SRI LANKA
SCIENCE & TECHNOLOGY INDICATORS
PART IV

M. A. T. DE SILVA
GEETHIKA YAPA
A. W. J. KARUNASINGHE

Commonwealth Science Council

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SWEDISH AGENCY FOR RESEARCH COOPERATION WITH DEVELOPING COUNTRIES

DECEMBER 1996

SRI LANKA
SCIENCE & TECHNOLOGY INDICATORS

PART IV-CONSTRAINTS AND OPPORTUNITIES FOR SCIENTIFIC RESEARCH IN SRI LANKA.

M A T DE SILVA

GEETHIKA YAPA

A W J KARUNASINGHE

Natural Resources Energy & Science Authority of Sri Lanka
47/5 Maitland Place
Colombo 7.

December 1996

National Science Foundation
(NSF)

is the successor to the

Natural Resources, Energy & Science Authority of Sri Lanka
(NARESA)

From 1 April 1998

ACKNOWLEDGEMENTS

This study was supported by grants provided by the Commonwealth Science Council and the Swedish Agency for Research Co-operation with Developing Countries. The generous assistance provided by these two international agencies is gratefully acknowledged. We also wish to express our gratitude to the Director General of Natural Resources, Energy and Science Authority (NARESA) for the co-operation and encouragement extended to us throughout the course of this study.

Many of the field studies may not have been possible if not for the unstinted co-operation extended to us by the heads of research organisations, project leaders and respondent researchers. We thank them all for their support.

NARESA which provided strong logistic support was instrumental in clearing many administrative obstacles. Thanks are also due to Mr Wasantha Amaradasa for carrying out some of the data analysis.

Finally we wish to acknowledge with gratitude the services provided by Miss Sandhya Gunawardhana, Miss Monika Wijemanna and Mrs Chandra de Silva in respect of secretarial and word processing assistance.

Foreword

On the eve of commemorating 50 years of independence, it is fitting that Sri Lanka should look back and review its performance in the field of science and technology. Can Sri Lanka be contended with the progress that has been made in this sector? What has been the contribution of S & T to the national development effort of the country? Whilst it is true that the standards of living in Sri Lanka had increased substantially over the past few decades, yet how much of this social progress can be attributed to the efforts of the Sri Lankan scientific community?

Much has been said about the constraints and opportunities for scientific research in Sri Lanka. But there has been no solid basis to establish such claims. Neither do we have the facts and figures to demonstrate and quantify the efforts of Sri Lankan Scientists in the cause of national development.

It is in this context that we should recognize the current study on "Constraints and Opportunities for Scientific Research in Sri Lanka", which attempts to identify and analyse these issues.

During a past era when resource inputs for scientific research, were not matters of much concern, Sri Lankan scientists were able to engage themselves in scientific activities of their own choice. That situation no longer exists today, and as a result the accountability factor has to be taken note of in all scientific work. A significant consequence of this phenomenon is the current efforts by all scientific research organisations to prioritize research.

The current study evaluates some of the on-going and proposed programmes designed to evolve procedures for priority setting in research, as well as for measuring accountability in research. It is hoped that the facts, figures and material presented in this report will be of value to those engaged in research management, policy analysis and science and technology administration.

M. Watson
Acting Director
National Science Foundation

PREFACE

The Report on **Constraints and Opportunities for Scientific Research in Sri Lanka** constitutes the fourth volume in the series of studies undertaken under NARESA's Programme on Science Statistics and Indicators.

The study initiated in 1990 included several time-consuming field surveys, most of which undertaken by the research team without the involvement of any kind of temporary staff. By doing so the study ensured uniformity and consistency in the data collection exercises. It was however, unfortunate that due to unavoidable circumstances, the publication of this Report was delayed by two years.

Many of the issues are contentious and are bound to generate intensive discussion and debate. It is indeed the wish of the Research Team that the findings of this study would be subjected to such critical review.

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ABBREVIATIONS

AEA	-	Atomic Energy Authority
ARP	-	Agricultural Research Project
ARTI	-	Agrarian Research and Training Institute
ARS	-	Agricultural Research Station
ARU	-	Adaptive Research Unit
BMAR I	-	Bandaranaike Memorial Ayurvedic Research Institute
CARI	-	Central Agricultural Research Institute
CARP	-	Council for Agricultural Research Policy
CISIR	-	Ceylon Institute of Scientific and Industrial Research
CRI	-	Coconut Research Institute
DEA	-	Department of Export Agriculture
DOA	-	Department of Agriculture
FD	-	Forest Department
FMRC	-	Farm Mechanisation Research Centre
FCRDI	-	Field Crops Research and Development Institute
GNP	-	Gross National Product
GERD	-	Gross National Expenditure on Research and Development
HARTI	-	Hector Kobbekaduwa Agrarian Research and Training Institute
HORDI	-	Horticulture Research and Development Institute
IDRC	-	International Development Research Centre
IFS	-	International Foundation for Science
IFS	-	Institute of Fundamental Studies, Sri Lanka
MRI	-	Medical Research Institute
NARA	-	National Aquatic Resources, Research and Development Agency
NARESA	-	Natural Resources, Energy and Science Authority
NARS	-	National Agricultural Research System
NBRO	-	National Building Research Organisation
NERD	-	National Engineering Research and Development Centre
NIV	-	New Improved Varieties (of rice)
NRS	-	National Research System
NSC	-	National Science Council of Sri Lanka
OIC	-	Officer-in-Charge
OIV	-	Old Improved Varieties (of rice)
R & D	-	Research and Experimental Development
RARC	-	Regional Agricultural Research Centre
RARDC	-	Regional Agricultural Research and Development Centre
RBRS	-	Rice Breeding Research Station
RRDI	-	Rice Research and Development Institute
RRI	-	Rubber Research Institute
SAREC	-	Swedish Agency for Research Co-operation with Developing Countries
Sc.	-	Science
S & T	-	Science & Technology (also Scientific & Technical)
SLAAS	-	Sri Lanka Association for the Advancement of Science
SRI	-	Sugarcane Research Institute

TRI	-	Tea Research Institute
UNESCO	-	United Nations Educational, Scientific and Cultural Organisation
UNIDO	-	United Nations Industrial Development Organisation
US-NAS	-	United States National Academy of Sciences
Vet.Sc	-	Veterinary Sciences
VRI	-	Veterinary Research Institute.

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CHAPTER 1

INSTITUTIONALIZATION OF SCIENTIFIC RESEARCH IN SRI LANKA

1.1 In Retrospect

The earliest event of scientific significance for Sri Lanka (or Ceylon as it was then known), appears to be the establishment of the Royal Botanic Gardens at Peradeniya in 1822, which concentrated on introduction, selection and acclimatization of indigenous and exotic species of flora (1). Of the more important economic plants which came to be introduced into the country include, tea, cinchona, rubber, cocoa, sisal hemp; trees such as mahogany, Grevillea, Cupressus, Acacia and Eucalyptus species; fodder grasses such as *Bracharia*, *Panicum* and *Paspalum spp*; green manure trees Erythrina and Gliricidia and a range of fruit varieties such as durian, cherimoyer, avocado pear and tree tomato (1).

During the middle of the last century, the establishment of plantation crops gained grounds, and despite of the fact that a fatal fungal disease had taken toll of the first coffee industry in the Island, testing, multiplication and distribution of plants of commercial value continued. Such work required expanding of experimental facilities for propagation of planting material, and this resulted in the establishment in 1860, of the Hakgala Gardens (for propagating cinchona) and the Henaratgoda Gardens in 1876 for accommodating 2000 seedlings of *Hevea brasiliensis* (1).

The next significant landmark was the establishment of the Colombo museum in 1876, with separate sections for biology and entomology, followed by sections on geology, mineral science and petrological sciences in 1877 (2).

In the meanwhile, the founding of the world's oldest journal devoted to tropical agriculture, titled *Tropical Agriculturist,* in 1881 by A.W. Fergusan and J. Fergusan, was indeed a remarkable event in the historical progress of science and technology in Sri Lanka (3).

It is relevant to mention here that although forestry issues were discussed by British Authorities at a much earlier period, and in fact a Superintendent of Forests had been appointed in 1811, four years before the fall of the Kandyan Kingdom, the office of the Conservator of Forests was established only in 1887 , with a British Forester R. Thompson as the first Conservator. In 1899, with the creation of the Forest Department, the sole administration of forests came under one authority (4).

In 1880, with the appointment of Henry Trimen as Director of the Royal Botanic Gardens at Peradeniya, work of high scientific merit was initiated. His treatise on the "Flora of Ceylon", the first volume of which appeared in 1893, is acknowledged as a masterpiece in taxonomic Botany. After Trimen was succeeded by T.C. Willis in 1896, some of the pioneering experimental studies on rubber tapping were initiated.

This was also the period when the study of the factors governing variation of crop yields, eg. soil and climate, variety, pests and diseases were considered important for experimental studies. Willis is also responsible for establishing the first agricultural experimental station at Peradeniya in 1901 and the Dry Zone Research Station at Maha Illuppallama in 1903. These were indeed the initial moves to institutionalize scientific research in Sri Lanka.

The formation of the Ceylon Agricultural Society in 1905 was yet another milestone in the progress of scientific research, because this society was later destined to be the nucleus for the future Department of Agriculture.

