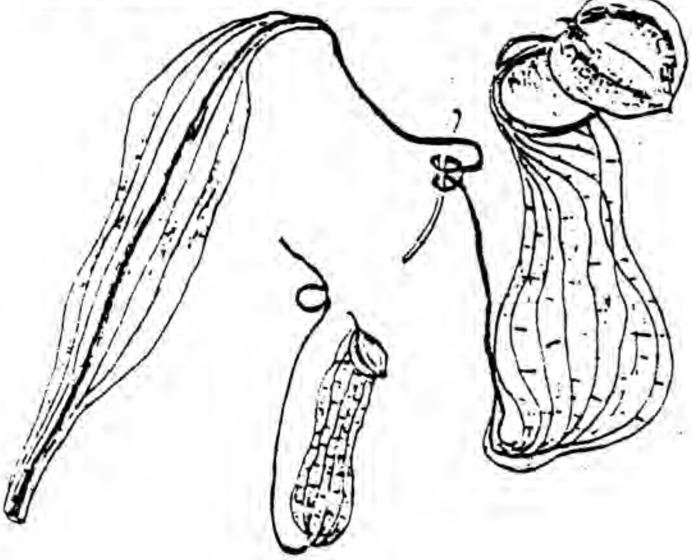
Selaginella sp.

Selaginella sp.

Observation point 1a - Some features of the skid trail

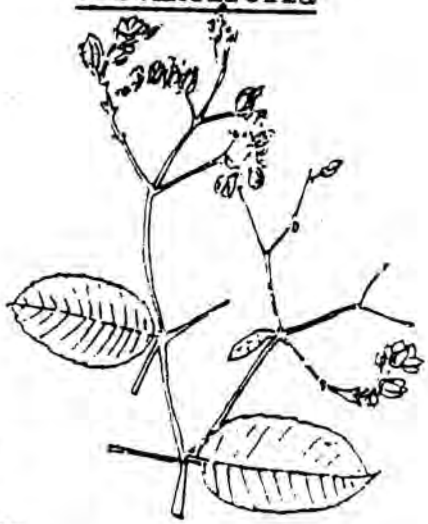
This skid trail was abandoned about 10-12 years ago and the vegetation you see here now has come up since then. Already you must have noticed that the skidding road is only about 2m wide.It is not as wide as the main access road to Sinharaja. Thus, the gap in the forest created by the skidding road is much smaller than the gaps on the main access road. The crowns of the smaller trees on either side of this trail have already closed up in most parts. Consequently, much shade is cast on the ground and a higher humidity prevails here. These conditions are favourable to the growth of many different moisture and shade loving species, such as Selaginella and Coleus among other plants, that you see along this trail. Of course leeches will continuously accompany you along the trail and will be a persistant hindrance to your concentration, but you soon get used to them.

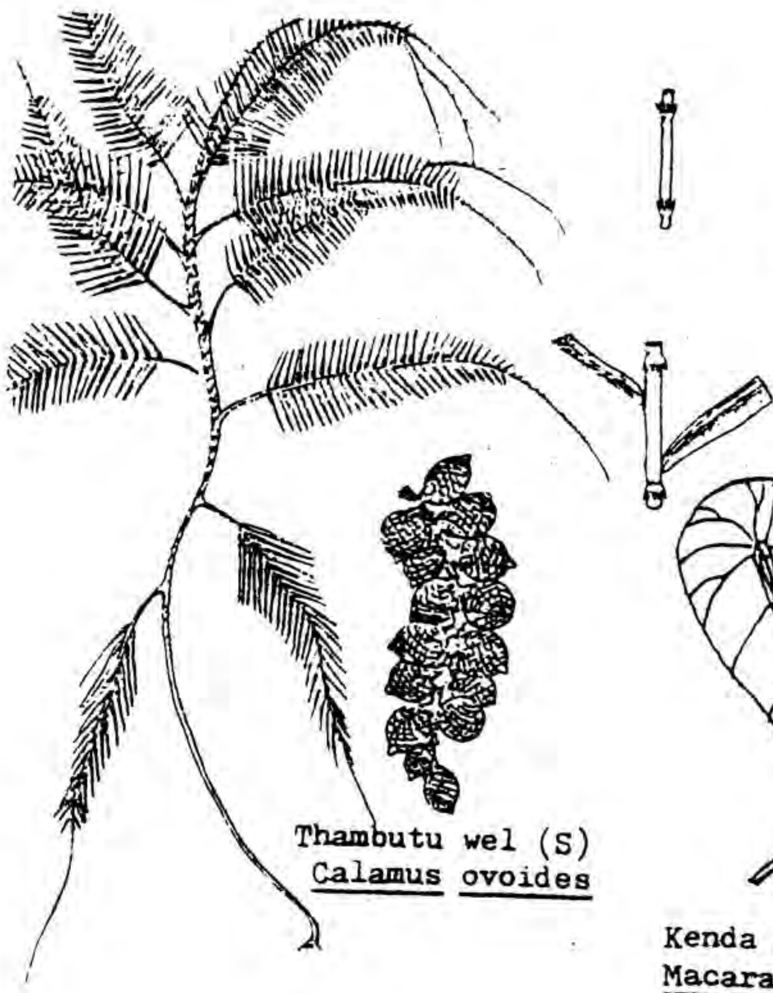
Observation point 1b & 2



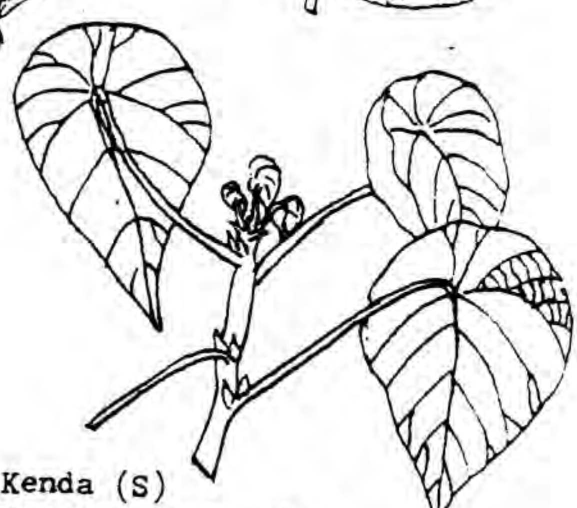
Bandura (S)
Nepenthes distillatoria

Kekiriwara (S)
Schumacheria
castaneifolia





Thambutu wel (S)
Calamus ovoides



Kenda (S)
Macaranga peltata

Observation Point 1b - Some forest gap species

At this observation point two species of Cane may be seen, but superficially they resemble each other. The first of them is Thambutu Wel (A) (Calamus ovoideus). Note the regular ring like arrangement of spines on its stem. The second is Ma Wewal (B)(Calamus zeylanicus) in which the spines on the stem are closely distributed all over it. Notice how these Canes support themselves by means of the long whiplike structures at the ends of their leaves. If you are here between December and March you may see their flowers and/or fruits at the upper ends of these climbers. Their stems are used to turn out many articles of domestic use that one can imagine.

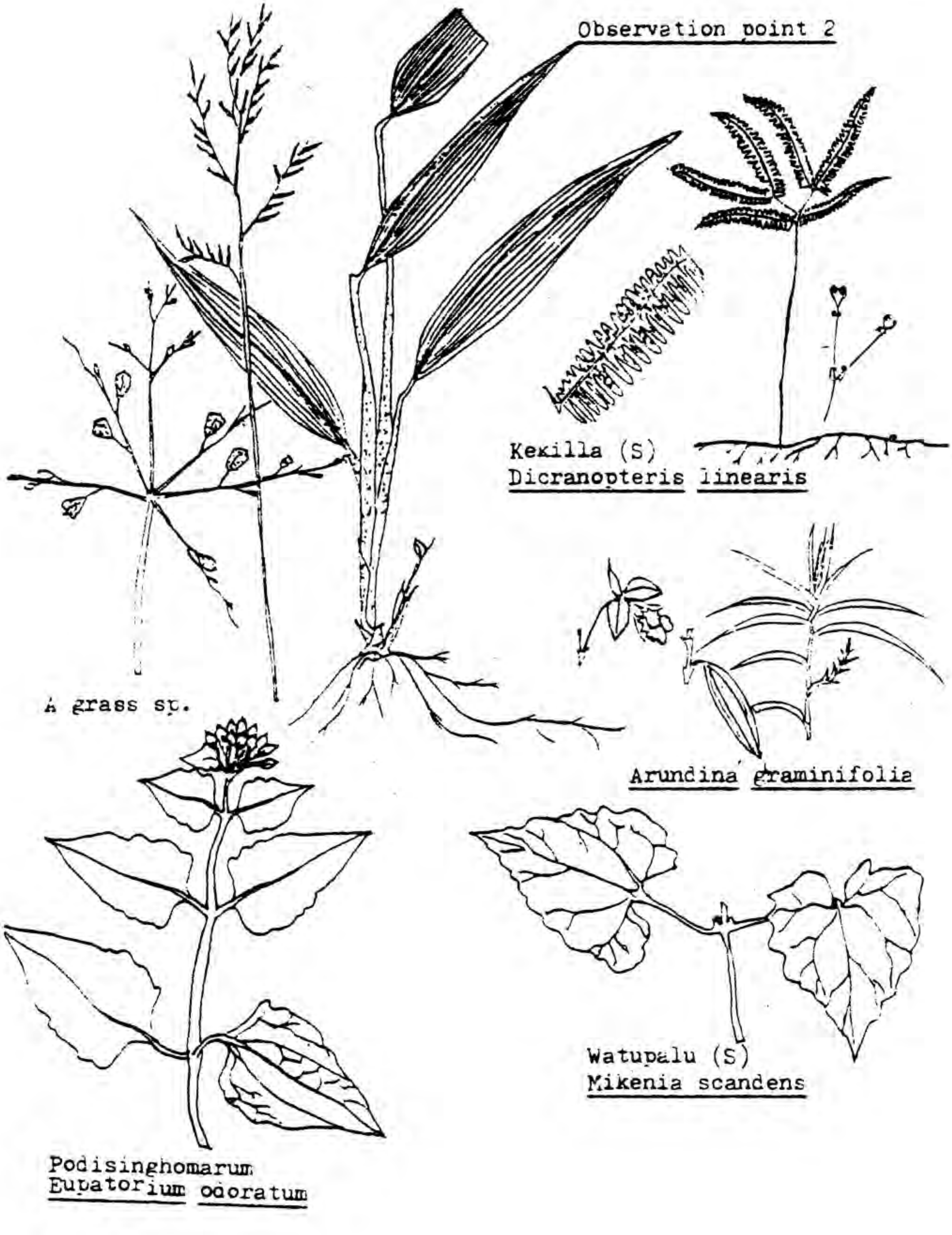
Beneath the Cane is Katakalu Bowitiya (Cleidemia sp.). It is a small shrub growing well in these trails. It has oppositely arranged, very hairy leaves. Touch them and feel their texture. The leaf margin is serrated and its surface crimpled. While the flowers of Cleidemia are small and white, their fruits when mature are deep ink blue with a large number of tiny seeds which are possibly dispersed by birds. The local name Katakalu Bowitiya has been given because of the nature of the fruit which leaves a black stain in the mouth (Kata = mouth; Kalu = black). Around 1977 this plant was hardly common along these trails. It has only become abundant recently. It is an introduced plant.

On the ground itself is a trailing plant with succulent stems. It can root along the stem at intervals, thus colonizing bare areas. It appears like a light green carpet in some areas. This species is Schizostigma hirsuta. All the parts of this plant are covered with hairs. It has white flowers and greenish white fruits, which when mature are edible. Although this plant grows well in the fringe of forests, it does not grow so well in the dense shade of undisturbed forests.

One of the plants supporting the Thambutu Wel is Kekiriwara (C) (Schumacheria castaneifolia).

On the opposite side of the road, the tall tree is Kenda (D) (Macaranga peltata). This is one of the first tree species that grow in disturbed areas. Hence it is also called a pioneer species or a secondary forest species. Observe its crown - spread, you will see how the leaves are arranged at the ends of branches so as to capture maximum sunlight. If you are here at the time sunlight falls directly on the crown it is a beautiful sight to see the light filtering between the leaves and how the neighbouring leaves do not shade out each other.

Beneath the Kenda is Bata (Ochlandra stridula) which comes up in disturbed areas as well. The stems of Bata are used for construction poles of mud huts and their leaves for roof thatching.


Observation point 2
Kekilla (S)
Dicranopteris linearis
A grass sp.
Arundina graminifolia
Watupalu (S)
Mikenia scandens
Podisinghomarum
Eupatorium odoratum

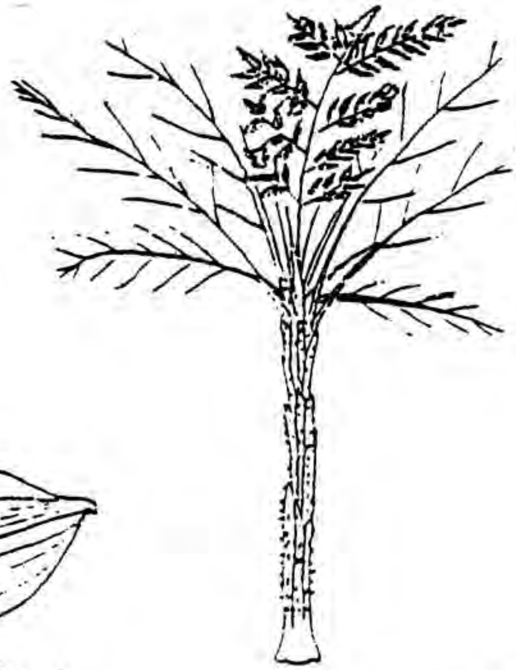
Observation Point 2 - Open Area on Skid Trail

This point represents an open area on the skid trail. As there are no trees on the right much sunlight reaches the ground. Hence sun loving ferns like Baru Koku (Blechnum orientalis) and Kekilla (Dicranopteris linearis), grasses like Paspalum sp. and Pennesetum sp. and weed species like the shrub Podisinghomaram (Eupatorium odoratum) and the climber Watu Palu (Mikenia scandens) as well as the purple flowered orchid species Arundina graminifolia may be seen here.

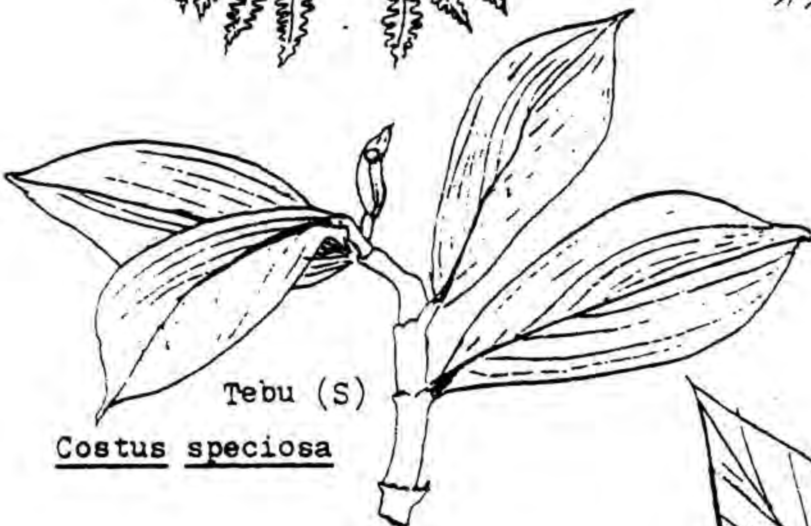
The sapling bearing the label OP 2 is Thiniya Dun (Shorea trapezifolia). One of the canopy dominant members in the family Dipterocarpaceae. If you look at the skyline ahead to your right the tallest tree with the umbrella like crown is a mature individual of this same species. A better view of its parachute like branching pattern may be seen from Observation Point 4 along this trail.

Behind the Shorea sapling note the Bandura or Pitcher plant Nepenthes distillatoria. See how it supports itself and how the pitchers are positioned. (Further details of it are given in the Main Logging Road guide).

Observation points 3 & 4

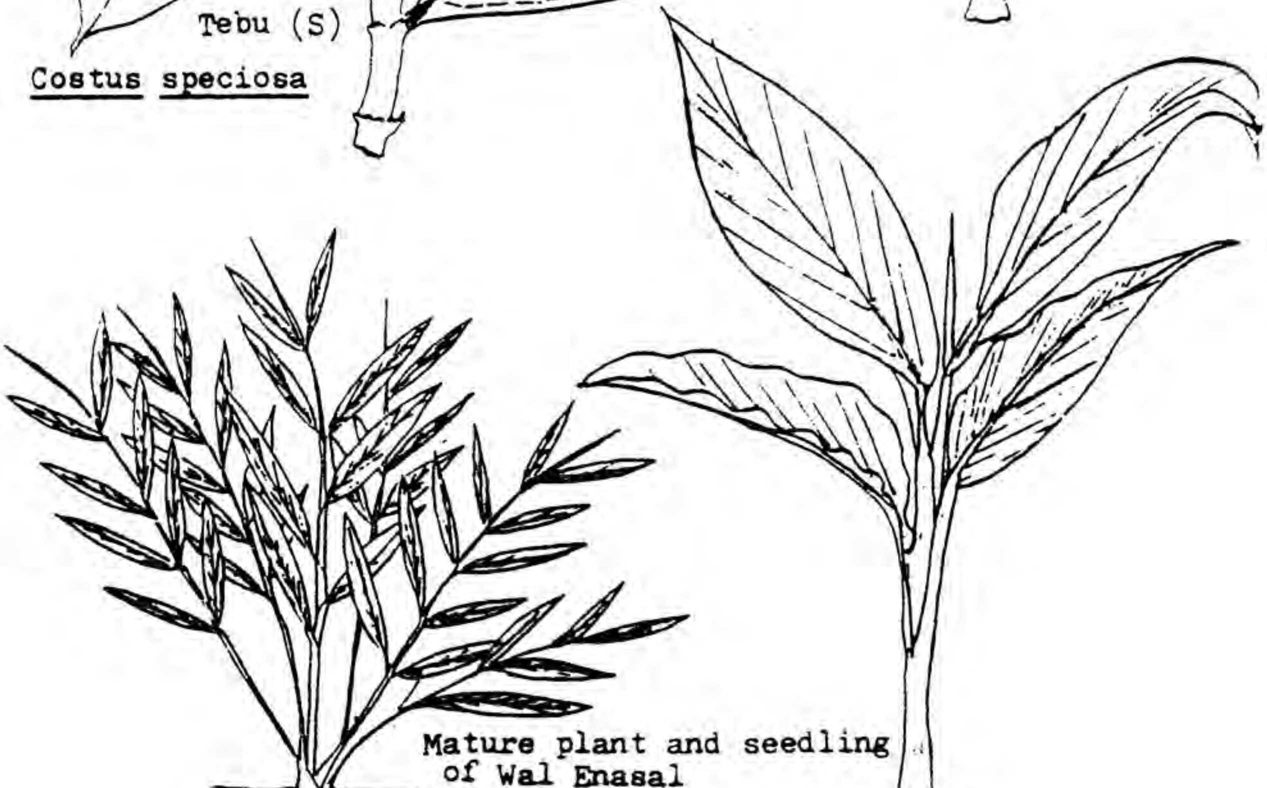


Part of leaf and tree of Ginihota (S). Cyathia walkeri



Tebu (S)

Costus speciosa



Mature plant and seedling of Wal Enasal

Elattaria cardomum var. major

Observation Point 3 - Few indicator plants of disturbance and high humidity

On the bank on your left are some species which grow luxuriently in moist, shady and disturbed areas.

a) A moss which is one of the first colonizers of bare areas.

b) Young plants of many fern species (Blechnum, Pteris, Adiantum, etc.) growing between the moss.

c) Selaginella

d) The large tree fern Ginihota (Cyathia walkeri). Observe how large a single leaf is. They are about 1-1.5m long. Turn a leaf over and see whether there are any spores or the "seeds" from which new plants may arise. Note their appearence and arrangement.

e) Tebu, a wild ginger (Costus speciosa), which grows in shade. It is easily recognised by the spirally arranged leaves around the stem. Its flowers are bright red and held in clusters at the ends of their slender stems. Its young leaves are edible and its rootstock has medicinal properties.

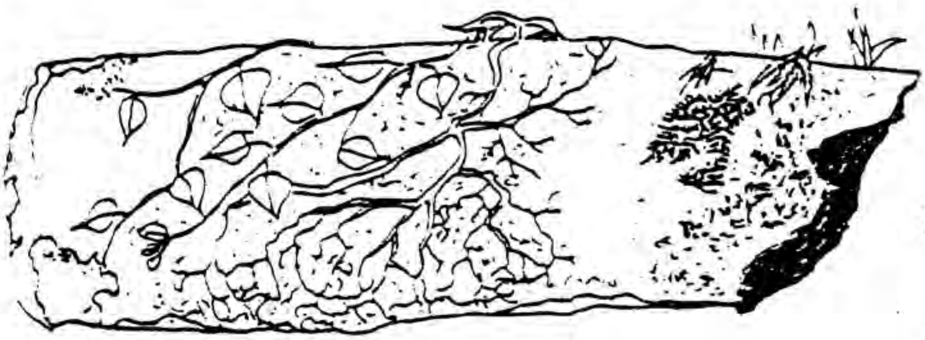
f) You will see the delicate, fine epiphytic bryophytes which hang down from twigs. You will read more about them later on along this trail. Do you think they are of any use to the higher plants?

Observation Point 4 - Wal Enasal or Cardomum - a wild spice species

On the right hand side of the path is a bush with leaves over 2m tall. Each leaf has a long main axis or rachis and a number of small leaflets, which may appear to you like leaves, arranged on either side of it. The stem is not normally visible as it runs horizontally below the ground as in ginger. This is a species of wild Cardomum (Elettaria cardomum var. major). Its flowers arise near the base of the plant. Several flowers are borne on a trailing stalk. Each flower is white with pink streaks within it. Enasal too grows well in slightly disturbed areas.

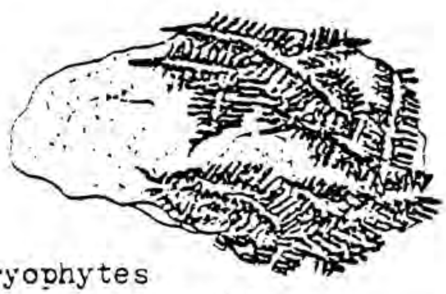
The cultivated Cardomum grows at much higher elevations. This wild species however, can be grown in the lowland wet zone. Before this forest was made a conservation area, wild Cardomum was one of the minor forest products collected by the villagers for their livelihood.

Observation point 5 - Different habitats where plants grow

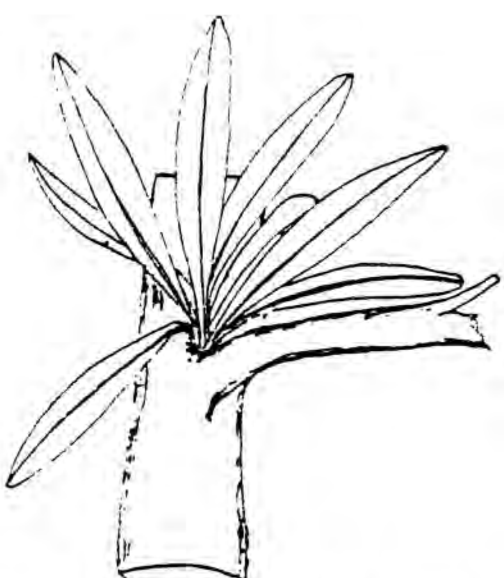


Selaginella sp.

Bryophytes on leaves and tree trunks



Bryophytes growing on rocks



Fern growing on the bark of a branch

Bryophytes on leaves and twigs

Observation Point 5 - Entry to the undisturbed forest

Within the shade of the forest the temperature is relatively cool (about 23-25 C at day time) and the humidity high (over 90%) even on a dry day. The soil too has a fair amount of moisture in it. Look around and you are bound to see many different plants growing together. Although the trees form the most obvious component of the vegetation, the entire size range of plants, ranging from microscopic algae and fungi, through mosses and liverworts, to herbaceous and shrubby flowering plants may be seen here. The forest is formed not only by plants but by all the groups of animals as well. Just look at a 4sq.m patch of forest and try counting the number of plants you see in it. Only a rainforest can sustain so many plants within such a small area. With disturbance the number of different plants a given area can support also decreases.

Observe where the plants are growing. Some grow directly on the soil. Others on rock surfaces, fallen tree trunks, cracking or flaking barks, small twigs, even leaf surfaces of the living plants. These plants growing on other living plants are called epiphytes ("Epi" = on; "phytes" = plants). The outer bark of trees is usually dead. They provide decomposing bark material which can also trap moisture, so naturally, epiphytes find it a suitable place to grow on, and at the same time get enough sunlight for their growth.

Before you leave this point observe the fallen log. What do you see on it? Notice the intricate network of roots that ramify in it as well as the mosses, liverworts, ferns and climbers that grow on it.

It is generally felt that removal of mature trees that would die anyway out of the forest would do no harm to the forest ecosystem. Removal of trees mean removing some of the nutrients that help to maintain this system. Even before this tree trunk is completely converted to soil, plants already grow on it and use up the nutrients in it.

This way nutrient losses, if any, out of the system are a minimum. Removal of a large number of trees would certainly upset the delicate equillibrium in this forest.

As you go along, notice the decomposing tree trunks and look for the organisms growing on them.

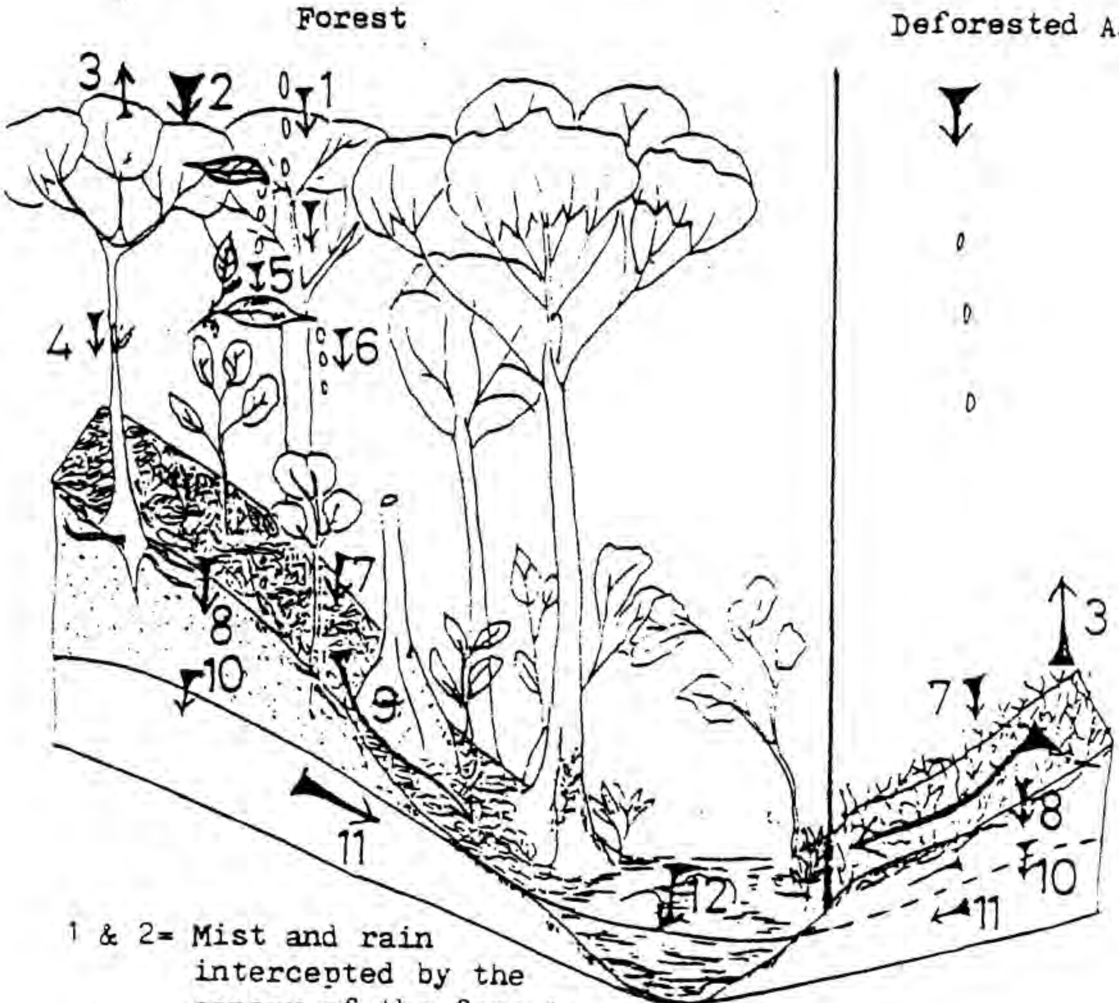
Halmandiya Dola

Observation point 6 - **Halmandiya Dola**

1 = Fallen tree trunk with a luxurious growth of bryophytes and other plants.
2 = Different types of ferns.
3 = The "ant plant" - Gal Karanda (S), Humboldtia laurifolia

Observation point 6

The path of water from rain and mist through a forest and a deforested area. Do you see how much water the forest can retain?



