SCIENCE EDUCATION SERIES

No. 2

FORESTRY
WITH SPECIAL REFERENCE TO SRI LANKA

by

L. C. A. de S. Wijesinghe

NATIONAL SCIENCE COUNCIL OF SRI LANKA
47/5 Maitland Place
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Preface

I am grateful to the Science Education Research Committee (SERC) of the National Science Council (NSC) for having given me the opportunity of writing this booklet in it's programme for producing reading material on scientific topics.

I was practising forestry for two decades prior to joining the NSC, and in writing this booklet I have been able to draw on my experience. It would seem presumptious to attempt to encompass the subject of forestry in a single little volume. However, for practical reasons, a limit of 40 pages had to be set by SERC for manuscripts produced on this programme, and authors were expected to conform to this limit as far as possible. I have therefore had to deal with some topics only superficially. Indeed some aspects of forestry have been left out altogether. For example, I have not dealt with the properties and possible uses of Sri Lanka timbers; but information on this subject is available in publications of the Forest Department, reference to which is made at the end of the relevant chapter.

With different aspects of forestry being included in the science courses of the secondary schools and the universities, and increased public interest being shown in forestry, this booklet is intended to give the reader an overview of the subject and stimulate his interest in it. For more extensive reading, supplementary reading material has been cited.

The photographs appearing in this publication are from the Forest Department's collection. I wish to thank the Conservator of Forests for having allowed me to use them.

The manuscript for this publication was originally completed in February, 1979. As publishing was to commence only in the latter part of 1980, I have revised the manuscript to update the information.

L. C. A. de S. Wijesinghe

Colombo,
24 September, 1980.

FOREWORD

The dissemination of scientific information is one of the main functions of the National Science Council. The National Science Council Journal provides a medium for the publication of scientific research papers, while "Vidurava," the quarterly science bulletin of the National Science Council, contains scientific articles of a general nature which are of interest to the public.

There is still a wide gap in the availability of reading material on scientific subjects of local interest. One result of this is that science students confine their reading only to their school notes and to the few available text books which are mostly published abroad. In an attempt to improve this situation, the Science Education Research Committee (SERC) of the National Science Council decided to publish a series of booklets on scientific topics of local interest and supplementary reading material for students and the general public. The authors who have been selected by the Committee to prepare these booklets are experts in their respective fields. The manuscripts that were submitted by the authors were examined by referees before being accepted for publication. The views expressed in these publications are those of the authors and not necessarily those of the National Science Council.

In conclusion I must thank the Science Education Research Committee of the National Science Council, and in particular its Hony. Director, Prof. K. Jayasena, for the work they have put in to make this project a success.

R. P. Jayewardene
Secretary-General
National Science Council of Sri Lanka

14 November, 1980.

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Chapter 1

INTRODUCTION

It would be desirable to begin an account of forests and forestry by defining these terms. A forest may be defined as an extensive stretch of land covered with a rather tall and dense tree growth. Forestry, in its broadest sense, is the science and art of raising and/or managing forests. The trees in a forest need not necessarily have sprung up there by natural means; in fact many forests in the world today are either wholly man-made (called forest plantations) or are natural forests that have been modified to a greater or lesser extent by man.

In many countries, including Sri Lanka, land which has had no forest cover in the recent past is planted up with forest species. This practice is called *afforestation.* If the land on which a forest plantation is raised had earlier contained a forest cover, then the practice is called *reforestation.* Reforestation is practised extensively in Sri Lanka.

There are other terms that are used when referring to forests. "Scrub" is a type of open woodland where there are no tall trees. "Jungle" is an Indian word adapted for use in English, and it generally refers to a whole range of tree and shrub growth with a suggestion of wildness for which the term "bush" is used in Australia and throughout Africa.

We know from observations that an area which is left bare is always subject to colonization by plants. What species of plants colonize the area will depend firstly on what propagules reach the area by dispersal from plants outside it. It will also depend on climatic and soil factors in relation to the tolerance limits of the species whose propagules reach the area. The colony of plants so established is not stable. The plants exert an influence on the habitat e.g. organic material accumulates due to the death and decay of the plants. The effect of these changes is generally to improve the soil conditions and the micro-climate. Under the changed conditions new plants which had earlier found the area inhospitable get established and the original colonizers get gradually displaced. This process of change is called *plant succession.* It could be observed everywhere, even in one's own garden if left unattended. Eventually, if left to nature, shrubs and, later, trees could colonize the area. The process of succession leads finally to the establishment of a stable *climax* community. The climax community that develops in

an area is, therefore, the highest expression of the factors of climate and soil that influence vegetation. In most areas of the world the stable climax ecosystem is forest, and at one time, before modern man's drastic impact on natural vegetation, most of the land area of the world was actually covered by forest. Much of this has now been cleared for shifting cultivation, organised agriculture, providing raw materials for industry, and so on.

From what has been stated above it is clear that in any area there is an interaction between the organisms on the one hand and the soil and climate on the other. A climax forest is then the stable ecosystem that develops in an area. In such an ecosystem the biotic factors (trees, shrubs, herbs, animals and micro-organisms including those in the soil) are in equilibrium with each other and with the abiotic factors, the climate and soil. If the climax ecosystem in an area is destroyed and the area left to nature, the process of succession will start again leading eventually, perhaps after many decades or even a few centuries, to the climax.

Foresters of today recall that up to two or three decades ago few people besides themselves took the subject of forestry seriously. In fact the widely held concept in countries like Sri Lanka at that time was that forests represent unutilized land and a storehouse of timber. If either land or timber was required the forest was cleared. The situation has changed dramatically in the past few decades, and considerable concern is now being expressed at the large scale destruction of forests that is taking place worldwide; whereas earlier one spoke only of what one could get out of the forest by way of timber and other products, it is now recognised that forests have an equally important role to play in ameliorating the human environment. Forests therefore have two distinct functions in relation to man. These could in short be described as the productive and protective functions.

The protective benefits derived from the forest are described in Chapter 2. With regard to production, timber is the principal product of the forest. It is a material of the utmost importance to man and is today used for wide ranging purposes such as the manufacture of paper and rayon, for building construction work, and for transmission and telegraph poles. Besides timber, there are numerous other products that are derived from the forest. These include lac (an important industry in India), medicinal products (eg. Aralu, Bulu, Nelli, Weniwelgeta, etc.), turpentine (from *Pinus*), beedi leaves (from *Diospyros melanoxylon*), etc. These are collectively called minor forest produce (see Chapter 8).

Protection and production appear to be conflicting interests; one demands that the forest be conserved and the other that it be exploited. Then again, for production to go on on a sustained basis one must ensure that removal does not exceed growth. All these factors and many more have to be resolved in the scientific management of forests which is an intricate exercise demanding a knowledge of numerous disciplines like botany (growth, flowering and fruiting), soil science (soil preferences of different species), zoology (effect of insects and other animals on the trees and on timber in use), engineering (forest roads and buildings), economics (many forest projects have to be justified on economic grounds), and so on. Now perhaps one understands why forestry is defined as the science and art of managing forests. The management must be done in such a way that man derives the optimum benefit on a sustained basis.

Most countries carry out periodic surveys and inventories of their forest resources. A comprehensive inventory of Sri Lanka's forests was published in 1961 (based on aerial photographs taken four to five years previously). Since then no island-wide survey of the forests has been carried out. The 1961 survey indicated that 44 per cent of the land area was under forest. Since then the area of forest has dropped sharply. For administrative and legal purposes Sri Lanka's forests (nearly all of which are state-owned) are classified into three broad categories: "Reserves", "Proposed Reserves", and "Other State Forests." The last mentioned have been either cleared or so heavily exploited that they could hardly be described as forests in their present condition. Large extents of some of the Proposed Reserves and even some of the Reserves have also been cleared. In the absence of any accurate estimate of the area of forest at present, one can only attempt an informed guess. In the Wet Zone (including the wet regions of the up-country) there are about 300,000 acres under forest. In the Dry Zone the area recorded as forest is about five million acres, but if one excludes the heavily degraded forests and the scrublands, the balance would be only about two million acres.

When referring to the area of forest in Sri Lanka the forest plantations have not been taken into account as, compared to the extent of natural forest, the total area of plantations is small (approximately 260,000 acres in the whole island up to 1979). This is because the forestation programme had been stepped up only in recent years.

Social Forestry

Recently, the concept of "social forestry" has been introduced and given increasing prominence in India. In Sri Lanka, according to

the 1979 Administration Report of the Conservator of Forests, pilot projects under a social forestry programme were initiated in the administrative districts of Badulla, Kandy, Matale and Nuwara Eliya.

As stated earlier, the forest has basically two functions in relation to man. Based on these two functions, any national forest policy should aim at optimising the benefits to be derived by society from the forest. The concept of social forestry is not a radical departure from these accepted principles of classical forestry. However, the concept is useful in that it helps to place an emphasis on the benefits to be derived from the forest by the local community.

The broad objective of a social forestry programme would be to provide optimum benefits to the local community. In the sphere of production, these benefits could be the production of fuelwood, small-sized timber for rural housing, sticks and poles for agricultural needs, and so on. With these benefits accruing to a rural community, it should be possible to obtain the ready assistance of the people for carrying out forestry operations and, more important, for safeguarding the forest from illicit fellers.

Social forestry programmes have a special relevance to countries like Sri Lanka where a high proportion of the population lives in rural areas. Such programmes could be profitably introduced to new settlements in the Mahaweli development area.

Chapter 2

BENEFITS FROM THE FOREST

Indirect Benefits

Forests exert a profound effect on the environment, generally making it more congenial to man. These are the protective benefits from the forest referred to in the last chapter. Some of the main influences forests have on the environment will be considered in this section. Conserving forests is necessary also for preserving the indigenous gene pool represented by the natural vegetation of a country.

Forests and Rainfall

As has been stated earlier climate and soil are important environmental factors that determine the type of forest that develops in a given area. But the forest also interacts with the climate and soil and modifies these factors. The effect forests have on rainfall which is an important climatic factor will be considered in this section.

The factors that cause the south-west and north-east monsoons which are the major determinants of the rainfall regime of the island are located far away from the country, and the presence or absence of forests can have no effect on them. However, forests could influence precipitation in the following ways :

(a) Evapotranspiration and the upward movement of a warm, moist air current occurs in the forest as a result of solar radiation. When this air rises well above the forest canopy and is cooled in the upper atmosphere it can no longer retain the water it was able to carry as vapour when it was warm, and the vapour then condenses and falls as rain. This is called convectional rain.

(b) The relative humidity in a forest is usually much higher than outside. This is due to the greater evaporation and transpiration within the forest and the restricted air movement as a result of which humid air tends to remain *in situ*. If there is a big difference between day and night temperatures as is the case in the months, January and February, particularly in the Dry Zone, the moist air that is trapped in the forest

during the day cools at night and this results in the condensation of water vapour which drips from the leaves and flows down the stems to add moisture to the soil.