It has been claimed that between 1901 and 1912, Willis had assembled a galaxy of scientific expertise, comprising T. Petch (mycologist), M.K. Bamber (agricultural chemist), E.E. Green (entomologist), H.F. Macmillan (horticulturist), G.W. Sturgess (animal husbandry specialist), H. Wright (rubber and cocoa specialist) and N.K. Jardine (coconut specialist), whose scientific contributions had been recognized to be of the highest calibre (5). Thus by this time the country's scientific activities in tropical agriculture had reached a threshold level to justify a strong lobby for the siting of the proposed Imperial College of Tropical Agriculture, in Sri Lanka. Unfortunately this move was foiled, and the proposed institution finally materialized in Trinidad (5). However, at the time of Willis's retirement in 1912, the stage was set for the establishment of the Department of Agriculture with separate divisions for botany, mycology, entomology, agricultural chemistry etc. Thus for the first time, research, extension and other scientific work in the field of agriculture came under one administrative authority. It is significant that amidst these ongoing activities to indigenize and institutionalize an alien scientific culture in the country, there were a few enterprising individuals, such as Gate Mudaliyar A.E. Rajapakse, who continued to engage in single plot scientific experimentation as a private enterprise (6).

Although the Dry Zone Research Station at Maha Illuppallama predates even the formation of the Department of Agriculture, it is recorded that due to its initial failures in determining the most suitable crops for cultivation under rain-fed conditions, the station had to be closed down in 1919. However, several decades later, when a number of dry-farming schemes were opened in the North Central Province, it became clear that permanent farming could not be sustained without intensive scientific crop management. This led to the re-opening of the Maha Illuppallama Research Station in 1950 with a grant from the Government of New Zealand, to investigate cropping patterns for the two distinctly different ill-drained and well drained soil types of the region.

State intervention in initiating scientific work in the field of veterinary sciences is said to have occurred for the first time in the 1890's, when the colonial administration of the time appointed the first Government Veterinary Surgeon (7). Subsequently in 1911, the Government established the first Veterinary Laboratory which was later destined to be the nucleus for the creation of a fully fledged scientific organisation for veterinary work. This laboratory which was initially located in Colombo, was moved to Peradeniya in 1939, and two years later located in permanent quarters at Peradeniya.

Agriculture, Forestry and Veterinary Sciences were not the only disciplines to have early beginnings for scientific work in Sri Lanka. During the first decade of this century, two other events of great significance occurred. The first of these was the creation of De Soysa Bacteriological Institute in January 1900. It is claimed that although two well known Sri Lankan doctors held the post of Acting Director of this Institute between 1900 and 1903, it had to await the arrival of Aldo Castellani (later Sir Aldo Castellani) to take over as its first permanent full-time Director. Castellani who was an internationally recognized physician and researcher, had instituted a strong but unsuccessful bid to establish a Medical Research Institute, prior to his premature retirement in 1915 (8).

The second important event was the establishment of the Mineral Survey in 1903, with Ananda Coomaraswamy as the Principal Mineral Surveyor. Over the years the functions of this institution changed from mineral surveys to geological surveys and geological mapping and it is now known as the Geological Survey and Mines Bureau (9).

Institution building for scientific research took a massive stride during the second and third decades of this century, when initiatives were taken by the British authorities to set up research stations for the plantation sector. These were mainly to serve the British economic and trade interests, since the research policies of these institutes were very much guided by advisory committees based in London (2). In the plantation sector, the first research institution to appear in 1910 was the Rubber Research Institute at Agalawatta. This was followed by the Tea Research Institute at Talawakelle in 1918, and the Coconut Research Institute at Lunuwila in 1928.

During the second quarter of this century the gradual depletion of forest resources in the country was causing grave concern. A report prepared by Sir Harry Champion in 1935 on the "Management and Exploitation of Forests of Ceylon" highlighted this calamity inducing the authorities to establish for the first time a Silviculture Research Unit in the Forest Department in 1937 (10).

During the same period major changes took place in the health and medical sciences disciplines, with the Bacteriological Institute whose primary function was to carry out routine medical tests, expanded its activities by the introduction of a mycology laboratory and an entomological laboratory in 1922. In 1936, the Pasteur Institute which had been set up in 1918, was also absorbed into the Bacteriological Institute, and two years later a Department of Nutrition was added. In 1942, a Department of Parasitology was set up and in 1944, the Department of Blood Plasma was added. Finally in March 1946, due to the efforts of the first Sri Lankan Director of the Institute, A. Nimalasuriya, the Bacteriological Institute was re-constituted as the Medical Research Institute. By then this institution possessed the nuclei of almost all sections of medical laboratory disciplines, required essentially for clinical back-up of curative and preventive medical services (8).

In the field of Veterinary Sciences, the Veterinary Laboratory set-up in 1911 was upgraded as the Veterinary Research Laboratory in 1951, but performed only diagnostic work (11). However, in 1955 as a result of a major outbreak of *Haemorrhagic septicaemia,* better facilities for bacteriological work as well as for vaccine production against the disease were established. The success of these programmes led to increased recruitment and training of scientific personnel, and specialisation in several disciplines. Thus in 1967, when the Veterinary Research Laboratory was finally moved to Gannoruwa and institutionalized as the Veterinary Research Institute, there was adequate expertise in a number of different areas to enable several divisions to be created in the Institute.

After the country gained independence, a massive thrust was made to forge agricultural development. It necessitated extensive catering to regional needs and also strengthening of the eight Regional Research Centres of the Agriculture Department serving 8 major agro-ecological divisions of Sri Lanka. The Central Agricultural Research Institute at Gannoruwa (CARI), which served the mid-country wet zone was the largest multicrop research organisation in the country. The CARI's main laboratory complex, built with a generous grant from the Government of Australia, was inaugurated in 1967.

About this time the ever increasing demand for spices, cocoa and coffee led to the creation of the Department of Minor Export Crops in 1973. This Department was entrusted with the task of improving the productivity and quality of cinnamon, cocoa, coffee, pepper, cardamom, clove, nutmeg, citronella, lemon grass, vanilla, betel and arecanut. Research in these commodities however, had to await the establishment of good research infrastructure in Matale around 1979. By the mid 1980's with the expansion of research facilities, the Department was renamed Department of Export Agriculture.

Among plantation research institutes, the Sugarcane Research Institute (SRI), was indeed the last to appear on the scene, when a sprawling laboratory complex was established at Uda Walawe in 1984.

It has also to be recorded that from the early 1950s there had been a strong lobby for the recognition of the indigenous medical and health care system in the country. In 1962 in response to these pressures the Government established the Bandarnayake Memorial Ayurvedic Research Institute at Nawinna, with three research divisions for chemical research, drug research and literature research.

The beginnings of industrial research can be traced back to the creation of an Industrial Research Laboratory in 1941, and the Rubber Service Laboratory in 1948. The resources of these two institutions were later transferred to the Ceylon Institute of Scientific and Industrial Research, which was established in 1955, on the recommendation of the World Bank, to provide the expertise and services required by the industry. Although the creation of this major scientific institution was a giant step in institutionalization of industrial research, it is claimed that the World Bank move was a connivance to pacify an aggrieved scientific community, which was agitating for an autonomous National Research Council (2). In 1974, as a further measure to promote industry based technological research, the Government created the National Engineering, Research and Development Centre, at Ja-ela. A fairly detailed account of the institutional framework and progress in R & D in the industrial sector is given elsewhere (12), and hence in this study only occasional references will be made to the industrial sector constraints to research.

Unlike agriculture, the fishery sub-sector had remained relatively marginalized in R and D. Research was handled by the Fisheries Research Institute, which was the research arm of the Ministry of Fisheries until the late 1970s. However, with the creation of the National Aquatic Resources, Research and Development Agency in 1981, new life was injected into this vital subsector. The main areas of activity of this organisation include, coastal in-shore fishing, prawn fishery, coral reef management, ornamental fishery, fish-technology development, geological, geophysical and hydrography surveys and coastal environmental management.

In recent years interest generated in aquaculture and aquatic research, together with the proliferation of research in biological science, leading even to the establishment of specialized courses in fisheries biology in universities, has now brought a spurt of scientific work in this area of economic activity.

During the last 25 years, Sri Lanka has witnessed a phenomenal growth in the physical development of the built environment, with the contribution of the construction industry to Gross Domestic Product increasing from 2.9 percent in 1977 to 4.0 percent in 1986 and to 6.9 percent in 1995. This has necessitated an increasing input of scientific research to harness the potential of material, physical and human resources, available in the country. It is in this context that the National Building Research Organisation was created in 1984, under the Ministry of Local Government, Housing and Construction, by bringing together all laboratories and building research facilities available with different agencies, under one organisation.

Finally, the year 1981 saw the establishment of the Institute of Fundamental Studies, which after a slow start got into full operation in 1984, in the fields of earth and space science, life sciences, physical and chemical sciences, philosophy and mathematics. Its main research thrust has been in new disciplines and frontier sciences.

Although the above discussion concentrated on the key research organisations in the country, a large number of other scientific institutions were also created. Some of these were major public sector organisations with facilities for in-house scientific research, such as the Cement Corporation, the Ceramics Corporation, as well as the Agrarian Research and Training Institute.

A few others such as the Natural Resources, Energy and Science Authority, the Council for Agricultural Research Policy, the Central Environmental Authority and the Atomic Energy Authority, sponsor research and monitor scientific activities. Still others such as the Sri Lanka Standards Institution, the National Zoological Gardens, the Department of Wild Life Conservation, the Industrial Development Board, the Survey Department and the Department of Meteorology provide the back-up services for research and development work. Finally there are the Institutes of Higher Education, where both academic and applied research is carried out, providing not only the necessary scientific and technical human resource potential, but also assisting in enhancing and building the capability for research through postgraduate training activities. A review of such scientific organisations, and professional bodies, has been presented in a previous study (13), for which reference could be made for further information.