1 & 2 = Mist and rain intercepted by the canopy of the forest

3 = Evapo-transpiration from leaf surfaces

4 = Stem flow

5 = Interception by epiphyllous bryophytes and leaves of understorey trees

6 = Through fall

7 = Absorption by leaf litter on soil surface

8 = Infiltration through humus and soil

9 = Surface run off when litter and soil are saturated

10 = Soil water reaching the ground water table

11 = Movement of ground water to streams

12 = Stream flow

Observation Point 6 - The Stream Halmandiya Dola, some aspects of forest hydrology and shade loving ferns

Here you cross the Halmandiya Dola (Dola = stream). During the rainy season this stream has clear flowing water. During the dry season there is little or no water in it. It is this stream that supplies the drinking water at the field station. Therefore, PLEASE DO NOT POLLUTE IT.

Look around you and see what happens to rain water that falls on the forest. Rain water cannot fall directly on the soil surface. It is first trapped by the crowns of the canopy trees or by the vegetation below it. Some of the water that is intercepted by the foliage will remain on the leaf surfaces and get evaporated. The rest will flow down to the soil via other plant surfaces or its own stem. At the soil surface, the decaying leaves and humus layer get soaked and only when these surfaces are fully saturated that surface run off begins. This water and the water that enters the soil water table eventually gives rise to streams as the one you see here. Can you imagine what would happen to all the rain water if there was no vegetation and humus? It would all flow away leaving a very dry environment. Trees on the other hand are able to trap and keep a large proportion of the rain water in the enviroment itself.

How does the water continuously flow in these streams? At night the temperature outside the forest decreases by about 8-10 C (night temperatures are between 18 - 24 C, day temperatures 26 - 30 C at the field station. Within the forest the corresponding temperature ranges would be even lower). As a result night mist is a frequent feature in these rain forests.

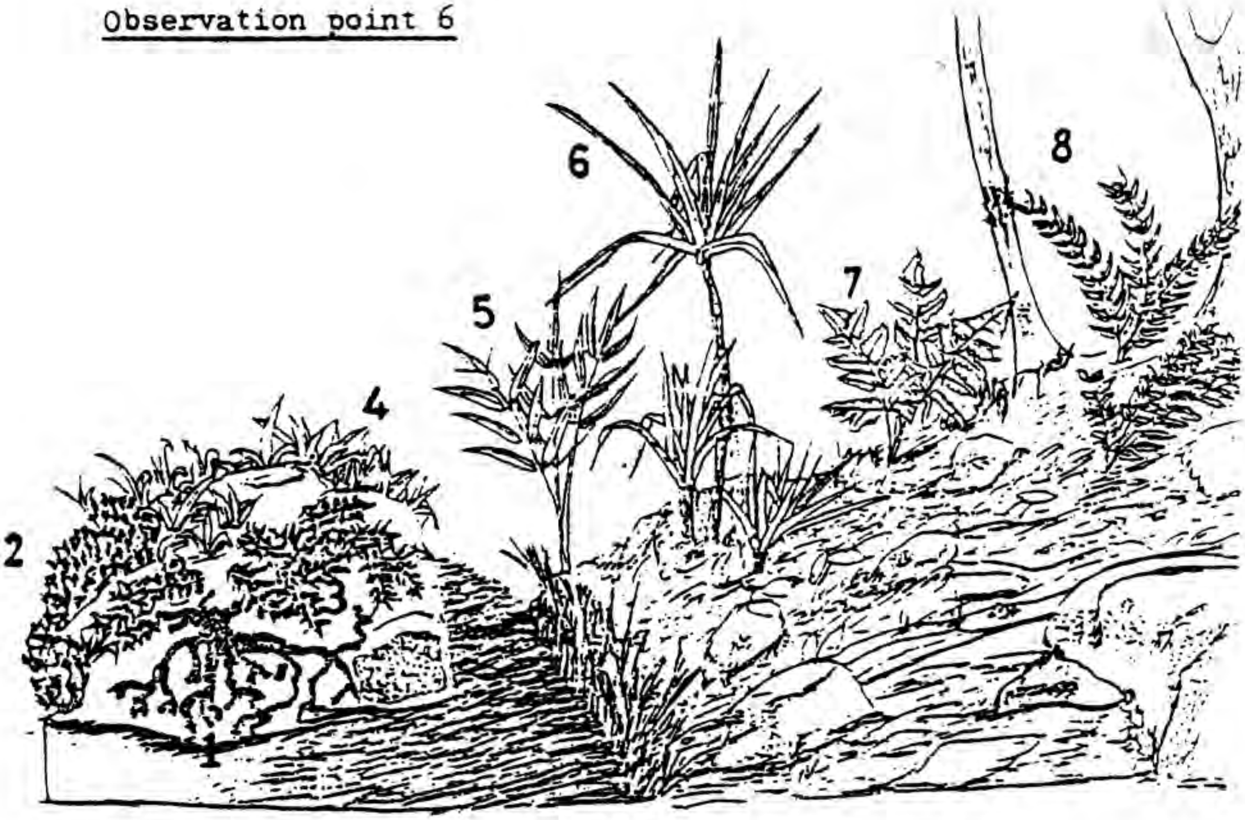
The mosses and lichens have the ability to absorb this moisture and if there is a lot of water as during the rainy period they become spongy and succulent. Look at the leaf surfaces and other plant parts and see whether you can recognise this group of plants which make a valuable contribution to maintain the high humidity of the rain forest environment.

The water in this stream is very clear even when the rainfall is very heavy. Though the land is quite steep the soil does not erode away. You will learn the reason for this at Observation Points 7 and 8.

Before you go on notice some of the plants around the stream. The ferns you see here are water loving ones. Their presence indicates high moisture. They are Pyrrosia gardneri, a simple leaved trailing stemmed plant, often seen on rock surfaces; Bolbitis sp., Adiantum, Tectaria paradoxa, Trigonospora zeylanica and Cyathia sinuata. These ferns have been illustrated for you.

The twiggy treelet behind the fallen tree trunk, is Gal Karanda (Humboldtia laurifolia). The young twigs of this plant are swollen. In their hollow cavities live an ant species. There is a special association between these ants and the plants. The ants do not harm the plant and the plant does no harm to the plant. PLEASE DO NOT DESTROY THE PLANT, but certainly look at it.

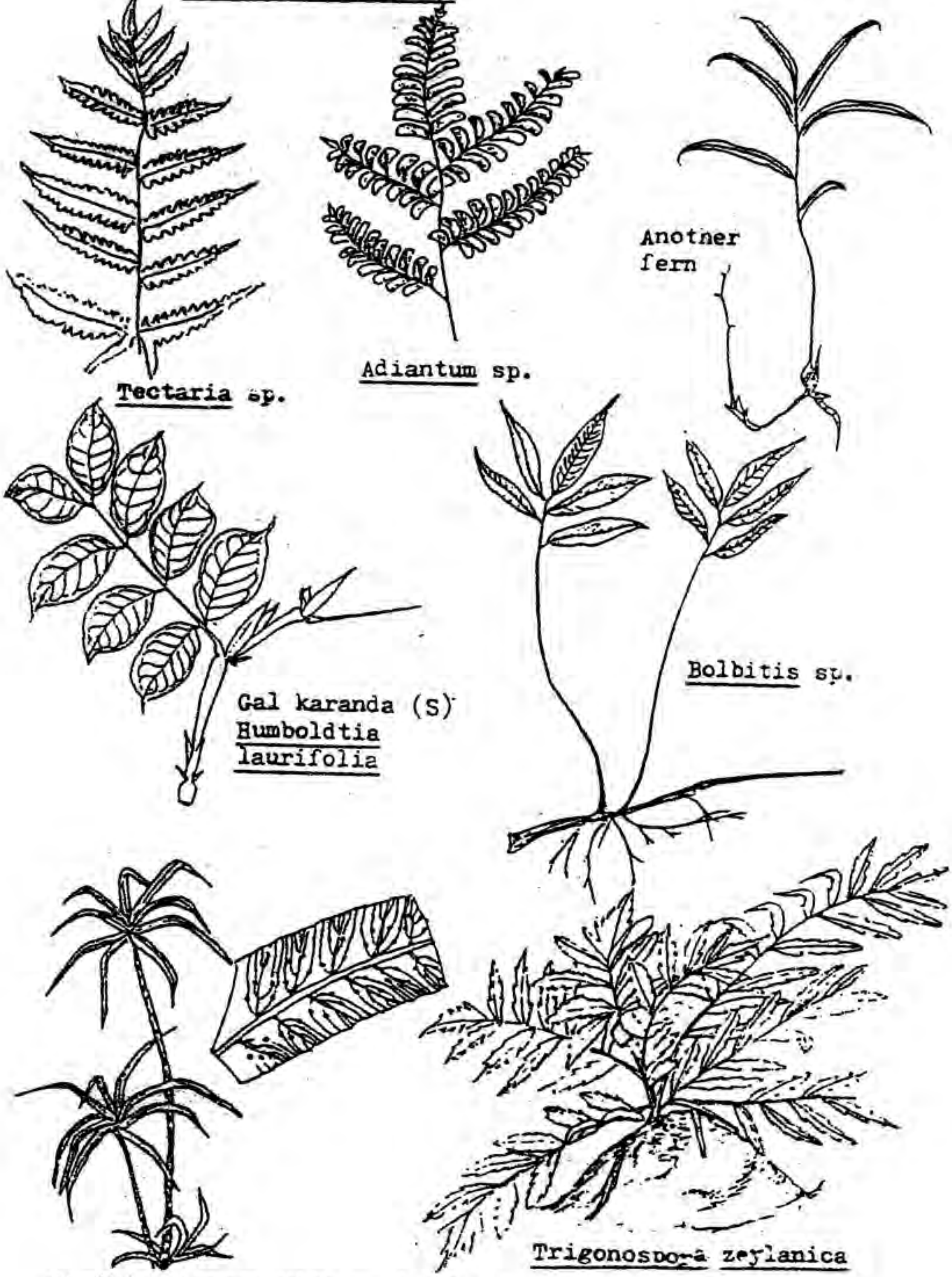
Observation point 6



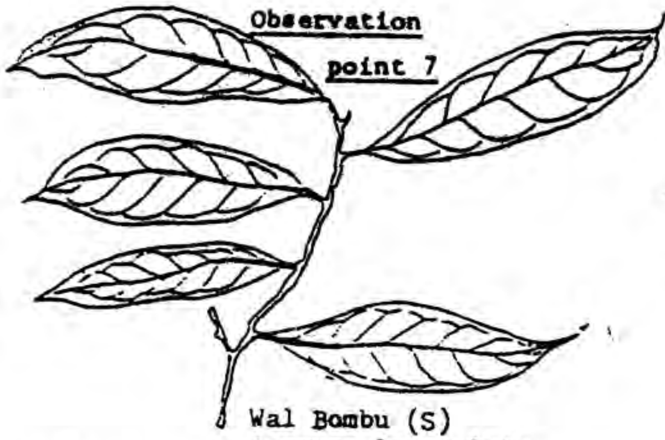
The near bank of Halmandiya Dola

1 = Selaginella
2 = Moss sp.
3 = Bryophytes
4 = Pyrrosia gardneri
5 = Bolbitis sp.
6 = Cyathia sinuata
7 = Tectaria sp.
8 = Trigonospora zeylanica

Observation point 6

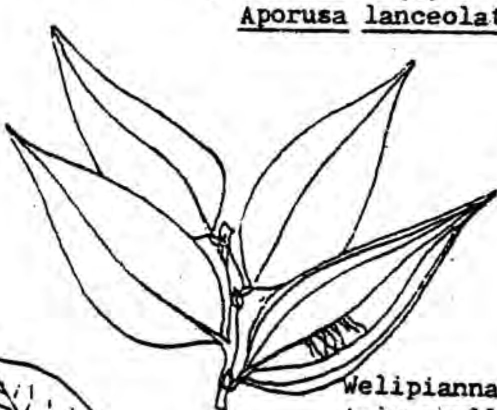


Cyathia sinuata with part of the under surface of leaf.

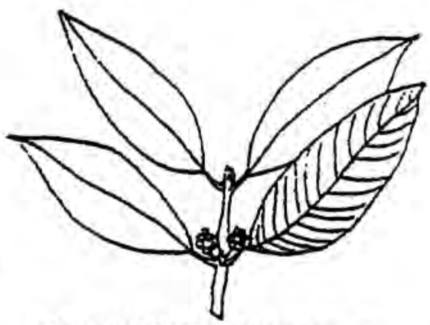


Wal Bombu (S)
Aporusa lanceolata

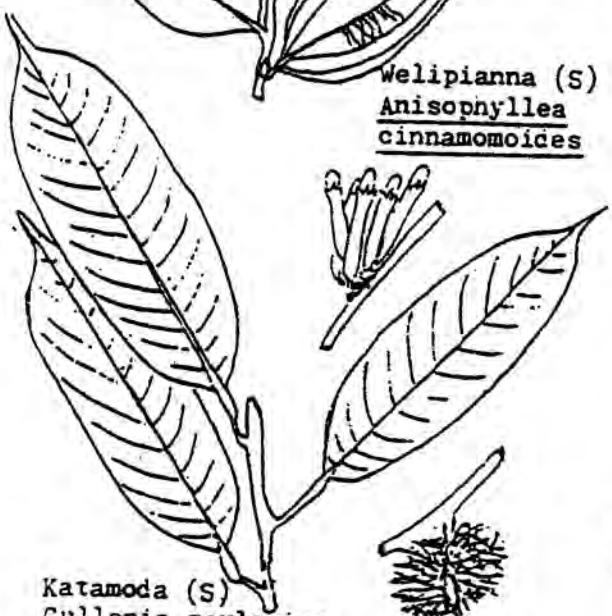
Gal Karanda (S)
Humboldtia laurifolia



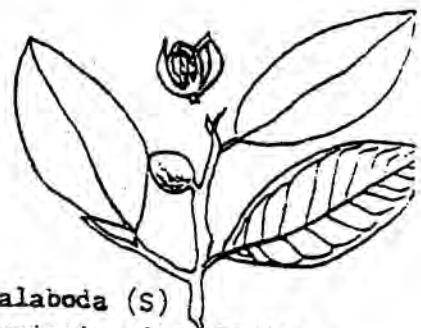
Welipianna (S)
Anisophyllea
cinnamomoides



Urophyllum ellipticum



Katamoda (S)
Cullenia zeylanica



Malaboda (S)
Myristica dactyloides

Observation Point 7 -- Plants of different forest strata and some features of the vegetation

From this point observe the stratification or layers within the forest.

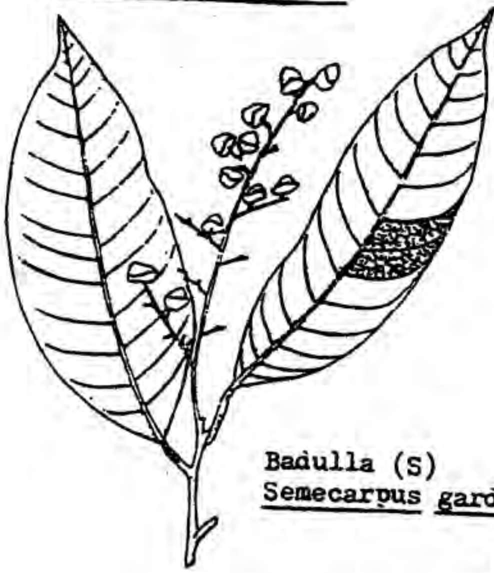
The ground layer is sparse. There is a lot of bare ground where the decomposing leaves are seen. The soil is dark brown in colour because of the large amount of decomposing leaves (on the skid trail you came through it was reddish yellow). Crush a little of the soil between your fingers. It is fine and not so sticky. This is because there is the right amounts of clay, silt and humus in it. Notice the intricate network of roots that grow on the soil surface. These roots, leaf litter and humus protect the soil and prevent its erosion. As compared to this in deforested areas there are fewer roots, much less humus and relatively little vegetation to protect the soil from erosion.

In the ground layer, are shade loving plants such as the ferns, members of the ginger and grass families Zingiberaceae and Graminae respectively, and seedlings of plants that grow in the strata above it.

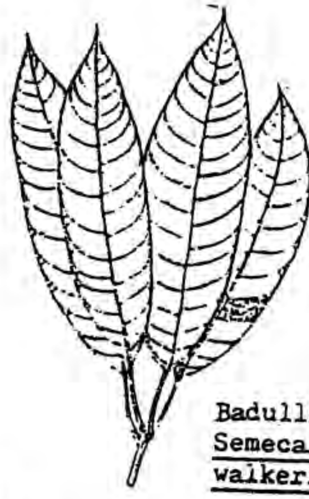
In the 3-5m layer are plants like Beru (A1) (Agrostistachys coreacea), Gal Karanda (A2) (Humboldtia laurifolia), Pinibaru (A3) (Memecylon sp.), Urophyllum ellipticum (B1) and Wal Bombu(B2) (Aporusa lanceolata).

A few of the species characteristic of the 10-15m layer are Madol (C) (Garcinia hermoni), Athuketiya (D) (Xylopia championi) and Badulla (E) (Semecarpus gardneri and Semecarpus walkeri).

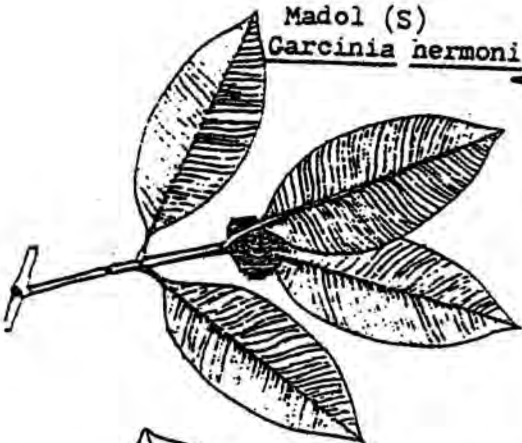
Observation point 7



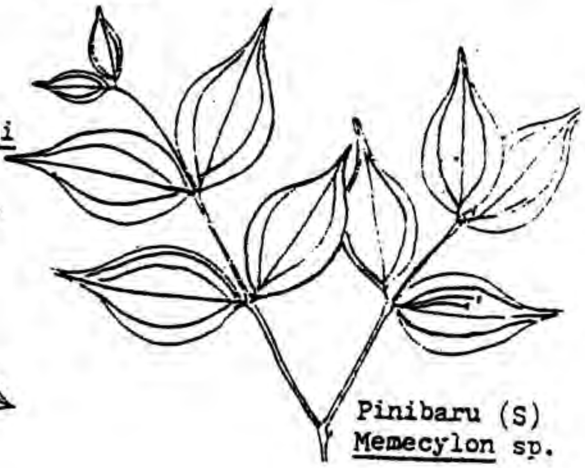
Badulla (S)
Semecarpus gardneri



Badulla (S)
Semecarpus walkeri

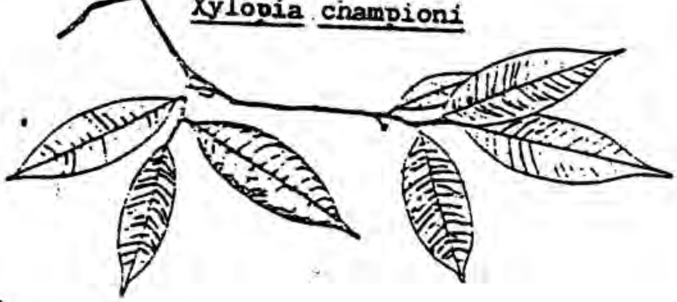


Madol (S)
Garcinia hermoni



Pinibaru (S)
Memecylon sp.

Uruhonda(S)
Urandra apicalis



Athuketiya (S)
Xylopia championi

In the sub canopy layer are species like Katamoda (Cullenia zeylanica and Cullenia rosayroana), Malaboda (F) (Myristica dactyloides) and Uruhonda (Urandra apicalis).

Species that are found in the upper most strata are Na (G) (Mesua nagassarium), Thiniya Dun (Shorea trapezifolia) Beraliya (Shorea megistophylla), Navada (Shorea stipularis), Welipianna (Anisophyllea cinnamomoides), Hora (Dipterocarpus zeylanicus) and Thalang (H) (Litsea gardneri).

The obvious lianas here are Bambara Wel (Dalbergia championii) and Apassa Wel (Uncaria thwaitesii).

Some of the trees also bear epiphytic bryophytes, ferns, orchids and herbaceous root climbers. Almost all of them have crustose lichens of different shades of green, white or grey growing on their tree trunks.

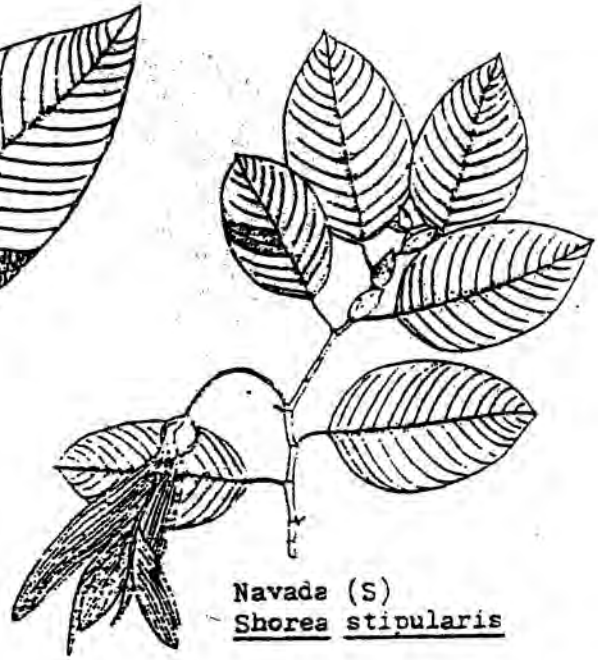
Notice the straight tall tree trunks without any branches on the lower parts of their stems. They are called " pole trees" because of this. Some of the very big trees have spreading bases or buttresses which give them much stability so that they do not get blown down easily. The crowns of these trees are exposed to the air at heights of 25 - 30m and are also subject to strong winds.

Another feature of the vegetation in rain forests is that most plants have relatively large leaves. Small leaved species are few. On the other hand leaves of the dry or montane zone forest trees are much smaller.

As compared to the skid trail you came through and the road sides of the main access road, isn't the undisturbed forest easy to walk through? One of the ways to find out whether a forest has been disturbed or not is to look inside a forest and see how sparse or dense the understorey vegetation is; sparse suggests that it is undisturbed and dense that it is disturbed.

Observation point 7

Hora (S)
Dipterocarpus zeylanicus



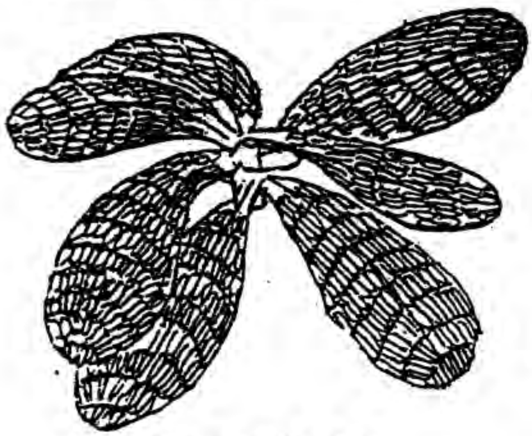
Navada (S)
Shorea stipularis

Na (S)
Mesua nagassarium

Apassa Wel (S)
Uncaria thwaitesii

Beraliya (S)
Shorea megistophylla

Observation points 8 & 9



Acranthera ceylanica

Na (S)
Mesua nagassarium

Stemonoporus sp.

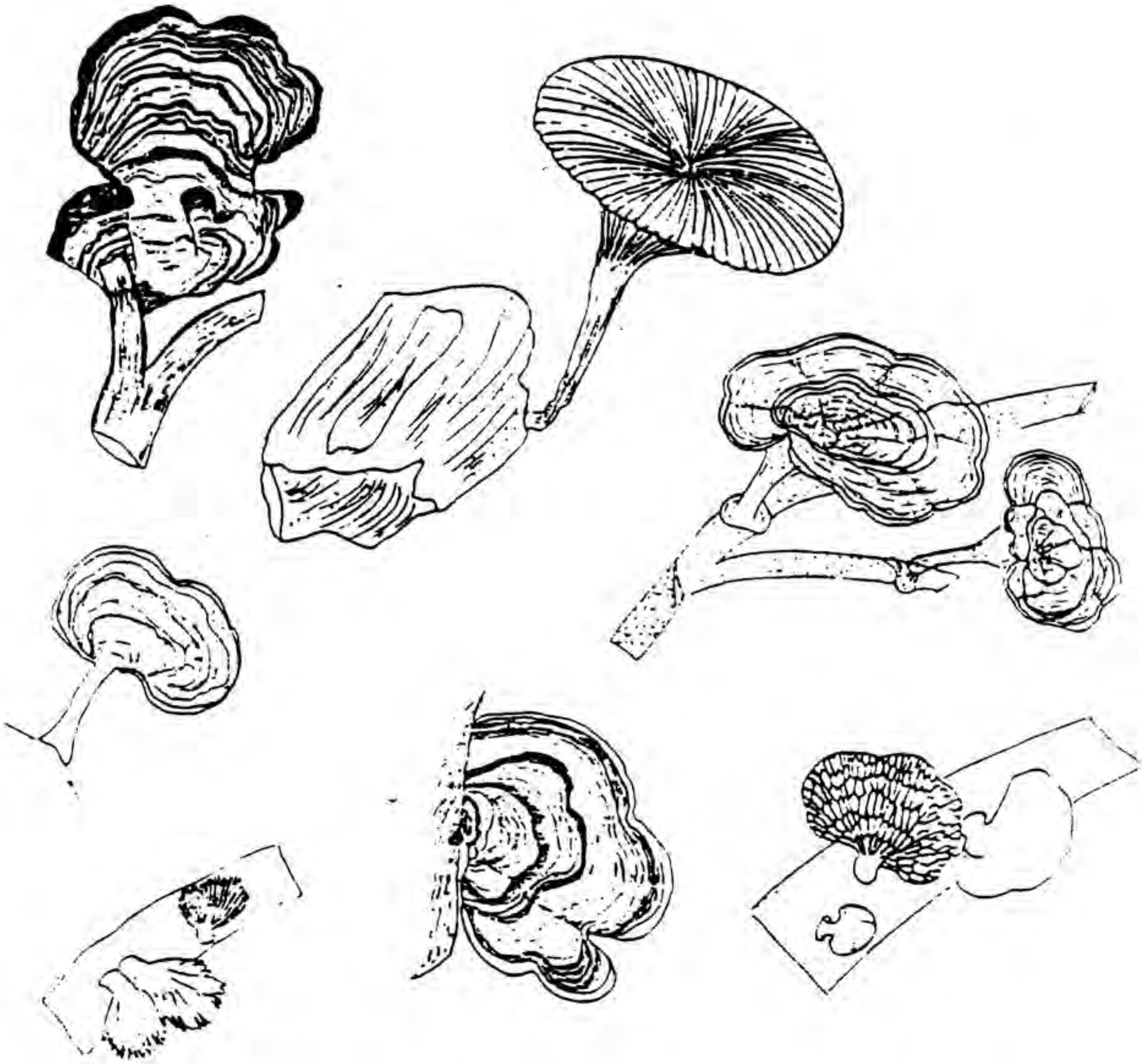
Kalumediriya (S)
Diospyros quaesita

Observation Point 8 - Rocks and Roots, their role in soil formation and soil conservation

Notice how rocky this area is. Yet it has a reasonable cover of vegetation upon it. Even saplings of Beraliya (A) (Shorea megistophylla) and Etamba (B) (Mangifera zeylanica) and big trees of Na (C) (Mesua nagassarium) are seen here even though there is hardly any soil. The crevices, depressions and cracks in the rocks retain decaying leaves. The large roots growing on the rocks also retain leaves. Thus, together they provide a surface for growth of plants. The large roots also bind the rocks. Thus, even during heavy rains they will not get dislodged. Earthslips have never been seen by us in these well forested, undisturbed areas despite the heavey rainfall these areas receive. Imagine an exposed surface without such roots. Would not much erosion take place on them?