(e) When moisture laden winds blow over mountain ranges they are deflected upwards into the cooler altitudes where moisture condenses and comes down as rain. If the mountain ranges are forest-clad the winds are deflected to a greater height because of the presence of the forest canopy and this results in a greater cooling effect and consequent increased moisture condensation.

Effect of Forests on Wind

Forests have a profound effect in reducing wind velocity and so rendering wind-swept areas more hospitable. Hence it is a common forestry practice to raise forest plantations in the form of shelterbelts in areas devoid of forests and subjected to strong winds. Shelterbelts of Eucalypts and other species have been raised by the Forest Department in the wind-swept Dry Patanas in Keppitipola (at one time called Palugama) between Welimada and Nuwara Eliya and at Harasbadde (near Ragala) to serve as windbreaks. Windbreaks of forest plantations are raised in the form of belts more or less at right angles to the general wind direction. A single row of trees is inadequate to serve as an effective windbreak. At least three rows are required; the middle row consisting of trees with high crowns, and the two lateral rows of shorter, low-branching trees. Five rows will be more effective but obviously take up a good deal of space, and one has to contend with the agriculturist who would probably claim that the additional land could be put to to better use.

A windbreak slows down the velocity of winds on the leeward side up to a distance of about 20 times the height of the break. Over extensive areas, therefore, it is necessary to have a series of parallel windbreaks.

Effects of Forests on Soil

A forest soil generally differs appreciably in its physical features from the soil in an open area. It generally has a crumb structure and a high water-holding capacity; there is a constant input of organic matter in the form of litter and other decomposing plant and animal remains. There is also a rich microflora and microfauna. The soil of a forest generally acts as a sponge taking up rain water when available in quantity and releasing it gradually afterwards.

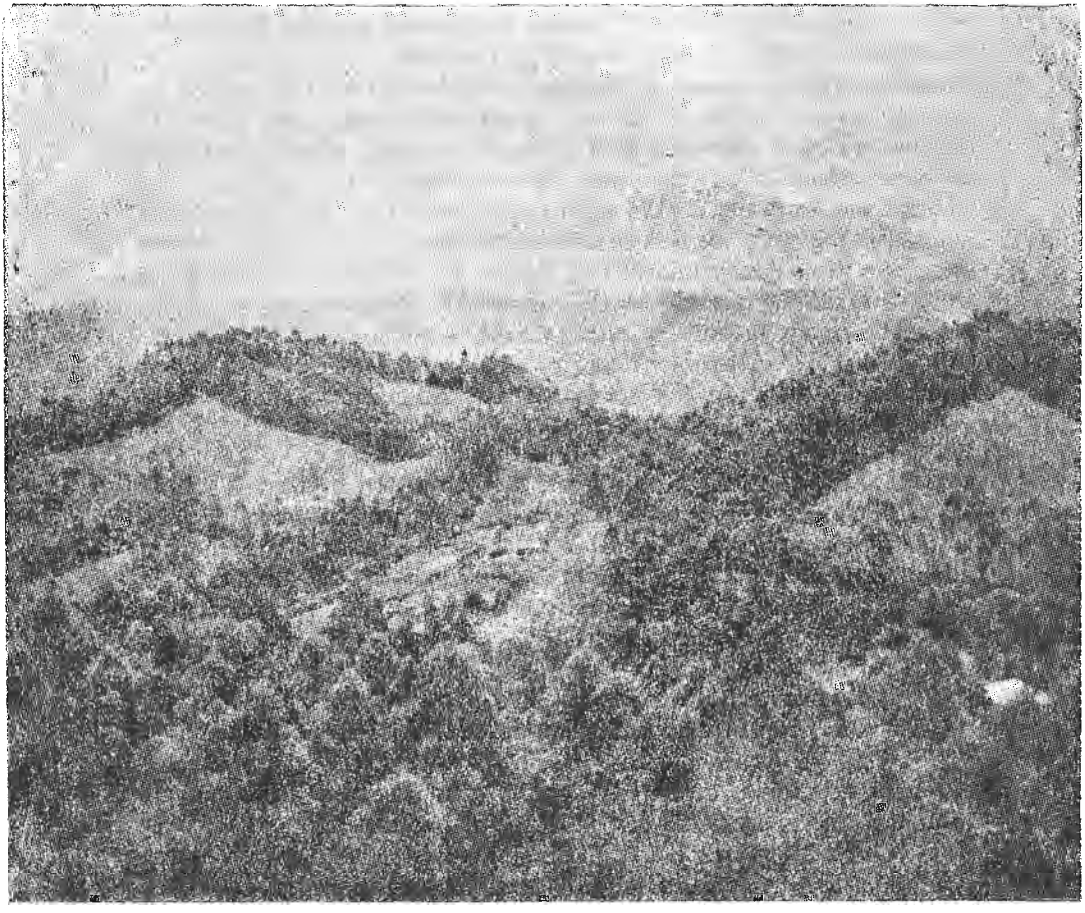

Plate 1. Shelterbelts of Forest Plantations raised on the Dry Patanas in Harasbadda, near Ragala

What happens during heavy rain in a forest ? At first the leaves and branches get wet and a fair quantity of water is used up in this. With continued rain the water reaches the ground as stem flow (down the stems of the trees) and as drip from the leaves. The impact of the rainfall on the soil surface is therefore much less severe than if the rain were to fall directly on the soil as in a deforested area. Moreover, the soil in a forest is protected by a more or less thick layer of leaf litter which is absent in an open area. Having reached the surface of the mineral soil the water is then readily absorbed by it. As the soil gets saturated, the water percolates downwards to the water table. When there is a prolonged period of rain the water table rises, and the water in the soil, moving laterally, emerges as springs. Even in rainless periods the soil is moist because of its high water holding capacity and there is a reasonable dry weather flow in the water courses. When there is heavy rainfall in a forest, even if there is surface run off, the water is found to be clear and silt-free.

In an area that is deforested the rain drops strike the soil surface directly, and, in consequence, the spongy, crumb structure of the soil is soon destroyed. This process is accelerated because of the reduced input of organic matter. Hence, a good part of the rainfall in a deforested area flows along the surface as run off and it carries with it the top soil causing sheet and gully erosion. The silt and other soil particles that are carried by the force of the flowing water ultimately get deposited in the beds of rivers. This occurs as the carrying power of the water drops due to a slowing down of the rate of flow.

This deposition, occuring year after year, causes a raising of the river bed and consequently an increase in the incidence and intensity of floods. At the other extreme, during rainless periods, the soil which had retained only a small fraction of the rain water received during the preceding wet weather, soon dries up and the dry weather flow of springs is reduced to a trickle or disappears altogether. So with extensive deforestation the intensity and frequency of floods increases during the rainy periods and the drought conditions become acute during the rainless months. This effect of forests on the water regime of the soil and on the environment in general is more important than an increase in the rainfall that forests could bring about.

Conservation of the Gene Pool

Another benefit of considerable importance is the preservation of the gene pool (sum total of the genetic material) represented by the flora of a country. This is of special importance in Sri Lanka where

about ¼ of the flowering plants are *endemic* to the country i.e. they are species that are found only in Sri Lanka. Unless suitable extents of natural forests are preserved without exploitation there is the very real danger of extinction of some of the endemic species, and hence the loss forever of the genetic material (represented by these species) that has evolved over millions of years. This applies to animals too. For this reason, the Forest Department has demarcated certain natural forest areas in the major bioclimatic zones of the island and declared them as special reserves under UNESCO's Man and Biosphere Programme. One of these is the Sinharaja Reserve where timber felling which had been done in about ¼ of the 22,000 acre Reserve has now ceased.

Direct Benefits

A supply of wood which is the main product of the forest is the principal direct benefit man derives from forests. Wood is one of the oldest construction materials known to man and it still continues to be widely used. Wood is light in relation to its strength, and as a result of this, quite large sizes can be handled manually. It is also comparatively easy to work with simple tools, and it can be used for virtually any construction work. Wood is also used for a variety of other purposes such as the manufacture of rayon, fibre board and particle board. It is therefore easily the most important and useful product obtained from the forest.

In Sri Lanka about five million cu. ft of timber (firewood excluded) are extracted from the state forests annually. Wood is used in its natural form by sawing or by peeling into veneer at the plywood mills at Gintota and Kosgama, or is chipped and reconstructed into particle board at the Kosgama Wood Working Complex. Wooden poles are put to many uses: transmission and telegraph poles, fence posts, and as a construction material in rural housing. One of the most important uses of wood in Sri Lanka as well as in other developing countries is as a domestic fuel.

Besides wood there is a host of other products that could be obtained from the forest. These are collectively called minor forest produce, and they have been described in Chapter 8.

Supplementary Reading Material

Abeywickrema, B.A. (1955) The Origin and Affinities of the Flora of Ceylon. *Ceylon Association for the Advancement of Science, Proceedings of the* 11 *Session,* 99.

Champion, H. G. (1954) *Forestry.* Oxford University Press.

Kitteridge, Joseph (1948) *Forest Influences.* McGraw-Hill Book Company, Inc. New York.

Wijesinghe, L. C. A. de S. (1962) Some Aspects of Land Use in the Dry Montane Grasslands. *The Ceylon Forester* Vol. 5 No. 3, 128.

Wijesinghe, L. C. A. de S. (1971) The Role of Forestry in the Development of Ceylon's Land Resources. *Ceylon Association for the Advancement of Sciences' Proceedings of the* 27 *Session.* 179.

Chapter 3

NATURAL VEGETATION TYPES OF SRI LANKA

The main natural vegetation types of Sri Lanka are as follows:

(a) Tropical Rain Forest (Wet Evergreen Forest),
(b) Tropical Montane Forest,
(c) Dry Mixed Evergreen Forest,
(d) Thorn Forest,
(e) Savannah,
(f) Grasslands.

Tropical Rain Forest

The Tropical Rain Forest or Wet Evergreen Forest is the climax vegetation of the low and mid-country Wet Zone. It is the highest type of vegetational development that is to be found anywhere in the world. It is similar to the forest type in other parts of the humid tropics like the Amazon, Congo and Malaysia. The uniqueness of this type of vegetation is seen in its structural complexity and in the number and variety of the species of flora which surpass anything we could find oustide the humid tropics.

The region in Sri Lanka where the Rain Forest is the climax vegetation is the south-west part of the country from the coast to the middle elevations. At higher elevations the structure of the forest changes, and at about 5,000 ft and over the climax vegetation is the Tropical Montane Forest.

Although once extensive, the Rain Forest is now confined to a few areas (in the region described above), notably, Sinharaja, Kanneliya, Dediyagala and Bambarabotuwa.