1.2 Highlights of Scientific Work During Colonial Times

Although it may be contended that organized scientific research on a professional scale originated only during the first quarter of the present century, scientific work of high calibre originated almost simultaneously with the creation of the Royal Botanic Gardens at Peradeniya, a hundred years earlier. The initial studies understandably focussed largely on the local flora, and the introduced exotic ornamental and economic plants. Thus the earliest work was on systematic botany, leading subsequently to horticulture and agriculture. The succession of scientific talent in the disciplines of botany, mycology, entomology and agricultural chemistry from the second half of the 19th century to the first few decades of the present century reflects the changing priorities and demands of the country towards an agro-economic development strategy. However, the circumstances which attracted to this small Island Colony from overseas, a succession of star-studed scientific personnel, many of whom later had the distinction of being elected Fellows of the Royal Society, seem incredible and in-explicable.

Most of the initial work in the various disciplines were inevitably experimental studies for the collection and recording of baseline data. Subsequent work focussed on issues such as methods of cultivation, selection of better strains and species, prevention and cure of diseases and the determination of the value of manures for different crops.

Joachim (1) summarises the progress of agricultural research during the British Colonial period in the following terms:
"The stages in the development of agricultural research in the Island may briefly be summed up as follows:

(i) The plant introduction and acclimatization phase; (From 1822 to about 1849)

(ii) the stages in the testing, multiplication and distribution of economic plants of possible commercial value. Thwaites and Trimen, especially the former, share the honours in regard to these aspects of the economic development of the country; (From 1849 to about 1895)

(iii) the study of the effects of soil, climate, variety, manuring, cropping systems etc. on crop yields, the control and investigation of pest and diseases, and the investigation of methods of manufacture of the products for the market. To Willis and his colleagues we are largely indebted for a record of fruitful activity in these directions. This work was consolidated during Stockdale's regime; (From 1896 to about 1915).

(iv) the monocrop stage when the economic and technical problems connected with the production of well established commercial crops *viz.*, rubber, tea and coconut necessitated concentrated team-research on these crops. (From 1916 to about 1948)"

It is of significance to record that in 1880, despite efforts of an internationally reputed mycologist Marshall Ward, specially brought in to deal with the coffee disease caused by *Haemilia vastatrix*, the thriving coffee industry collapsed, and by 1895 coffee ceased to be a major export commodity for the country. It is interesting to note that cinchona which was introduced during 1861-1863, and experimental selections carried out at Hakgala Gardens, soon succeeded coffee as the major plantation of the Island. This crop later progressed so rapidly that during the period 1884-1888, its annual production was said to have been almost 50 percent of the world production (1).

Turning to other scientific efforts, a discovery of great importance to the rubber industry was made by J. Parkin, Scientific Assistant to Willis in 1898-1899, who demonstrated for the first time the use of acetic acid for coagulation of rubber latex, a method which received universal acceptance (1).

Apart from such work on commercial crops, pioneering research work was also initiated in horticultural and food crops, after the founding of an experimental station, and later the Department of Agriculture in 1912. Iliffe's work on isolation of high yield strains of paddy in 1921, led to the successful selection of the popular 6-months paddy variety *Kohumawi* pureline, B11, which was specifically suitable for the Central Province. However, it was left for L. Lord, who succeeded Iliffe in 1926 to initiate statistically designed experimental work based on the techniques established by R.A. Fisher. His pureline selections of *Deveredderi*, *Vellai Illankalayan*, *Pachchaiperumal* and *Podiwi*, were considered to be some of the best among the older improved varieties, and these latter two were subsequently to become the parental lines for some of the most important rice varieties in breeding studies at the Batalagoda Rice Breeding Station (14).

In the commercial crops sector, the adoption of R.A. Fisher's technique of experimentation, contributing to very low standard errors, paved the way for highly successful and reliable research findings. The classical factorial experiments initiated by T. Eden in 1931 for tea, and by M.L.M. Salgado in 1935 for coconut are considered to be the first long term statistically designed field experiments of their kind anywhere in the world (2,15). It is to be noted that the experiment at Lunuvila stood for 30 years, while one of the replicates of Eden's experiment in number 3 field at St. Coombs Estate, Talawakelle continues to be maintained as a monumental landmark in tea research (15). The results of Eden's experiment over 5 cycles have shown that nitrogen gives proportional increases of crop upto 801b per acre.

The tea industry also benefitted from the work of Gadd, who in 1928 showed that starch is normally present in only the roots of the tea bush, a finding which led to the recommendation of light pruning at lower elevations (because of lower starch reserves), and "rim - lung" pruning in other areas (1). In the field of biochemistry the significant findings on enzymes responsible for tea fermentation paved the way for investigations on the production of quality tea.

While still on the tea industry, it is necessary to make reference to the valuable contribution to pest and disease control work during the early 1940's. The effective biological control of tea tortrix (*Homona coffearea*) by the introduced parasite *Macrocentrus homonae,* resulted in the removal of the pest from the list of noxious and notifiable pests (1). The other significant work was on shot-hole borer, where it was shown that the attacks fade out during the third year from pruning, leading to a revision of traditional pruning methods (1).

Research on rubber began about two decades before the establishment of the Rubber Research

Institute, because by that time a boom in the industry had resulted in the expansion of the area under rubber from 422 ha in 1898 to 60,700 ha by 1907. As stated earlier Parkin's pioneering work on the coagulation and functions of rubber latex at the turn of the country, and the investigations on the diseases and physiology of rubber by T. Petch, were two of the landmark events in the early phase of rubber research in Sri Lanka. Although breeding and propagation work had also commenced quite early, extensive clonal studies at the Rubber Research Scheme demonstrated that the locally selected clones, Millakande 3/2, Wagga 6278 and Hillcroft 28 compared favourably with the best foreign clones imported during 1932. Subsequently during the period 1939 - 1945, cross- breeding trials directed towards improvement of yields, led to the selection of clones RRIC 36 and RRIC 45, confirming the transmissibility of vigour and yield characteristics of the clones AV 157 and Tjir 1 respectively (16).

The investigations during the early 1940's on the rubber leaf disease caused by *Oidium heveae* proved beyond doubt the efficacy of sulphur dusting for its control. Although a number of other leaf diseases on rubber have been identified and treated since 1905, the country has been spared of the most destructive of them all, the South American Leaf Blight caused by *Microcyclus ulei*, largely due to stringent phytosanitary screening measures on exotics, and the vigorous breeding programme for disease resistance clones.

The rubber industry also benefitted from the chemical investigations on latex, especially measures for prevention of premature coagulation of latex in the case of some clones, and prevention of enzymatic discolouration of coagulum in the manufacture of crepe rubber.

The experimental studies on the third major tree crop coconut, dates back to the period 1912-1914, when simple single plot fertilizer tests were carried out at Peradeniya and Maha Illuppallama. However, the subsequent work pioneered by Gate Mudaliyar A.E. Rajapakse with private funds on private property deserves special mention. During 1917 to 1927, using what may be considered as unorthodox techniques, Rajapakse visibly demonstrated the importance of potassium in the nutrition of Coconut (1,6). Later after the Coconut Research Scheme came into existence, Salgado using modern tools of scientific experimentation, laid out the first classical field experiment on coconut. This experiment initiated in 1935, was destined to generate for 30 years some of the most fundamental scientific information on the behaviour of adult coconut palms to the treatment of nitrogen, phosphorus and potassium fertilizers (17, 18). Salgado's subsequent work on the nutrition of the coconut palm led to the discovery that coconut water could be used to estimate the plant content of potassium directly without a preliminary removal of sugars. Using this technique he demonstrated that the potash content of nut water increased linearly with applied increments of manure, and more interestingly coincided with the yield response curve of palms due to such corresponding increments of applied potash (19).

In the plant breeding side, the Geneticist concentrated on the selection of high yielding mother palms for the production of quality seedlings. Substantial work of significance also resulted from the technological work at the Institute on the value added products of coconut, especially copra, oil, shell charcoal, husks and soap manufacture.

Among other crops, the work at the Department of Agriculture led to significant achievements in the introduction and selection of superior strains of Tuticorin chilli, a cotton of medium staple (BP. 79), and a range of non-lodging, borer resistant, sucrose-rich sugar-cane varieties, all of which performed well in the dry zone areas.

However, in relation to land use investigations, the pioneering work of Joachim and his associates during the period 1935 to 1945, on the systematic classification of the Sri Lankan soils, stands as a landmark achievement of the period in the field of agricultural sciences (20, 21). This decade of extensive profile studies and soil reconnaissances, culminated in the presentation of the first generic classification, and the first provisional soil map of Sri Lanka.

1.3 Milestones in Creative Research Since Independence

1945 - 1960

The expansion of science and technology during the early phase of the post-colonial period of Sri Lanka was visibly rapid. This was partly due to the pressures built up by the emergence of an educated class resulting from the educational reforms of the 1940's combined with new avenues for training abroad, and partly by the demand pulls originating from the development aspirations of an emerging sovereign state.

Sri Lanka no doubt had a proud record in the Eastern Hemisphere for high quality scientific research in agriculture. However, the most significant feature during the early post colonial era, was the sustained effort in the plantation sector to shake off the remnants of colonial domination in the research institutes for tea, rubber and coconut. In the Tea and Rubber Research Institutes, from the very inception, the Directors as well as the sectional heads of the various research divisions were mostly British Nationals, while at the Coconut Research Institute, the Director was a British National. This was probably inevitable as the commercial interests in these very vital economic sectors needed adequate safeguards for the Colonial Rulers. In fact in the case of tea and rubber, research policies were inevitably guided by the discussions and suggestions made by what were referred to as the "Scientific Advisory Committees" based in London (22,23,24).