Along the way there is a herbaceous plant resembling a domesticated indoor plant, growing close to the ground in very wet areas. This is Gondiva (Acranthera ceylanica). Its leaves are hairy, dark green and crimpled. Like this one, there are many species of horticultural, medicinal and agricultural value in the forest that man could bring into domestication.

Observation point 9



The fruiting bodies or reproductive structures of different wood decomposing fungi.

Observation Point 9 - Decaying Trees, fungi as decomposers, Stemonoporus, & Kalumediriya (Calamander)

A fallen tree trunk of Na (Mesua nagassarium) and two dead trunks still standing on either side of it may be seen here. The tree on the far side has spreading buttresses and is that of a Shorea sp. That on the near side does not have buttresses. Both show how trees die naturally in the forest. First they shed their leaves, twigs and larger branches. Only then does the stem start rotting away while it is still standing. Trees that die naturally do not cause much damage to the vegetation around it. However, should a tree fall due to wind or when they are cut down for timber, then a certain degree of damage is caused to the surrounding trees.

If you look carefully on the decomposing tree trunks you will see many different wood rotting bracket fungi and even mushroom fungi. These fungi are of different shapes, sizes, textures and colours. Just as the trees are important to the forest, these fungi are vital in the decomposition of complex organic material into simple inorganic substances. Only the latter can be absorbed by the roots of higher plants, but these fungi can use complex substances for their growth. It is the fungi, along with the ants, termites, earthworms and other soil animals that form a link between the dead material and higher plants. If these organisms are not present there would be a great accumulation of dead material. Do you think this important group of plants and animals would survive, if the area is disturbed or deforested. Some of the many fungi that help in decomposition of dead material have been illustrated for you.

Before you leave this point look at the small tree marked (B). It is a Stemonoporus and belongs to the most primitive group in the rain forest dominant family Dipterocarpaceae. It is a group found only in Sri Lanka and no other rainforests in the world. If we do not protect and look after them in these rain forests they would be lost to the world.

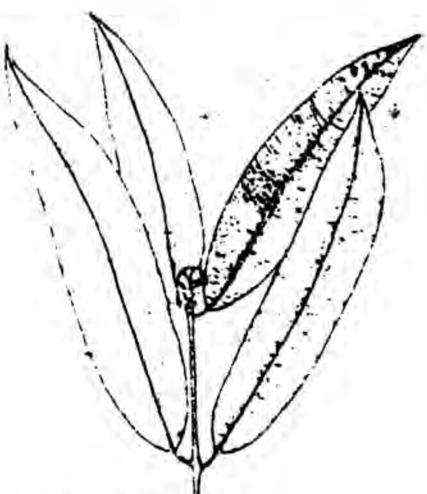
Tree C that you see on your left and further down, is Kalumediriya or Calamander (Diospyros quaesita). It is a member of the Kaluwara or Ebony family Ebenaceae. If you care to go down you will see it growing on a rock surface. The bark of these trees are usually darker compared to the rest of the species. Do you recognise its darker colour? In this species there are separate trees that bear the male flowers and female flowers. Only the latter will produce fruits. The wood of Calamander is durable, ornamental, and highly priced. Unlike the Ebony (Diospyros ebenum) which grows only in the dry zone and has a timber that is black throughout, Calamander has timber that is black but with yellowish brown bands. Calamander grows only in the rain forests of the lowland wet zone of the country.It is a very rare species and what you see here is among the very few left in Sri Lanka. Is there some way you would like to conserve such rare species only found in Sri Lanka?

Observation point 10

Anastomosing roots of a dead Fig tree that has died

Bala (S)
Notnopegia beddomei

Beraliya (S)
Shorea disticna



Diya Na (S)
Mesua thwaitesi

Kirihembiliya (S)
Palaqium petiolare

Observation Point 10 - A dead, fallen and decomposing strangling Fig

At this point the most obvious feature is the dead Fig tree (A1). In its centre would have been the host tree that once supported it. Although the host tree gave its seed a place to germinate, establish, and grow, with time it has destroyed the supporting tree and consequently itself as well.

This point also shows the destruction caused by prematurely falling trees. Notice how many trees have been thrown over here. If you look up you will see that the crowns of many smaller trees have been blown down. Notice the gap created in the canopy and the sunlight reaching the ground. This encourages some of the smaller plants that are sun loving to grow up fast.

In some of the damaged trees you may observe the sprouting of young leaves, near the base if the tree is broken as in A2 or along the trunk of the bent tree (A3). A2 is Welipianna or Anisophyllea cinnamomoides and A3 is Bala or Nothopegia beddomei.

The large canopy tree (B) with plank buttresses is Shorea distica, a member of the family Dipterocarpaceae. The sapling (C) is Diya Na (Mesua ferrea) of the Clusiaceae, the Goraka and Domba family. You might sometimes see the white resin of Diya Na hardened on its stem.

The tree bearing the Observation Post label is Myristica dactyloides of the Nutmeg family, Myristicaceae. Notice the stilt roots at the base of the tree. Several other rain forest species also show this feature. Tree D is a sapling of Palaquim petiolare. Mature individuals of this species grow right up to the canopy. It is a member of the Sapotaceae, the Sapadilla or Sapota and Lawulu family.

One of the fallen trees has been uprooted turning the soil with it. It shows the shallow and horizontally spreading root system of the plant, which is so typical of rain forest species.

Can you guess the reason why the trees have surface feeding root systems? The depression also shows one of the ways in which soil is mixed up in the forest. Can you guess other ways? Burrowing animals, earthworms, termites, wild boar and porcupine are a few animals that help to mix up the soil. As you continue along the trail look out for these animals or signs that suggest their activity.

Observation Point 11 - Another fallen tree trunk

At this point you see how the roots of this fallen tree have brought up the soil on which it has been growing, leaving behind a large depression on the ground.

Note the primary colonizers of this exposed soil. They are mostly bryophytes and ferns and a few seedlings of higher plants. These plants can grow here without competition from the roots of other plants. Only when they are much bigger and well established that they would have to compete with the neighbouring plants.

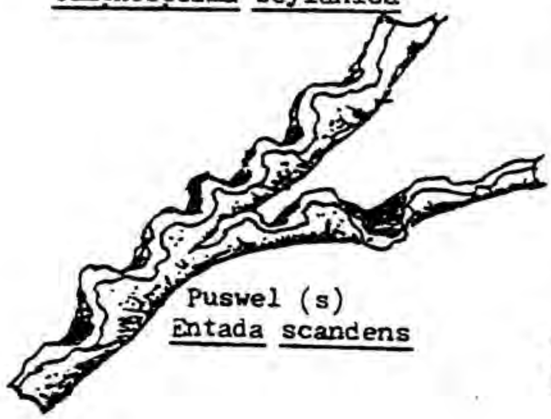
In time the depression will fill up with decomposing leaf material and the micro-site will provide a favourable spot for the growth of other plants. Does this not remind you of the refuse pits in home gardens, where kitchen refuse and leaf litter are collected and dumped. After allowing the collected material to rot for a while, the humus formed is dug out and used to nourish other plants or a new plant may be grown in the pit itself. The forest has its own way of creating such pits. Isn't it?

Observation point 12

Kurumbetiya (S)
Syzygium rubicundum

Etamba (S)
Mangifera zeylanica

Aridda (S)
Campnosperma zeylanica



Puswel (s)
Entada scandens

Angana (s)
Timonius jambosella

Observation Point 12 - Primary forest species, a peculiar woody climber, and rare species

The following trees may be seen here:

A) Kurumbetiya (Syzygium rubicundum) of the Guava family Myrtaceae. This species produces a large number of small fruits which are eaten by birds when mature. They are dark blue in colour.

B) Angana (Timonius jambosella) of the coffee or Ixora family, Rubiaceae.

C) Athuketiya (Xylopia championii) of the Anoda family, Anonaceae.

D) Aridda (Campnosperma zeylanica) of the Mango family, Anacardiaceae.

E) Thiniya or Dun (Shorea congestiflora) of the family Dipterocarpaceae.

The liana or woody climber you see ahead fluted to one side is Puswel (Entada scandens). See how it spreads through the forest.More about it is described in the guide to the vegetation of the Main Logging Road.

Epilogue

Walking through the trail it would have struck you that there are so many different plants. As much as 40% of these different types of trees or tree species are extremly rare and are represented only by one individual of its kind in an area of 2.5ha. Yet they contribute to the richness of the forest. A good example of one of them you have already seen is Kalumediriya or Calamander. If these forests are destroyed the world will never be able to produce this beautiful and very rare timber. We would only know it from the antique furniture that has been made from it.

Having gone through the trail, we hope that you have a better idea of what a natural forest appears and feels like. At a time when forests are rapidly disappearing, much effort is being made to conserve these unique habitats. In five different parts of the undisturbed natural forest in Sinharaja, in an extent of 25ha, there are 211 different types of trees or tree species. Of them over 64% i.e. 135 species are endemic or found only in the lowland wet zone of Sri Lanka. These endemics are not found in any other part of the world. If they are destroyed or made extinct, then the world will lose them altogether. So the forest you have just walked through is exclusive to Sri Lanka because of its high endemic componant. Let us conserve what little is left of this rich, complex, valuable and fragile habitat. Protect this legacy gifted to us by Nature carefully, so that sons and daughters of future Sri Lanka and the world at large may benefit from it. Do not let it be DESTROYED because we know little about it.

List of Animals of Sinharaja

Although it is quite difficult to observe a good proportion of the animal species in Sinharaja, yet you would wish to know what species do exist there. Consequently, the following pages list some of the species of the major animal groups that have been sighted. Alongside their name, the feeding habit of the animal, whether insectivorous (I), carnivorus(C), herbivorous (H) or omnivorus (O) has been indicated. According to the vertical stratum each animal occupies, they have been grouped as (G) ground- or (T) tree-dwellers.

Mammals

English Name	Local Name	Food Habit	Inhabiting-vertical strata in forest
Leopard	Kotiya	C	G,T
Fishing Cat	Handun Diviya	C	G,T
Otter	Diya Balla	C	G
Torque Monkey	Rilawa	C,H	T
Purple Faced Leaf Monkey	Hali Wandura	H	T
Loris	Una Hapuluwa	H,I	T
Pole Cat	Uguduwa	H,I	T
Golden Palm Civit	Ranhothambya	C,H	T
Mouse Deer	Meeminna	C,H	G
Barking Deer	Weli Muwa	H	G
Sambhur	Gona	H	G
Porcupine	Iththewa	H	G
Fire back squirrel	Pulutu lena	H	T
Giant squirrel	Dandu lena	H	T
Flying squirrel	Hambawa	H	T
Bat	Wavula	I,C	Aerial
Common Fruit Bat	Maha Wavula	H	T
Shrew	Hik Meeya	I,O	G
Rats	Meeyan	C,H	G,T
Ant Eater (Pangolin)	Kaballawa	C	G
Bandicoot	Uru Meeya	H	G

Birds

Above The Canopy & Canopy Layer	Local Name	Food Habit
Spine Tail Swift	Katupenda-Thurithaya	I
Edible Nest Swiftlet	Kadal-Thurithaya	I
Serpent Eagle	Sarapakussa	C
Black Eagle	Kalu Kussa	C
Crested Hawk Eagle	Konda Kussa	C

Canopy Layer		
Jungle Owlet	Wana-Bassa	C
Chestnut Backed Owlet	Pitathambala Wana-Bassa	C
Frogmouth	Madimuhuna	I
Brown Hawk Owl	Dumburu Ukusu Bassa	C
Little Scops Owl	Singithi Bassa	C
White Headed Starling	Hisa Sudu Sharikawa	H,I
Sri Lanka Grackle	Lanka Sela Lihiniya	I,H
Orange Minivet	Maha Miniviththa	I,H
Layards Parakeets	Alu Giraw	H
Green Imperial Pigeon	Maila Goya	H

Sub Canopy Layer		
Crested Drongo	Kalu Silu Kauda	I
Crested Goshawk	Siluwath Kurulugoya	C
Blue Magpie	Kehibella	I,H
Red Faced Malkoha	Vatha Rathu Malkoha	I,H
Yellow Fronted Barbet	Ranalal Kottoruwa	H

Understorey Tree & Shrub Layer		
Trogon	Lohawannichchiya	I
Bronze Winged Pigeon	Nila Kobeyiya	H
Azure Blue Fly Catcher	Nil Radamara	I
Yellow Browed Bulbul	Kaha Caluguduwa	I,H
Black Bulbul	Kalu Caluguduwa	I,H
Black Fronted Babbler	Hisa Kalu Panduru Demalichcha	I,H
Rufous Babbler	Ratu Demalichcha	I,H
Ashy Headed Babbler	His Alu-Demalichcha	I,H

Ground Layer

Spurfowl	Haban Kukulá	H/I Granivorus
Jungle Fowl	Wali Kukula	H/I Granivorus
Spotted Wing Thrush	Tithpiya Thirasikaya	I
Scaly Thrush	Pethigomara	I

Arthropoda	Local Names

1. rustacea

Crabs
Shrimps

2. Insecta

Above Ground

Bees	Bambaru, Debaru, MeeMesso
Flies	Masso
Mosquitoes	Maduruwo
Bugs	Keedewo
Butterflies, Moths	Samanalayo, Salabayo
Dragonflies	Bath Kuro
Beetles	Kuruminiyo
Cicardas	Rahaiyo
Grass Hoppers	Palangetiyo
Leaf Insects	--
Stick Insects	--

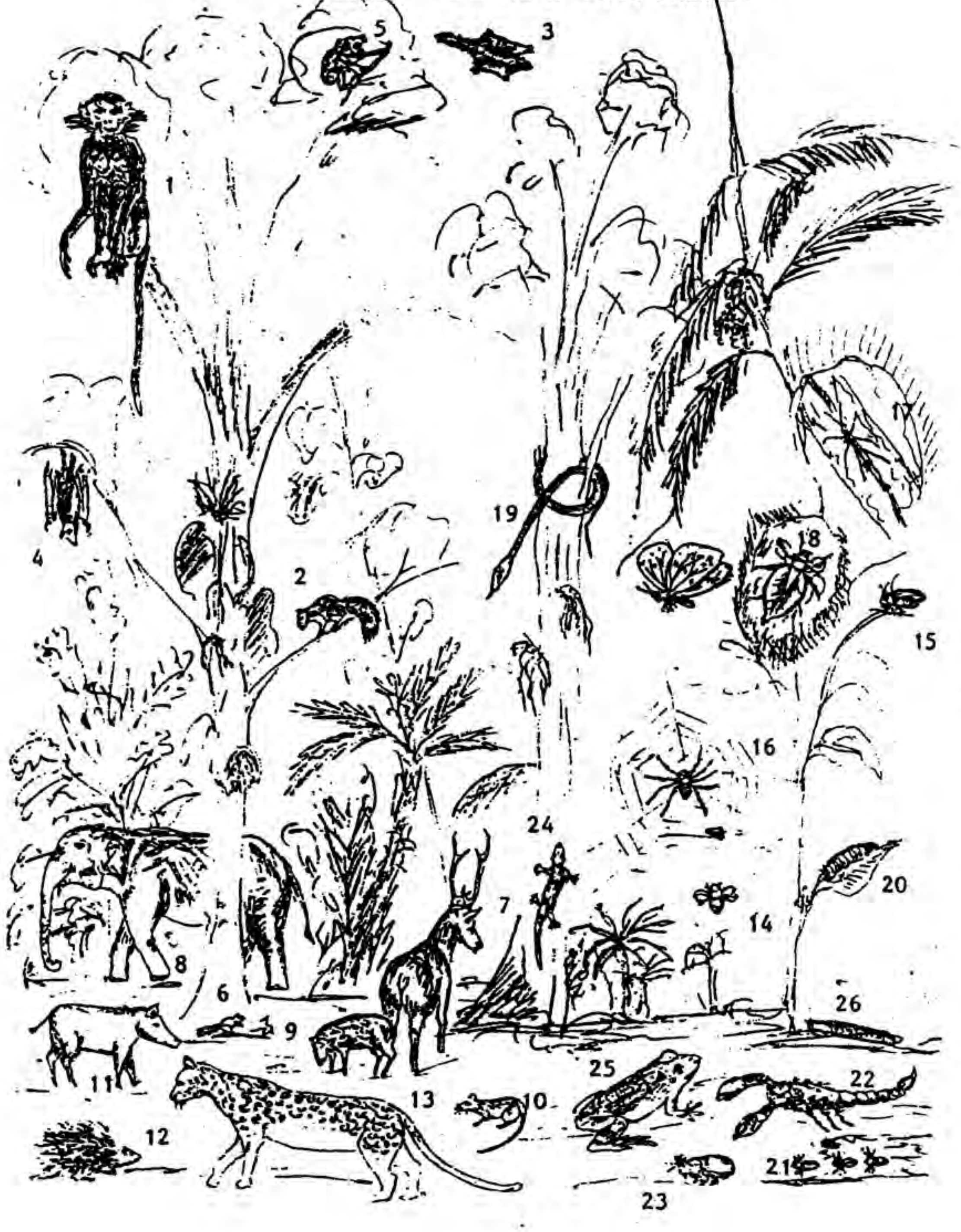
<u>Ground Level</u>	
Mosquitoes	Maduruwo
Ants	Kumbi
Termites	Weyo
Mites	Kinitullo
Grass Hoppers	Palangetiyo
Mole Cricket	Bin Ura

3. Arachnida	
Tarantula	Divi Makuluwa
Wood Spiders	
Web Spiders	

4. Myriopoda	
Millipede	Hekarella, Kitul Etaya
Centipede	Paththaya

<u>Annalida</u>	
Leeches	Koodello
Earthworms	Gedawilo

Mammals & Other Animals



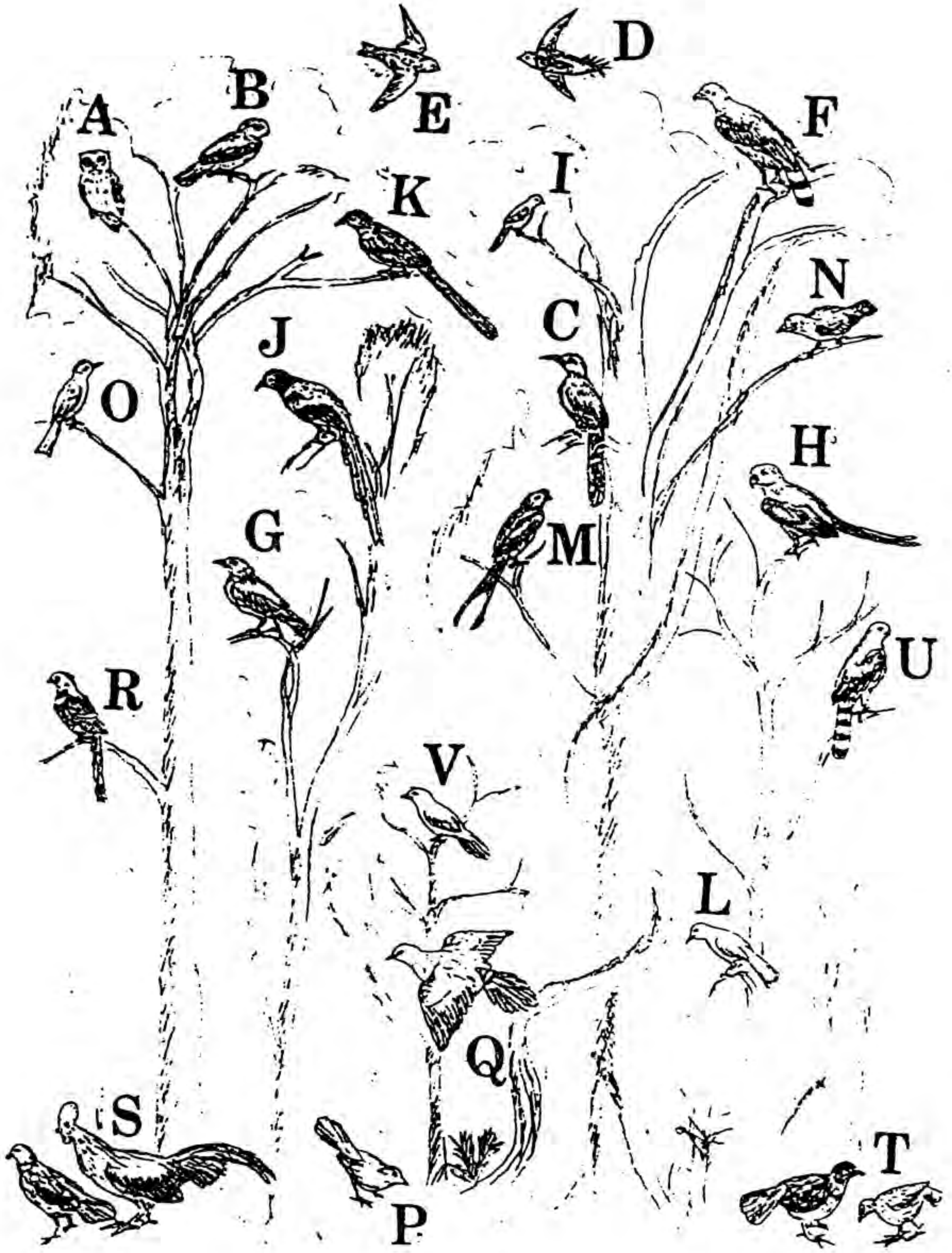
Some Animals in the Forest

Mammals:

		English Name	Sinhala Name
1	=	Purple•faced leaf monkey	= Hali Wandura
2	=	Giant squirrel	= Dandu lena
3	=	Flying squirrel	= Hambawa
4	=	Insectivorous bats	= Kiri wavulan
5	=	Loris	= Una hapuluwa
6	=	Fireback squirrel	= Pulutu lena
7	=	Sambur	= Gonna
8	=	Elephant	= Aliya
9	=	Mouse Deer	= Meeminna
10	=	Rat	= Miya
11	=	Wild boar	= Wal Ura
12	=	Porcupine	= Iththewa
13	=	Leopard	= Kotiya

Other Animals:

		English Name:	Sinhala Name
14	=	Fly	= Massa
15	=	Bees	= Meemassa
16	=	Spider	= Makuluwa
17	=	Stick Insect	= -
18	=	Leaf Insect	= -
19	=	Serpent	= Sarpaya
20	=	Catapillar	= Dalambuwa
21	=	Termites	= Weya
22	=	Scorpion	= Gonussa
23	=	Beetle	= Kuruminiya
24	=	Lizard	= Katussa
25	=	Frog	= Gemba
26	=	Giant Millipede	= Hekeralla


A
B
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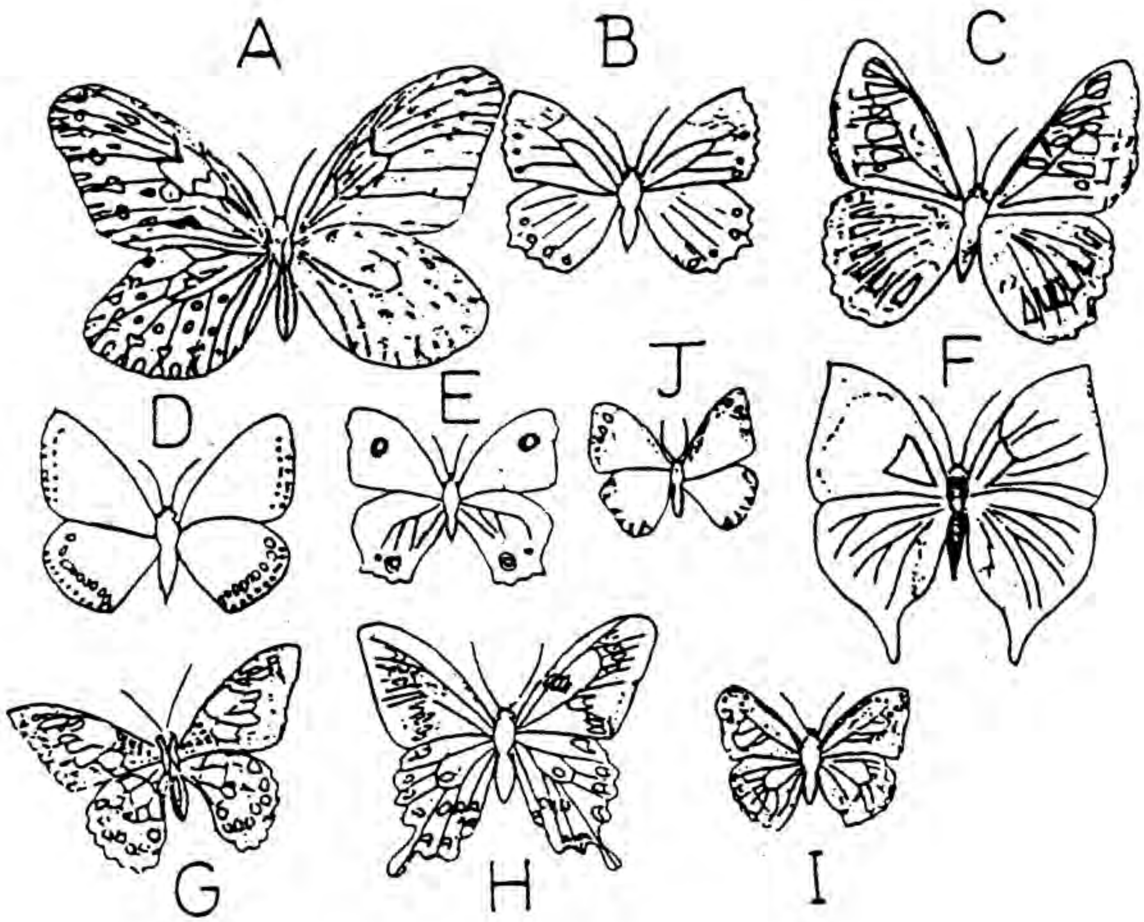
P