The Rain Forest shows marked stratification in profile (fig. 1). The tallest trees are called the Emergent Dominants. These trees are somewhat scattered, their crowns not forming a continuous canopy. They grow to a height of about 125 ft. The main species forming Emergent Dominants are *Dipterocarpus zeylanicus* (Hora), *D. hispidus* (Bu Hora), *D. glandulosus* (Dorana), *Palaquium petiolare* and *Shorea* spp. (earlier called *Doona* spp. (Dun).

Below the Emergent Dominants is the main canopy layer comprising species like *Chaetocarpus castanocarpus* (Hedawaka), *Calophyllum* spp., *Mesua ferrea* (Na), *Myristica dactyloides* (Malboda), *Mangifera zeylanica* (Etamba), etc. These trees may reach a height of 75 to 100 ft. They, as well as the Emergent Dominants, have tall columnar trunks with little taper and, often, with well buttressed bases.

Below this canopy layer there are generally two more strata of trees, followed by shrubs. The ground is covered by herbs including ferns and *Seleginella.* Woody climbers and epiphytic ferns and orchids are common. Another characteristic feature of this type of forest is that the leaves of many species have drip tips. Most of the trees are evergreen.

The species of the Tropical Rain Forest are so numerous that if one enumerates the trees in an area of a few acres there may be a few species that are represented by only one or two trees or are not represented at all though found elsewhere in the forest. In the Forest Inventory of 1961, estimates of timber volume were made by measuring all trees over 4 inches in diameter in the sampled areas, and the species with the highest volume in the Rain Forest were found to be *Shorea* spp., but they still represented only about ten per cent of the total volume of timber in the forest.

The Tropical Rain Forest, although so rich in species, has a soil that is generally very impoverished. The available nutrients produced by rock weathering and by the decomposition of organic matter are either rapidly absorbed by the all-pervading roots in the soil or are leached out because of the heavy and constant rainfall. So the nutrients are found in the vegetation and not in the soil. That is why destruction of a Rain Forest is practically an irreversible process. The process of succession leading back to the climax forest type will take place (though very slowly) if left to nature, but in practice this is never allowed to happen due to continued interference by man. The large extents of abandoned wastelands clothed with grasses, ferns (mainly Kekilla) and scrub, with occasional patches of manioc raised by villagers, are mute testimony of what happens when the rich Tropical Rain Forest is destroyed for shifting cultivation.

Tropical Montane Forest

At elevations of about 5 000 ft and over on the wet south-west slopes of the mountain ranges, the climax vegetation is the Tropical Montane Forest. Here the dominants are nowhere near as tall as those of the Rain Forest, and there is no prominent multi-storied

FIG. 1 Profile diagram of a Tropical Rain Forest.

structure. The dominant trees have dense, spreading, flat-topped crowns The main tree species are *Elaeocarpus* spp., *Michelia nilagirica* (Sapu), *Mastixia* sp., *Syzygium* spp., *Calophyllum walkerii*, etc. In the undergrowth *Strobilanthes* spp. are common. The branches of the trees are covered with lichens, mainly *Usnea barbata*.

Dry Mixed Evergreen Forest

The climax vegetation of the plains of the Dry Zone is the Dry Mixed Evergreen forest. This region which covers about 2/3 of the area of Sri Lanka receives an annual rainfall of 50 to 75 inches. By world standards a rainfall of this magnitude is much more than what a region described as "Dry" would receive. However, the region is so called because for about four months in the year (June to September) very dry conditions prevail, and there is scarcity of moisture in the soil.

Within the Dry Zone there are some areas that are more moist than others, and correlated with these differences in climate, there are differences in the structure and composition of the forest. Many of the highly prized timber species of Sri Lanka are among the dominants of the Dry Mixed Evergreen Forest,eg. *Chloroxylon swietenia* (Burutha), *Manilkara hexandra* (Palu), *Diospyros ebenum* (Kaluwara), *Vitex pinnata* (Milla; also found in the Wet Zone), *Berrya cordifolia* (Halmilla) and *Alseodaphene semecarpifolia* (Wewarana). One of the most widespread species is *Dryptes sepiaria* (Wira), which is useless except as a fuelwood.

The forest canopy is more open and very much inferior in height to that of the Wet Everygreen Forest. Below the dominants are smaller trees and shrubs, but there is no multistoried structure of the type seen in the Rain Forest. Unlike in the Wet Zone, the soils of the Dry Zone are generally relatively rich in plant nutrients. As is implied by the name given to this forest type a fair proportion of the dominant tree species are either deciduous or semi-deciduous.

Thorn Forest

This is the typical vegetation type of the two Arid Zone regions in the Mannar and Hambantota districts where the annual rainfall is less than 50 inches and the period of drought appreciably longer than in the Dry Zone. The vegetation is a type of low, open, thorny scrub. Species like Palu and Wira found in the Dry Zone areas occur here too but their growth is stunted. Species with thick leaves, thorns, and other xeromorphic features are common. These include *Salvadora persica, Cassia spinaria, Zizyphus* sp., *Dichostachys cinerea*, etc.

Savannah

The savannah is a plant community consisting of scattered trees and an undergrowth of grasses, mainly *Imperata* (Iluk). The grasses are highly inflamable and fires are of frequent occurence. The trees are fire resistant. They are mainly of the following species: *Careya arborea* (Kahata), *Terminalia belerica* (Bulu), *T. chebula* (Aralu), *Phyllanthus emblica* (Nelli), *Anogeissus latifolia* (Dawu) and *Pterocarpus marsupium* (Gammalu). The savannah type of vegetation is found on the eastern slopes of the central hills in the Bible, Ekiriyankumbura and Medagama areas.

Grassland

Grasslands are found all over the island, and of these the best known are the montane grasslands. The grasslands of the Uva basin are the most extensive of the montane grasslands, and they belong to the category called the Dry Patanas. The rainfall regime of this region is similar to that of the moister parts of the lowland Dry Zone. Although the climate and soil are very favourable to the growth of exotic species like *Eucalyptus* spp. and *Pinus caribaea*, no indigenous trees are found in the area except in sheltered ravines. The dominant grass is *Cymbopogon* spp. The mature grass is wiry and coarse and hence not palatable to cattle. The villagers, therefore, set fire to the grass so that with the onset of the rains a fresh flush will come up. The tender shoots so produced are suitable for grazing.

Extensive afforestation has been carried out in the Uva basin; the main species used were *Eucalyptus grandis* and *E. robusta*, and more recently, *Pinus caribaea*.

The wet montane grasslands or Wet Patanas occur at high elevations over 5000 ft. The best known area of Wet Patanas is Horton Plains. The dominant grass is *Chysopogon zeylanicus*. A characteristic feature of these grasslands is the presence of trees of *Rhododendron zeylanicus* which have a gnarled and stunted form.

The Talawa grasslands are a type of formation that occurs in the Wet Zone lowlands. These grasslands occur in a region where the climax vegetation is the Topical Rain Forest. The destruction of the forest in the past, and the occurence of periodic fires which prevent the natural succession back to forest, have resulted in the establishment of an apparently stable grassland community.

Mention should also be made here of the Kekilla fernlands which occur in the same bioclimatic region as the Talawa grasslands, and are also the result of clearing and burning of the original forest vegetation. The dominant species is the fern, *Dicranopteris* (*Gleichenia*) *linearis* (Kekilla). These fernlands occur in less degraded sites than the grasslands.

The Talawa grasslands and Kekilla fernlands are taken up for afforestation with *Pinus caribaea* by the Forest Department in its annual planting programme.

Although the climax vegetation of the Dry Zone is the Dry Mixed Evergreen Forest, scattered patches of grassland, of size varying from a fraction of an acre to hundreds of acres in extent, occur in this region. These grasslands are the dry Damana grasslands and the wet Villu grasslands. The Damanas of the Dry Zone correspond to the Talawas of the Wet Zone, and are also the result of clearing of the original forest (for cultivation) and repeated firing accompanied by site degradation. The Villus are found in permanenty moist sites around ancient tanks and large water holes and by river banks.

Other Communities

Other specialised communities occur in areas with peculiar edaphic factors. Of these, the mangrove plants perhaps form the most specialised group. They are found in the coast near lagoons and the mouths of rivers where the areas are subject to frequent inundation with aline water. Vivipary is the most interesting specialised feature found in some of these mangrove plants. This is where the seed germinates while the fruit is still attached to the plant. The young seedling with a well developed hypocotyl is dislodged from the parent plant, and it would then float in the water until it gets a foothold in the soil. If the fruits or seeds were dispersed in the normal way there would be little chance of germination in an inundated area. *Rhizophora* spp., *Bruguiera* sp. and *Aegiceras* sp. are plants that exhibit this phenomenon. Another special feature of the mangrove plants is the possession of various types of aerial roots that (a) serve to provide for the intake of air which then diffuses down to the submerged underground parts, and (b) provide additional anchorage to the plant.

Mangrove vegetation does not occur extensively in Sri Lanka and is not considered to be of great economic importance in forestry. However, the bark of some species of mangrove plants serves as a source of tannin for the leather industry.

Supplementary Reading Material

Arulchelvam, K. (1968) Mangroves. *The Ceylon Forester*, Vol. 8 Nos. 364, 59.

Holmes, C. H. (1951) *The Grass, Fern and Savannah Lands of Ceylon, their Nature and Ecological Significance*. Imperial Forestry Institute, University of Oxford.

Holmes, C. H. (1956) The Broad Pattern of Climate and Vegetation Distribution in Ceylon. *The Ceylon Forester*, Vol. 2 Nos. 4, 209.

Koelmeyer, K. O. (1957) Climate Classification and the Distribution of Vegetation in Ceylon. *The Ceylon Forester*, Vol. 3 No. 2, 144.

Richards, P. W. (1957) *The Tropical Rain Forest*. Cambridge University Press.

Rosayro, R. A. de (1943) The Soils and Ecology of the Wet Evergreen Forests of Ceylon, Parts 1 and 2. *Tropical Agriculturist*, Vol. 98, Nos. 2 & 3, 4 & 5.

Rosayro, R. A. de (1951) Ecological Conceptions and Vegetational Types with special reference to Ceylon. *Tropical Agriculturist*, Vol. 106, No. 3.

Chapter 4

SILVICULTURE AND FOREST MANAGEMENT

The term Silviculture is used to cover all the techniques of raising, tending and regenerating a forest crop, and is directly comparable with the cognate terms Horticulture and Agriculture for garden and field crops respectively. It should be noted that silviculture is basically concerned with crops of trees, thus contrasting with arboriculture where the stress is on the care of the individual tree. The study of plants in relation to their environment is ecology, so that silviculture is in fact applied forest ecology.