It may appear strange that even almost 10 years after gaining independence, Sri Lankan scientists occupied only minor positions in these research institutes. Records however, show that the Boards of Management and the chairpersons of these Boards were predominantly Sri Lankans, being mostly the English educated and British trained elite representing the different sectors of each industry (22, 23, 24). Thus probably due to a lack of qualified and experienced local scientists during this period, even the Sri Lankan dominated Boards of Management favoured the recruitment of non-nationals to the key positions in these institutes.

During the early post colonial era, the main thrust of research in tea, rubber and coconut was the production and distribution of high yielding planting materials. The Coconut Research Institute (CRI) took the unique step in establishing an `isolated seed garden' in a 200 acre forest reserve at Rajakadaluwa in the North Western Province (25). This seed garden which was believed to be the first of its kind anywhere in the world, was established to bring up a generation of high yielding mother palms for the production of quality seed nuts for the entire country. About the same time the Rubber Research Institute (RRI) carried out extensive studies to develop planting materials (clones) which were not only resistant to oidium leaf disease, but also to diseases such as the "South American Leaf Blight" and phytophthora bark disease. The RRI through a series of intercountry agreements obtained disease-resistant clones from Latin American countries for their breeding experiments (22, 23).

The major scientific achievements in the coconut industry during the late 1950's include, (a) the development of the "Generator Process" for the production of vinegar from coconut toddy, which reduced the period of acidification (vinegar formation) of the existing "Vat Process" from 90 days to about 5 days (25), (b) establishment of the first pasture experiments under coconut (5) and (c) the commencement of the internationally known nutrient culture experiment on coconuts in giant size concrete pots (26). The last named experiment initiated in 1956 with dehusked and amputated coconut seedlings using the technique of subtractive intermittent flow, was considered the first of that magnitude anywhere in the world (26).

In 1958, an event of historical significance occurred, when for the first time two well known Sri Lankan scientists were appointed as Directors' of the Tea and Coconut Research Institutes respectively (26, 27). In 1959 the Tea Research Institute (TRI) also made a major scientific and technological breakthrough in made tea, when it developed powdered (instant) tea from fresh mid-country tea leaves (28,29). However, during the same year the so-called "oil-spot disease" in tea was discovered in some plantations of the Nuwara Eliya district, which led to the initiation of a pathological study of this disease (29).

In contrast to the plantation crop research sector, the rice and subsidiary crop research area did not suffer from a shortage of trained and qualified Sri Lankan researchers during the early postcolonial period. Hence high calibre scientific research of direct relevance to the people of the country were produced by the various research divisions of the Department of Agriculture. The creation of a Division of Horticulture in 1941 set the trend for research in a wide range of field crops. These included fruits such as pineapple, oranges and mango, and minor agricultural crops such as cocoa, sugar cane, cotton, arecanut, coffee, citronella etc. (30).

During this period the crisis resulting from the fall in foreign exchange reserves, prompted concerted efforts in increasing agricultural productivity through the introduction of disease resistant high yielding planting materials in a wide range of food crops (14). While the major thrust in dry zone agricultural experimentation was at the Maha Illupallama Research Station, rice breeding studies were concentrated largely at the Central Rice Breeding Station at Batalagoda (31, 32). The programme on rice research at Batalagoda was mainly to meet the demand for varieties which could be harvested within periods ranging from 3 to 6 months. However, by mid 1950's it was realised that the normal method of selecting high yielding purelines within the traditional varieties of rice could at most increase production by only 10 percent. Therefore if a substantial increase in rice productivity was to be achieved, it was deemed necessary to commence extensive cross breeding (hybridisation) research with a range of local and foreign planting materials (14). The first success in this new line of research came in 1957 when the variety called H-4 was produced (14,32). This 4 to 4 1/2 months variety was released to farmers in 1958, and within a short period became a popular variety. This was then followed by a series of new varieties which could be harvested from periods ranging from 3 months (H-10 variety) to 6 months (H-9 variety) (14). Similar work was carried out at Maha Illuppallama leading to the development of improved varieties of dry chillies (MI-1 and MI-2 varieties), Maize (T-48 var.), mungbean, cowpea, black gram and groundnut (31).

While in the agricultural sector scientific and technological advancement was substantial, industrial research during the early 1950's was still in its infancy. The most significant development during this period, was the establishment of the Ceylon Institute of Scientific and Industrial Research (CISIR) in 1955 as an autonomous corporate body. Its creation preceded a report prepared by a World Bank Mission, one of whose members became its first Director (33).

This institution operating with a limited budget of Rs. 5.0 million spread over a five year term, and with a very small scientific staff, made a very valuable contribution to the tea, rubber and coconut industries. It developed a simple method for bottling of coconut toddy, and also initiated a study on bottling of coconut cream (milk) in 1956, and later examined the possibility of producing edible proteins from coconut milk and poonac (34). In 1958, it associated itself with the Tea Research Institute in making Instant Tea (33). In relation to the rubber industry, it initiated work on making new formulations of rubber products both from latex and dry rubber, which helped in the manufacture locally of slippers, play balls, soles, mats and erasers (35). But CISIR considers as its most important contribution during this period, to the scientific and technical assistance provided to the bicycle tyre and tube industry which led to the successful launching of the first tyre and tube factory in Sri Lanka (35).

In the field of veterinary research, studies on the Newcastle Disease led to the development locally of an oral vaccine for the effective control of this disease, which had caused a serious set back to the development of the poultry industry. Previously mortality in affected flocks often exceeded 95 percent (11).

1960-1970

The year 1960 stands as a landmark for product diversification in the tea industry, since ministerial sanction was granted for the establishment of an Instant Tea Industry in Sri Lanka (29). In the field of scientific research, the TRI succeeded in finding a suitable soil fumigant to combat the highly destructive root disease called Poria. It also began extensive studies in relation to the nematode pest which attacked mature tea plants. The problem of zinc deficiency which appeared in certain areas was resolved when it was found that sprays of zinc sulphate solutions were effective in eliminating this disorder (29). Concerted efforts in all these fronts, combined with the use of high-yielding clones of tea, helped the industry reach a record production of 6000 1b of made tea per acre during the mid 1960's (29).

The year 1960 marked the Golden Jubilee of the Rubber Research Institute. Established in 1910, this is considered to be the oldest research institution for rubber. The rubber industry for the first time became exposed to a major challenge with the introduction of synthetic polymers (synthetic rubber) into the market (36). Therefore the need to diversify and also bring down the production costs of rubber and its products became imperative. Systematic studies carried out by the RRI during this period helped the rubber industry to reduce costs to a certain extent, when it was demonstrated that the sulphur dusting levels to control leaf disease, could be reduced from 108 kg per hectare to 36 kg per hectare (36).

In 1960 research on coconut palms entered a new phase of advancement with the introduction of radio-active isotope assay methods for fertilizer experiments. This was the first occasion when tracer techniques were used in plantation crop research in Sri Lanka. Using the radio-active isotope of phosphorus (P^{32}), CRI was able to demonstrate that when a phosphorus fertilizer was applied to the base of an adult coconut palm, it would be absorbed and transported to the crown of the tree within two hours of application (37). CRI was also able to resolve the nutrient disorder which appeared during the late 1950's causing intense yellowing of coconut leaves. After lengthy investigations CRI developed methods to diagnose the problem and trace the disorder to a deficiency of magnesium (38).

The coconut industry however, faced a new challenge with the appearance of an unknown disease known as the "leaf-scorch disease" during 1960 - 1961 (37). This disease which initially caused wilting of the leaves followed by drooping of the fronds, led ultimately to death. Although the researchers at the CRI began to investigate it from several different angles, the causative agent remained unknown.

In the food production front, the severe restrictions on import of essential items demanded the ingenuinity of the scientists, not only to devise non-traditional cropping, but also to develop new substitutes. The success of these ventures were evident by the early 1960's when the possibilities of reaching self-sufficiency in crops such as potato were being discussed.

However, with mounting land pressures and increasing invasion by substitution agriculture into marginal lands, the need for systematic survey and classification of the Islands soils became evident. Thus between 1959 and 1961, F.R. Moorman and C.R. Panabokke using modern concepts and new survey techniques, established for the first time the Great Soil Groups of Sri Lanka (39). Subsequent studies by Panabokke and his team of researchers on the characteristics and distribution of the major soil groups and also on their relation to productivity and agricultural quality, led to the preparation of the "Hand Book of the Soils of Sri Lanka" (40).

In the field of rice research H-series of varieties (commonly referred to as "Old Improved Varieties" (OIV) continued to gain in popularity, and by 1962 the average yields increased to 2.5 tonnes per ha from the previously stagnant national average of 1.5 tonnes per ha in the 1950's (32). Modern tools of research including the use of radio-active isotopes were used in rice research to investigate the timing of fertilizer application and utilization of fertilizers.

In the industrial sector, the CISIR with grossly inadequate financial support for meaningful research, continued to work on agro-industrial products and wastes. Its important contributions during the early 1960's include the preparation of waterless cleaners, development of methods for bottling condensed coconut cream, techniques for sterilisation of desiccated coconut, preservation and canning of fruits, introduction of refinements for coconut arrack preparation and studies on coconut shell charcoal manufacture (35). Research work was also carried out on the extraction and properties of vegetable oils, including rice bran-oil.

During 1965 the benefits of the breeding programme for high yielding tea, combined with scientific cultivation practices helped Sri Lanka to become the world's highest exporter of made tea. The tea industry also made history when a low country tea estate growing selected TRI 20 - series clones yielded 8000 1b of made tea per acre (29).

Following comprehensive studies, the Tea Research Institute in 1966 was able to make a breakthrough in the control of the meadow nematode infestation of tea plants which had become a menace in new clearings. The same year however, the widely used of the pesticide Dieldrin for the control of the shot-hole borer beetle had to be withdrawn because of severe side effects, and in its place alternative methods of control were introduced (29).