Some Birds seen in Different Strata of the Forest

English Name	Sinhala Name
A = Little Scops Owl	= Singithi Bassa
B = Brown Hawk	= Dumburu Ukusu Bassa
C = Grey Hornbill	= Alu Kandetta
D = Spine Tail Swift	= Katupenda Thurithaya
E = Edible Nest Swift	= Kadal Thurithaya
F = Crested Hawk Eagle	= Konda Kussa
G = Sri Lanka Grackle	= Lanka Sela Lihiniya
H = Layards Parakeet	= Alu Giraw
I = Orange Minivet	= Maha Miniviththa
J = Blue Magpie	= Kehibella
K = Red Faced Malkoha	= Vatha Rathu Malkoha
L = Yellw Browed Bulbul	= Kaha Galuguduwa
M = Crested Drongo	= Kalu Silu Kavda
N = Yellow fronted Barbet	= Mukalana kottoruwa
O = Black Bulbul	= Kalu Galuguduwa
P = Ashy Headed Babbler	= Hisa Alu Demalichcha
Q = Bronze Winged Pigeon	= Nila Kobeyiya
R = Trogon	= Lohawannichchiya
S = Jungle Fowl	= Wali Kukula
T = Spur Fowl	= Haban Kukula

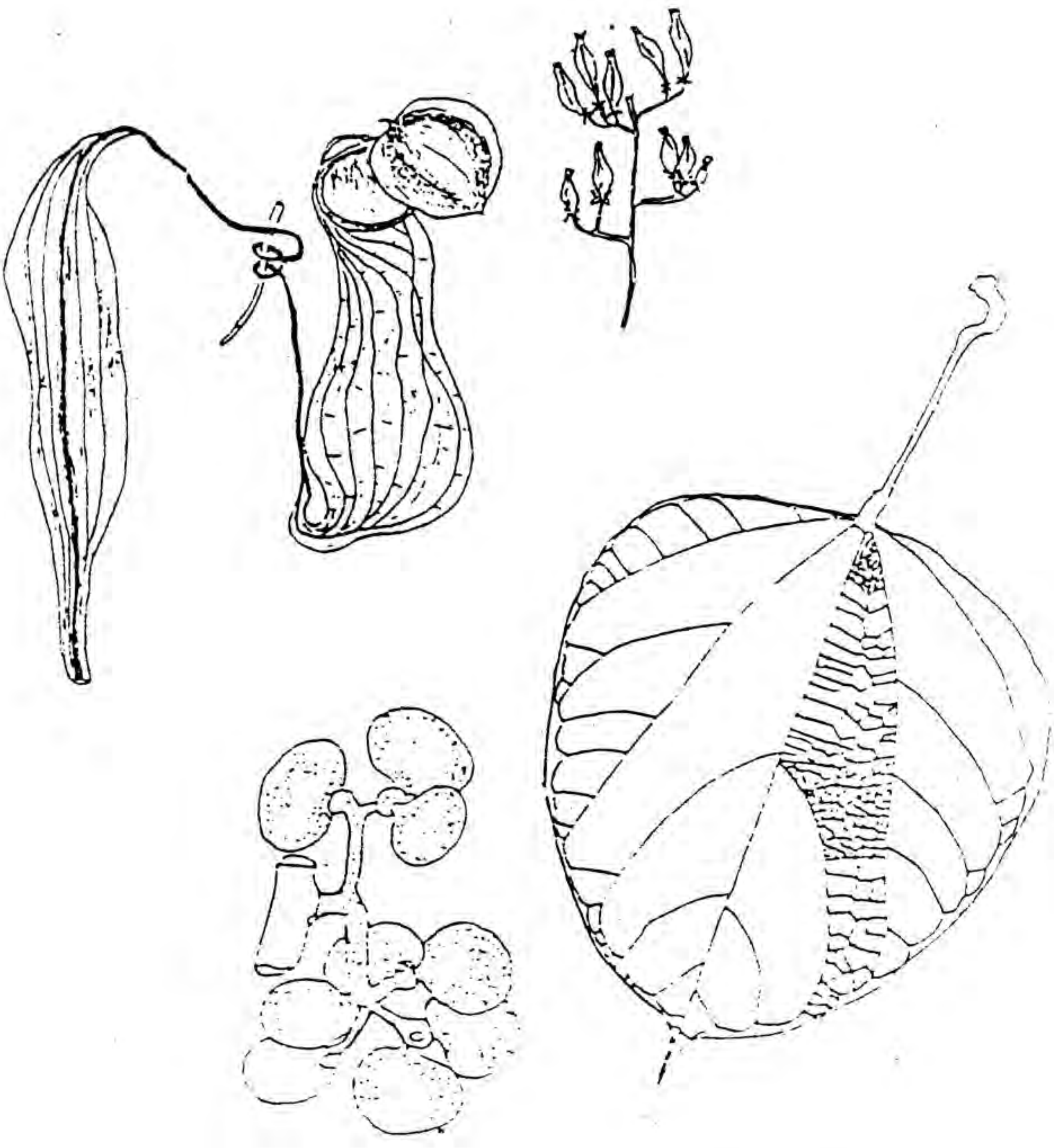


A = Ceylon tree Nymph
B = Common palm fly
C = **Clipper**
D = Double banded black crow
E = Common evening brown
F = Blue oak leaf
G = Lime butterfly
H = Common mormon
I = Painted lady
J = Common albatross

List of Botanical Names	Family	Local Name
Arundina graminifolia	Graminae	--------
Agrostistachys coreacea	Euphorbiaceae	Beru
Aporusa lanceolata	Euphorbiaceae	Wal Bombu
Anisophyllea cinnamomoides	Rhizophoraceae	Welipianna
Acranthera ceylanica	Rubiaceae	Gondiva
Calamus ovoide	Palmae	Thambotu Wel
Calamus zeylanicus	Palmae	Ma Wewal
Cleidemia sp.	Melastamataceae	Katakalu Bowitiya
Coleus sp.	Labiatae	-----
Costus speciosa	Zingiberaceae	Thebu
Cullenia zeylanica	Bombacaceae	Kataboda
Cullenia rosayroana	Bombacaceae	Kataboda
Campnosperma zeylanica	Anacardiaceae	Aridda
Garcinia hermoni	Clusiaceae	Madol
Dipterocarpus zeylanicus	Dipterocarpaceae	Hora
Dalbergia championi	Leguminosae	Kalu Bambara Wel
Diospyros quaesita	Ebenaceae	Kalumediriya
Humboldtia laurifolia	Leguminosae	Gal Karanda
Litsea gardneri	Lauraceae	Thalang
Macaranga peltata	Euphorbiaceae	Kenda
Mangifera zeylanica	Anacardiaceae	Etamba
Memecylon sp.	Melastomataceae	Pinibaru
Mesua nagassarium	Clusiaceae	Na
Mesua ferrea	Clusiaceae	Diya Na
Mikenia scandens	Compositae	Watupalu
Myristica dactyloides	Myristicaceae	Malaboda
Nepenthes distillatoria	Nepenthaceae	Bandura Wel
Nothopegia beddomei	Anacardiaceae	Bala
Ochlandra stridula	Bambusaceae	Bata
Palaquium petiolare	Sapotaceae	Kirihembiliya
Paspalum conjugatum	Graminae	----------
Penesetum sp.	Graminae	-----------
Schizostigma hirsuta	Rubiaceae	-----------
Semecarpus gardneri	Anacardiaceae	Badulla
Semecarpus walkeri	Anacardiaceae	Badulla
Shorea congestiflora	Dipterocarpaceae	Tiniya
Shorea distica	Dipterocarpaceae	Beraliya
Shorea megistophylla	Dipterocarpaceae	Maha-beraliya

Shorea stipularis	Dipterocarpaceae	Nawada
Shorea trapezifolia	Dipterocarpaceae	Yakahalu Dun
Schumacheria castaneifolia	Dilleniaceae	Kekiri Wara
Stemonoporus sp.	Dipterocarpaceae	Mandora
Syzygium rubicundum	Myrtaceae	Kurumbetiya
Timonius jambosella	Rubiaceae	Angana
Uncaria thwaitesii	Rubiaceae	Apassa Wel
Urandra apicalis	Icacinaceae	Uruhonda
Urophyllus ellipticum	Rubiaceae	----------
Xylopia championi	Anonaceae	Athuketiya

GUIDE TO THE ROADSIDE SECONDARY VEGETATION OF SINHARAJA



GUIDE TO THE ROADSIDE SECONDARY VEGETATION OF SINHARAJA

by

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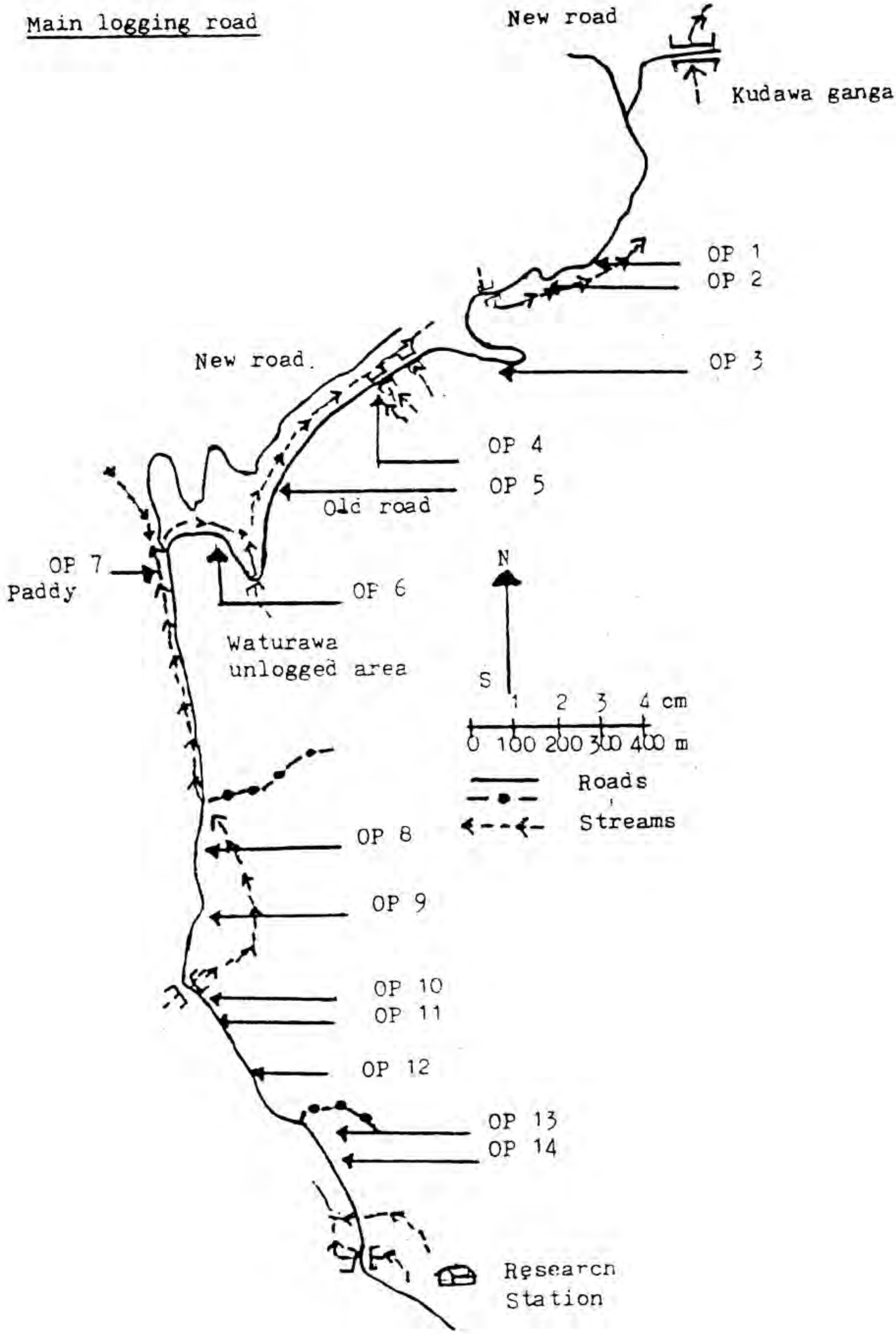
- & D. Welagedara -

Prepared for the field exercises at Sinharaja for the Regional Training Workshop on the Ecology and Conservation of Tropical Humid Forests of the Indomalayan Realm

- 1st to 5th March 1987 -

- SINHARAJA -


Main logging road
New road
Kudawa ganga
OP 1
OP 2
OP 3
New road
OP 4
OP 5
Old road
OP 7
Paddy
OP 6
N
Waturawa
unlogged area
S
1 2 3 4 cm
0 100 200 300 400 m
Roads
Streams
OP 8
OP 9
OP 10
OP 11
OP 12
OP 13
OP 14
Research
Station

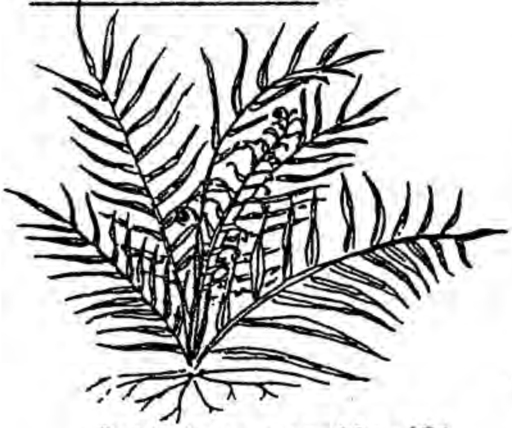
Trail Through Disturbed Area-Main Logging Road

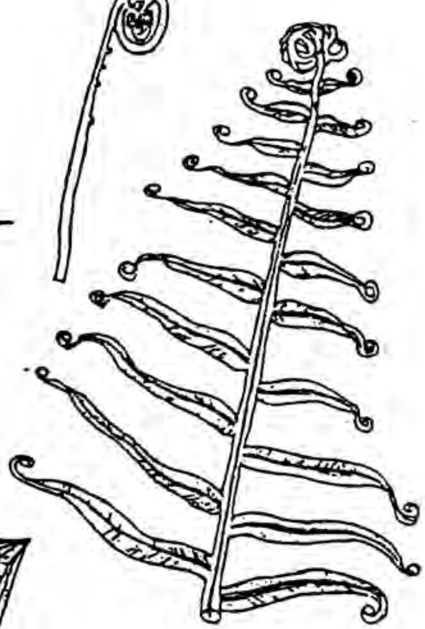
This trail is 4.7 km long. It follows the abandoned access road part of the way and the presently used motorable road the rest of the way. It was constructed during the logging project at Sinharaja between 1972 - 1977. The 14 observation points are sign posted. At each point, your attention is drawn to various plants which are labelled using the letters of the alphabet.

This trail depicts the roadside vegetation composed of a) secondary species abundant in disturbed areas, b) primary forest species that tend to grow better in disturbed areas or at the forest fringe and c) primary forest species that have survived the disturbance due to the logging project. Attention is also drawn to sites subject to shifting cultivation at present and in the past. It also describes the colonization of bare areas by the different groups of plants.

As the trail is through an open area, the best time to study it is either early morning or late evening so as to avoid the hot sun.

Observation Point 1





Paththara weralla (S)
Blechnum orientale

Maha Bowitiya (S)
Melastoma malabathricum

Arundina graminifolia

Hora (S)
Dipterocarpus zeylanicus

Observation Point 1 - Some common Roadside Species

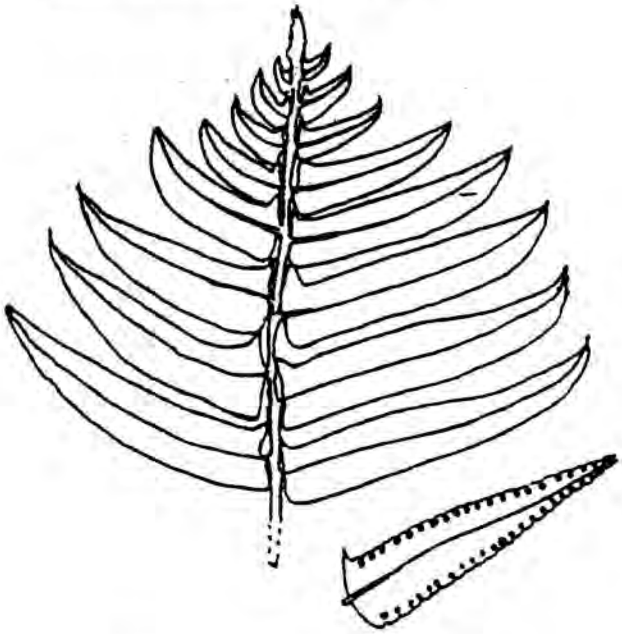
Along the road side most plants seen are secondary species, i.e they are plants which grow in disturbed areas. The tall tress on the left are common Jak trees (A) (Artocarpus heterophyllus) planted in 1979. Beneath them is one of the commonest roadside ferns called Paththera Weralla, Paththera Koku or Baru Koku. (B) Blechnum orientalis). The very young leaves of this fern, like most ferns are tightly coiled and brownish red in colour. When leaves unfold the tips of the leaflets bear this same colour giving it a beautiful appearence. The very young coiled leaves of this plant are edible and used by villagers as a vegetable.

The grass with the bottle brush-like inflorescence is (C) Pennesetum orientale. It is a recent introduction to the forest possibly brought in by the movement of vehicles through the forest during the logging project. It grows well by roadsides but is absent within the undisturbed forest.

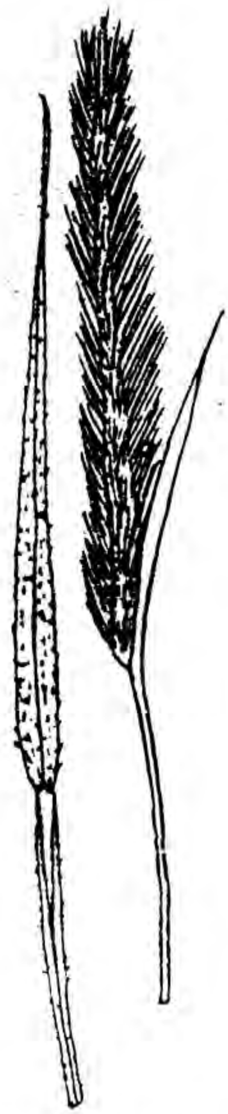
The shrub with oppositely arranged broad leaves and purple flowers is Maha Bowitiya (D) (Melastoma malabathricum). Its dehiscent fruits show a fleshy portion which bears on its surface tiny dull orange coloured seeds. In some trees the fleshy portion is white in colour in others it is deep purple. They are edible. Birds often eat them as well, thus dispersing the seeds that escape digestion. It is among the first species to grow in disturbed areas.

The beautiful light and dark purple (E) orchid is Arundina graminifolia. This too is seen in disturbed roadsides. Its six sided, green fruits contain a large number of minute powdery seeds which are easily wind dispersed when the fruit splits.

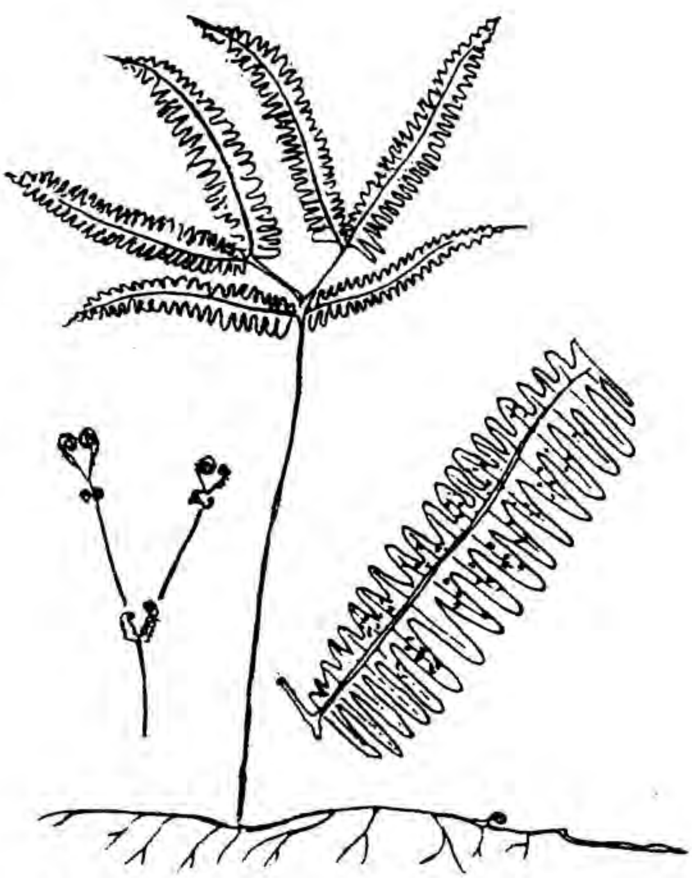
Observation Point 1



Nephrolepis sp.



Pennesetum
orientale



Kekilla (S)
Dicranopteris linearis

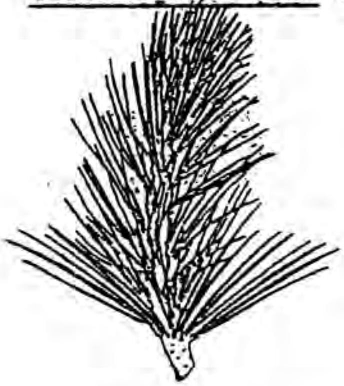
Furthermore the plant produces small plantlets vegetatively. Therefore, it can propagate well. It is a species not seen in undisturbed parts of the forest.

On eitherside of the road you can observe saplings of Hora (F) (Dipterocarpus zeylanicus) which have been planted in 1982.

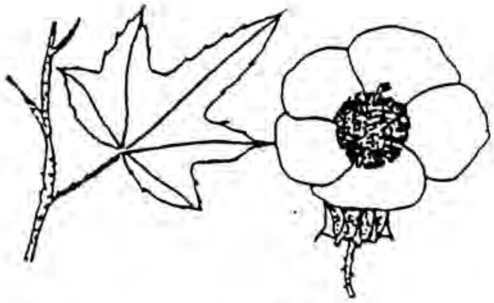
On the right bank of the road observe the Bata or Bamboo species (G) (Ochlandra stridula) with slender stems.

Other ferns in the vegetation here are Kekilla (H) (Dicranopteris linearis) and Nephrolepis. Kekilla is a fire resistant fern. It has a trailing stem which grows close to the ground or beneath the soil surface, thus escaping damage by fire. The leaves are borne on tall stalks that help to raise them well above other vegetation. Thus it gets shaded out only with difficulty. The trailing stem also roots at different places. Therefore, it can colonize bare areas.

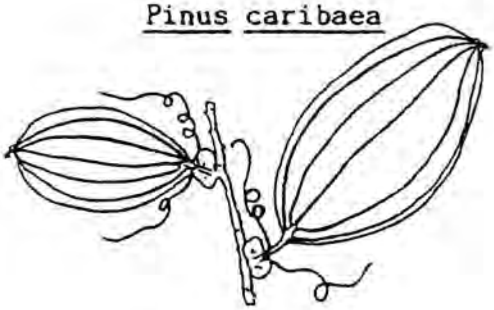
Observation Point 2



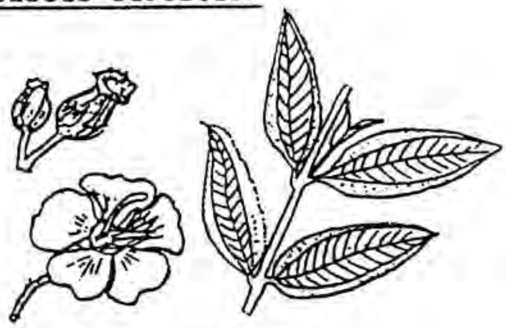
Pinus caribaea



Napiriththa (S)
Hibiscus furcatus



Kabarassa (S)
Smilax sp.



Heeen Bowitiya (S)
Osbeckia octandra

Weraniya (S)
Hedyotis fruticosa

I - Dipterocarpus zeylanicus
II - Artocarpus nobilis
III - Trema orientale
IV - Homalium zeylanicum

Observation Point 2 - Dipterocarpus Strand

The tall tree in the fore-ground is a Liyan (A) (Homalium zeylanicum). Its leaves are shiny with a finely serrated margin, Young leaves are crimson in colour.

The tall trees behind the Liyan, with grey coloured bark and straight stems are Hora (Dipterocarpus zeylanicus). Most of the trees you passed growing on either side of the stream on your left belong to this species and to the family Dipterocarpaceae. It is one of the dominant families in Sinharaja forest. The leaves of Hora have a fan like appearence because when they are very young they are folded like a fan. Young leaves are also protected by leaf-like structures which are hairy and pale pink on the outside but a deeper and brighter pink on the smooth inside. The hairs on them repel water thus protecting the young bud. These leaf-like structures cover the ground during the season when young leaves emerge. The fruits of Hora have two long, flattened, broad wings. They act like a propeller when the fruit falls from the tree. Young fruits are deep majenta in colour and hang downwards.

The tree to the right of the Liyan is Bedi del (B) (Artocarpus nobilis). Its leaves are superficially similar to those of Hora, but they are larger. Fruits and seeds of Bedi del are quite small compared to those of jak. The seeds can be cooked as a vegetable and they have a medicinal value as well. The plant belongs to Moraceae, the Nuga and Bo family.

Immediately next to the Bedi del tree is a Gedumba(C) (Trema orientale). It has spreading pendulous branches. When examined closely the two halves of each leaf are unequal in shape. Leaves have fine hairs on them. The fruits are small and many birds feed on them. Gedumba is a secondary tree species coming up in disturbed areas. However, like Kenda (Macaranga peltata) it does not regenerate in shady areas. Across the road and right ahead is the palm Kitul (D) (Caryota urens). It is also called the fish tail palm because of the shape of its leaflets. The flowers of kitul start blooming from the top towards the bottom. With the blooming of the uppermost flower, vegetative growth of the tree ceases. The strands bearing flowers are often more than 2 metres long and are pendulous. Mature fruits are eaten by Pole cats. Seeds are not digested and pass through unharmed. Before the individual flowers bloom the stout stalk of the flower bearing part of the plant when cut and treated in a special way yields large amounts of sap which is collected in pots or tins hung beneath it. This sugary liquid can be fermented into an alcoholic beaverage called toddy, or concentrated into a sugar candy called jaggery. The trunks of untapped mature trees, after flowering gives a carbohydrate commonly called kitul flour. The wood is used for building purposes and the leaves may be used to obtain kitul fibre, which was widely used in the past. The upper part of the stem and leaves are relished by elephants.