The primary object of silviculture is to give the trees the best possible conditions for growth, and to ensure that the trees that are lost by death or harvesting are replaced with new stock. Operations carried out to achieve these ends are called *tending* and *regeneration* respectively.

Forest management is not a subject in itself, but it is the practical application of silviculture, technology, economics etc., to a forest in order to achieve a certain desired objective. The object of management of a particular forest may be, for example, to produce fuelwood to a particular town on a sustained basis without causing any adverse effects to the soil and the water regime of the locality such as may be caused by excessive felling. The plan indicating the operations that have to be carried out year by year and the section of the forest where each operation has to be carried out in a given year is the Management Plan or Working Plan.

Before managing a forest in order to achieve certain desired objectives one must have some basic information on the forest. Unlike in agriculture where invariably one starts with the basic questions of what, how, when and where in relation to the possible crops that could be raised, in forestry one generally starts with a forested land, and the forester has to plan its management. So the first thing one should know is the area of the forest – forests may extend over many hundreds or thousands of acres. This is determined by ground surveys, but, today survey plans can be revised or even new surveys carried out using remote sensing methods, the most practical – at least in Sri Lanka – being aerial photography. The forests of Sri Lanka were surveyed and mapped out

using aerial photographs in the period 1956 to 1961 by a Canadian firm with local counterparts under a Colombo Plan agreement. But since 1961 no systematic surveys of the forests of Sri Lanka have been carried out except for the survey of forest plantations and some sporadic surveys of a few natural forests.

The preparation of a survey plan is the first step in forest management. One should then know the composition and the volume of standing timber, species by species. Determining this in tropical forests is a complex matter for, as was seen in the description of the natural forests of Sri Lanka, the forests contain a bewildering number of species, and, moreover, the proportion of the different species varies considerably from place to place even within a small area. The forest inventory of 1961 shows that the most abundant species in the Wet Zone forests are the *Shoreas* (Dun), but even so, these account for only ten per cent of the total timber volume in these forests. By contrast, forests of the temperate zone contain only a very few dominant species, and this makes management of such forests relatively easy.

It is generally impractical and uneconomical to carry out a 100 per cent enumeration of the trees in a forest and to record their measurements. Instead, a sample comprising, say, a number of ¼ acre or 1/10 acre plots distributed at random over the entire forest is used for obtaining the relevant data, and the data so obtained are applied to the forest as whole.

One should then have some knowledge of the value of the different species. The principal product of the forest is generally timber, and if the forest is to be managed so as to provide a sustained yield of utilisable timber, one should know the quality and possible uses of the timber of the different species. The management practices can then be directed towards increasing the proportion of the more desirable species and reducing the number of unwanted ones.

The forester should then have information on the mode of regeneration, the seeding habits, the degree of viability of the seeds, the tolerances (eg. whether light demanding or shade tolerant) and the numerous other factors influencing plant growth in relation to the species he is interested in. For example, seedlings of *Dipterocarpus zeylanicus* are light demanding, and even though there may be a good seed fall, many seedlings may not survive unless the canopy is opened to permit the entry of light to the forest floor. Broad-leaved Mahogany (*Swietenia macrophylla*), which is an exotic to Sri Lanka but is propagated here, demands shade in early life but requires ample light once it reaches the pole stage.

Finally, for good forest management, it is essential to have data on the rate of growth of the desired species. In agriculture the harvest in generally obtained once and for all for a particular crop. In forestry, for one thing it takes years to obtain the principal product, timber, and for another the harvest is not obtained in a once and for all operation; at intervals of a few years some trees are felled and removed in operations called thinnings or selection fellings. In most management operations, after a series of thinnings the crop is finally clear-felled at the end of the rotation and the area reforested. By studying the rate at which trees grow one could make an assessment of the *annual increment* per acre of a forest which is given in terms of cubic ft per acre per year.

To take a simple example, consider a forest plantation of a single species, say Teak, and assume the standing volume of a 20-year plantation to be 1 200 cubic ft per acre. Ten years later the same plantation is re-measured and may be found to have a standing volume of 1600 cubic ft per acre. If during this period the plantation had been thinned once and the thinnings amounted to 300 cubic ft per acre, then the increment during the 10-year period is 1600 + 300 – 1200 or 700 cubic ft, and the annual increment of the plantation between the 20th and 30th year is 70 cubic ft per acre. The annual increment of a species growing in a particular site is an index of the quality of the site.

In the temperate forests the growth of a tree is easy to assess because of the presence of annual rings. By making a boring from the surface to the centre of the tree and extracting a fine core of wood the width of the annual rings could be measured and the rate of growth assessed. In the tropical forest, where most trees do not possess annual rings, growth can be assessed by periodic measurement of the trees.

Now how does one set about managing a natural forest in order to achieve a particular objective? Let us say that the objective is that the forest should provide the maximum amount of timber on a sustained basis to feed a timber industry without causing damage to the soil and water resources of the area as might easily happen if felling is excessive. If the forest inventory has given the annual increment of the forest in relation to the utilisable species, then, theoretically, this quantity of timber can be harvested every year from the forest in perpetuity. Taking a hypothetical example which again is over-simplified to make the explanation easy, if a forest is 10 000 acres in extent and the increment of utilisable timber 50 cubic ft per acre per year, then the forest could provide 500 000 cubic ft per year indefinitely. In practice it is not possible to scour the entire forest every year and to pick a tree here and a tree there for felling to make up the 500 000 cubic ft. So what could

be done is to divide the forest into a number of blocks (say, 10) and to carry out the felling operation only in one block each year. The entire annual increment is harvested from this block which is then allowed to rest for 10 years, and during this period the other blocks are taken up, one each year. In the 11th year the first block will be due for felling again.

If one considers the bases on which fellings are carried out in managed forests one could recognize two distinct systems, the Selection Felling system and the Clear Felling system.

Selection Felling

In this method of harvesting, the trees which are to be felled are picked out individually in the annual felling block. Various factors are considered when selecting the trees for felling, one of which is the maturity of the tree. This method of management is practised to perfection in the forests of Switzerland where clear felling of forests even in small blocks at a time is prohibited by law. It requires considerable expertise to plan forest management according to this system; and even the felling and removal of the selected trees without causing excessive damage to the standing trees and to young plants require great skill. On the selection system land is never left bare since at no stage is any clear felling carried out. Another characteristic feature of a forest managed under the selection system is that the trees are not of even age in any area of the forest i.e. there is an intimate mixture of trees of all ages within the forest. In Sri Lanka this system is in operation in the Jak-Mahogany forest plantations of the Kurunegala district. In the natural forests of the Wet Zone a simplified form of this system is practised.

Clear Felling

Clear felling, as the term implies, is the complete removal of the forest cover. A forest plantation is generally clear felled when the trees show a sharply declining growth rate, at which stage it would be more economical to harvest the timber and reforest the area rather than allow the crop to remain. If the forest plantations were originally raised, a block every year, then these plantation blocks will reach rotation age sequentially, and in any year the plantation block that has reached rotation age will be clear felled to supply timber, and the area reforested. Plantations raised on this system will be even-aged i.e. all the plants in an annual planting block will be of the same age.

Clear felling is not entirely confined to forest plantations. Natural forests have often to be cleared for reforesting. This is done extensively in Sri Lanka, particularly in the Dry Zone where degraded natural forests are cleared, any valuable timber removed, and the area reforested with species like Teak and *Eucalyptus camaldulensis*. On the clear felling system, the bulk of the yield is obtained when the crop is harvested at the end of the rotation. However, intermediate yields are also obtained at various stages during the rotation from thinning operations. When a plantation is raised the seedlings are planted out at a relatively close spacing (eg. 10 ft x 10 ft or 8 ft x 8 ft). After a few years the plantation has to be thinned as it would otherwise get over-crowded when the plants keep growing in size. In the first thinning operation the plants removed are of small pole sizes, but in subsequent thinnings the trees that are removed could be used for a variety of purposes eg. telegraph poles, saw timber etc. Marking of trees for thinning is generally done by an experienced forester since it is one of the most important of silvicultural operations. The general principle is that when there are trees which are too close together and are interfering with each other's growth, the better formed trees are left to grow further, perhaps up to rotation age, and the others marked for removal at the thinning operations.

Supplementary Reading Material

Andrews, J. R. T. (1961) *A Forest Inventory of Ceylon*. The Government Press, Ceylon.

Johnston, D. R., Grayson, A. J., and Bradley, R. T. (1967) *Forest Planning*. Faber and Faber Ltd., 24 Russel Square, London.

Chapter 5

REGENERATION

Regeneration is perhaps the most fundamental concern of the forester. In general, regeneration could be either natural or artificial. In natural regeneration one makes use of natural seed fall from the parent trees to produce the new crop. In artificial regeneration the new crop is raised by planting (reforestation, afforestation). Examples of natural and artificial regeneration are described below.

Natural Regeneration

Selection forests

In selection forests, regeneration is mostly, if not entirely, by natural seed fall. In the Jak-Mahogany Selection forests referred to in the last chapter prolific natural regeneration of Mahogany is commonly observed.

In the natural forests of the Wet Zone the Selection system, is not strictly observed, but as a general rule trees that have a girth (measured at 4.5 ft from the ground) of over 5 ft are felled if the species is an utilisable one. After a felling operation is carried out in a forest block it is rested for a period of about 20 years. During this period seedlings come up in the gaps created by the fellings, and in 20 years these would have reached pole sizes. In the meantime trees that were just below 5 ft girth at the original enumeration may, after 20 years, attain a girth in excess of 5 ft and be liable to be marked for felling at that stage. Where there are a number of trees of over 5 ft girth such as may be the case when a virgin forest is taken up for exploitation, the silvicultural rules specify that, irrespective of the girth, marking for felling shall be done in such a manner that no large clearing will appear once the marked trees are felled. In practice therefore no more than 4 or 5 trees should be felled in an acre even in a well stocked natural forest of the Wet Zone. On an average about 300 to 400 cubic ft per acre could be removed from such a forest. If these rules are carefully followed no over-exploitation would occur in the natural forests of the Wet Zone since the removal of up to 500 cubic ft from a well stocked natural forest is well within the resilience limits of the ecosystem, and recovery will be complete during the rest period that follows. In actual practice many of the

more accessible natural forests have been heavily over-exploited in the past resulting in degradation beyond the stage from which they could recover their original form. For many such degraded forests the only practical way of putting the land into productive forestry is to reforest the areas artificially.