During the same period, the need for multiple cropping became evident, in order to meet the increasing demand for import substitution in essential foods. Hence the Coconut Research Institute for the first time embarked on a number of experiments on inter-cropping under coconuts. Among the first crops to be tested were cowpea, green gram, ground nut, paddy and pineapple (41).

In the rubber sub-sector because of the need to diversify product development in the rubber industry to meet the challenge of synthetic rubber, the Rubber Research Institute expanded its activities in rubber chemistry and technology. In 1969 it commenced work on many fronts which not only helped greater local utilization of rubber based products, but also developed new chemical technologies to improve the dynamic and technological properties of rubber (42).

The RRI also embarked on a programme to increase yields by the external application of substances known as stimulants. One of these called Ethrel was able to increase latex production by 25 per cent initially (43).

In rice research, the awareness that H-4 and other 'H' series rice varieties produced during the 1950's were not without defects, provided the impetus for further investigations. It was clear that the variety of agro-climatic systems in the country and the range of soil-water relations that exist, demanded extensive investigation. This led to the development of what was called the "Co-ordinated Rice Varietal Trials" (14). The attempt to replace the existing rice varieties with the so-called miracle rice IR-8, produced by the International Rice Research Institute in Philippines, was resisted by the Sri Lankan rice breeders on the grounds that it needed high standards in cultivation and management practices. It was also shown that its dwarf stature did not suit many Sri Lankan situations. The stand taken by the Sri Lankan scientists was later proved to be correct when a better adaptable and intermediate stature variety called BG-11-11 was produced in 1970, which fared much better than IR-8 under local conditions (14).

In the meanwhile scientific research at the Maha Illuppalama Research Station, resulted in new agro-industrial crops such as castor, sun-flower, lemon grass and soya bean, coming into the limelight. Remarkable advances were made in the cultivation of soyabean, which later acquired a popular status in the cropping patterns of the dry zone farmer (31).

Between 1967 and 1968 studies were successfully conducted by CISIR on the dehydrogenate of caster oil which could substitute linseed oil used in the paint industry. In relation to coconut products, the CISIR successfully carried out investigations on briquetting of coir dust and in the bottling of king coconut and young coconut water (Kurumba). CISIR also developed methods for making ligno-plastic wood (44, 45).

In the field of medicine, although research in tropical medicine and healthcare systems have been going on without much publicity at the University Medical Faculties, the Medical Research Institute, and in hospitals, it has to be recorded that in 1967, Dr. K.N. Seneviratne and Dr. O.A. Peiris had the distinction of receiving the UNESCO/SLAAS "Scientists of the year" award for a technique developed for recording nerve pulses. Using this technique they showed that diabetic patients responded differently from healthy persons (46).

In the field of veterinary research, the Central Poultry Research Station carried out extensive studies on poultry breeding, nutrition and management. As a result of this work this station was able to introduce in 1966-1967, the so-called "Rho-whites". The Rho-White was a popular tinted egg layer produced through the hybridisation of the male Rhode Island Red (R.I.R.) and the white Leghorn, for a duel purpose (egg and meat) chicken (47).

1970 -1980

During this period the main scientific activities in the plantation sector were in disease control and plantation management. The TRI made a discovery of importance in the control of the dreaded weed, commonly known as "Cootah grass", when it was found that the herbicide called "Glyphosate" could effectively destroy it (29). TRI also developed new methods of pest control, involving a technique whereby the growth of insect pests were blocked making them abnormal and deformed (29).

In the manufacturing technology of tea, the introduction of the so-called "Fluid Bed Drier" to the industry, resulting in a significant saving in energy use, revolutionised the technology of tea drying (29).

In the early 1970's there appeared under strange circumstances a disease of the coconut palm. First observed in the southern suburbs of Colombo, it rapidly spread to the city and its immediate environs. This infestation was discovered to be caused by the Philippine coconut leaf miner, *Promecotheca cumingi* (48, 49). Within a few months of its appearance, an estimated 30,000 acres of coconut plantation were considered to be affected. The CRI scientists approached the problem systematically, after initially assembling together almost the entire entomological talent in the country. After a few initial failures to breed some of the parasites of the pest imported from Fiji and Singapore, a major breakthrough in biological control was achieved when two parasites *Dimmockia javanica* and *Pediobus parvulus* were found to be very effective in destroying the pest (48). Thus within two years of its appearance, the devastating pest was brought under control by the research team using a biological weapon, in what has been described as one of the finest examples in scientific co-operation (49, 50, 51).

Pest damage was not limited to the plantation sector. In 1973 a major outbreak of brown planthopper destroyed an area of over 40,000 acres of paddy in the Amparai district. Although chemical pesticides such as carbaryl dust, diazinon granules and sprays of malathion and fenitrothion were effective, sudden and widespread infestations required aerial sprays for quick containment. Methods of such treatment were worked out, and by 1974 the Department of Agriculture was able to make specific recommendations for the effective control of this infestation (52).

In the field of rice breeding, the decade marked the second stage of the hybridization programme with the introduction of the Bg series of new varieties commonly referred to as the "New Improved Varieties" (NIV). The varieties BG 11-11 (4 1/2 months) Bg 34-6 (3 1/2 months), Bg 34-8 (3 months) and Bg 3-5 (5-6months)released to farmers between 1970 and 1973, combined the dwarf plant character with high levels of resistance to lodging and prevalent diseases. In fact under good management practices, the yield potential of these NIV's reached 7 tonnes per ha, which was a substantial improvement over the OIV. The rapidity with which those new varieties gained popularity in the country can be gauged by the fact that within 5 years of their release 55 percent of the land area under cultivation, came under these new introductions, and this no doubt provided the incentive for further research. Infact between 1975 and 1978, three new varieties, Bg 90-2 (4-4 1/2 months), Bg 94-1 (3 1/2 months) and Bg 94-2 (3 1/2 months) were released, which under good management practice, approached a record yield potential of 10 tonnes per ha. In 1979 two high yield varieties Bg 400-1 (4-4 1/2 months) and Bg 276-5 (3 months) with resistance to gall midge and tolerant to iron toxicity were released, and in 1980, the brown plant hopper resistant 4-4 1/2 month variety Bg 379-2 was released. Thus by 1980, NIV comprised 65 percent and OIV 20 percent of the total land area under rice cultivation, with only 15 per cent still remaining under the traditional low-input rice varieties (32).

The rubber industry during this period continued to expand its work on new products. A development of major significance, was the demonstration by the Rubber Research Institute of the simple method of removing proteins from rubber latex using the juice of pineapple. By using this simple and efficient technique the technological properties of rubber was immensely increased (53).

Clonal improvement in rubber research entered the third phase after 1970, when apart from yield factors, characters such as growth habit, latex properties, bark characteristics, disease and wind resistance were given high consideration. This led to the development of the RRIC 100 series clones, with significantly increased vigour, yields and resistance to Oidium leaf disease and Phytophthera bark disease. The clones RRIC 117, 121 and 130 released for small scale planting were also resistant to South American Leaf Blight, and were at that time the highest yielding rubber clones bred anywhere in the world with these characteristics (54).

Reference to much of the work in the area of industrial research during the period has been made elsewhere (12), and therefore in this brief review no effort will be made to discuss work in this sector.

Aside of the scientific work performed at the specialized agencies mandated to carry out pre-planned and prioritized scientific investigations, the period 1970 to 1980 saw the emergence of a spurt of curiosity oriented research activity in the academe. The catalytic impulses for this trend included (a) the availability of new financial resources for research from international funding agencies eg. US-NAS, BOSTID, IFS, SAREC, IDRC and UNESCO, (b) the establishment of a Government fund for scientific research to be disbursed through the newly created National Science Council of Sri Lanka and (c) the emergence of a young and veritable pool of foreign trained academics whose research ambitions were fuelled by creative desires as well as by the echoes of the 'publish or perish' paradox for career enhancement. It is significant that the common initial thrust of all research funding agencies was to enhance research capability building through (a) acquisition of equipment and consumables to strengthen research infra-structure, (b) development of postgraduate programmes for human resource development and (c) orienting and re-habilitation of the foreign trained Sri Lankan scientists to serve the national needs. However, as could be expected, a substantial component of scientific work in the higher education sector was directed towards basic and academic research, with a few activities impinging on new frontier disciplines.

In numerical terms most number of research grants were provided by the National Science Council (NSC) and the International Foundation for Science (IFS). NSC saw the successful completion of 153 research grants during the period 1970 to 1980, with investigative work on process technology and food science comprising 12 percent, Natural Products Chemistry 9 percent, pests and diseases control studies of plants 7.2 percent and forestry ecology, and farming systems studies making up 4 percent each. In the fields of medical and veterinary sciences, investigative work on diseases were the most popular, with 15 completed studies on human diseases (of which 4 were on liver diseases) and 5 completed projects on livestock disease. On the other hand, the IFS which provided 34 research grants to Sri Lankan scientists during the period saw 24 completed projects, of which four were in natural products chemistry and four in food science. This survey shows the research orientation of the free thinking scientific community of the country during this period, and the significance attached by these researchers to work on food sciences, natural products chemistry, and diseases of fauna, flora and man.

1981-1992

The sponsorship for research outside the departmental budgets continued to increase. However, this was mainly due to assistance provided by foreign funding agencies.