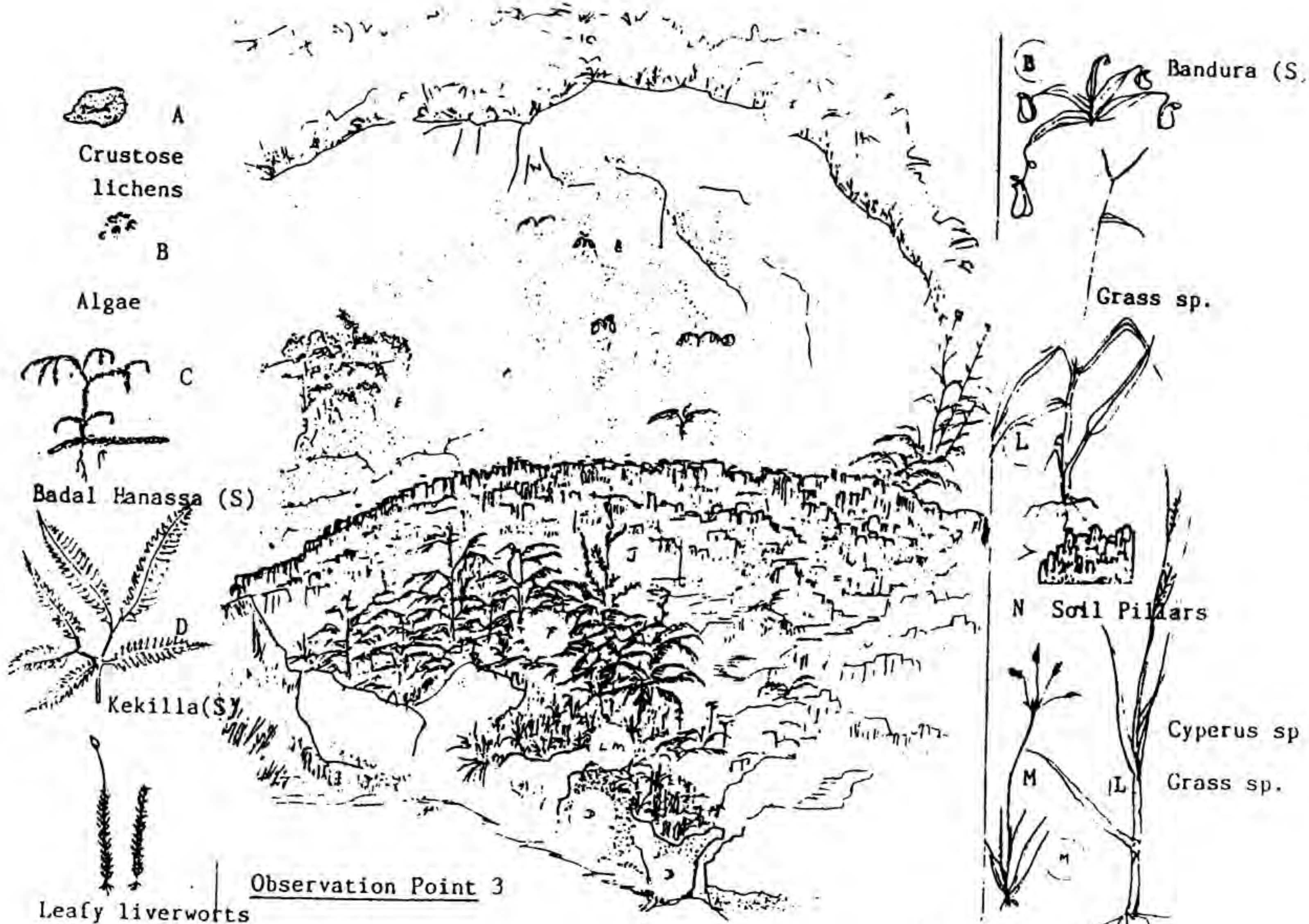
Behind the kitul is a stand of Pinus planted in 1978 in a Kekilla fernland, which is the common vegetation that comes after reforestation of the primary forest.

The tree on the right by the road and close to the osbervation point is a small Liyan (E) (Homalium zeylanicum). Its mother tree is possibly tree (A) on the opposite side.

As you proceed on the trail you will see a light yellow large flowered prickly plant. The centre of the flower is black. Its leaves are five lobed with a fine toothed margin. This plant is Na Piriththa (Hibiscus furcatus) of the Shoe Flower and Bandakka (ladies fingers) family Malvaceae. There are no species belonging to this family in the undisturbed parts of the forest.

Growing in a similar area as Napiriththa is also Kabarassa (Smilax sp.) . This too has spines and spring like structures near the petioles of the leaves by means of which they can climb on other vegetation. The leaves of this plant too resembles those of Cinnamon.

Two other plants which grow in these roadside areas are Weraniya (Hedyotis fruticosa) and Heen Bowitiya (Osbeckia octandra). Werania has clusters of small white tubular flowers which are frequently visited by butterflies. It belongs to the coffee family, Rubiaceae. Heen Bowitiya has pink flowers that superficially resemble those of Mana Bowitiya, but are much smaller. The fruits of Heen Bowitiya are not fleshy and dehiscent like those of Maha Bowitiya. Seed dispersal is through small pores seen at the top of the fruits. Heen Bowitiya is a member of the Melastomataceae.


A
Crustose
lichens
B
Algae
C
Badal Hanassa (S)
D
Kekilla(S)
Leafy liverworts
Observation Point 3
B
Bandura (S)
Grass sp.
L
N Soil Pillars
M
L
Cyperus sp
Grass sp.

Observation Point 3 - Early stages of secondary growth, Soil formation & Weathering

The first plants to colonize bare surfaces are crustose lichens (A) which are seen as black patches on this cut surface. They flake when wet. In addition, bright yellowish coloured patches of threadlike algae also colonize the land at this stage. These plants grow adpressed to the soil surface. One of the few higher plants that can grow on exposed surfaces as this is Bandura or the Pitcher Plant (B) (Nepenthus distillatoria). These plants grow in nutrient poor soils. The Pitcher Plant can trap and digest small insects obtaining their nitrogen supply from it. The first plants or pioneers or primary colonizers to invade bare areas improve the soil, retain moisture and upon their death provide humus. Slowly they build up the soil.

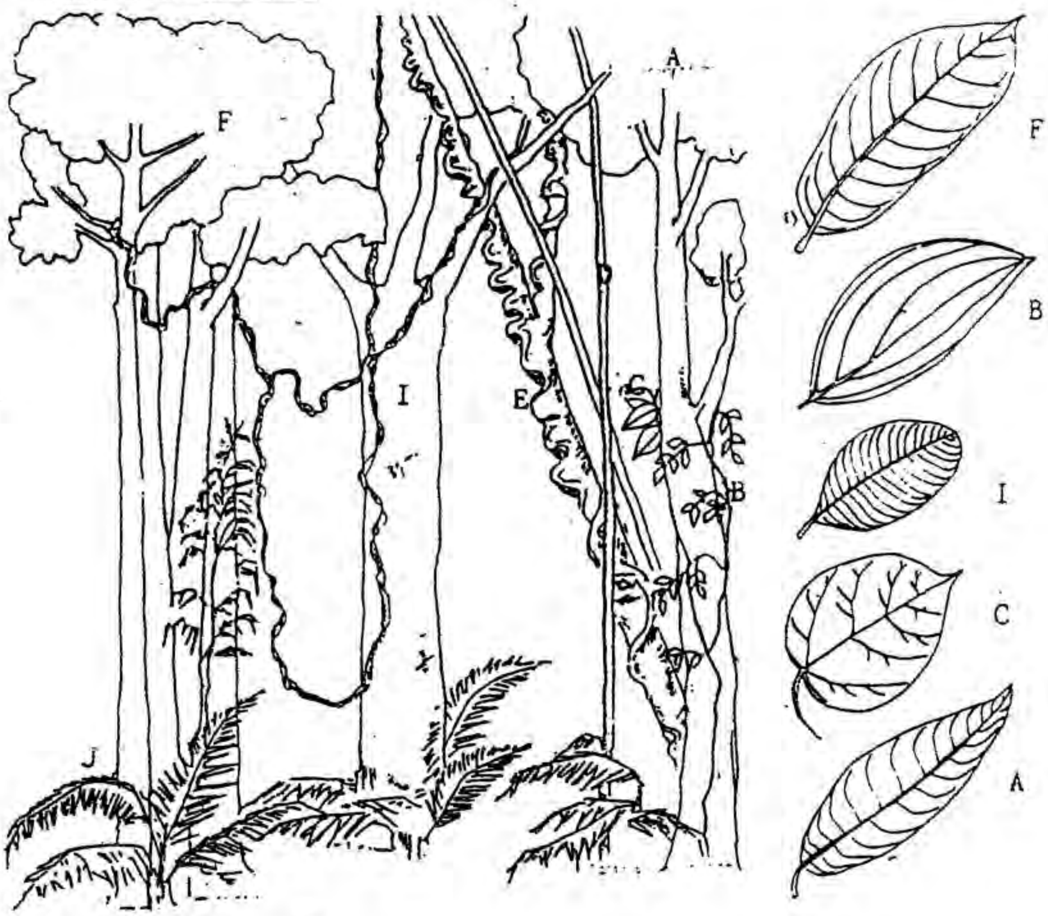
The second group of plants or secondary colonizers are the leafy liverworts (C) and mosses (D). Leafy liverworts grow adpressed to the ground. Mosses which grow erect are a few centimetres tall. They have small spirally arranged leaves and grow in moist crevises of these exposed areas. These plants in turn, bind the soil further and improve it with time. They also have the ability to retain moisture.

The third group of plants or tertiary colonizers are Badal Hanassa (E) (Lycopodium cernum) and some fern species. They have very light wind dispersed spores (their propagating structures) which help in their multiplication. In addition, they have trailing stems which root at intervals and when severed each rooted part may give rise to a new plant. Among the ferns Dicranopteris (F) and Blechnum (G) are common.

The fourth group of plants to grow in such habitats comprise some of the flowering plants. They are the orchid Arundina graminifolia (H), Melastoma malabathricum or Maha Bowitiya (I), Osbeckia octandra or Heen Bowitiya (J), Hedyotis fruticosa or Weraniya (K), and several grass species (L & M).

Where the surface is not covered by vegetation, fine sand and clay get washed away leaving small pillars of soil (N). On top of each of these pillars is a pebble or stone which gives the pillars its shape. The stone helps to protect the soil beneath it while that around gets slowly washed away. These columns also give some indication of the extent of erosion. The exposed soil is reddish brown in colour with larger sand particles and without humus. Soil animals in these areas are also extremely poor. These exposed areas are also subject to wide fluctuations in temperature, mositure and sunlight. Therefore, only the hardiest plants can grow on them. However, most of the plants seen here, cannot compete in dense vegetation.

Observation Point 4



Dalbergia championi

Freycinetia walkeri

A = Kobomella (S) - Vernonia arborea
B = Wal gammiris (S) - Piper sp.
C = Ficus laevis
E = Puswel (S) - Entada scandens
F = Iriya(S)- Horsfieldia irya
G = Freycinetia pycnophylla
I = Alubo (s) Syzygium maku
J = Paththara weralla (S) Blechnum orientalis

Observation Point 4 - Some Climbers

Tree (A) with non flaking bark is a member of the compositae, the sunflower family. It is known as Kobomella (Vernonia arborea). The bark also has patches of lichens which appear white and mosses which appear green or black. In Sri Lanka this is the only species of the compositae which grows into a big tree, all others are either herbs or shrubs. The small leaved climber on this tree is Wal gammiris or Mala gammiris or a wild pepper species (B) (Piper sp.). Its fruits are not as strong or hot as the domesticated pepper. The large heart shaped leaves is the second climber on this tree. It is Ficus laevis of the Nuga family. (C). Both these climbers are fixed to the supporting tree by their adventitious roots.

In the space within this forest patch two large lianas (woody climbers) are also seen. The straight stemmed one is known as Bambara wel (D) (Dalbergia championii) and is used for hauling logs by elephants. The liana whose stem is fluted and wavy on one side is Puswel (E) (Entada scandens) Both lianas have compound leaves which are only seen on the crowns of the canopy tree. Leaves of Puswel are much smaller than those of Bambara wel which are also pendulous. The uppermost part of the Bambara wel is often seen standing out extending above the canopy as slender branches. The fruits of Puswel are characteristic in that they are large and spirally coiled. They bear several large, flat, more or less square shaped, shiny brown seeds. These seeds are used by children to play hopscotch. They are also made into ornamental chains. The wood is reported to be of medicinal value.

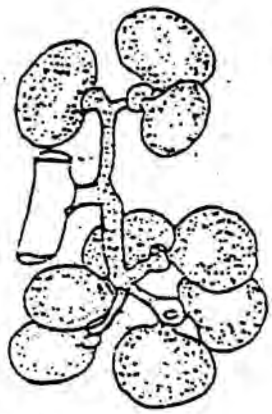
The large trees to the left, with multicoloured bark that flakes away in large pieces is Iriya (F) (Horsfieldia irya). It has relatively large leaves.

Their underside is covered with fine yellowish brown hairs. The flowers of **Iriya** are small and borne on slender branches. They are very fragrant, particularly at dusk and are yellow in colour. It belongs to Myristicaceae or the Nutmeg or Sadikka family.

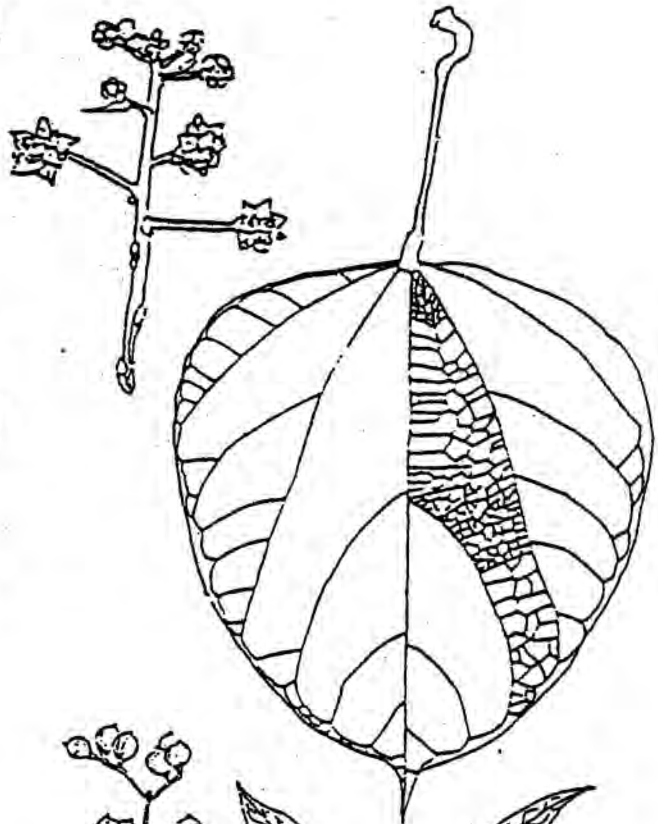
Two climbers are seen growing on the Iriya trees. They are root climbers. In both the leaves are spirally arranged on branches that extend outwards from the supporting tree. The small leaved climber is Freycinetia pycnophylla (G) and the large leaved one Freycinetia walkeri (H), belonging to the Pandanaceae, the Wetakeia and Rampe family. The large tree in the background is Alubo (I) (Syzygium makul). It has an ash colour stem whose bark flakes in membranous or tissue paper-like pieces. The fruits of Alubo are fleshy and single seeded. When mature they are reddish blue in colour and eaten and dispersed by birds. They can be eaten by man as well. It is a member of the Myrtaceae, the Jambu, Pera and Eucalyptus family.

In the fore ground by the road is the fern, Baru Koku or Paththara Weralla (Blechnum orientalis (T) and the shade loving grass Lophatherum gracile.

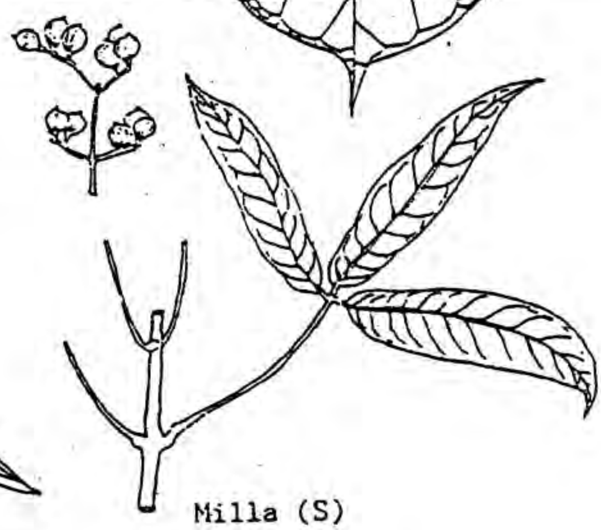
Observation Point 5



Weniwelgeta (S)
Coscinium fenestratum



Welipianna (S)
Anisophyllea cinnamomoides



Milla (S)
Vitex pinnata

Observation Point 5 - Welipianna-Milla
(Anisophyllea - Vitex) stand

On your left, the young tree supporting the climber with circular shaped leaves, is Welipianna (A) (Anisophyllea cinnamomoides). Mature trees of this species reach the canopy of the forest. On young twigs, very small and large leaves may be seen alternating with each other. When the twig is old, the small leaves fall off leaving only the large ones. The arrangement of veins on these leaves resemble those of Kurundu or Cinnamon. The scientific name Anisophyllea cinnamomoides is given because of these features of the leaves. 'Aniso' means different 'phyllea' refers to leaves. This species belongs to Rhizophoraceae, the dominant family of the mangroves. Welipianna is one of three species of Rhizophoraceae which grow in the interior of the country away from the magroves.

Tree (B) is Kobomella (Vernonia arborea) which you have already seen in Observation Point 4.

The trees with trifoliate leaves, that are oppositely arranged is Milla (C) (Vitex pinnata). The leaf stalks of young leaves are winged in this species. Milla flowers are purple in colour and are visited by bees. The single seeded small fruits are eaten by birds, such as Flower Peckers and Bul Buls. Milla is one species which grows in the forests of the wet zone as well as those of the dry zone. The wood of Milla provides valuable timber. It is one species that will not rot when used in contact with the ground. When milla trees die in the forest, the heart wood remains without decomposing even for several decades of years. The bark is reported to be used as a formentation for rheumatic swellings. The wood is yellow in colour and may be used as a dye. The tree belongs to Verbenaceae, the Teak , Gandapana and Balu Naguta family.

The climber (E) growing on Welipianna is Weniwelgeta (Coscinium fenestratum). it grows to be a woody climber or liana and is usually more abundant along roadsides than within the undisturbed forest. Its large leaves are alternately arranged on slender twigs that hang downwards. In this species there are separate male plants bearing the pollen flowers which do not set fruit and female plants bearing flowers that develop fruits. The fruits are one seeded and about the size of marbles. They are eaten by Pole cats, but the hard seeds are not digested by them and pass out unharmed with their faecal matter. Such seeds are found to germinate much faster than those which escape being eaten by Pole cats. The woody liana is yellow in colour, and its water extract, believed to have anti-tetanus properties is widely used in Sri Lanka to treat common colds, fever, body aches and injury due to rusty nails or wire.

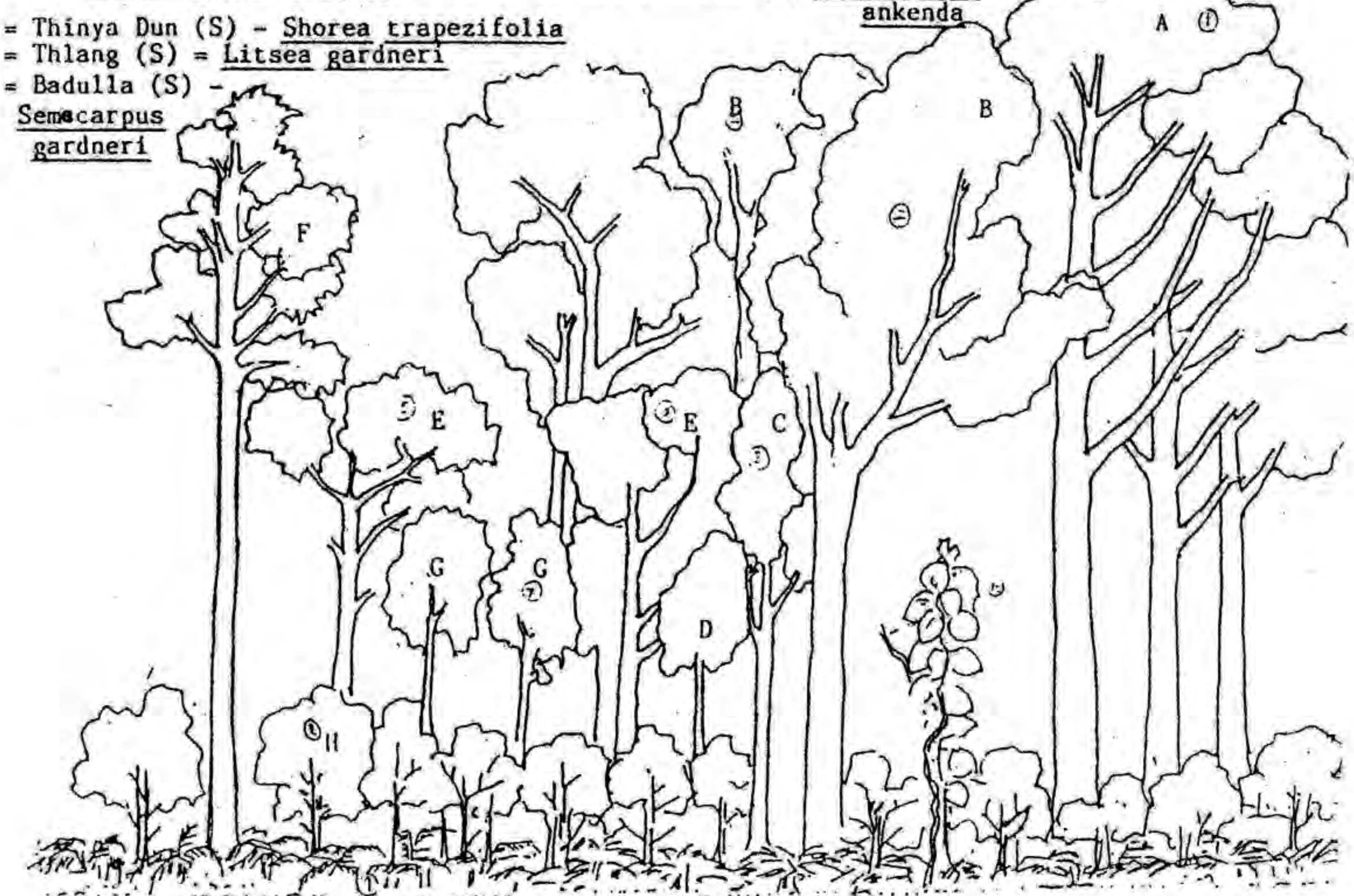
About half inch wide stems of this species, twisted together is used to tie cattle as a substitute for rope.

In areas like Nawalapitiya and Pundaluoya, pieces of the stem of Weniwelgeta are put into Kitul sap when it is being concentrated to form jaggary. In Sinharaja it is not used for this purpose. Instead, the bark of Hal (Vateria copallifera) and Navada or Hulan Idda (Shorea stipularis) are used. Their function is to arrest the fermentation of the sugary sap.

Observation Point 6

A = Thinya Dun (S) - *Shorea trapezifolia*
B = Thlang (S) = *Litsea gardneri*
C = Badulla (S) - *Semecarpus gardneri*

D = Aridda(S) - *Campnosperma zeylanica*
E = Lunu-ankenda (S) *Evodia lunu-ankenda*



F = Havari nuga(s)-*Alstonia macrophylla* G = Kekriwara (S) = *Schumacheria castaneifol:*
H = Weraniya (S) -*Hedyotis fruticosa* I =Weniwelgeta (S)-*Coscinium fenestratum*

Observation Point 6- Patch of Regenerating Forest

The following plants may be observed here.

(A) Thiniya Dun (Shorea trapezifolia), the canopy tree on the extreme right, which shows parachute like branching and small leaves. It is a member of the Dipterocarpaceae, one of the dominant families in rainforests of the lowland wet zone of Sri Lanka.

(B) Thalang (Litsea gardneri), is the low branching tree, with relatively large leaves. Each leaf has distinct veins and its undersurface is light brown to whitish in colour. The cream coloured flowers of this species are borne on small branches. They are visited by birds (flower peckers, Sun Birds), bees and butterflies.

(C) Badulla (Semecarpus gardneri) represented by a sapling here has large bright green hanging leaves. The exudate or secretions of this species causes irritation to the skin and the plant should be handled with care. This too has cream coloured flowers that are visited by bees. It is a member of Anacardiaceae, the Cadju, Amba and Ambarella family.

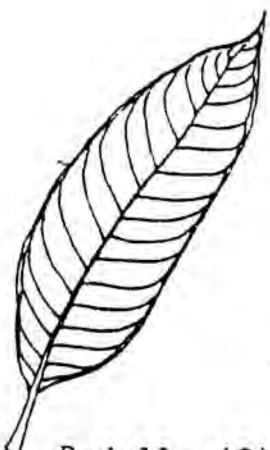
(D) Aridda (Campnosperma zeylanica), a canopy species is represented here as a sapling. Its mature leaves are held vertically upwards. Young leaves are slightly brown in colour. This belongs to the family Anacardiaceae.

(E) Lunu-ankenda (Evodia lunu-ankenda). This normally grows into a small tree. It is one of the late colonizers of disturbed areas. The leaves of this species are trifoliate and when crushed they have a citrus smell. It has white flowers which are visited by bees and butterflies. It belongs to Rutaceae, the Dodan, Dehi and Karapincha family.

Observation Point 6

Aridda (S)
Campnosperma zeylanica

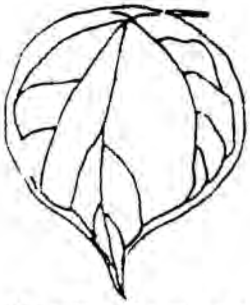
Kekiriwara (S)
Schumacheria castaneifolia



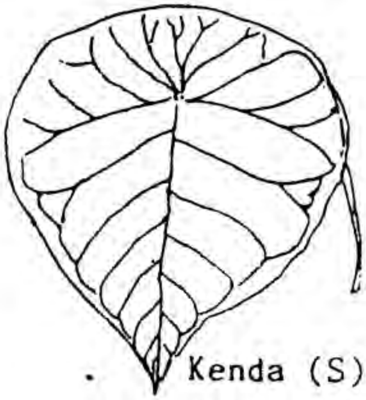
Badulla (S)
Semecarpus gardneri

Havari Nuga (S)
Alstonia macrophylla

Thalang (S)
Litsea gardneri



Weniwelgeta (S)
Coscinium fenestratum



Kenda (S)
Macaranga peltata

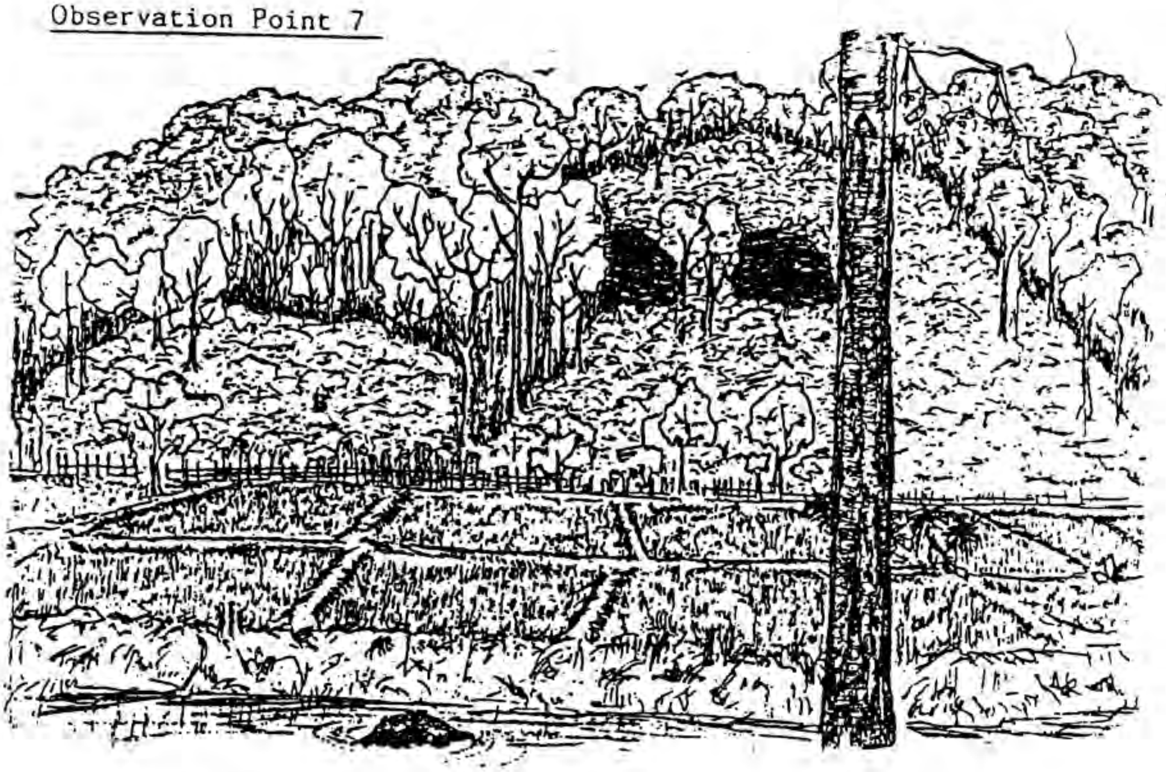
(F) Havari Nuga (Alstonia macrophylla) is the tall tree on the extreme right with a whorled branching arrangement. It has bright green mature leaves and yellow coloured old leaves. This species has been accidentally introduced to Sinharaja sometime during the logging project. It belongs to Apocynaceae, the Araliya and Idda family.