Shelterwood Regeneration

In this system of regeneration the majority of the final crop trees are removed in a felling operation carried out when the crop is mature. Some mature trees are left behind at a roughly uniform spacing to provide seed and to shelter the seedlings that come up. These trees are the "seed bearers." After an year or two the seed bearers are removed in one or more successive felling operations, care being taken to avoid excessive damage to the seedlings that should have by then become established in the area. In Sri Lanka shelterwood regeneration is not practised widely, but the writer has observed *Dipterocarpus zeylanicus* regenerating under these conditions. An initial felling operation that opened up the canopy resulted in prolific natural regeneration of *Dipterocarpus* (the seed coming from seed bearers in the area), and in a few years a pole crop consisting of 75 per cent *Dipterocarpus* was found in the area.

Clear felling

In the Landes in France, *Pinus maritima* is clear felled at rotation age and in the following season a crop of new seedlings comes up from seed already lying on the soil or released from cones left with the felling debris. In Sri Lanka the writer has practised this type of regeneration with *Acacia mollissima* in the Nuwara Eliya District. The mature *Acacia* is felled and the material used as firewood (the bark of this plant is rich in tannin but is not yet commercially exploited for this purpose). The twigs and small branches that are left behind are burnt. With the rains the seed that is on the ground germinates, and supplemented by seed from the adjoining plantations, a complete carpet of seedlings is formed within an year or two. The burn after felling does not destroy the seed.

Artificial Regeneration

Obviously, artificial regeneration is the only method applicable when exotic species are raised for the first time, since there could be no seed bearers from among the indigenous flora. In Sri Lanka the bulk of the forestation programme is carried out through artificial regeneration. In artificial regeneration, the plants are raised as seedlings in forest

nurseries. With species like *Pinus caribaea, Eucalyptus* spp., and *Albizzia moluccana,* all of which are exotics, as well as with indigenous species like *Pericopsis mooniana* (Nedun) the seedlings are transplanted into containers after a short period in the seed beds. The containers used are polythene bags of various sizes eg. 9 inches x 4 inches. The polythene bags are perforated at the base to allow for drainage of water, and they are filled with a special potting mixture before transplanting. In the case of Teak, the plants are allowed to grow in the seed bed, and when they are about two to three ft in height they are uprooted and 'stumped.' Stumping is done by cutting across the seedling sharply leaving about eight inches of root and half inch of shoot. In the planting season these carrot-like stumps are prepared in the nurseries, transported to the planting centres, and planted out in crow-bar holes leaving only the short stem-tips protruding from the soil surface. Planting is done at various spacings, the commonest being 10 ft x 10 ft. In the case of plants in polythene bags, the bag is completely removed before planting. If this is not done the almost non-degradable polythene prevents free root development for several years and this often results in the death of the plant.

The most important forest plantation species in Sri Lanka is Teak. Teak is not indigenous to Sri Lanka; it was introduced to the country in the 17th century. Later, in the 19th century, it began to be grown as a forest plantation crop but only on a very restricted scale. The Teak planting programme was stepped up only in recent years. It is a species that is suited to the Dry and Intermediate climatic zones, but could also be raised in well drained soils in the Wet Zone. The reforestation programme with Teak is now entirely confined to the Dry Zone where adequate land is available.

In the Dry Zone, reforestation is done on what is called the chena-reforestation system. On this scheme, land (mostly degraded natural forest) is blocked out and given on lease to applicants, a five acre block to each. The lease holds good for three years. The lessee is expected to clear the area, supplying any utilizable timber to the State Timber Corporation. The Corporation pays the lessee for the service of felling and extracting the timber. Any timber and firewood not required by the Corporation can be purchased by the lessee at a prescribed royalty rate, and he could generally make a small profit by selling this timber and firewood in certain areas where there is a demand for these materials. By July the felling is complete, and the felling debris is on the ground. By late August the area is burnt. Planting is done with the first rains in October. The lessee is expected to plant the forest species at the

required spacing (generally 10 ft x 10 ft) and he is permitted to use the intervening space to raise cash crops. The cash crops bring the lessee a fair return, and besides, he is also paid a cash reward (by the Forest Department) in the first, second and third year of the lease provided he has done the preparatory work, the planting of the forest species and the maintenance of the plants satisfactorily. A survival rate of 80 per cent is considered the minimum acceptable standard for payment of rewards.

Besides Teak, *Eucalyptus camuldulensis* is also planted in the Dry Zone. Small extents of other species like Margosa, *Casuarina*, etc. are also planted. The solid bamboo, *Dendrocalamus strictus,* was planted at one time, but for various reasons reforestation with this species has now been discontinued.

In the Dry Patanas of the uplands extensive afforestation is being carried out with *Pinus caribaea.* In field trials carried out in the late 1960s it was found that this species was also very well suited for reforesting sites in the low country Wet Zone which have suffered severe degradation as a result of shifting cultivation. Sites covered by the fern, *Dicranopteris linearis* (Kekilla), or by grasses and scrub are particularly suited for reforesting with *Pinus caribaea* which shows phenomenal rates of growth on such sites.

At high elevations in the Montane Zone the species used for forestation are *Eucalyptus grandis* (extensive plantations are seen in the Gurutalawa area), *E. microcorys* (seen in Kandapola), and *Pinus patula.* Cypress was raised extensively earlier, but the planting of this species is now done only on a small scale. *E. robusta* (Red Gum) was at one time popular as a fuelwood species and was used for planting on the Estate Fuelwood Scheme. This scheme is an arrangement whereby tea estate owners plant up small blocks every year. When a plantation reaches the age of ten years it is felled for fuelwood, and the shoots springing up from the stumps (called coppice shoots) are allowed to grow up to form a new plantation.

In the low country Wet Zone, besides *Pinus caribaea, Albizzia moluccanna* is used for reforestation. This species, unlike *Pinus,* requires a relatively good soil and is quite unsuitable for planting in abandoned chenas.

With a current annual forestation programme of nearly 20 000 acres, the area of man-made forests has risen sharply and now stands at 257 500 acres (up to 1979). This figure includes the Teak plantations destroyed by the 1978 cyclone estimated at 25 000 acres.

The Use of Exotic Species For Forestation

Except for very small areas where indigenous species (eg. *Periconsis mooniana*) have been planted, almost the total extent of man made forests is of exotic species, notably, Teak, *Eucalyptus* spp., *Pinus* spp., *Albizzia moluccana, Dendrocalamus strictus*, *Cupressus* sp. etc. The question is often asked of foresters as to why only non-indigenous species are planted. It would be difficult to give a complete answer to this question in the limited space available here, but the reader is reminded that all plantation and agricultural crops of economic importance in Sri Lanka are exotics: tea, rubber, coconut, rice, maize, sorghum, etc.

The forester is concerned not only with conservation, for if this were the case forestry would have no status as a science. He has to manage the forests in his charge so that they would be of maximum benefit to the community for all time. One of the objectives of management is the sustained production of wood to meet the demands of the community or of the country as a whole. In doing this the forester has usually to use land which is unsuitable for permanent agriculture. In Sri Lanka, forest plantations have to be raised on impoverished soils in abandoned chenas, on the wind swept dry montane grasslands, and other such areas. Most indigenous forest tree species do not thrive on such sites.

The selection of species for forestation is not a simple process. It is based on field trials using indigenous species as well as exotic species that have been planted elsewhere in the world. When exotic species are experimented with, the choice is restricted to those where the local site conditions (climate, soil etc.) fall within the tolerance limits of the species tried. It is based on such trials, replicated over a number of years and covering a number of sites, that species are finally selected for forestation on an extensive scale. The criteria for assessing the suitability for raising as plantations are (a) ease and cost of propagation and of establishment of the plantation, (b) degree of survival, (c) rate of growth and (d) importance of the species.

Supplementary Reading Material

De Rosayro, R. A. (1949) Land Utilization in the Montane Grasslands (*patanas*) of Ceylon. *Ceylon Geogr. Soc. Bull.* Vol. 4 Nos. 1 and 2, 27.

De Rosayro, R. A. (1957) Afforestation for Protection and Conservation in the Upcountry Patanas. *The Ceylon Forester*. Vol. 3 No. 1, 30.

Vivekanandan, K. (1978) *Forest Tree Planting Handbook*. Forest Departments Colombo 2, Sri Lanka.

Wijesinghe, L. C. A. de S. (1978) Why are Exotic Species Used for Forestation. *Economic Review*. Vol. 4 Nos. 2 and 3, 24.

(Useful information on forestry activities in Sri Lanka could be obtained from the annual administration reports of the Conservator of Forests published by the Forest Department, Colombo 2.)

Plate 2. Plantation of *Pinus caribaea* (2 years) raised on a degraded site in Kottawa, near Galle