In the national scene, the declining prices for major agricultural commodities, especially of rubber and tea, had crippling effect on the industry, that necessitated extensive diversification strategies for products and processes. There is no doubt that the research community responded to these demands by diverting their attention to new alternatives enabling in some instances for local adaptations. Thus for example, the Rubber Research Institute demonstrated successfully that mixtures of formaldehyde stabilized natural rubber containing room temperature vulcanizing systems and bitumen emulsion, were very effective water-proofing material (55). The RRI also later developed a novel latex based cement with improved drying characteristics to be used in tyre re-treading and repair industry. The bond strength of this new material has been found to be comparable to those currently used solvent based cement (55). Another significant development was the invention of a very practical method to produce economically, non-toxic grades of depolymerised natural rubber and latex starting with field latex. This method does not require elaborate equipment to produce this high value-added speciality rubber (56).

It is relevant to note that the year 1984 marked the 75th anniversary of rubber research in Sri Lanka. The RRI commemorated the occasion with an International Rubber Conference in which 100 foreign delegates participated.

In coconut new priorities for research were established by the Coconut Research Institute in 1984, devoted largely to management issues with new technology. In product development, a beverage with an agreeable taste was produced by CRI from nut water of fresh mature coconut (56). CRI also experimented and demonstrated the agronomic and economic feasibility of mixed cropping models with coffee, cocoa, and pepper under coconut. In pest and disease management of coconut new inroads were made to the biological control of the black beetle using a fungal pathogen *Metarhizium anisopliae* (57).

In tea, an inexpensive method for the control of Poria root disease using a fungicide instead of the usual soil fumigation procedure was demonstrated to effect a saving of about Rs. 4000/- per ha (58). Another milestone in tea research was the development of a method for micro-propagation of tea using shoot tips as explants through tissue culture techniques. This is considered to be the first recorded instance of such work (58).

In horticultural research, with the increase in the area under cultivation in crops such as cowpeas and soyabean, during the early 1980's, emphasis shifted to the agronomic aspects of these crops. A number of research activities on soyabean were initiated under the International Soya Bean Programme.

A crop which had not received much attention in the past was sugarcane. Although an institute for sugarcane research was initiated by an Act of Parliament in 1981, it organized itself only in 1984. Since then breeding, tissue culture, agronomy, pest control, water management as well as farm mechanisation research have been initiated. The breeding programme resulted in the introduction of a number of new varieties of which the variety Co 1163 has shown to be of high promise, out performing in all aspects the initially established commercial variety Co 775 (59). Propagation of sugarcane through tissue culture work has also gained much importance. Over 200 caliclones obtained by tissue culture are being subjected to intensive care and selection. One of caliclones so obtained, has remained free of mosaic disease (which affects all clones) for over two years in the field. In 1986 the entomologists at the Sugarcane Research Institute identified for the first time in Sri Lanka a clone (Co 731) which was resistant to termite attacks (59).

As indicated earlier, the impetus for research through foreign sources of funding resulted in a distinct impact not only in research capability building, but also in making substantial inroads to new areas of research. During 1979/80, the National Science Council was instrumental in persuading the Swedish Agency for Research Co-operation with Developing Countries (SAREC), to sponsor research in new areas considered vital for the country's progress. One of the first projects supported by SAREC was on liver diseases, carried out jointly by the Departments of Microbiology and Pathology of the University of Peradeniya and the Medical Research Institute in Colombo. The studies involving 600 cases of chronic liver diseases clearly showed that toxins in food consumed and excessive use of alcoholic beverages were major causes of such liver diseases. A second project on plant virology carried out at the Central Agricultural Research Institute, Gannoruwa, on passion fruit, pumpkins, pepper, papaw and centella, demonstrated the complex interplay of weeds and insect vectors in transmitting viruses to horticultural crops.

In 1983, SAREC agreed to support an ambitious multidisciplinary research programme to upgrade the indigenous water buffalo. The study which covered almost all aspects of buffalo development and management, involved more than 100 scientific personnel drawn from the Veterinary Research Institute, Faculties of Veterinary Medicine and Animal Science, Engineering, Agriculture and Social Sciences of the University of Peradeniya, the Department of Agriculture, and the Agrarian Research and Training Institute.

This research programme which has gone on for more than 10 years and resulted in several scientific publications, postgraduate theses and a monograph incorporating the most recent findings of research, has been considered a unique example of a well focused and co-ordinated scientific effort, devoted to a core issue of the rural socio-economic structure. Some of the main findings during the initial phase (1984-1989) were (a) that with a chromosome number of 50, the indigenous buffalo of Sri Lanka belong to the river type - a finding of significance in breeding and genetic improvement, (b) that in many districts, the animal suffers from deficiencies in copper, sodium, zinc, calcium, phosphorous and selenium, (c) that the major cause of infertility is attributed to postpartum ovarian inactivity, influenced by season of calving and intensity of suckling, (d) the intestinal parasite *Neoascaris vitulorum* is transmitted from mother to calf through milk, with susceptibility and death occurring mostly during the first month of life, and (e) that the draught capacity can be increased by changing the commonly used yoke with a harness construction.

Another major research programme sponsored by SAREC during 1984 to 1989 was the Inland Fishery Research Programme, carried out by the Zoology and Botany Departments of the University of Ruhuna in collaboration with the Institute of Freshwater Research in Sweden. The study undertaken in five reservoirs in the Southern Province, namely, Muruthawela, Ridiyagama, Badagiriya, Yodawewa and Tissawewa, showed that sizeable populations of minor cyprinids could be exploited from these reservoirs (60). Other significant findings include, (a) the discovery using electrophoretic studies that there was pronounced mixing of *niloticus* and *mossambicus* stocks, (b) the widespread occurrence of *Machrobracim* and *Atyide* species of freshwater prawns, (c) the occurrence in four reservoirs of two tropical species of eel, *Anguilla bicolour* and *Anguilla nebulosa*.

In general the research team demonstrated for the first time, that a new fishery could be established leading possibly to a three - fold increase in inland fish production, by systematic management of inland reservoirs (60).

CHAPTER 2

THE RESEARCH SYSTEM

2.1 The Research and Development (R&D) Process

One of the key elements of a country's policy on science is its policy on scientific research. More specifically it is the orientation of research towards satisfying the basic aspirations of the people on the one hand, and facilitating achievement of the national development objectives on the other hand. It is therefore obvious that the thrust of scientific progress as well as the deployment of all available resources for research and development should be discreetly evaluated and monitored. Unfortunately the phenomenal increase in the costs of research during the past few decades, combined with dwindling resources, have compelled the decision-makers to tighten the grip on research expenditure curtailing much of the needed basic scientific work. The net result has been the failure to maintain minimal standards to sustain a genuine scientific effort.

It has been said that the general reluctance to increase financial support for scientific research is often linked with the lack of visibility in the immediate benefits of research. But more often it is due to ignorance and reluctance to appreciate the scientific needs of a rapidly changing technological scenario that is being fuelled by a global economic transformation.

How could these debilities be overcome? It is clear the State must in the first instance ensure an in-built consultative process in national planning. This needs a pool of academics and professionals which should include not only practising scientists and engineers, but also economists, sociologists and even lawyers specialized in issues such as intellectual property rights and technology transfer negotiations. Secondly, mechanisms must be set in place to identify priorities and goals of scientific research. These must be based not only on current development policies, but also on assessments of basic needs and aspirations of the people. Evidently such a mechanism must also identify the human, financial and physical resource availability and requirements to generate the type of scientific culture necessary to deliver the goods. Thirdly, there has to be an installed capacity to monitor and evaluate research findings, for which there should not only be guidelines, but also a set of appropriate measures, yardsticks and possibly even indicators of impact.

The R and D process begins with the identification of specific research themes and projects in the light of chosen priorities for research. Project identification and formulation of the project proposals are the responsibility of the respective research establishments. These can take a variety of forms as may be seen from the later chapters of this study. In the normal course of events, once the projects have been identified and the proposals finalized,resource allocations take place in accordance with the scope of activities and the operational time frame.

A schematic presentation of the core activities in the R and D process are presented in Figure 2.1 to show the input-output flow. The research system can be considered to be made up of several types of investigatory activities extending from fundamental research to experimental development. In most literature, fundamental research is generally identified with basic research and is described as curiosity-oriented research, which leads to the increase of the stock of useful knowledge which may be drawn on unpredictably in various ways and at various times in the future. For the purpose of international comparison, UNESCO defines basic (or fundamental) research as "any experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular or specific application or use in view".