(G) Kekiriwara (Schumacheria castaneifolia) is a small treelet. It has a slender, frequently unbranched stem with a small crown at the top. The flowers of this species are small and yellow in colour and hang down on slender stalks. The poles of the species are very strong and may be used to construct racks or platforms.

Schumacheria is only found in Sri Lanka and no where else in the world. The ancestral forms of this species were among the first to have formed during evolution of the flowering plants.

A few other species present here are Weraniya , Kekilla and Weniwelgeta which you have met earlier along the trail.

Observation Point 7



Shifting Cultivated Area and Paddy Fields

Near Waturawa

Observation Point 7 - Shifting Cultivated area

The slope beyond the paddy field shows how villagers have invaded the forest for shifting cultivation. A block of land near the fringe of the forest is cut down, burnt and cultivated for several years. There are no agrochemical inputs to this type of cultivation which depends entirely on nutrients available in the soil. After a few years of cultivation the fertility of the land decreases and the land is then abandoned. It is allowed to rest for several years during which time secondary vegetation returns to the land. Consequently the soil is improved again. Once the block of land is abandoned, another adjoining it is cultivated, repeating the process once more. Hence, the term 'shifting' cultivation. The area in front with small trees (A) is a result of shifting cultivation in 1968-1969.

In cultivated and abandoned areas, Kekilla (Dicranopteris linearis) takes over the land giving rise to a fernland. If such fernlands are allowed to grow without burning secondary tree species (Havari Nuga (Alstonia macrophylla), Kampoththa (Aporusa cardiospermum), Bombu (Symplocos sp.), Kenda (Macaranga peltata)) begin to grow as seen in the area immediately above the exposed rocks. If the fernland is repeatedly burnt, then the vegetation continues to remain as a fernland.

The tall trees on the crest of the slope are remnants of the original forest.

In forest ecosystems, most of the nutrients are in the living component (i.e. algae, fungi, bryophytes, ferns, flowering plants and animals). The soil itself has very little nutrients as compared to the living component. That is why shifting cultivated areas have to be abandoned after some time.

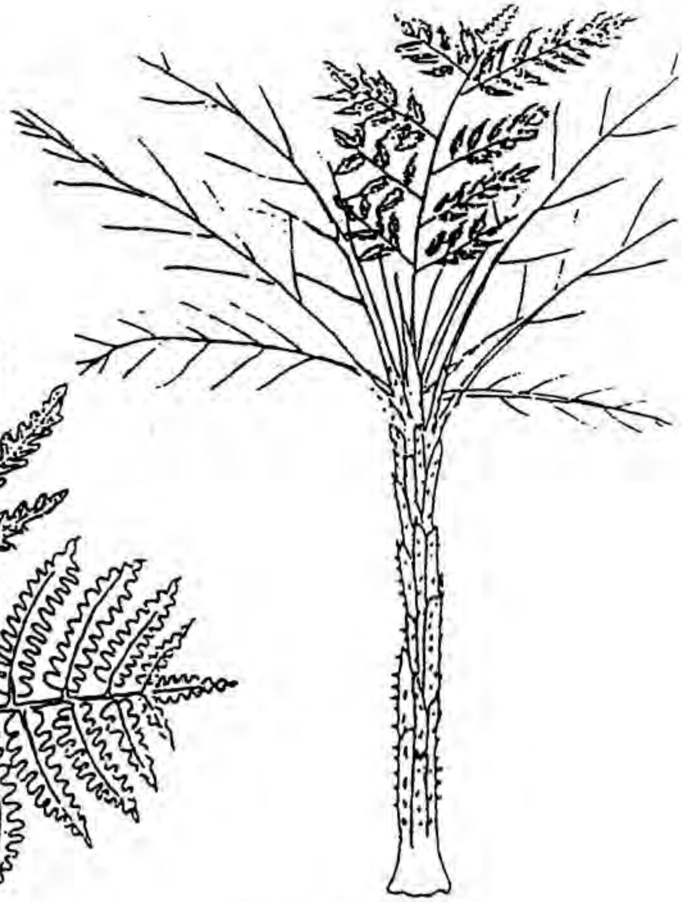
On crevises of the exposed rocks, grasses and other secondary shrub species have established. If this area continues to be undisturbed they would be replaced by late colonizing tree species.

In the patch of fernland (B) indigenous species like Pelan (Bhesa zeylanica), Thiniya Dun (Shorea trapezifolia), Kokum(Kokoona zeylanica) and Uruhonda (Urandra apicalis) have been planted in early 1986.

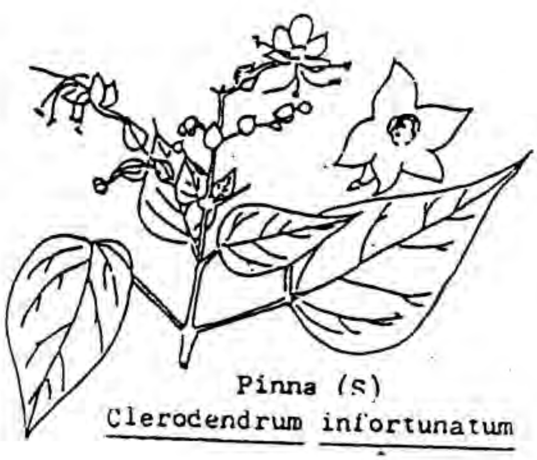
The paddy field here has been cultivated for over 50 years. Martin, a very knowledgeable and long standing resident of the area, now one of the caretakers of the field station, says that elephants frequently devastated this paddy field during the period before 1958. The last time elephants were sited in this part of Sinharaja, he says is 1959, the year when a motorable track was made into the forest, right up to the present field station. Although, elephants are never seen now,on many occasions, Sambur and Wild Boar have destroyed these paddy fields to such an extent that the cultivator is compelled to abandon them.

The tree with the observation point label is a Badulla tree (Semecarpus sp.)

Observation Point 6



Ginihota (S)
Cyathia walkeri



Pinna (S)
Clerodendrum infortunatum

Podisingho-Maram (S)
Eupatorium odoratum

Observation Point 8 - More Road Side Species

On your left is the tree fern (A) (Cyathea walkeri) locally called Ginihota. Its dark chocolate brown coloured stem is covered by stiff scales and sheathing bases of dead leaves. This species grows near moist habitats of both disturbed and undisturbed areas.

The four pole trees beyond the fern are Iriya (B) (Horsfieldia irya) which you have already seen at observation point 4 where the Puswel grows.

The small treelets (C)are Kekiriwara (Schumacheria castaneifolia) and the climber with conspicuous white leaf like structures is (D) Mussanda frondosa. You will read more about this species later on at Observation Point 13.

The large shrub (D) is Pinna (Clerodendrum infortunatum).. It has heart shaped leaves which are arranged in opposite pairs. The young parts of the twigs are quadrangular in shape. The tubular flowers of Pinna are white in colour, arranged in groups or inflorescences and held well above the leaves. At first the outer petals or calyx is light green but after pollination they enlarge, turn red and represents a shallow funnel. Within it is a single black fruit. These fruits with their persistent calyx are quite attractive. It belongs to the Milla, Teak and Balunaguta family, Verbenaceae.

Pinna too is a species of disturbed areas. It is a common species by the roadside in Sinharaja. It is not seen in the undisturbed forests.

Do you recognise the common roadside species you have seen before. They are the following:

i) Kekilla or _Dicranopteris linearis_

ii) Maha Bowitiya or _Melastoma malabathricum_

iii) Napiriththa or _Hibiscus furcatus_

iv) _Pennesetum orientale_

v) Podisingho-Maram or _Eupatorium odoratum_

vi) Paththara-Koku or _Blechnum orientale_

vii) Weraniya or _Hedyotis fruticosa_

Observation Point 9

A = Degraded forest with lines

B = Canopy of relatively undisturbed forest

C = Abandoned shifting cultivated area

Observation Point 9 - Another shifting cultivated area

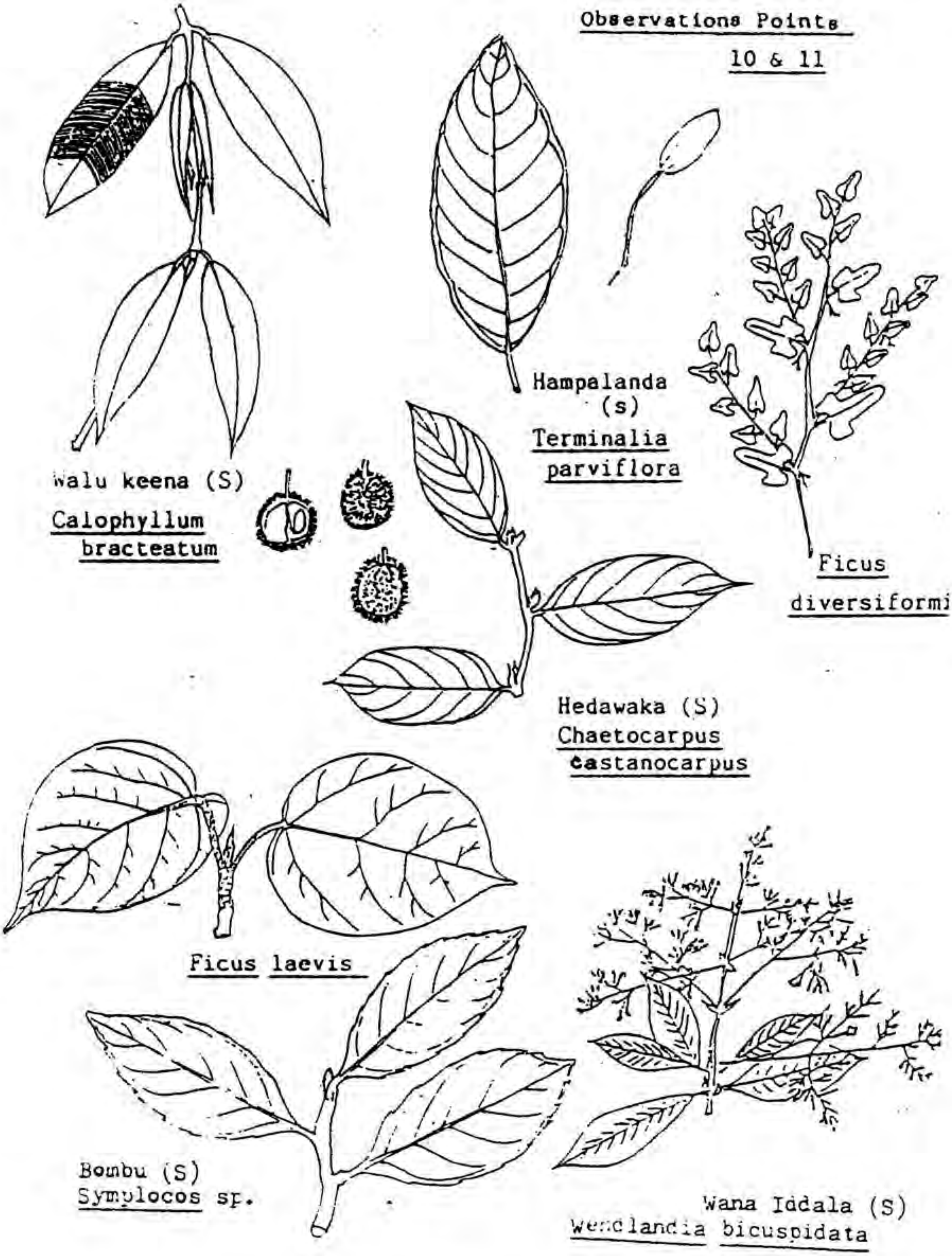
On the upper part of the slope beyond the valley, the vegetation is relatively undisturbed, where as the lower part of the slope has been subject to shifting cultivation in the past and then abandoned in 1965. The vegetation that has grown since then, is what is seen here now, Notice the difference in the canopy of the two vegetation types. In the undisturbed area, the canopy is more less continuous and there are very few creepers growing on it. In contrast, that of the disturbed forest is broken up and discontinuous. Large numbers of lianas are also seen growing on the canopy of this vegetation.

Most of the tallest trees in the skyline are Shorea species. Notice their spreading crowns and their branching pattern which resembles the cords of a parachute.

A better view of the valley below can be seen from further on at Observation Point 10. This valley had only been cultivated for one year (1965) and then abandoned. Although a seed source of primary forest species surrounds it, there are very few primary species growing in it , possibly because it is a water logged area.

Puwak (Areca catechu) and Kos (Artocarpus heterophyllus) seen on the far left are species planted by men when the area was cultivated.

Observations Points 10 & 11



Observation Point 10

From this point too the undisturbed forest on the ridge , the patchy disturbed vegetation on the slopes and valley may be seen.

Wana Iddala (A) (Wendlandia bicuspidata) a species of disturbed areas and commonly seen in forest fringes. The bark of this species has characteristic vertical fissures and is brown in colour. Leaves of this species are arranged in whorls. Each whorl having 3 leaves, Young leaves are reddish brown at the base and are held upright, unlike those of most forest species which * white, borne in groups or inflorescences, which project well above the branches. These flowers are visited by bees & butterflies. The species is a member of the Coffee and Ixora family,Rubiaceae.

The wood of this species is very hard and therefore it is used for poles in the construction of village homes & scaffoldings. The poles are also used for live fences. The plant has the ability to sprout from the base.

The small treelet (B) is Bombu (Symplocos sp.). This species is often seen in disturbed areas. It has white flowers that hang downwards and are borne in conspicuous groups,

The large tree (C) growing at the bottom of the bank is Gedumba (Trema orientale). It has a whitish bark. You came by this species in Observation Point 2. The tree is one of the first to grow in disturbed habitats. It regenerates only in light. Therefore young plants are not seen growing in the shade.

The hill on the opposite side of the road here is called Leopard Rock because at one time it used to be one of the sighting points of this wonderful animal.

[*hang downwards. The flowers of this species are]

Observation Point 11 - Three Primary Forest Species

At this point the trees of interest are Hedawaka (A) (Chaetocarpus castanocarpus), Hampalanda (B) (Terminalia parviflora) on the left hand side of the road and Walu keena (C) (Calophyllum bracteatum) on the right hand side of the road.

Hedawaka is a subcanopy tree, with a non flaking bark. Its flowers are inconspicuous, but its small fruits are covered by fine prickles which turn from green to bright red when mature., These prickles easily stick to clothing and are quite difficult to remove. Villagers advise us not to stand beneath fruiting trees of Hedawaka and look up in case detached prickles of these fruits should get into the eye. The wood of Hedawaka is sought after for fuel wood as it has a high calorific content and it is one of the few species that will burn when freshly cut. This belongs to Euphorbiaceae, the Kenda, Rubber and Nelli family.

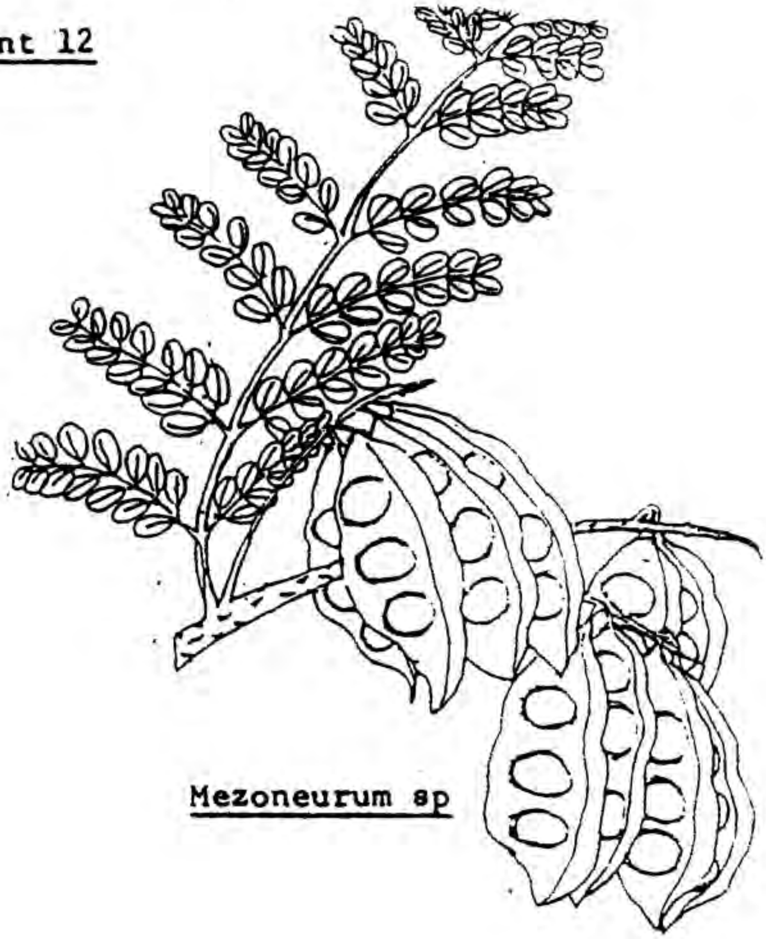
On the Hedawaka are several creepers. Two of them are lianas. One with rope-like markings and the other is flat and ribbon like. Both climb to the canopy in search of light. A root climber with small leaves is also present. This however, has a slender stem and is adapted to grow in shade.

Hampalanda is a canopy species, also with a non flaking bark, which like that of Hedawaka supports crustose lichens. The tree flowers profusely and its flowers are visited by several species of bees and butterflies. It belongs to Combretaceae, the Aralu, Bulu and Kumbuk family.

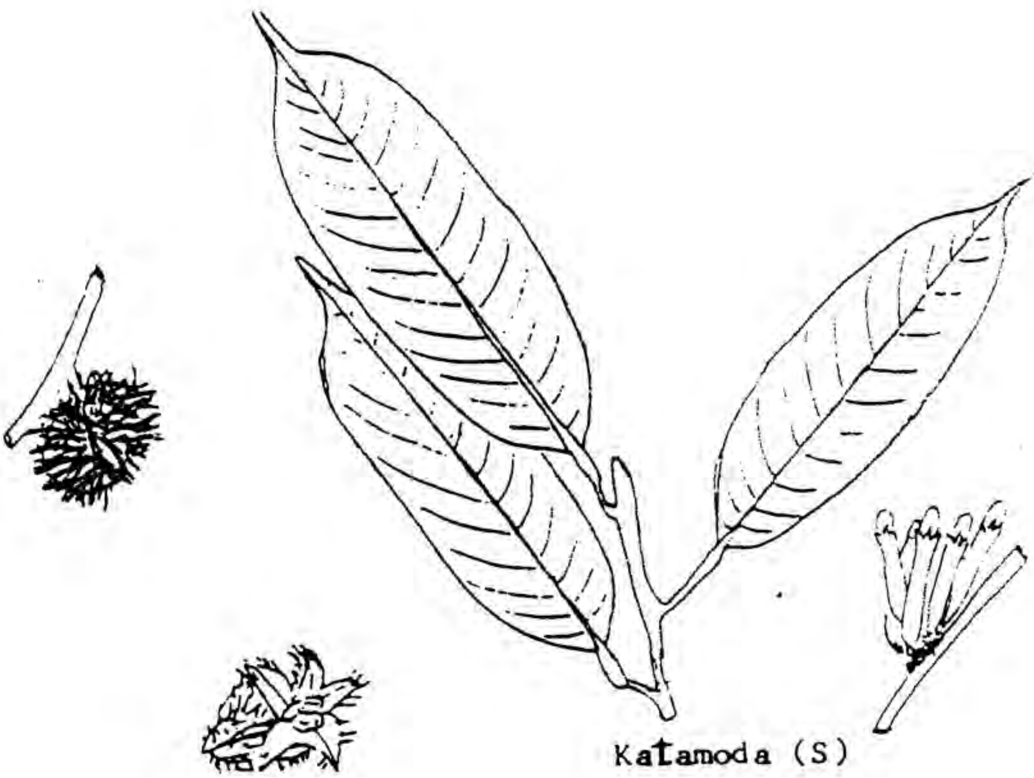
On the Hampalanda is a climber with heart shaped leaves. It is Ficus laevis and belongs to the Nuga family. Another root climber is Ficus diversiformis which grows on barks of trees and rock surfaces.

On the right hand side of the road and growing on the bank is a beautiful ornamental tree, with pendent leaves and branches. This is Walu Keena (Calophyllum bracteatum). It has oppositely arranged leaves and every alternating pair is smaller in size. Young leaves have a characterisitc white colour that makes the tree very attractive. This belongs to Clusiaceae, the Mangosteen, Goraka and Na family.

Observation Point 12



Mezoneurum sp



Katamoda (S)

Cullenia ceylanica

Observation Point 12 - Abandoned logging yard

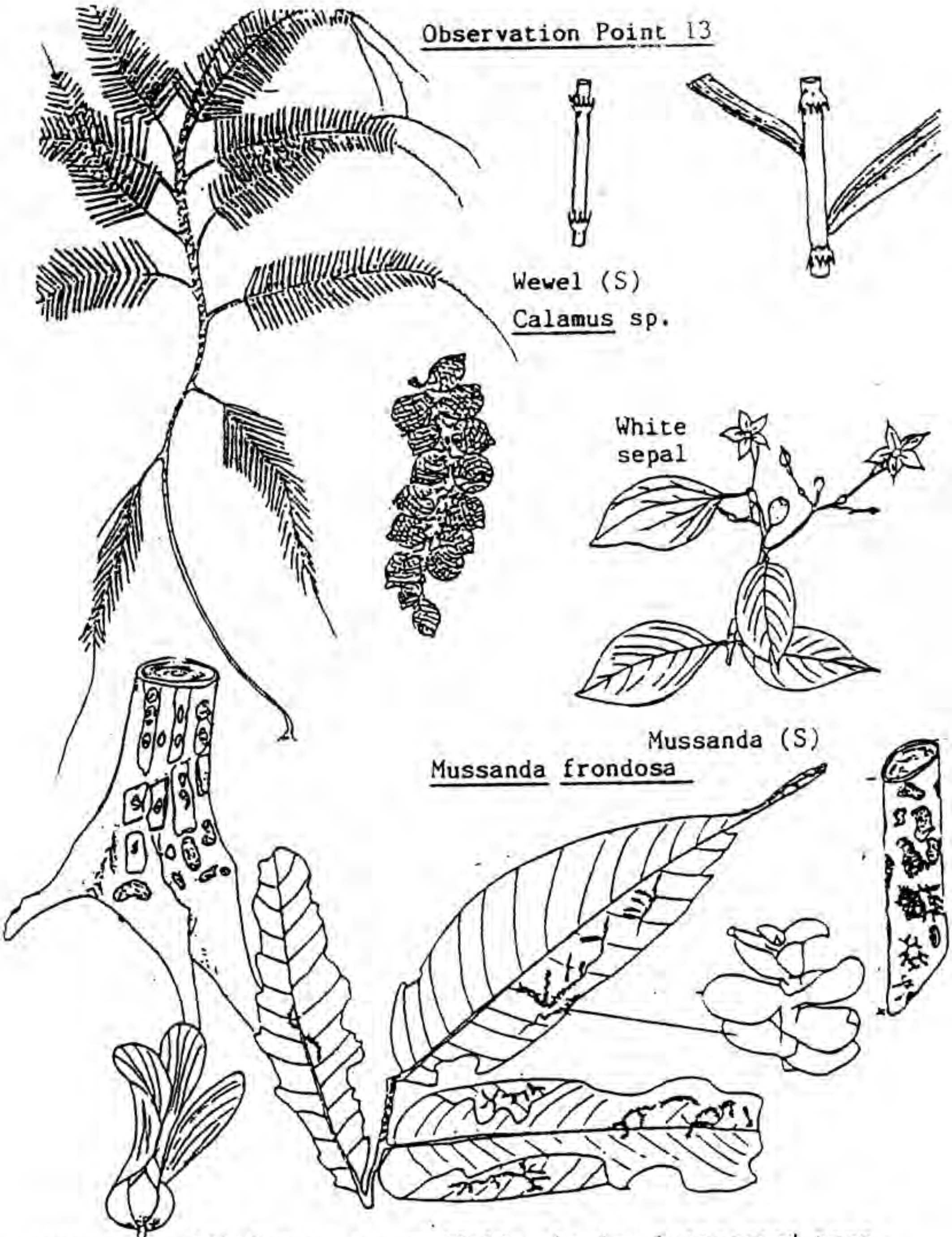
During the logging project, this open area on the right was used for collection of logs before their transport to the plywood factory. In preparation of the area, the top soil has been buldozed away, and what remained heavily compacted by logs stored here and machinery used. The substratum being exposed to sun and rain has been eroded and whatever nutrients it had leached away. It is such an environment that plants have colonized, established and grown to give the present vegetation you see today. Most of the common species you see here are ones you have already encountered, between observation posts 1-9.

On the opposite side of the road too, a large area has been cleared to provide storage space for logs as well as access to the interior of the forest to fell timber. These access roads that are on steep slopes, sometimes as much as 60°, are called skid trails.

The system of felling adopted during the logging project is selective logging where only a few large trees per ha were removed for timber. However, these logging roads and skid trails open up the forest to a large extent, changing the microclimate of these forests. Furthermore, when a tree is cut and dragged out to the timber yard many more trees along its path are also damaged or uprooted. Consequently , large gaps which let the sunlight through to the lower strata of the forest are created. On your left, in the angle between the skid trail, and main logging road that you are traversing, is a Katamoda (A) (Cullenia ceylanica). When you look up at the tree from beneath it has a yellowish appearence, because the under surface of its leaves are covered with golden coloured scales.

The elongated, golden coloured, tubular flowers of this tree are borne on branches. During the flowering season many animals visit it. Among them are the Giant Squirrel, Southern Purple Face Leaf Monkey, bats and birds. Its fruits are large and resemble small durian fruits. They have spines on them. The fleshy part covering the seeds are edible and eaten by monkeys, squirrels and bats.

As you continue along the road, you will see a thorny climber with very small leaves scrambling on the crowns of most plants. If the climber is in fruit you will certainly not miss it, for it's mature pods are purplish red in colour and hang downwards in groups. This plant is Mezoneurum sp. a member of the Leguminosae, the Bean, Cowpea or Dambala family. It is a species, common in disturbed areas.



Thiniya Dun (S) <u>Shorea trapezifolia</u> showing buttressed tree base, fruit, leaves with epiphytes and epiphytic lichens on stem.