Plate 3. Young plantations of Teak (2 years) with cash crops

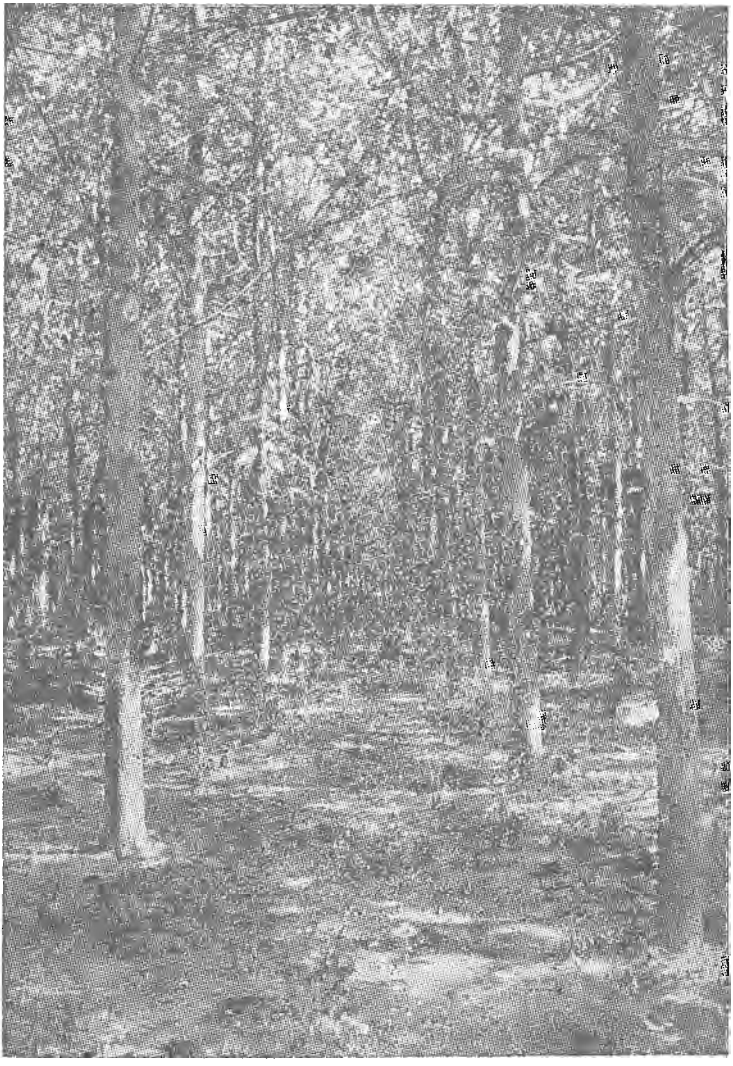

Plate 4. Teak Plantations (10 years) in Vakaneri

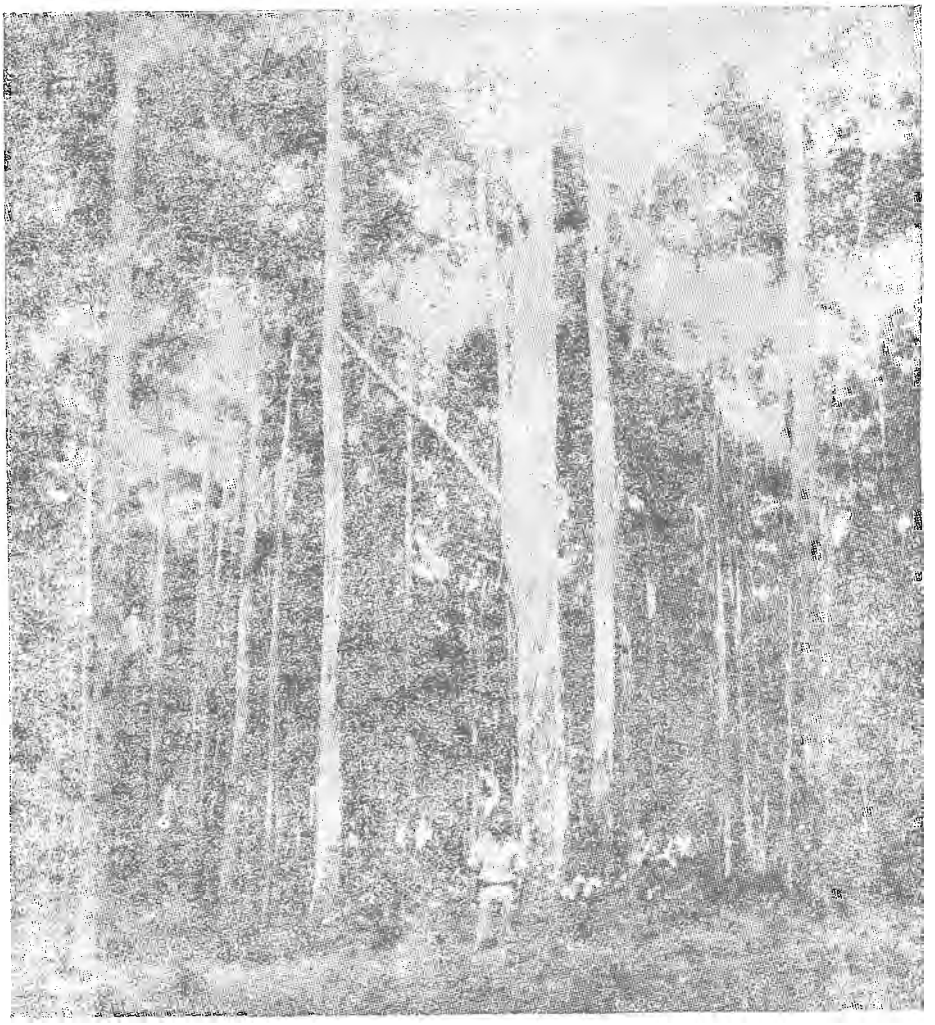

Plate 5. Plantations of *Eucalyptus grandis* raised on the Dry Patanas in Erabadda, near Welimada

Chapter 6

FOREST PROTECTION

Forest protection is one of the most important functions of the forester. The main agencies of forest destruction are insects and other animals, fungi, and man himself.

Insects and fungi cause destruction of trees and of timber in use, particularly when used outdoors. It should be realized that in a natural ecosystem the fungi and insects are important components of it. By feeding on organic matter they function in the role of consumers in the complex food chains of the forest ecosystem. Even the fungi and insects that feed on living trees do not generally upset the balance of a natural ecosystem as they are themselves kept in check by various factors eg. the parasites that attack insect pests. In a forest that is managed to fulfil a desired objective, the more the forest departs from the natural state the greater the likelihood of insect pests and other agencies causing destruction. It is easy to see, for example, how a forest monoculture could be very susceptible to destruction by insects or fungi. If the forest species is a host to a particular insect pest, the single species plantation will provide the ideal breeding ground for the pest, and its population would increase exponentially causing widespread destruction. Despite this danger, many forest plantations are raised as monocultures all over the world, since mixed plantations are not easy to raise and maintain. So is it with agriculture. Adequate measures have therefore to be taken to detect, and when detected, to apply control measures against pests.

The problem of protecting a forest from insects and fungi is a complex one. Insecticides and fungicides that are used in agriculture cannot be used by the forester except in forest nurseries because of the expense, the extent of land involved, and the difficulty of reaching the pests and parasites. So far the only insect attack that may be considered to have reached epidemic proportions in the Sri Lanka forests, though not destroying the host, is Teak defoliation.

Two caterpillers are responsible for this: *Hyblaes puera* and *Hupalia machaeralis*. Teak is a deciduous tree that sheds its leaves about July. At one time the spread of the defoliators was most evident shortly before leaf fall so that the physiological effect of insect attack was not considered

serious. In recent years, however, they are seen to attack the new flush, and defoliation at this stage year after year can cause a decline in the vigour of the Teak trees. In the case of insect pests in forests, biological control methods are recommended i.e. the parasites that attack the pest in its natural environment are isolated and identified, bred in laboratories and then released in large numbers. This was done to control the *Promototheca* beetle that posed a serious threat to our coconut plantations some years back. There are parasites that attack the Teak defoliater caterpillar, but successful control of the pest using the parasites has not yet been possible even in India where research on these lines is being carried out.

Fungal attack is still less easy to control. Fungi generally gain entry into the plant through the root and are hence difficult to reach. The most practical method of controlling the spread is to fell the infected trees, burn the material, and isolate the residual trunks by digging trenches round them. Other methods of controlling fungal attack are to use disease resistant clones, to plant species in mixtures, and to have plantation blocks separated by belts of natural forest.

The forest has also to be protected from various animals besides insects. In many parts of the world goats are a serious menace to the forests eg. in Greece and Cyprus. In Sri Lanka new plantations have to be protected from cattle especially in the up-country area where the traditional grazing grounds – the Patanas – are taken up for afforestation. Other animals that cause damage to young plants are sambhur and porcupine, but they are found only in isolated areas and do not cause serious problems. One of the most serious problems affecting forest plantations is the destruction of Teak plantations by elephants. This is really a problem of recent occurrence. Up to a few years ago the elephants left the Teak plantation alone except for a few trees that may be destroyed by the movement of herds through the plantations. Recently, however, they have started actively destroying young plants and feeding on the bark and the apical parts. Several hundreds of acres have been destroyed in this way in Habarana, Puttalam and other areas. The change in the feeding habits have no doubt been brought about by the restriction in the natural feeding grounds caused by continued forest clearing.

Fire is a serious hazard in the Dry Zone and in the plantations raised on the montane grasslands. In Sri Lanka, fires that spread into forest plantations are caused by man, in most cases through carelessness. Firelines are opened round plantations in the more vulnerable areas as a protection against fire. The firelines are belts of about half chain

wide where the grass and other vegetation are compeltely removed so that a fire that starts outside a plantation will not spread into it. Internal firelines are also opened to contain fires that occur within the plantations. The opening and maintenance of firelines are expensive operations. Greater public-spiritedness among the people could reduce the need for firelines and hence effect considerable savings in the cost of raising plantations. Fire warning boards have been displayed in many areas to obtain the co-operation of the public. In some countries like Canada and Australia the fire hazard is a very serious one, and a fire once started may destroy several hundreds of acres before it is brought under control. Fire control watch towers are put up is these countries to help in early detection.

In Sri Lanka as well as in many other countries, man is the most serious cause of forest destruction. The 1961 Forest Inventory shows that there were over two million acres of land which had lost its forest cover as a result of being subjected to shifting cultivation (chena lands). Besides the chenas, the extensive areas of forest classified as "unproductive" have been rendered so largely due to human activity. It is not only for cultivation that forests are destroyed; illicit felling of timber also takes place both in the natural forests and in plantations. Legislation alone cannot curb this menace; it requires a sense of patriotism among the people.

Chapter 7

FOREST ECONOMICS

Forest economics is an important branch of forestry. However, of necessity, the subject can be dealt with only superficially here.

The study of the economics of forestry operations is made complex by two factors, namely, (a) the long gestation period before the benefits of a forestry enterprise are obtained and (b) the benefits are generally obtained at intervals of a few years (thinnings), culminating with the final yield at rotation age; the costs, likewise, are spread unevenly over the lifetime of the crop.

A forester has to justify his projects on economic criteria, and it is only by so doing that he could obtain the required funds in the face of competing demands for capital. If not armed with an economic assessment, therefore, the forester would be at a considerable disadvantage compared to his counterparts in agriculture, industry etc. The forester has to provide a cost-benefit analysis of his proposed project. The costs and benefits have to be estimated and the figures discounted to the year zero. Different rates of discounting can be selected, and by the use of tables the calculation could be greatly simplified. The difference between the discounted benefits and discounted costs is the net present value (NPV) of the project at a particular rate of discounting. Other ways of expressing the profitability of the project is to calculate the internal rate of return (IRR) or the benefit/cost ratio.

For the purpose of illustration, a simplified example of a *Pinus* plantation can be taken. Assume that the plantation is raised on Patana grassland on a ten year rotation for producing pulpwood, and that the yield is a once and for all one obtained at the end of the rotation, there being no intermediate yields in the form of thinnings. The costs and benefits are shown in the table on page 38. From this table it is seen that if the costs and benefits are discounted at eight per cent the project will have a net present value of Rs. 119.81 per acre. The internal rate of return is obtained by working out the NPV at different rates of discounting, plotting the results on a graph and determining the rate of return that gives a zero NPV.

Having said that much about the discounted cash flow in relation to forestry projects it is necessary to express reservations about the unqualified acceptance of this method of evaluating forestry projects in relation to other projects. If the benefits from forestry are fully reflected in the returns by way of timber or other produce, then one could not object to an alternative investment that gives a better IRR being preferred to the forestry project. However, as described in Chapter 2 there are a number of indirect benefits which are not easy to quantify or to place a monetary value on. The economic benefits from such indirect effects of forests can be quite considerable; consider for example the reduction in the incidence and intensity of flash floods. It is sometimes possible to prepare the benefit stream placing a hypothetical value for such indirect benefits.