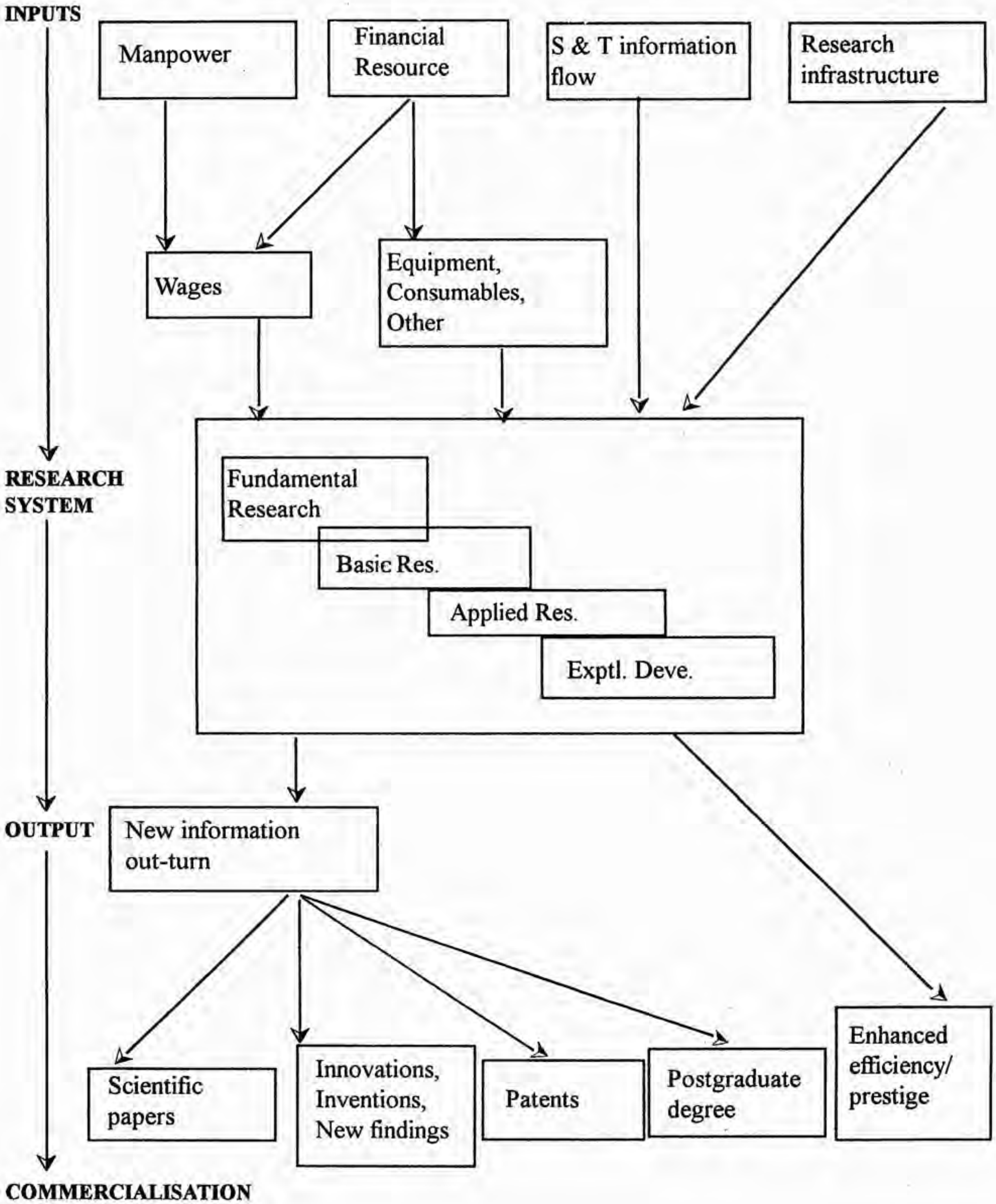
According to these two definitions, basic research includes theoretical studies leading to the understanding and discovery of the fundamental laws of nature, in addition to other investigatory activities directed towards increasing the stock of useful basic knowledge. More specifically basic research would include, for example, theoretical and experimental nuclear physics, space research, astro-physics, etc. on the one hand, and exploratory studies leading to isolation and identification of the active principles in plant extractives on the other hand. The former type of research which is not of immediate relevance to the poorer developing countries could be identified as "less expedient basic research", (or more appropriately as fundamental research), while the latter type of research which is of great significance to the developing world could be identified as "expedient basic research" (or simply as "basic research"). A bifurcation of these two types of scientific activities has become increasingly important for science-planners in third-world countries, because of the need to draw a clear distinction between what may be considered luxury expenditure on fundamental research activities as against profitable investment on relevant basic research. The general reluctance of science-planners and research managers in third-world countries to allocate adequate financial and other resources for essential basic research activities is largely due to the distorted perception and mysticism associated with the term "fundamental research". For want of a better nomenclature therefore, these two terms have been used with the following connotations. Basic research is defined as curiosity oriented experimental and exploratory research activities which would lead to an increase in the stock of useful basic knowledge which could be utilized immediately or in the near future. Fundamental research is then defined as theoretical and experimental studies leading to the understanding and discovery of the fundamental laws of nature(61).

In Figure 2.1 fundamental research is seen to overlap partially with basic research. This is to indicate the existence of common grounds. Applied research may be broadly considered to be of three types, namely, "mission-oriented", "problem solving" and "stop gap". The main distinction between the first two is the coverage and approach to a research problem. Whilst a "mission-oriented" research programme may be described as a multi-faceted problem for which a multi pronged attack is directed, a "problem-solving" research project relates to a specific problem. "Stop-gap" research can be described as experimental studies devoted to the search for missing or incompletely understood scientific or technological information required to complete the R & D chain. Stop-gap research is often required in experimental development work to complete the technology-package in an innovative or inventive process (61).

2.2 Output of Research and Accountability

As illustrated in Figure 2.1 one of the features of research is the generation and out-flow of

Figure 2.1: FLOW CHART OF CORE ACTIVITIES IN THE R & D PROCESS



new information, a part of which is systematized and embodied in scientific papers and patents, which are thus recognised as products of research. Since the information out-turn is an intermediate stage in the research process, a further output would be the flow of innovations and inventions, which are again measurable. There is however, an inevitable time-lag before the occurrence of an invention, which makes its assessment a difficult problem.

The common parameters for measurement of quality of basic research are (1) scientific publications and citations (2) discoveries or major contributions to the advancement of science (3) peer evaluations, and (4) grant of honorific awards or positions. Two additional yard-sticks are available for the measurement of applied research and experimental development. These are patents and innovations. Since each research activity may involve more than one of the above output components, the ranking or assessment of each such component will lead to a partial indicator. These partial quality indicators are relevant and necessary, and are frequently used in advanced countries for determining trends in research - a pre-requisite for identifying guidelines and options for policy formulation.

Over the past few decades, counts of publications and patents have been used not only for the measurement of productivity, but also to compare the research performances of different countries (62,63,64), universities, institutions and laboratories (65,66,67,68), of individuals or groups of researchers (66, 67,70,71), and also between fields of study (63,65,66). Other measures of research output include counts of citations (69), patents, inventions and innovations (72).

However, many of the productivity measures used have an elitist outlook, with emphasis on scientific eminence and elegance rather than on relevance to society. Science planners in developing countries therefore need to look for other parameters which could not only measure productivity in terms of numbers of publications etc., but also on the societal relevance of such scientific work. A conceptual framework for such a quantitative evaluation of scientific research was proposed by Byatt and Cohen (73). Recently using a related concept, a methodology was evolved in which the so-called "factors of production" in academic research were identified, and conceptually demonstrated to deliver output products of determinable value (61). An outline of the procedure used in this technique is given below.

Unlike investments in productive or development enterprises, investments in scientific research and experimental development projects are not easily amenable to a cost-benefit analysis. The obvious reason for this is the lack of an acceptable measure to determine quantitatively the outcome of scientific research. As mentioned earlier, although some types of simple measures or counts are available for output measurement of research, social impacts of such research are not discernible.

In a recent study however, an effort was made to compute in quantitative terms, of what may be considered as the official recognition of a specific outcome of a scientific research programme, *viz* new and advanced knowledge.

According to this evaluation procedure (61), the increase in research capacity that follows the acquisition of new and advanced knowledge by researchers ensures greater utility value to society, and this can be looked upon as a direct societal benefit. The award of a postgraduate degree to such a researcher is assumed to imply not only the acquisition of new and advanced knowledge, but also the eligibility to a higher status for the recipient in his profession and career. Associated with this recognition is then a leap in remuneration and other benefits. In institutes which perform R & D, or carry out specialized activities such as teaching or servicing of research, advanced training and postgraduate qualifications for its scientific personnel are pre-requisites for improving career prospects. A research scholar who receives a post-graduate degree is therefore seen as a "value added" product of scientific research. In Sri Lanka like in most other poorer developing countries, the price that is paid for this value-added product is very low by standards available in the developed and newly rich countries. Nevertheless this concept could be used as a measure of the societal benefits for the new knowledge gained as a result of scientific research. This is the philosophy that was advanced in this study to evolve a measure for a quantitative evaluation of an output component in academic research i.e. production of new knowledge (61).

It is to be noted that production of postgraduates is only one output component of scientific research, which can in most situations be of minor significance. Hence production of new knowledge and production of postgraduates are not necessarily equivalent. However, where promotion of postgraduate training is a primary objective as in universities, this is a significant output and deserves special merit.

Accordingly, the computation specifies that if "I" is the investment on research proportional to the effort required for the production of a postgraduate, and "R" is the wage increase (on an annual basis), for obtaining a postgraduate degree, then the returns on this investment is conceived by the ratio R/I. In order that this ratio would be comparable, and hence used as a partial indicator of research output, the values for "I" and "R" have to be determined according to a standard procedure(61). In Sri Lanka, the wage structure of the state sector, is relatively uniform with the minimum and maximum wages payable being determined by Government. Therefore, although it is possible to determine the price tag for a higher degree, market imperfections due to state interventions provide an unrealistically low figure for this value-added product.

In this evaluation methodology, the principle used for quantifying and placing a monetary value for new knowledge gained in academic research was extended to scientific publications. Scientific publications in prestigious journals are sometimes equated to postgraduate degrees. On this assumption, the study connotes that the material presented in two scientific publications in refereed journals, of which at least one is an international journal, could be considered in academic and new knowledge context to be equivalent to a masters degree.

On this basis, the ratio on societal benefits takes the form R'/I, where R' is the monetary return for the new knowledge contained in two research publications.

If however, in a research project, two scientific publications have resulted in addition to the award of a postgraduate degree, an additional weightage is not given to these publications because, it is the understanding that the material in such papers would already be incorporated in the Master's degree work. On the other hand if four publications have resulted from the project in addition to the master's degree, additional weightage is granted for two of these publications and accordingly the ratio will be modified as follows:

$$\frac{R + R'}{I}$$

Where R + R' represent the total monetary gains from the products of new knowledge gained through a scientific research activity.

Using this ratio for data computed from a study of 234 completed research grants awarded and administered by the Natural Resources, Energy and Science Authority, it was shown that rates of return for the different scientific disciplines ranged from 12.5 percent to 16.2 percent per annum (61).