Observation Point 13 - Saplings of *Shorea trapezifolia*

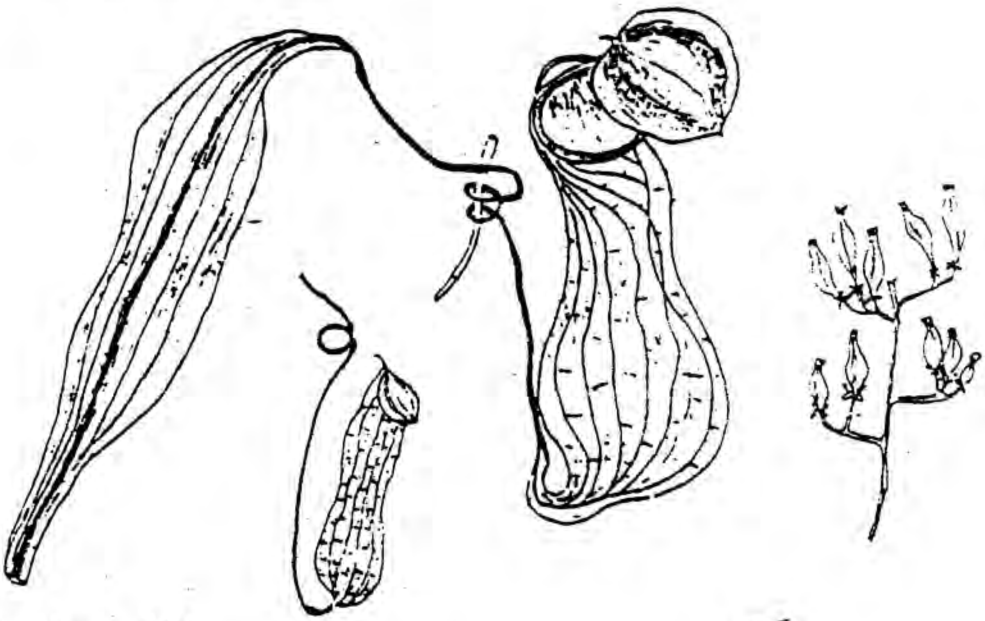
Six saplings on the left bank here, are developing trees of Thiniya Dun (A) (*Shorea trapezifolia*). They have grown after 1977 when the logging project was withdrawn. The lower branches of these saplings are very short lived. They die possibly due to shading and as a result the stems are thin and tall. Hence they are also referred to as pole trees. On top of the bank and just before these 6 Thiniya Dun saplings is possibly their mother tree, labelled ST 13. It is partly covered by the tree in front which is another species of Keena (*Calophyllum* sp.). Notice the expanded base of ST 13. These are its buttresses which provide it a broad base providing much stability to these tall trees. Note the flaking bark of the mother tree as compared to those of the saplings, which have lichens and bryophytes of different colours.

On your way to the field station from here or even on your way up, you would have certainly seen the gigantic (B) cane species or wewel which over top the canopy. Although these canes look alike, there are three different species, Ma wewel or Wanduru wel (*Calamus zeylanicus*), Thambutu wel (*Calamus ovoides*) and sudu wewel or Ela wewel (*Calamus rivalis*). wewel grows well in disturbed areas where the canopy has been opened up. In forest patches surrounding the early part of this trail and towards Kudawa, wewel is not so common because villagers have exploited it mostly for weaving of baskets and other domestic products. In this part of the forest they are abundant because collection of wewel is now prohibited.

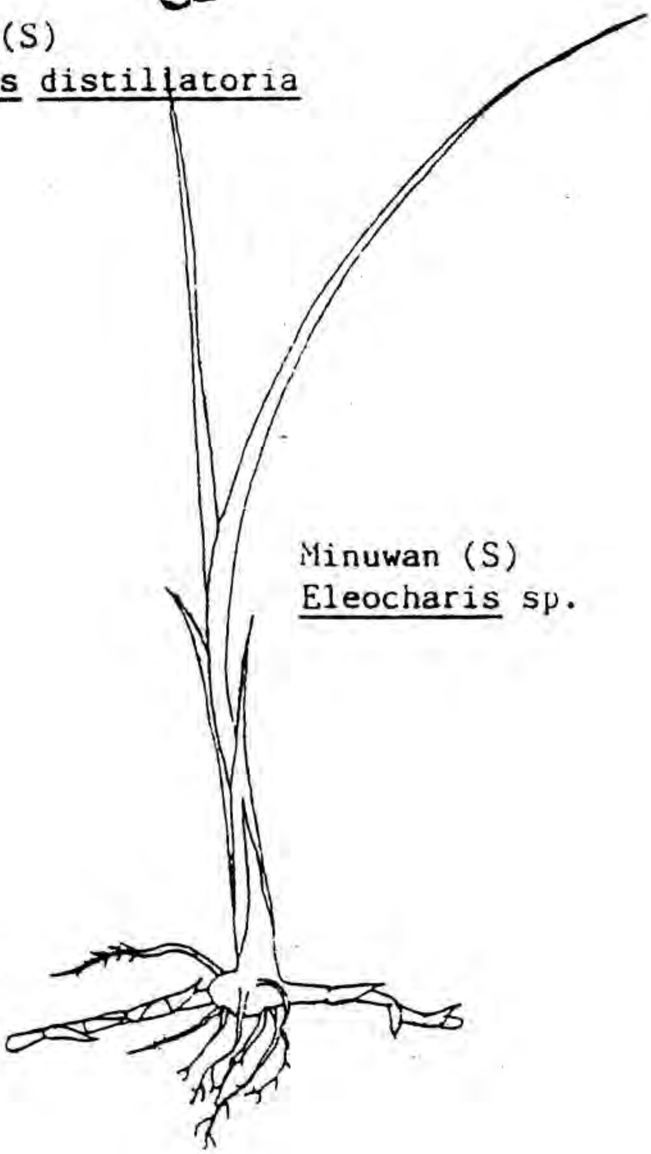
The wewel plant consists of a very long slender stem, which is protected by sheathing leaf bases. That part of the leaf which bears the leaflets are over 2m long. The upper most part of the leaf is drawn out into a long whip like structure. The different parts of the leaf (the basal sheath, middle portion and the whip-like terminal) have spines which are differently shaped. Its flowers are borne in conspicuous bunches. Fruits are one seeded, attractive and covered by brown scales. The fleshy portion covering the seed is edible and eaten by Pole cats.

Wewel belongs to the Palmae, the Puwak, Kitul and Pol family. Another plant that stands out in the vegetation is the climbing shrub (C) Mussanda or Wel Butsarana(Mussanda frondosa) because of its attractive white leaf-like structure, which is part of the flower. It is one of the sepals (ie. one of the parts of the outer whorl of the flower immediately outside the petals) which is enlarged. The petals of Mussanda are small, bright orange and fused basally to form a tube. The upper part of the petals appear starlike. Butterflies are often seen at them collecting nectar. Its fruits are many seeded. The plant grows in disturbed habitats and belongs to Rubiaceae, the Coffee,Rathmal and Weraniya family.

Observation Point 14



Bandura (S)
Nepenthes distillatoria



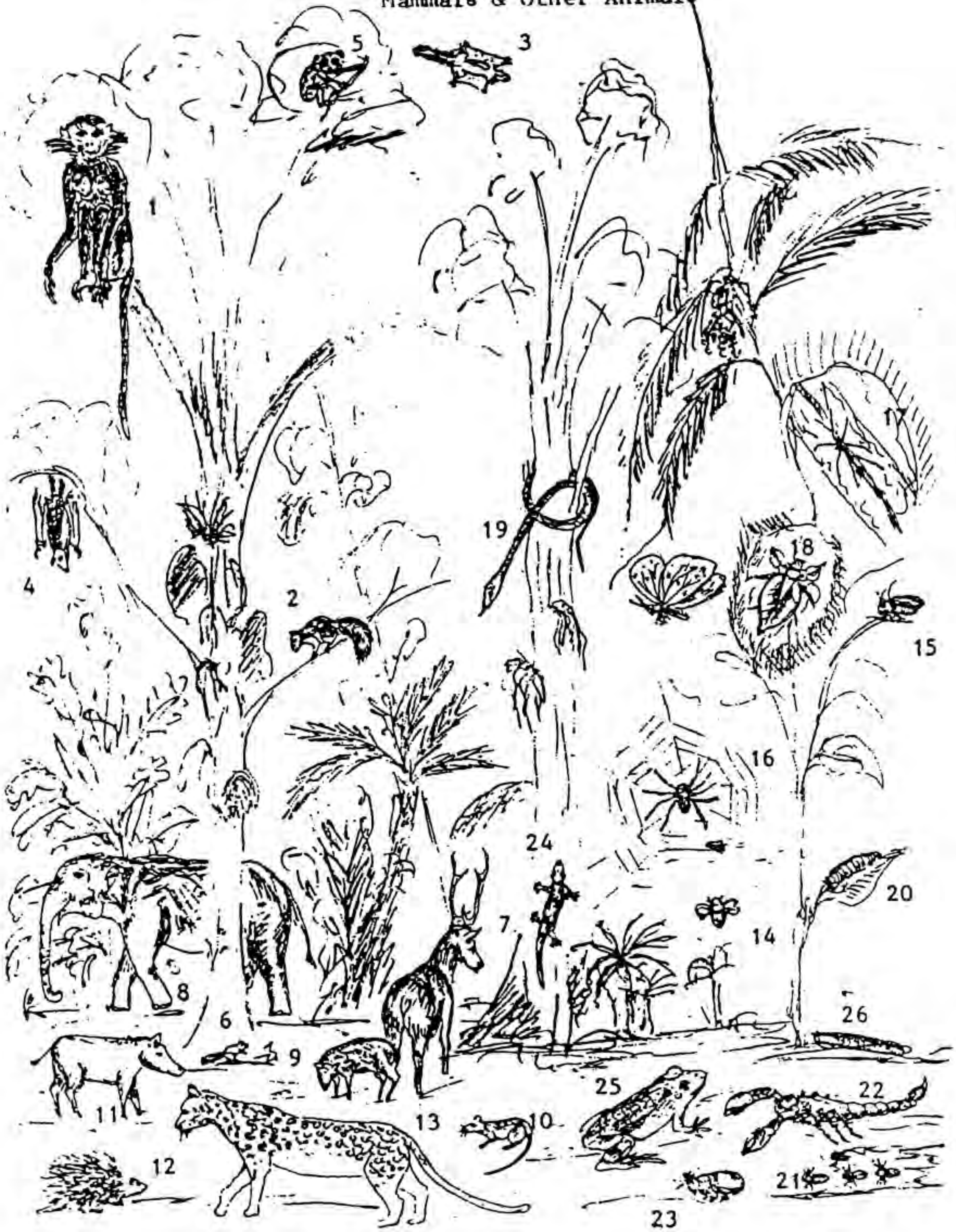
Minuwan (S)
Eleocharis sp.

Observation Point 14 -Pan Wila or Reed Bed and Pitcher Plants

To the left is a marshy area where (A) Pan or Reeds (Eleocharis) called 'Minuwan' is seen to grow. These plants have been introduced by man in 1973/1974 during the logging project at Sinharaja. Periodically the plants are removed dusted with ash, sun dried and used in weaving mats and baskets. In the foreground the pitcher plant or Bandura (B) (Nepenthes distillatoria) is seen creeping on shrubs and treelets. The part that helps the plant to climb is the long cylindrical portion between the pitcher and leaf-like portion. This can easily coil round small twigs. The pitcher, even before it opens contains a watery liquid which can digest insects that enter the pitcher and drown in this liquid. Once the lid of the pitcher opens, it never closes again. when the pitcher is closed and even when it is open, the lid possibly keeps away rain water that may enter it. In this species there are separate male plants which produce the pollen and female plants which produce fruits.

The stem of the plant can become quite thick and it is used for tying in the construction of wattle and daub houses and ladders.

Mammals & Other Animals



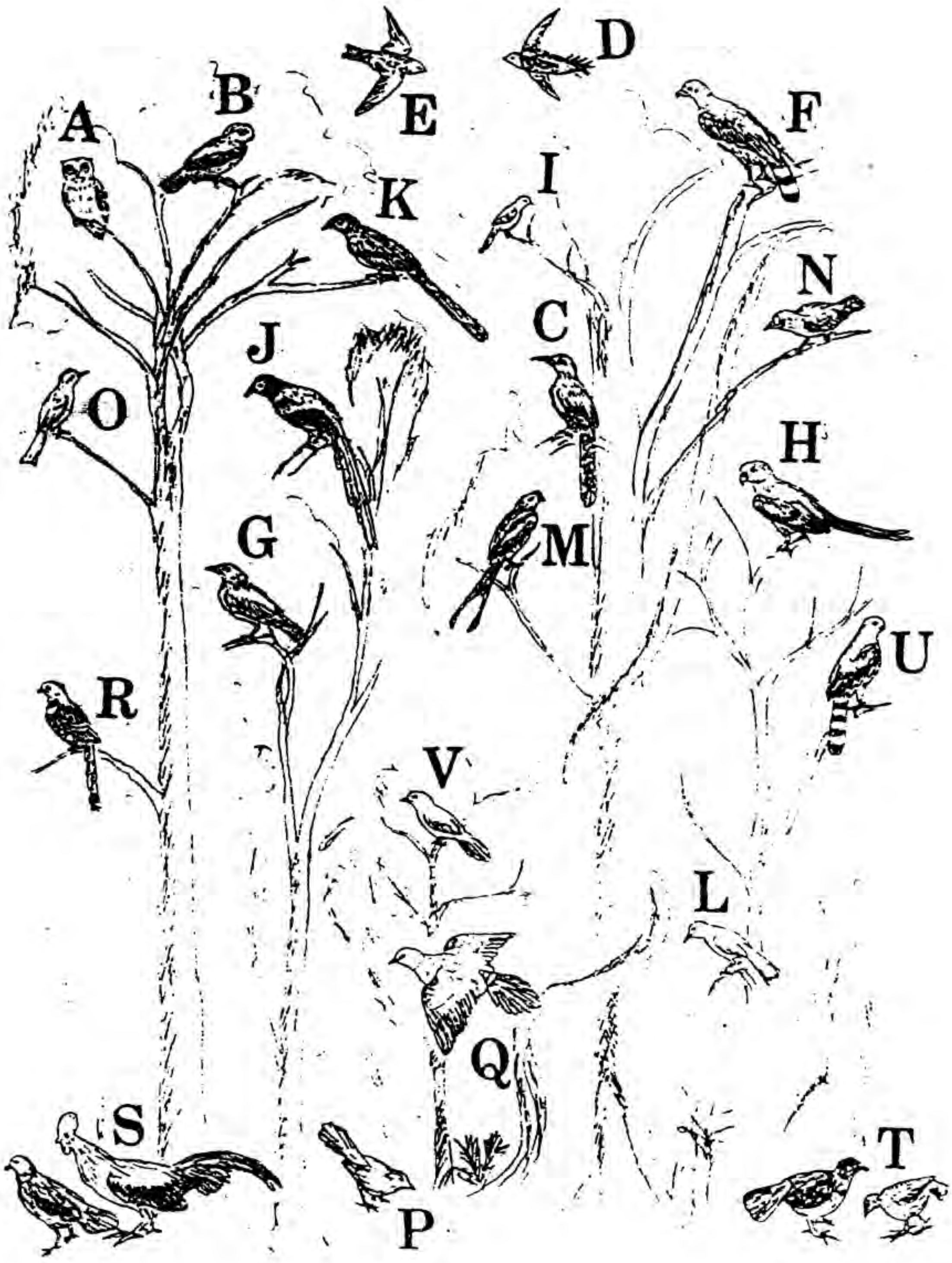
Some Animals in the Forest

Mammals:

English Name			Sinhala Name
1	=	Purple faced leaf monkey	= Hali Wandura
2	=	Giant squirrel	= Dandu lena
3	=	Flying squirrel	= Hambawa
4	=	Insectivorous bats	= Kiri wavulan
5	=	Loris	= Una hapuluwa
6	=	Fireback squirrel	= Pulutu lena
7	=	Sambur	= Gonna
8	=	Elephant	= Aliya
9	=	Mouse Deer	= Meeminna
10	=	Rat	= Miya
11	=	Wild boar	= Wal Ura
12	=	Porcupine	= Iththewa
13	=	Leopard	= Kotiya

Other Animals:

English Name:			Sinhala Name
14	=	Fly	= Massa
15	=	Bees	= Meemassa
16	=	Spider	= Makuluwa
17	=	Stick Insect	= -
18	=	Leaf Insect	= -
19	=	Serpent	= Sarpaya
20	=	Catapillar	= Dalambuwa
21	=	Termites	= Weya
22	=	Scorpion	= Gonussa
23	=	Beetle	= Kuruminiya
24	=	Lizard	= Katussa
25	=	Frog	= Gemba
26	=	Giant Millipede	= Hekeralla



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Some Birds seen in Different Strata of the Forest

English Name	Sinhala Name
A = Little Scops Owl	= Singithi Bassa
B = Brown Hawk	= Dumburu Ukusu Bassa
C = Grey Hornbill	= Alu Kandetta
D = Spine Tail Swift	= Katupenda Thurithaya
E = Edible Nest Swift	= Kadal Thurithaya
F = Crested Hawk Eagle	= Konda Kussa
G = Sri Lanka Grackle	= Lanka Sela Lihiniya
H = Layards Parakeet	= Alu Giraw
I = Orange Minivet	= Maha Miniviththa
J = Blue Magpie	= Kehibella
K = Red Faced Malkoha	= Vatha Rathu Malkoha
L = Yellw Browed Bulbul	= Kaha Galuguduwa
M = Crested Drongo	= Kalu Silu Kavda
N = Yellow fronted Barbet	= Mukalana kottoruwa
O = Black Bulbul	= Kalu Galuguduwa
P = Ashy Headed Babbler	= Hisa Alu Demalichcha
Q = Bronze Winged Pigeon	= Nila Kobeyiya
R = Trogon	= Lohawannichchiya
S = Jungle Fowl	= Wali Kukula
T = Spur Fowl	= Haban Kukula

List of Animals of Sinharaja

Although it is quite difficult to observe a good proportion of the animal species in Sinharaja, yet you would wish to know what species do exist there. Consequently, the following pages list some of the species of the major animal groups that have been sighted. Alongside their name, the feeding habit of the animal, whether insectivorous (I), carnivorus(C), herbivorous (H) or omnivorus (O) has been indicated. According to the vertical stratum each animal occupies, they have been grouped as (G) ground- or (T) tree-dwellers.

Mammals

English Name	Local Name	Food Habit	Inhabiting-vertical strata in forest
Leopard	Kotiya	C	G,T
Fishing Cat	Handun Diviya	C	G,T
Otter	Diya Balla	C	G
Torque Monkey	Rilawa	C,H	T
Purple Faced Leaf Monkey	Hali Wandura	H	T
Loris	Una Hapuluwa	H,I	T
Pole Cat	Uguduwa	H,I	T
Golden Palm Civit	Ranhothambya	C,H	T
Mouse Deer	Meeminna	C,H	G
Barking Deer	Weli Muwa	H	G
Sambhur	Gona	H	G
Porcupine	Iththewa	H	G
Fire back squirrel	Pulutu lena	H	T
Giant squirrel	Dandu lena	H	T
Flying squirrel	Hambawa	H	T
Bat	Wavula	I,C	Aerial
Common Fruit Bat	Maha Wavula	H	T
Shrew	Hik Meeya	I,O	G
Rats	Meeyan	C,H	G,T
Ant Eater (Pangolin)	Kaballawa	C	G
Bandicoot	Uru Meeya	H	G

Birds

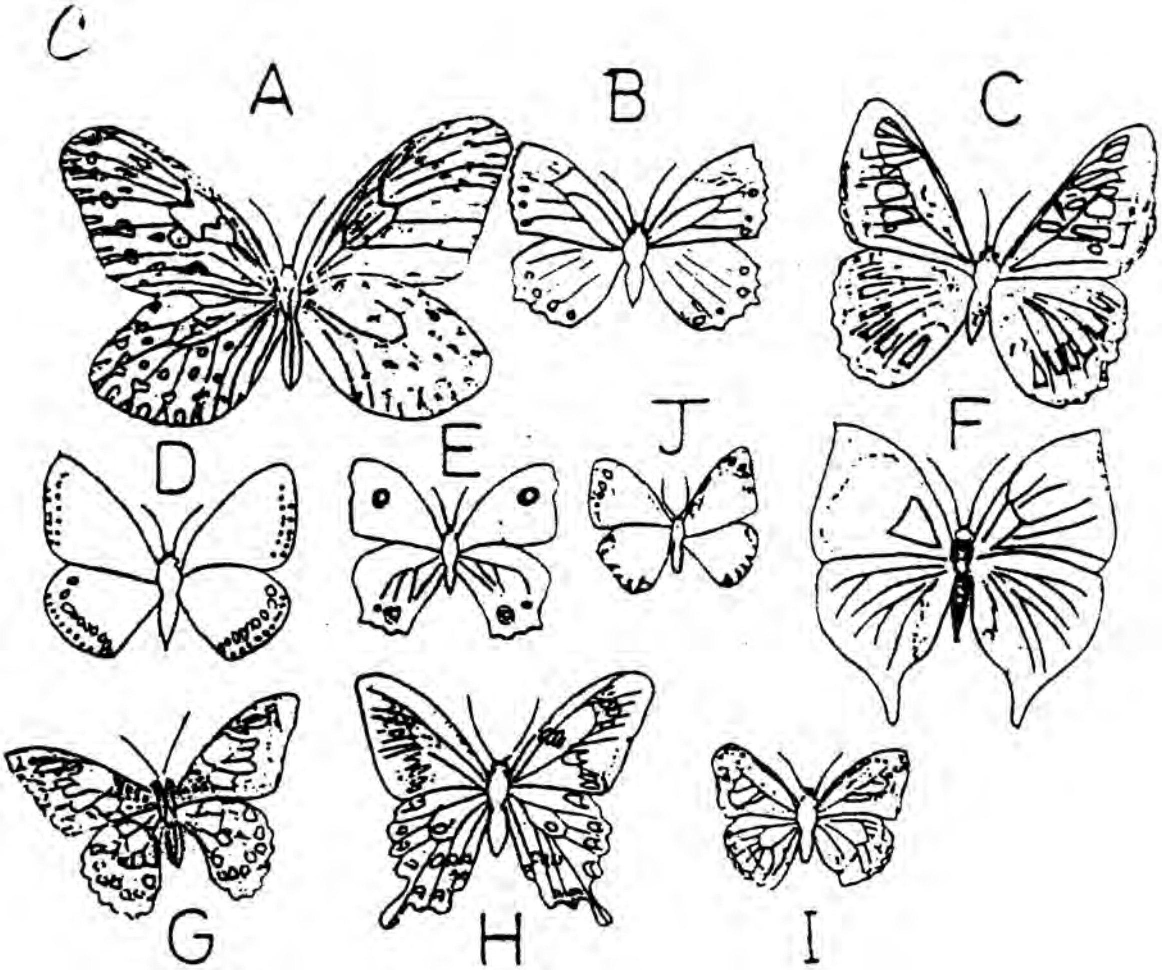
Above The Canopy & Canopy Layer	Local Name	Food Habit
Spine Tail Swift	Katupenda-Thurithaya	I
Edible Nest Swiftlet	Kadal-Thurithaya	I
Serpent Eagle	Sarapakussa	C
Black Eagle	Kalu Kussa	C
Crested Hawk Eagle	Konda Kussa	C
Canopy Layer		
Jungle Owlet	Wana-Bassa	C
Chestnut Backed Owlet	Pitathambala Wana-Bassa	C
Frogmouth	Madimuhuna	I
Brown Hawk Owl	Dumburu Ukusu Bassa	C
Little Scops Owl	Singithi Bassa	C
White Headed Starling	Hisa Sudu Sharikawa	H,I
Sri Lanka Grackle	Lanka Sela Lihiniya	I,H
Orange Minivet	Maha Miniviththa	I,H
Layards Parakeets	Alu Giraw	H
Green Imperial Pigeon	Maila Goya	H
Sub Canopy Layer		
Crested Drongo	Kalu Silu Kauda	I
Crested Goshawk	Siluwath Kurulugoya	C
Blue Magpie	Kehibella	I,H
Red Faced Malkoha	Vatha Rathu Malkoha	I,H
Yellow Fronted Barbet	Rannalal Kottoruwa	H
Understorey Tree & Shrub Layer		
Trogen	Lohawannichchiya	I
Bronze Winged Pigeon	Nila Kobeyiya	H
Azure Blue Fly Catcher	Nil Radamara	I
Yellow Browed Bulbul	Kaha Caluguduwa	I,H
Black Bubbul	Kalu Caluguduwa	I,H
Black Fronted Babbler	Hisa Kalu Panduru Demalichcha	I,H
Rufous Babbler	Ratu Demalichcha	I,H
Ashy Headed Babbler	His Alu-Demalichcha	I,H

Ground Layer

Spurfowl	Haban Kukula	H/I Granivorus
Jungle Fowl	Wali Kukula	H/I Granivorus
Spotted Wing Thrush	Tithpiya Thirasikaya	I
Scaly Thrush	Pethigomara	I

Arthropoda	Local Names
Crustacea	
Crabs	
Shrimps	
Insecta	
Above Ground	
Bees	Bambaru, Debaru, MeeMesso
Flies	Masso
Mosquitoes	Maduruwo
Bugs	Keedewo
Butterflies, Moths	Samanalayo, Salabayo
Dragonflies	Bath Kuro
Beetles	Kuruminiyo
Cicardas	Rahaiyo
Grass Hoppers	Palangetiyo
Leaf Insects	--
Stick Insects	--

Ground Level	
Mosquitoes	Maduruwo
Ants	Kumbi
Termites	Weyo
Mites	Kinitullo
Grass Hoppers	Palangetiyo
Mole Cricket	Bin Ura
Arachnida	
Tarantula	Divi Makuluwa
Wood Spiders	
Web Spiders	
Myriopoda	
Millipede	Hekarella, Kitul Etaya
Centipede	Paththaya
Annalida	
Leeches	Koodello
Earthworms	Gedawilo



A = Ceylon tree Nymph
B = Common palm fly
C = **Clipper**
D = Double banded black crow
E = Common evening brown
F = Blue oak leaf
G = Lime butterfly
H = Common mormon
I = Painted lady
J = Common albatross

List of Botanical Names

Alstonia macrophylla	(Apocynaceae)	Havari Nuga
Anisophyllea cinnamomoides	(Rhizophoraceae)	Welipianna
Aporusa cardiospermum	(Euphorbiaceae)	Kampoththa
Areca catechu	(Palmae)	Puwak
Artocarpus heterophyllus	(Moraceae)	Kos
Artocarpus nobilis	(moraceae)	Bedidel
Arundina graminifolia	(Orchidaceae)	----
Bhesa zeylanica	(Celastraceae)	Pelan
Calamus ovoides	(Palmae)	Thambutu Wel
Calamus rivalis	(Palmae)	Sudu Wewel; Ela Wewal
Calamus zeylanicus	(Palmae)	Ma Wewal Wanduru Wel
Calophyllum bracteatum	(Clusiaceae)	Walu Keena
Campnosperma zeylanica	(Anacardiaceae)	Aridda
Caryota urens	(Palmae)	Kitul
Chaetocarpus castanocarpus	(Euphorbiaceae)	Hedawaka
Clerodendrum infortunatum	(Verbenaceae)	Pinna
Coscinium fenestratum	(Menispermaceae)	Weniwegeta
Cullenia zeylanica	(Bombacaceae)	Katamoda
Cyperus sp.	(Cyperaceae)	----
Dalbergia championii	(Leguminosae)	Bambara Wel
Dipterocarpus zeylanicus	(Dipterocarpaceae)	Hora
Eleocharis sp.	(Cyperaceae)	Minuwan
Entada scandens	(Leguminosae)	Puswel
Eupatorium odoratum	(Compositae)	Podisinghomaram
Evodia lunu-ankenda	(Rutaceae)	Lunu Ankenda
Ficus diversiformis	(Moraceae)	----
Ficus laevis	(Moraceae)	----
Freycinetia pycnophylla	(Padanaceae)	----
Freycinetia walkeri	(Pandanaceae)	----
Hedyotis fruticosa	(Rubiaceae)	Weraniya
Hibiscus furcatus	(Malvaceae)	Napiriththa
Homalium zeylanicum	(Celastraceae)	Liyan
Horsfieldia irya	(Myristicaceae)	Iriya
Kokoona zeylanica	(Celastraceae)	Kokum
Litsea gardneri	(Lauraceae)	Thalang
Lophatherum gracile	(Graminae)	----
Macaranga peltata	(Euphorbiaceae)	Kenda
Melastoma malabathricum	(Melastomataceae)	Maha Bowitiya
Mezoneurum sp.	(Leguminosae)	----
Mussanda frondosa	(Rubiaceae)	Mussanda; Wel Butsarana
Nepenthus distillatoria	(Nepenthaceae)	Bandura