The concept of *opportunity cost* is worth mentioning in connection with forestry projects. Since most courses of action are selected from a range of alternatives, the decision to adopt one course of action means that the others are rejected. The cost of the chosen course may therefore be looked upon as the loss sustained by foregoing the opportunity afforded by the next best alternative. Opportunity costs may therefore be taken as being equal to the net benefit which could have resulted if the next best alternative had been selected. To illustrate this concept with a hypothetical example, take the case of a proposal to keep an extensive area under natural forest while selectively felling timber from it, as against an alternative proposal to clear the forest for agriculture. A straightforward discounted cash flow statement may indicate that the agricultural project is far more profitable. However, if the area is erodible and environmental hazards are expected if the forest is cleared, the opportunity cost of implementing the agricultural project is not only the value of the timber that may have been produced by the forest had it remained but also the protection to the environment that would have been afforded by the forest, and this effect can at times be quite considerable. In certain circumstances therefore, forestry projects may be selected in preference to others although the selection could not be justified entirely on the basis of a discounted cash flow.

There are other factors that have to be considered in evaluating the economic worth of a forestry project. Some of these are:

(a) Saving in foreign exchange. Import substitution of raw materials (eg. timber) is an important strategy in the economic development of many developing countries. In Sri Lanka the long-fibred pulp for the paper industry is imported, and one of the objectives of the forestry programme in the country is to produce pulpwood that can be substituted for the imported pulp. The benefits that can accrue

from such a programme is not merely the income that could be derived by the sale of the pulpwood to the Paper Corporation but also the saving in foreign exchange by eliminating the import of pulp. In the case of forestry products the saving in foreign exchange is generally higher than the revenue that would be derived by the sale of the material produced locally.

(b) Developing the rural economy. In many countries of the Third World priority is given to projects that bring about development in the rural sector. In this context, forestry projects being generally located in remote areas have a greater impact on the development of the rural sector than most other projects, and for this reason they would be given special weightage in comparison with alternative projects.

(c) Multiplier effects on the economy. With the development of forestry, forest products form the basis of various industries that are established such as saw milling, particle board manufacture, plywood production, etc. These linkages are not evident in a straightforward cost-benefit analysis of a forestry project.

Supplementary Reading Material

Anon (1974) *An Introduction to Planning Forestry Development*. Food and Agriculture Organization of the United Nations, Rome.

Gittinger, J. Price (1972) *Economic Analysis of Agricultural Projects*. The John Hopkins University Press, Baltimore and London.

Hiley, W. E. (1956) *Economics of Plantations*. Faber and Faber Ltd., 24, Russel Square, London.

Tisseverasinghe, A. E. K. (1965) The Economics of Forestry in Developing Countries. *Ceylon Association for the Advancement of Science. Proceedings of the 20 Session*, 53.

Cost and benefit streams (per acre) connected with the raising of a Pinus plantation on Patana grasslands

(All costs and benefits are given in rupees and are at 1978 estimated prices)

Costs :	Year 0	1	2	3	4	5	6	7	8	9	10
Planting material	270.00										
Ground preparation and planting	200.00										
First year maintenance including fireline clearing	(138.90)*	150									
Second year maintenance including fireline reclearing	(42.85)		50								
Third year fireline reclearing and maintenance	(31.76)			40							
Fireline reclearing	(36.68)				10	10	10	10	10	10	10
Overheads	50.00										
	(36.00)	25	15								
Total Costs (discounted at 8 per cent)	(806.19)										
Benefits :											
Sale of pulpwood less cost of extraction	(926.00)										2 000
Net present value at 8 per cent (926.00 – 806.19)	(119.81)										

* The figures in brackets are the discounted costs and benefits (at 8 per cent)

Chapter 8

FOREST UTILIZATION

Timber is the principal product of the forest. It is one of the oldest construction materials known to man and still continues to be widely used. Despite the fact that synthetic substitutes are being used for a variety of purposes, the world demand for wood is continuing to increase. It is indeed a good thing that wood substitutes have been developed, for otherwise, the destruction of forests for supplying the demands would have been calamitous.

Timber harvesting

The problems connected with timber utilization begin at the stage of harvesting. Felling, extracting the logs from the stump site to the nearest accessible point and haulage by road, railway, cableway or water are all aspects of utilization that call for careful study. In the more advanced countries like Switzerland and Germany, forests are provided with a network of roads. The road density to be aimed at is carefully worked out on the basis of a comparison of the cost of road construction and haulage by road on the one hand and the cost of extraction from the stump site to the road on the other. The latter where the logs have generally to be dragged out using machines or animals (eg. elephants) is the most expensive of the timber harvesting operations, and considerable savings could be effected by reducing the distance involved by building more roads. But the cost of road construction is also high, and hence the relative costs will have to be studied before a programme of road construction is started.

In Switzerland, Austria and southern Germany cable cranes and cableways are used extensively. The cable crane is particularly useful in selection felling operations as the logs could be picked up from the stump site, hoisted, and then transported along an overhead cable. Dragging along the ground with consequent damage to the standing trees is therefore minimized.

Special timber haulage tractors are also widely used in many industrialized countries. The most sophisticated of the machines fells the tree, lops off the branches and carries it from the stump site to the

road side. In these countries the escalation in the cost of forest operations is checked by increased mechanization and reduced dependence on labour.

In Sri Lanka, traditional methods of logging are still being widely practised. They consist of felling and cross cutting with axes, and extraction from stump to the road using elephants. In the Dry Zone, bullock carts are also used for the transportation of logs in the forest, the log being slung under the axle.

Mechanized logging is carried out in some forests where timber exploitation is done by the State Timber Corporation and the Plywood Corporation. In these mechanized logging operations, the trees are felled with chain saws, and extraction of logs is done using large, rubber-tyred logging tractors and agricultural tractors. The logging tractors are very efficient, but the costs of purchasing and maintaining them are very high. Transportation from the forest to the mill is done by road or railway or, occasionally, by water.

Sawing

For most construction work and for furniture making, timber has to be sawn before use, and this can be done either by hand saws or by machines. Hand-sawing of logs is done in Sri Lanka using a scaffolding on which the log is hoisted. A pair of sawers, one standing below the scaffolding and the other on the log, do the sawing together with an up and down motion of a long, two-handled saw. Sawing done in this manner is very accurate and causes little waste.

Machines for sawing are of various types. Some are very much like the handsaw-only faster ie. they have a reciprocating action either up and down as in the vertical frame saw or from side to side in a horizontal frame saw. The most common machine used in Sri Lanka is the circular saw. This is a round steel plate with cutting teeth on the rim. Its disadvantage is the high proportion of waste in sawing. Another type is the band saw which is an endless steel ribbon with cutting teeth on one edge. It may work horizontally or vertically. This is an accurate method of sawing with less waste than in the case of the circular saw.

All mechanical saws require maintenance by skilled technicians, and the frequent neglect of careful saw doctoring results in inaccurate sawing and considerable waste of wood.

Seasoning

Green timber ie. timber from freshly felled trees contain a high proportion of water – in the range of 50 to 200 per cent of the dry weight. This water is contained in the wood in two forms: (a) as "free water" which is found in the cell cavities and intercellular spaces and (b) as "bound" water in the cell walls.

When wood is exposed to the air it begins to dry, and in the process, what is first lost is the free water. As drying goes on, a stage is reached when almost all the free water is lost but the walls are still saturated with water. At this stage the wood is said to be at its Fibre Saturation Point (FSP). The FSP usually lies between 25 and 30 per cent moisture content. Further drying beyond this point results in the loss of the bound water. In practice a piece of wood does not dry uniformly. The surface layer dries first, and a moisture gradient is set up resulting in the movement of water from the core of the piece of wood to the surface. The surface layer therefore reaches FSP before the core.

When wood dries beyond the FSP an important physical change takes place; the wood begins to shrink. Shrinkage is not uniform; shrinkage in the tangential direction is much greater than in the radial direction (usually double), while longitudinal shrinkage is negligible. Because of the two factors, (a) the log from which the sawn timber is obtained being cylindrical in shape and (b) the shrinkage in the tangential direction being much higher than that in the radial direction, a piece of sawn timber often tends to warp when it shrinks on drying.

Drying of wood goes on till its moisture content is in equilibrium with that of the atmosphere. At this stage the timber is said to be *seasoned*. In Sri Lanka seasoned timber has a moisture content of around 15 per cent. It should now be obvious why timber has to be seasoned before it is used for furniture making. If unseasoned wood is used it will dry after it is made up into furniture, and shrinkage occurs resulting in the opening up of joints and warping of the planks. Even if a piece of timber is seasoned it will tend to absorb and give out small amounts of moisture as the moisture content of the atmosphere fluctuates, and this results in movement of the wood – expansion when it absorbs water and contraction when it dries. Hence one would have observed that drawers and doors tend to get jammed in wet weather.

There are other advantages in seasoning timber before use. When timber dries beyond its FSP it becomes stronger and more durable. Increased durability is due to it being less susceptible to attack by fungi

and insects. Timber being a natural, organic material, it is subject to attack by fungi and insects under certain conditions. Both fungi and insects need water to sustain life. Timber that has been dried to equilibrium moisture content does not contain sufficient moisture for the growth of most fungi and insects. Hence durability is increased.

Seasoning cannot be done by merely putting planks to dry out in the sun. Because shrinkage occurs as timber dries and the exposed surface dries faster than the inner parts, certain defects can develop if the timber dries too fast. One of these defects is called *case hardening*. If a piece of timber dries too fast the outer layers will dry below the FSP while the core is still at a moisture content higher than the FSP. The outer layers then tend to shrink but are prevented from doing so by the core which has still not begun to shrink, and the outer layers may set while under tension. The wood is then said to be case hardened. Subsequently the core dries below the FSP and tends to shrink but is prevented from doing so by the outer layers that have set. The core is then under tension and the outer layers under compression. Case hardening can give rise to "honey combing" and, if the piece of wood is resawn, to severe warping.

Timber has therefore to be seasoned under controlled conditions. It could either be air seasoned or kiln seasoned. In air seasoning the timber is stacked under cover and in such a manner that there is free air circulation between the pieces of sawn timber which are separated from each other by small pieces of wood called stickers. By this method it generally takes several weeks to obtain well seasoned wood.

In kiln seasoning the timber is placed (stacked as for air seasoning) in a closed chamber or kiln where both the temperature and humidity can be controlled. The temperature is raised, but by supplying steam the humidity is also increased and too rapid drying prevented. The temperature and humidity are controlled according to special kiln drying schedules – there being different schedules for different types of timber. Kiln seasoning can be accomplished in a few days.

Wood Preservation

Timber, like any other material, is subject to destruction by various agencies. The biological agencies of destruction are fungi and insects. As stated earlier, fungi do not normally attack dry timber, and hence if seasoned wood is used and the timber is not subject to wetting fungal attack will not occur. However, timber is often used out of doors and is hence exposed to rain, e.g. railway sleepers, electrical

and telegraph poles, etc. In such cases most timbers are not naturally resistant to fungal attack and have to be protected by suitable treatment. Preservative agents are selected that will render the timber resistant to attack both by insects and fungi.

Several different types of insects attack timber. Fresh logs are attacked by insects called ambrosia beetles. This group of insects cannot digest the wood but they tunnel into the wood and they feed on the fungi that grow on the walls of the tunnels. As soon as the moisture content of the wood falls below the level required for the ambrosia fungi to grow, the insects cease to attack. Another group of insects, the powder pest beetles, attack drier wood. These insects also cannot digest wood but they ingest the wood from which they use the starch and sugar. Both ambrosia beetles and powder pest beetles attack only sapwood which contains starch which is required for the growth of fungi on which the ambrosia beetles feed and which provides nutrition to powder pest beetles. The powder pest beetles too do not attack well seasoned timber.

The most destructive of all insects are the termites. There are many species of termites but they can be broadly divided into dry wood termites and ground dwellers. The former, as the name implies, could colonize dry wood but is generally found only in sapwood. Ground dwelling termites have their colonies in the ground from where they go along covered galleries made of earth in search of wood. When a suitable piece of wood is found they chew off fragments which they take to their underground nests and there form them into beds for the growth of fungi on which they feed. One of the most curious features about termite attack is that a piece of wood may be almost completely destroyed within leaving an outer shell untouched so that until the piece of wood gives way nothing is suspected.

To guard against attack by fungi and insects various types of preservatives are used. One of the most important of these is creosote obtained by the distillation of coal tar. It normally consists of aromatic hydrocarbons, phenols and tar bases. It is a recognized preservative throughout the world for railway sleepers, telegraph and transmission poles, marine timber, etc. The average life of a creosote-treated sleeper in the tropics is about 30 to 40 years. Sometimes a mixture of inorganic salts (e.g. salts of copper and arsenic) is used as a preservative. Though these salts are soluble in water, when absorbed by wood they are converted into an insoluble substance which is not washed away when the timber is wetted.

The durability of rubber wood can be increased considerably by treating with boron salts. The discovery in Sri Lanka of a method of treating the wood has had remarkable results in that rubber wood which was at one time thought to be fit only for use as firewood or for concrete shuttering planks, is now being treated with the preservative and used for furniture making and is also being exported to Britain.

The application of preservatives can be done in various ways. Brush coating of the preservative is the simplest but is obviously the least effective, for the agents of destruction could enter the wood through small openings and attack the untreated wood within. Impregnation is a more effective method of treatment. In this method the timber is placed in a tank which is then closed, and a vacuum applied. The heated preservative is then pumped into the tank, and after some hours the pressure in the tank is increased. Finally the surplus preservative is pumped out, and after a short period of vacuum to suck out any further free preservative, the tank is opened. By this method the preservative is made to penetrate the wood. Sleepers and telegraph and electrical transmission poles are treated in this way.

Plywood

The strength of wood is very much higher in the direction of the grain than at right angles to it. This is why a piece of wood can be fairly easily split with an axe but cannot easily be cut across. When wood is used for any purpose therefore it has to be sufficiently thick to compensate for the weakness across the grain.

In the manufacture of plywood, thin sheets of wood or veneers are glued together in such a manner that the direction of the grain is at right angles in alternate sheets. This distributes the strength of the wood evenly, and comparatively thin sheets of plywood can be used for purposes where thick sections would be necessary if solid wood was used.

A good part of the plywood manufactured in Sri Lanka at the two factories in Gintota and Kosgama is used for making tea chests. Other products turned out of plywood are flush panelled doors, ping pong tables, carrom boards etc. Thin veneers are also used to give a more beautiful finish to wood that is unattractive in appearance or to chipboard used for table tops etc. Since veneers are very thin, valuable wood could be put to better use this way than if such wood was used in the form of solid boards. Veneers are prepared either by rotary peeling or slicing using heavy machines.

Particle board

In the manufacture of particle board (chipboard) the wood is chipped, the chips dried and sprayed with glue, and then pressed into boards. Since what is used are wood chips, waste wood such as the cores that remain after logs are peeled to produce veneers can be used for the manufacture of particle board.

Fibre board

Fibre board is made by breaking down wood to its constituent fibres and pressing the fibres to form sheets. Boards of varying density are produced, the high density board being called hard board and the low density one insulation board. Hardboard can be used as a partition material and for furniture making, while insulation board can be used for ceilings.

Pulp and paper

In the manufacture of paper pulp also the wood is first reduced to its constituent fibres. This is done either mechanically or chemically or by a combination of the two. Mechanical or groundwood pulp is made by pressing a log against the rough surface of a fast rotating stone. The fibres are torn out of the wood by the stone. The pulp thus produced is not of high quality but the yield per unit quantity of wood is high. Such pulp is used for the manufacture of newsprint where high quality and keeping properties are not required.

In making chemical pulp the wood is first chipped. The chips are then "cooked" ie. placed in a digester together with the necessary chemicals and heated. This results in the separation of the fibres. The fibres are then washed and bleached. After bleaching they are washed again and then sprayed as a suspension in water on to a moving belt where they are pressed to form paper.

To be suitable for paper making the fibres of wood must have certain properties. Paper has traditionally been made from coniferous woods such as spruce. The fibres of these species are long and suitable for paper making. In tropical countries such as ours conifers do not occur naturally. In Sri Lanka, paddy straw mixed with imported coniferous pulp is used for making paper of good quality. It is expected to replace the imported pulp with pulp from locally grown *Pinus* species in due course.

The Rayon industry

The starting material for rayon manufacture is wood pulp. Pulp consists of celluloses. The first step in rayon manufacture is to treat the pulp with a concentrated caustic soda solution which dissolves out the celluloses that are not required for rayon manufacture leaving behind alpha cellulose. The alpha cellulose is treated with a chemical which varies with the process used. The product is then dissolved in an alkali, and the solution forced through fine spinnerets. The filaments that emerge are coagulated in a bath of acid to produce the yarn.

Fuelwood and charcoal

Fuelwood is one of the most important products from the forest. Wood is the main fuel used by the people of developing countries. In Sri Lanka over 90 per cent of house-holds use fuelwood for domestic cooking. Of the three sources of energy used in Sri Lanka, fuelwood is the main one accounting for 60 per cent of the energy consumed, while the other two, oil and electricity, account for 28 per cent and 12 per cent respectively (1977 estimates). Fuelwood is used not only for domestic cooking but also for a wide range of commercial purposes: bakeries, brick and tile kilns, tobacco curing, tea factories, etc.

Though fuelwood plays such an important role in the energy economy of the country, up to now, very little attention has been paid to ensuring a sustained supply of fuelwood to meet the future demands. This question is assuming special importance with the widespread opening up of forest land for the accelerated Mahaweli development programme. Plans for raising fuelwood plantations in some areas have now been made. The plans should be extended to cover more areas, and they should be put into effect as soon as possible bearing in mind that the plantations will take 10 to 15 years to become productive.

In many countries of the developing world wood charcoal is used for domestic cooking and heating. The conversion of wood into charcoal is done in kilns located within or in proximity to the forest. Though a certain amount of carbon is lost in conversion into charcoal, there are many advantages in using charcoal instead of wood. Wood contains a high proportion of water which is expelled on carbonization. Weight for weight, charcoal has a much higher carbon content and produces two to three times more heat than wood. The cost of transport which is by far the main cost component of fuelwood is therefore greatly reduced by converting the material into charcoal in or near the forest. Another point in favour of charcoal is that it is a smokeless fuel.

The State Timber Corporation started pilot scale production of charcoal in 1978, but progress since then has been slow. The Ceylon Institute of Scientific and Industrial Research has designed a charcoal cooker for domestic use. Judging from public response - in September, 1980, fifty cookers supplied to a sales point in Dehiwala once a week were being sold out within minutes - there should be no problem in popularising the use of charcoal for domestic cooking in all the urban and suburban areas at least.

With extensive clearing of forests taking place for development, there should be no time lost in stepping up the commercial production of charcoal. Moreover, is should be obvious that with Sri Lanka spending a good part of its foreign exchange earnings on oil imports, any course of action aimed at a more rational utilization of the energy resources of the country should receive the highest priority.

Minor forest products

There are numerous products besides timber that are obtained from the forest, and some of these are of considerable commercial importance.

Wattle extract for tanning leather is a product obtained from *Acacia mollissima*. This species is grown in the Kandapola area, but except for some trials that were carried out, no commercial extraction has yet being done. Species of mangroves and *Cassic auriculata* (Ranawara) also produce tanning material.

Various types of essential oils are distilled from forest species like *Eucalyptus* spp., cypress etc. The possibility of producing turpentine by tapping the bark of *Pinus caribaea* has been investigated and the result was very favourable. Oleoresin suitable for use as an incense is obtained from *Canarium zeylanicum* (Kekuna) by tapping the bark. Gums could be obtained from quite a few species. Trees of the family Dipterocarpaceae yield resins that can be used for making French Polish, varnish and similar products.

A number of products (bark, fruits, stems etc.) used in ayurvedic medicine are collected from the forest. Beedi manufacture is an important industry in Sri Lanka. The wrappers are the leaves of *Diospyros melanoxylon* a species which is found in Sri Lanka but not in adequate quantity to make commercial exploitation possible.

Supplementary Reading Material

Anon. (1962) *Timber and Its Uses.* Ceylon Forest Department, Colombo 7.

Anon. (1974) *Code of Practice for Seasoning of Timber.* Bureau of Ceylon Standards, 53, Dharmapala Mawatha, Colombo 3, Sri Lanka.

Henderson, J. Y. (1939) *Timber, Its Properties, Pests and Preservation.* Crosby, Lockwood and Son Ltd., Tudor Street, London EC 4.

Tisseverasinghe, A. E. K. (1969) Preservative Treatment of Rubber (*Hevea brasiliensis*) Wood by the Boron Diffusion Process. *The Ceylon Forester* Vol. 9 Nos. 1 & 2, 77.

Tisseverasinghe, A. E. K. (1970) The Utilization of Rubber Wood. *The Ceylon Forester*, Vol. 9 Nos. 3 & 4, 87.

Tisseverasinghe, A. E. K. (1971) *A Manual of Timber Utilization for Ceylon.* Forest Department, Colombo 7.

Wijesinghe, L. C. A. de S. (1978) Charcoal : A solution to fuelwood problems? *Karmanthu.* Vol. 5 No. 12, 11.

LOCATIONS OF THE MAJOR NATURAL FORESTS AND FOREST PLANTATIONS IN SRI LANKA (1979)