Ochlandra stridula	(Bambusaceae)	Bata
Osbeckia octandra	(Melastomataceae)	Heen Bowitiya
Pennesetum orientale	(Graminae)	----
Piper sp.	(Pipereareae)	Mala Gammiris; Wal Gammiris
Schumacheria castaneifolia	(Dilleniaceae)	Kekiriwara
Semecarpus gardneri	(Anacardiaceae)	Badulla
Shorea stipularis	(Dipterocarpaceae)	Navada; Hulan Idda
Shorea trapezifolia	(Dipterocarpaceae)	Thiniya Dun
Smilax sp.	(Smilacaceae)	Kaharassa
Symplocos sp.	(Symplocaceae)	Bombu
Syzygium makul	(Myrtaceae)	Alubo
Terminalia parviflora	(Combretaceae)	Hampalanda
Trema orientale	(Ulmaceae)	Gedumba
Urandra apicalis	(Icacinaceae)	Uruhonda
Vateria copallifera	(Dipterocarpaceae)	Hal
Vernonia arborea	(Composotae)	Kobomella
Vitex pinnata	(Verbenaceae)	Milla
Wendlandia bicuspidata	(Rubiaceae)	Wana Iddala

List of Non-Flowering Plants

Blechnum orientalis	(Blechnaceae)	Paththara Warella; Paththara Koku; Baru Koku
Cyathia walkeri	(Cyathiaceae)	Ginihota
Dicranopteris linearis	(Gleicheniaceae)	Kekilla
Lycopodium cernum	(Lycopodiaceae)	Badal Hanassa
Pinus carribaea	(Pinaceae)	----

List of Sinhala Names

Aridda	Campnosperma zeylanica	(Anacardiaceae)
Alubo	Syzygium makul	(Myrtaceae)
Badulla	Semecarpus gardneri	(Anacardiaceae)
Bambara Wel	Dalbergia championii	(Leguminosae)
Bandura	Nepenthus distillatoria	(Nepenthaceae)
Bata	Ochlandra stridula	(Bambusaceae)
Bedidel	Artocarpus nobilis	(Moraceae)
Bombu	Symplocos sp.	(Bombu)
Ela Wewal	Calamus rivalis	(Palmae)
Gedumba	Trema orientalis	(Ulmaceae)
Hal	Vateria copallifera	(Dipterocarpaceae)
Hampalanda	Terminalia parviflora	(Combretaceae)
Havari Nuga	Alstonia macrophylla	(Apocynaceae)
Hedawaka	Chaetocarpus castanocarpus	(Euphorbiaceae)
Heen Bowitiya	Osbeckia octandra	(Melastomataceae)
Hora	Dipterocarpus zeylanicus	(Dipterocarpaceae)
Hulan Idda	Shorea zeylanica	(Dipterocarpaceae)
Iriya	Horsfieldia iriya	(Myristicaceae)
Kabarassa	Smilax sp.	(Smilacaceae)
Kampoththa	Aporusa cardiospermum	(Euphorbiaceae)
Katamoda	Cullenia zeylanica	(Bombacaceae)
Kitul	Caryota urens	(Palmae)
Kokum	Kokoona zeylanica	(Celastraceae)
Kos	Artocarpus heterophyllus	(Moraceae)
Kenda	Macaranga peltata	(Euphorbiaceae)
Kekiriwara	Schumacheria castaneifolia	(Dilleniaceae)
Kobomella	Vernonia arborea	(Compositae)
Liyan	Homalium zeylanicum	(Celastraceae)
Lunuankenda	Evodia Lunu-ankenda	(Rutaceae)
Maha Bowitiya	Melastoma malabathricum	(Melastomataceae)
Mala Gammiris	Piper sp.	(Piperaceae)
Ma Wewal	Calamus zeylanicus	(Palmae)
Milla	Vitex pinnata	(Verbenaceae)
Minuwan	Eleocharis sp.	(Cyperaceae)
Mussanda	Mussanda frondosa	(Rubiaceae)
Napiriththa	Hibiscus furcatus	(malvaceae)
Navada	Shorea stipularis	(Dipterocarpaceae)
Pelan	Bhesa zeylanica	(Celastraceae)
Pinna	Clerodendrum infortunatum	(Verbenaceae)
Podisinghomaram	Eupatorium odoratum	(Compositae)
Puswel	Entada scandens	(Leguminosae)
Puwak	Areca catechu	(Palmae)
Sudu Wel	Calamus rivalis	(Palmae)
Thalang	Litsea gardneri	(Lauraceae)
Thambutu Wel	Calamus ovoides	(Palmae)
Thiniya Dun	Shorea trapezifolia	(Dipterocarpaceae)
Uruhonda	Urandra apicalis	(Icacinaceae)
Wal Gammiris	Piper sp.	(Piperaceae)
Walu Keena	Calophyllum bracteatum	(Clusiaceae)
Wana Iddala	Wendlandia bicuspidata	(Rubiaceae)
Wanduru Wel	Calamus zeylanicus	(Palmae)
Wel Butsarana	Mussanda frondosa	(Rubiaceae)
Welipianna	Anisophyllea cinnamomoides	(Rhizophoraceae)
Weniwelgeta	Coscinium fenestratum	(Menispermaceae)
Weraniya	Hedyotis fruticosa	(Rubiaceae)

Acknowledgements

The authors thank Dr. S. Kotagama, Open University, Colombo for the sketches of the animals and updating their names Mr. Martin Wijesinghe of the Forest Department and resident of Sinharaja for helping in the field, to map the trails and providing information on plants as well as of the area; last but not least, the Forest Department for all the facilities and funds provided for field work during the preparation of these trail guides.

FIELD PROGRAMME II

Reproductive Biology

Conducted by Dr(Mrs.) C.V.S. Gunatilleke

During the course of this programme the following will be observed.

1. Sexual systems in Plants

Flowers from roadside and forest species will be examined to study their floral features and the type of sexual system indicated by each of them.

2. Pollination Biology

a. Animal visitors to floral presentation will be examined. The role played by these animals as nectar or pollen robbers, chance visitors, opportunists or pollinators will be studied. Pollinator activity will be monitored over a period of time.

b. Self and cross pollinations will be carried out using emasculated and non emasculated flowers to impart the methodology involved in breeding experiments.

3. Reproductive Output

Field observations will be made to gather information on losses during the different stages of development between flower production and recruitment of seedlings into the population.

FIEID PROGRAMME (FAUNA) III

Conducted by Dr S.W. Kotagama

(i) Population Studies of Small Mammals and Birds

In this programme, the general methods used for studying small mammals and birds will be made. It will involve:

for mammals : The Mark Recapture Method using Sherman's and Tomhawk traps.

for birds : Using mist-nets for understory birds.

The following aspects will be discussed/studied.

(A) Mammals - Use of Grid/Line transect.
Methods of Marking Small Mammals.
Type and selection of bait.
Handling and Data collection
Analysis of data for determining Home Range, density etc.

(B) Birds - Setting of Nets,
Extraction of birds
Processing of birds.
Marking.
Release techniques.
Moult Studies
Analysis of data for species diversity, population estimates, distribution etc.

(ii) Study of Bird Flocks in Rain-Forest

High species diversity is a characteristic feature of Rain forest, and niche segregation is supposed to have been achieved by these organisms to enable them survive in this complex system. A classic example that shows this is the bird waves or mixed feed flocks.

Studies at Sinharaja has shown on the average upto 19 species of different birds are members of these flocks, occupying different levels of the forest and also different techniques of foraging.

Study: Make observation on bird flocks, on a Random, Single-site sampling system. Note the following: Height occupied (to the nearest 2m). Position on tree-bole, branch, twig, leaves. Activity when first sited.

BIRD RINGING

S.W. KOTAGAMA

Prepared for the field exercises
at Sinharaja of the Regional
Training workshop on
Ecology and Conservation of
Tropical Humid Forests of the
Indomalayan Realm

- 1st to 5th March 1987 -

- Sinharaja -

EXTRACTION TECHNIQUES

Experience has shown that not every one is endowed with the necessary physical attributes and temperamernt to make a good mist-netter. Good eyesight and steady but sensetive fingers are essential qualities, the latter being particularly important, since the highly skilled netter relies to a great extent on sense of touch. Patience and a calm disposition are equally necessary and peope who are inclined to fuss or become flustered would be well advised to keep away from mist -nets.

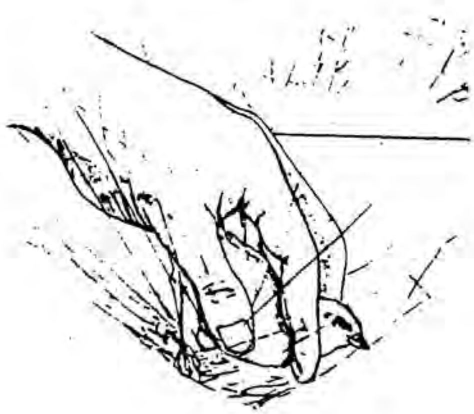
EVERY NETTED BIRD PRESENTS A UNIQUE PROBLEM

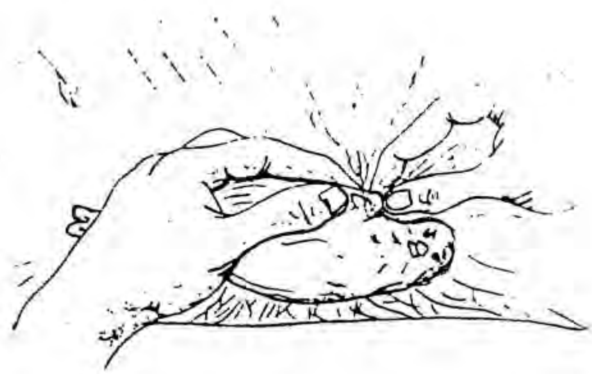
SAFE EXTRACTION TECHNIQUES MUST BE LEARNT BY WATCHING A PROFICIENT NETTER AT WORK, AND BY REPEATED PRACTICE UNDER SUPERVISON.

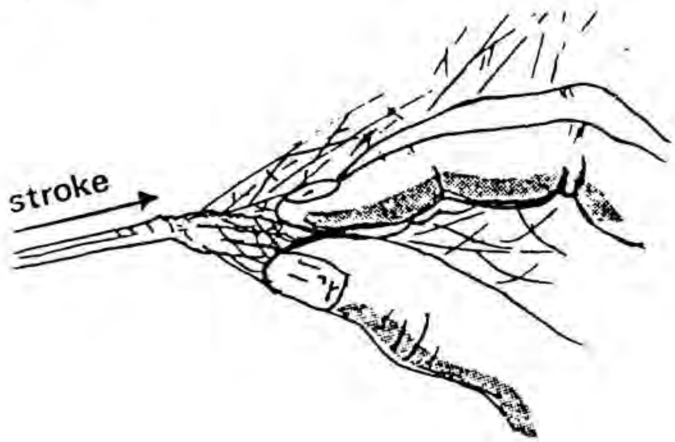
THE BASIC PRINCIPALS TO REMEMBER

* Extraction is an exact reversal of the stages by which it became entangled

* Extraction will be from the same side of the net as the bird first entered







CHOSE ALWAYS THE SIMPLEST APPROACH

When the bird is in a position that can be taken by the normal grip used for ringing - **DO SO**

REMOVAL OF NETTING FROM CLAWS

Hold the tarsus between middle finger and thumb, positioned about quarter of an inch above the foot, and with the forefinger and thumb of the other hand, repeatedly stroke the netting towards the toes.

REMOVAL OF NETTING FROM CARPAL JOINT

Part the net until it is possible to grasp the uppermost wing, holding it quite firmly between the forefinger and thumb, positioned over the base of the primaries, with the other hand clear the threads from the carpal joint.

THE BIRD'S SAFTEY IS THE PRIMARY CONCERN. IF EXTRACTION BECOMES DIFICULT THE NET MUST BE CUT.

THESE ARE ONLY IDEAS - EVERY BIRD WILL PROBABLY NEED A DIFFERENT METHOD.

HANDLING OF BIRDS

Effortless handling including transfer from hand to hand, is the hall mark of a **GOOD RINGER**. A poor handler of birds will never make a mist-netter.

THE WHOLE bird must be grasped. NEVER catch by a wing, leg etc. IT CAN LEAD TO INJURY of the bird.

Hold bird FIRMLY enough to prevent it struggling.

CARE MUST be taken not to exert PRESSURE ON the birds body - especially in the breeding season.

Keep WINGS under control and not allowed to flick.

The HAND should always be kept as dry as possible.

DO NOT hold the bird for long in the hand.

SMALL BIRDS (for transfer only - NOT for ringing)

Curve the 4 fingers (held together) lightly over the back and side, while the thumb is passed beneath the neck to meet them. THERE IS NO PRESSURE ON THE BODY.

FOR RINGING

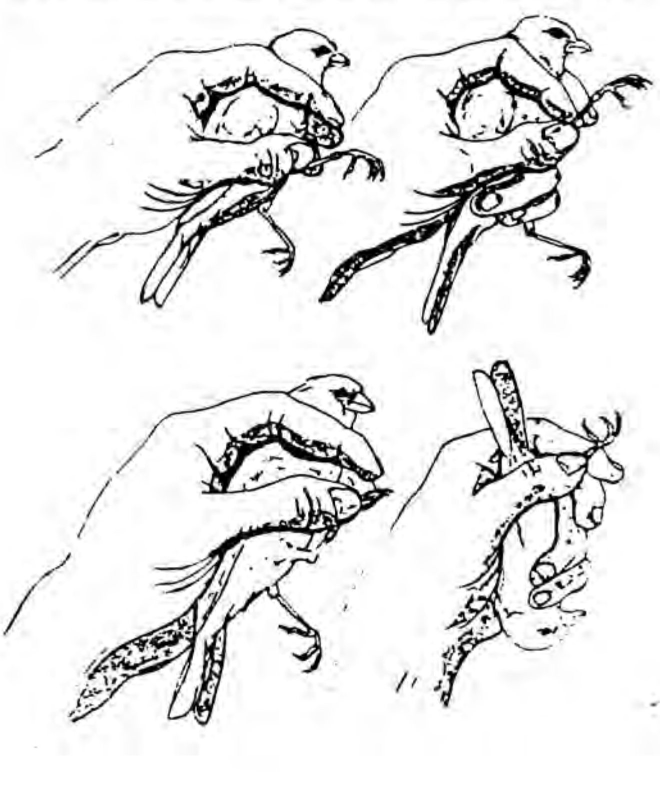
* The bird is held with its neck between the 1st and second fingers, the leg is controlled either by the thumb and forefinger or the thumb and 3rd finger.
* For small pulli(young), tiny species, and those with short tarsi -they are held as in Fig , or reverse hold Fig .
* LARGE BIRDS - ideally require two people, one to hld the bird, the other to put the ring.

IF ALONE - bird should be placed upside down along the lap and covered with a cloth so that only its legs are free.

*HERONS, GULLS etc (BIRDS THAT LUNGE WITH THE BILL)- should be hooded while handling.

*HAWKS, OWLS etc - Handle easily by giving some object to grasp in their talons and also by placing a hood over their head.

IF FOR ANY REASON A BIRD HAS TO BE KEPT FOR LONG - PLACE IT IN IN A DARKENED BOX OR BAG.



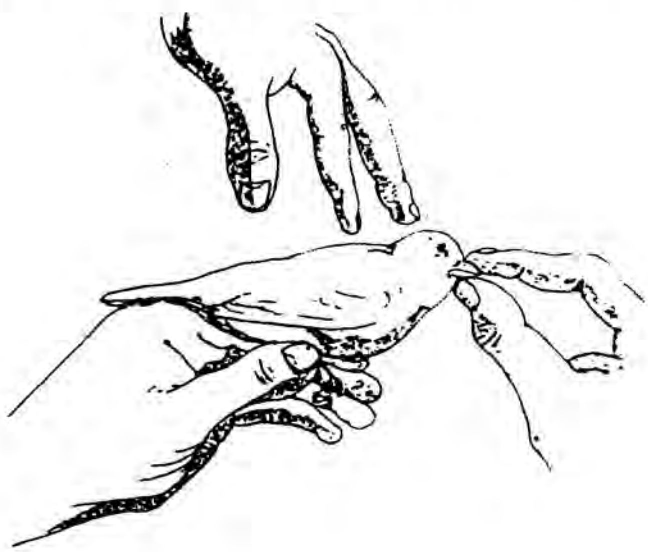
PASSING OF BIRDS

* To pass a bird from one person to another the safest method is in a BIRD BAG (cloth bag)

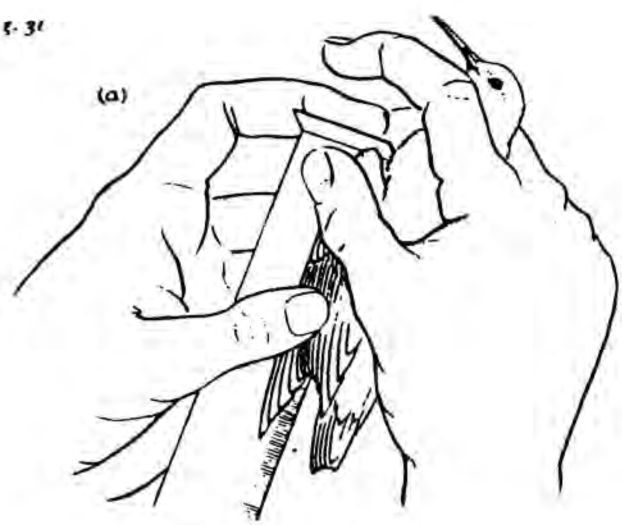
* ALTERNATIVELY-it may be held with the fingers of the left hand at the top of the thighs, while the beak is held between the forefingers and thumb of the right hand.

PHOTOGRAPHING

The bird is held with the left/right hand at the TOP OF THE THIGHS



(a)



Advantages/disadvantages

(i) Less satisfactory for medium size birds, especially fo. Waders & Swifts in which the primaries have marked lateral curve,

- degree of curvature can vary from time to time, dependng on weather, (dry or wet).
- can be affected by extraction of the bird from a mist-net.
- Comparable with museum skins in which shinkage always occurs.

(ii) Variation in the degree of pressure applied in holding the wing to the ruler will produce small difference in the measurements obtained.

(iii) Small differences in measurement may result from variation in the degree of straightness achieved.

Reduce errors due to alteration of the lateral currature during trapping & handling or occasional dampness.

For all other Purposes (except museum comparison) method (iii) is used - **THIS IS THE ONE ADOPTED FOR INTERNATIONAL EXCHANGE OF DATA.**

Accuracy - **SHOULD BE MEASURED TO THE NEAREST 1.0 mm.**

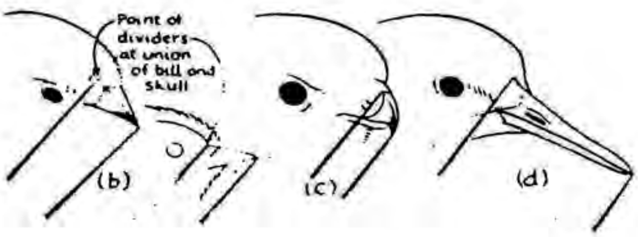
BILL

Orthodox taxonomic procedure is to measure from the tip of the bill to its union with the skull in small birds.

- the tip to the cere in owls and birds of prey.
- and the tip to the feathering in Waders and long billed birds.

The DIVIDERS MUST BE HELD in the same lateral plane as the bird's bill.

Accuracy - to the nearest 0.5 mm but to the nearest 1.0mm in species with long bills such as Heron, Curlew.



TAIL

Slide on unstopped rule along the under side of the rectrices - between the tail feathers and undertail coverts - until it comes to a stop at the root of the tail.

Alternatively - dividers may be used - hold the dividers in the same lateral plane as the tail. So that it is the side of the point which impinges against the body.

Accuracy - to the nearest 1.0 mm.

WARNING

Moult, abrasion or the loss of a feather may all cause false or misleading measurements to be taken.

Considerable variation may be encountered.

Re-measuring and or by taking complementary measurements on the other side of the bird <u>may result in better measurement</u>.

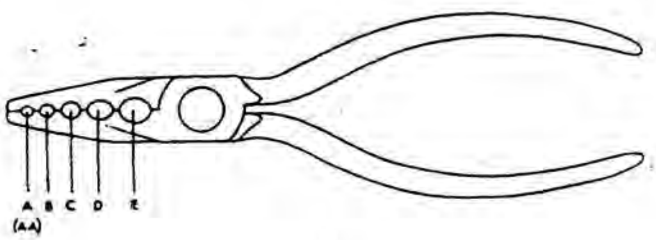
WEIGHING

Use of Pesolo Spring balance.
- Place bird in a tapering tube made of polythene, acetate or celluloid, or in a bird bag.

* Weight tend to vary with time of capture, **THEREFORE THE TIME CAPTURE SHOULD BE NOTED.**

Accuracy - around 0.1 gm (vary with balance).

OTHER INFORMATION TAKEN FOR SPECIFIC REASONS ARE:
WING FORMULA
& MOULT CONDITION



RINGING

*** A BADLY AFFIXED RING IS A SOURCE OF DANGER TO THE BIRD.**

Basic Procedure

* SELECT the correct Ring Size.
* Use PROPER RINGING pliers to close the ring.
* Examine the closed ring -
  (a) to see that it is thighlly closed.
  (b) to see that no projecting sharp corners are present.
  (c) to see that the lettering is not defaced.
  (d) to see that the ring is neither too tight nor too loose.
* WITHOUT DELAY ENTER in the ringing log.
* Record also details of lost or broken rings.

WEIGHT OF RING

For all species the weight of the recommended size of ring is negligible compared with the weight of the bird.

eg. Magpie Robin - av. weight - 21g.
Recommended Ring Size - A. Weight 0.047gm. i.e. about 0.2% of the birds weight.
(i.e. equivalent to 5 or 10 stone man and his shoes. Less than even the weight of the pair of shoes.)

RING FIT

TOO MUCH MOVEMENT OF THE RING ON THE LEG CAUSES WEAR. THEREFORE RING SHOULD FIT WELL WITH LITTLE MOVEMENT.

CLOSELY FITTING RING IS PREFERABLE TO A LOOS ONE. REDUCES the danger of objects getting between the ring and leg.

RING SHOULD NOT CONSTRICT THE LEG - ONE SHOULD BE ABLE TO MOVE IT UP AND DOWN A LITTLE - BUT IT NEED NOT BE FREE ENOUGH TO MOVE OF ITS OWN ACCORD.

METHOD OF CLOSING RINGS

THERE IS A STANDARD TWO-STAGE PROCEDURE.

STAGE I - differs accordingto initial shape, and strength of ringers fingers.

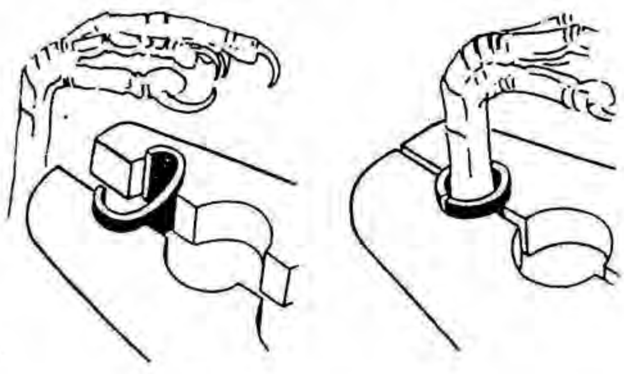
STAGE I

'C' Shaped Rings - Fit the ring in the appropriate hole of the pliers, with the gap aligned with the open jaws. Present the ring to the leg (or pass the leg within the ring) and squeeze gently so that the <u>two ends just meet</u>.

'V' Shaped Rings - Small rings may be squeezed sufficiently to complete stage I. Large rings use pliers.

STAGE II

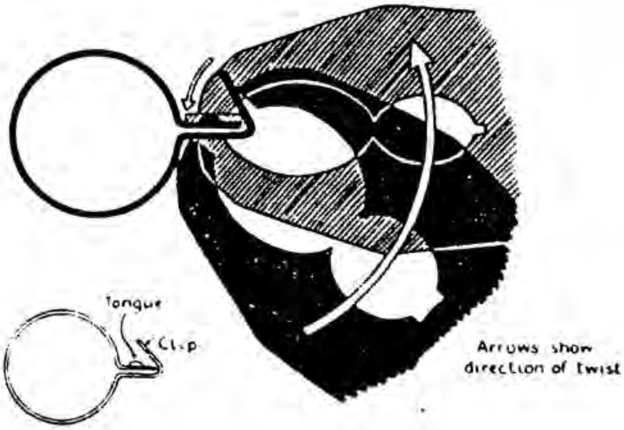
Ensure that the ring is in the appropriate hole, but rotate through 90 so that the loose butt joint already formed is at about the 3 o'clock position in the circumference of the curve, and press carefully at first, then firmly.

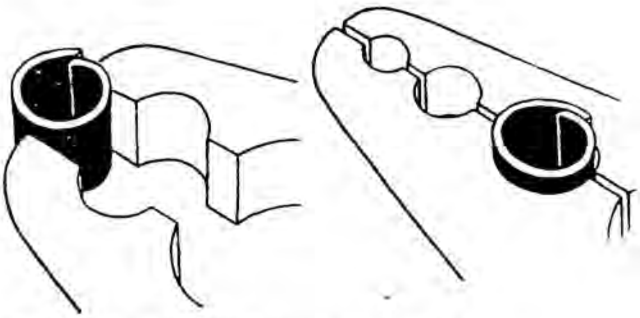


OVERLAPPING

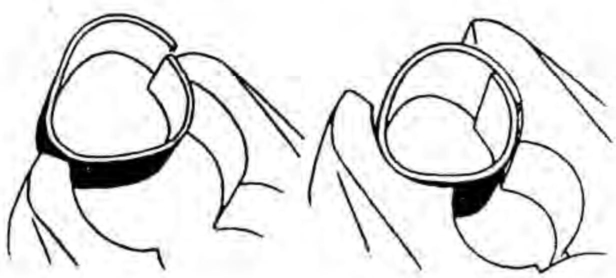
OCCASIONALLY IN THE INTEREST OF COMFORT AND SAFETY ONE HAS TO OVERLAP THE RING.

AFTER STAGE I AND II, - take hold of the ring at the tip of the pliers with one jaw located on one 'end' of the closed ring and the other diametrically opposite and squeeze <u>gently</u>, depressing the end just sufficiently to permit it to slide under the other: Relax grip -





Leg omitted from 24a-25b to show ring more clearly.



Replace pliers with the ends at 3 o'clock position, sque gently -to produce a neat overlap.

RINGING OF PULLI (Nestling & Chicks).

SAFTEY OF THE BROOD MUST ALWAYS COME FIRST.

* Do not ring if you think there is a danger of attracting a predator to the site.

* Do not ring unless the pulli are at the correct age.

COLOUR RINGS

COLOUR RINGING -
IS AN INVALUABLE AID, BUT HAS TO BE USED CORRECTLY, IN A WELL PLANNED SCHEME. INDISCRIMINATE COLOUR RINGING IS UNLIKELY TO PRODUCE ANY INFORMATION OF VALUE AND MAY WELL SPOIL ANOTHR RINGER'S WELL PLANNED STUDY BY DUPLICATING COLOUR CODES.

TYPES

FOR SMALL BIRDS - are made of Celluloid take the form of a simple split ring.

FOR LARGER BIRDS - Flat bands

Spirals.

METHOD OF FITTING COLOUR RINGS

Small rings - The 'fitting tool' (spoon) is pushed into the ring. This forces the two ends apart, thus creating a gap through which the leg of the bird may be passed. When the spoon is withdrawn the ring closes again. (its advisable to assist the process by squeezing between finger and thumb)

Larger rings - Open one end of ring. Place around tarsus and gently rotate to enclose tarsus with ring.

REMOVAL OF RING