Understandably, like most other evaluation procedures for R & D, the method described above is not without its share of merits and defects. Three major deficiencies have been identified, (a) lack of a satisfactory method for computing the real costs of research in terms that would facilitate international comparisons, (b) use of arbitrary assumptions and the subjectivity in determining the quality of journals, and (c) the parity valuation given for postgraduate degrees. Yet although tentative, this is one of very few attempts to quantify and evaluate in monetary terms the embodiment of new knowledge as a product of scientific research. The method no doubt could be subjected to further refinements.It could also be extended to other output components of research using similar arguments, so that through a summation, the total return on an investment could be computed.

It may be relevant to note that in the case of inventions and innovations, less complex procedures could be devised to compute the monetary benefits, if and when such inventions and innovations become tools or components in an economic activity.

The importance of assessing costs and benefits of research is partly to demonstrate returns and accountability in scientific research, and thereby allay the fears of authorities responsible for determining investments in R and D. As will be evident from Chapter 5 of this study, deployment of resources for research has taken a sharp downward trend in Sri Lanka during the past two decades. Therefore a concerted effort has to be made by science policy analysts, to provide facts and figures to illustrate the benefits of research in order to justify claims for enhanced sponsorship of R and D.

2.3 **Productivity in Research**

Three specific studies were undertaken during the period 1990 to 1992, to measure productivity of Sri Lankan researchers. The first of these was a field survey of a selected number of research organisations to investigate the systems and components which determine productivity and operational efficiency, aside of financial, physical and human resources constraints. The second study was an analysis of scientific communications presented by researchers at the annual sessions of the Sri Lanka Association for the Advancement of Science from its inaugural session in 1945 to 1989. And the third study involved an analysis of the research grants scheme of the National Science Council of Sri Lanka and its successor, the Natural Resources, Energy & Science Authority of Sri Lanka, from the first year of operation in 1970 to 1992.

2.3.1 **The Field Survey**

This study was initiated in a selected number of key research organisations in Sri Lanka. Among the 12 institutes selected, eight research institutes dealt with Agriculture, agrarian services and veterinary sciences, two institutions were associated with industry and technological research, one institution was on medical research and one institution was associated with construction industry research. The following are the constituent research organisation subjected to this investigation.

- Tea Research Institute, Talawakelle (TRI)
- Rubber Research Institute, Agalawatta (RRI)
- Coconut Research Institute, Lunuwila (CRI)
- Central Agricultural Research Institute, Gannoruwa (now renamed as Horticulture Research and Development Institute (HORDI)]
- Central Rice Breeding Research Station, Batalagoda (now renamed as Rice Research and Development Institute (RRDI)
- Agrarian Research and Training Institute, Colombo (ARTI)
- Veterinary Research Institute, Gannoruwa (VRI)
- Regional Agricultural Research Centre, Bombuwela (RARC) [now renamed as Regional Agricultural Research and Development Centre (RARDC)]
- Ceylon Institute of Scientific and Industrial Research, Colombo (CISIR)
- National Engineering Research and Development Centre, Ja-ela (NERD)
- Medical Research Institute, Colombo (MRI)
- National Building Research Organisation, Colombo (NBRO)

The study commenced with a listing of all sectional heads and project leaders of each institute, with the guidance of the Chief Executive of the institute. This was followed by a pre-arranged visit to each institute by the three member survey team. Prior to the visit however, a carefully structured questionnaire was served to each sectional head and project leader, to familiarize them on the scope and objectives of the study, but not to act on it. The feedback and information required in this study was extracted and summarized by the members of the survey team through informal interviews with the respondents.

Although a variety of issues were taken up for discussion, only one aspect, that is, productivity of research leaders will be analysed in this section. The response to the study from all institutions except the National Engineering Research and Development Centre (NERD) was excellent. Since there were difficulties in concluding the study project at the NERD Centre, the data from this institution have not been included, and only information obtained from the other organisations have been subjected to analysis. A total of 134 project leaders from eleven research organizations participated in this exercise. The scientific outputs comprising of publications, communications, inventions, innovations, adaptations, patents and reports emanating through the efforts of project leaders during the period 1985 to 1989 are summarized in Table 2.1.

A first impression of the data presented here is the magnitude of the output of scientific material in the form of publications from all institutions. During the 5 year period under consideration the average annual output of publications in refereed journals ranged from 21 for RRI to zero at ARTI. On the other hand, the average annual production of scientific communications ranged from 29 for CISIR, to 2 at the Bombuwela Regional Agricultural Research Station. However, it is discomforting to note, that commercialisation of research findings as evident from the number of inventions, innovations and adaptations, had taken a back seat during this period. The obvious conclusion to this situation is that scientific research policy and the research system of Sri Lanka have not been fashioned to be sensitive to user needs or to market signals. The fact that such a large number of scientific papers had received recognition for inclusion in refereed journals, clearly shows the distinction and the intrinsic scientific merit of research work carried out by Sri Lankan scientists. However does this mean that the outputs from most of these research institutions tend to display scientific excellence rather than to utility value? This phenomenon assumes offensive proportions when concerned authorities become subservient and insistent to the neo-colonial concept of "publish or perish"' in deciding appointments and promotions of scientific personnel to higher positions. Therefore if this trend has to be reversed, new or innovative policy instruments have to be set in place to re-orient research, and in consequence the performance of researchers. A mere reorganisation and re-structuring of the institutional framework for research will be inadequate without such a re-moulding of the philosophy of research.

Three institutions (CISIR, RRI, CARI) have introduced a significant number of technological changes through inventions, innovations and adaptations, but only RRI seems to have secured patents during the period under consideration. This field study also probed among others, the causes limiting best performance by research staff. The results of this study are discussed in Chapter 3 of this report.

2.3.2 Scientific Communications

In order to examine productivity and general trends in scientific investigations in Sri Lanka from another perspective, it was considered useful to analyse the scientific communications presented at the annual sessions of the Sri Lanka Association for the Advancement of Science (SLAAS). The SLAAS as the premier non-governmental scientific organisation in the country, provides a forum for presentation and dissemination of scientific research findings in all disciplines. Its recognition as an instrument of free expression makes its proceedings a barometer of scientific thinking and productivity in the country. The SLAAS is constituted of seven discipline-oriented sections and four statutory committees. Each year from its very inception, the Association has held its Annual General Meeting preceded by the Annual Scientific Sessions. Presentation of scientific papers are under the following major disciplines: Medical, Dental and Veterinary Sciences (Section A), Agriculture and Forestry (Section B), Engineering, Architecture and Surveying (Section C), Life and Earth Sciences (Section D), Physical Sciences (Section E 1), Chemical Sciences (Section E 2) and Social Sciences (Section F). Since the sectional disciplines were too broad in scope and coverage, in the current investigation the subject matter was disaggregated and the themes re-classified under the

Table 2.1: Research Output as a Measure of Productivity of Project Leaders of Selected Research Institutes (1985 to 1989)

Sector and Organization	Agriculture Animal Husbandry & Veterinary Research								Medical Research	Technological & Industrial Research	
Type of Research Output											
	CRI	TRI	RRI	HORDI	RARDC	RRDI	ARTI	VRI	MRI	CISIR	NBRO
Publications in refereed journals (No.)	69	49	107	69	11	14	-	35	32	42	18
Scientific Communications (No)	70	46	60	98	11	14	39	69	40	147	38
Number of inventions	-	-	5	20	-	-	-	-	-	3	3
Number of innovations	-	2	10	7	4	5	-	3	-	23	6
Number of adaptations	-	1	4	8	3	-	-	8	-	35	-
Number of patents	-	-	6	-	-	-	-	-	-	-	-
Number of reports	9	2	53	-	5	-	6	-	9	-	-

following headings : (1) Medical Sciences, (2) Dental Sciences, (3) Veterinary, Animal Sciences and Zoology, (4) Engineering Sciences, (5) Architecture and Surveying (6) Earth Sciences (7) Plant Sciences, Forestry and Agricultural Sciences, (8) Environmental Sciences, (9) Chemical Sciences, (10) Physics, (ii) Mathematics and Statistics and (12) Social Sciences. Table 2.2 and Figure 2.2 show discipline-wise growth in productivity of Sri Lankan scientists as evident from the number of papers read at the annual sessions of SLAAS from 1945 to 1989.

During a period of 45 years a total 4643 papers have been presented at an overall average of 101 papers per annum. In terms of numbers, plant sciences, forestry and agriculture had seen the largest number of papers, accounting for more than 25 per cent of all papers presented at the annual sessions. Chemical sciences come next with 19 percent, followed by medical sciences with 13 percent. The overall distribution of SLAAS communications during 1945 to 1989 is illustrated in figure 2.3. The growth in productivity (Figure 2.2) shows a fairly consistent trend, with a first peak during the early 1970's followed by a general decline in the 1980's and finally a steep increase during the second half of the last decade. The highest increase is in the fields of plant sciences, forestry and agriculture, where there has been a concentration of scientific effort. However, despite of a substantial shift in state policy towards industrial development since 1977, technology related disciplines such as engineering sciences, physics and earth sciences have shown only a modest growth in scientific activity.

2.3.3 **The Research Grants Scheme of NSC and NARESA**

In 1970, just 18 months after the creation of the National Science Council of Sri Lanka, the then Ministry of Scientific Research and Housing agreed to allocate funds for specific research projects to be selected and monitored by NSC. Thus for the first time, Sri Lankan researchers were given the opportunity of seeking sponsorship for creative, curiosity - oriented scientific research in any field of science. This research grant scheme initiated by NSC, continued to function almost in its original form under the Natural Resources, Energy and Science Authority of Sri Lanka (NARESA), which replaced NSC in 1982.

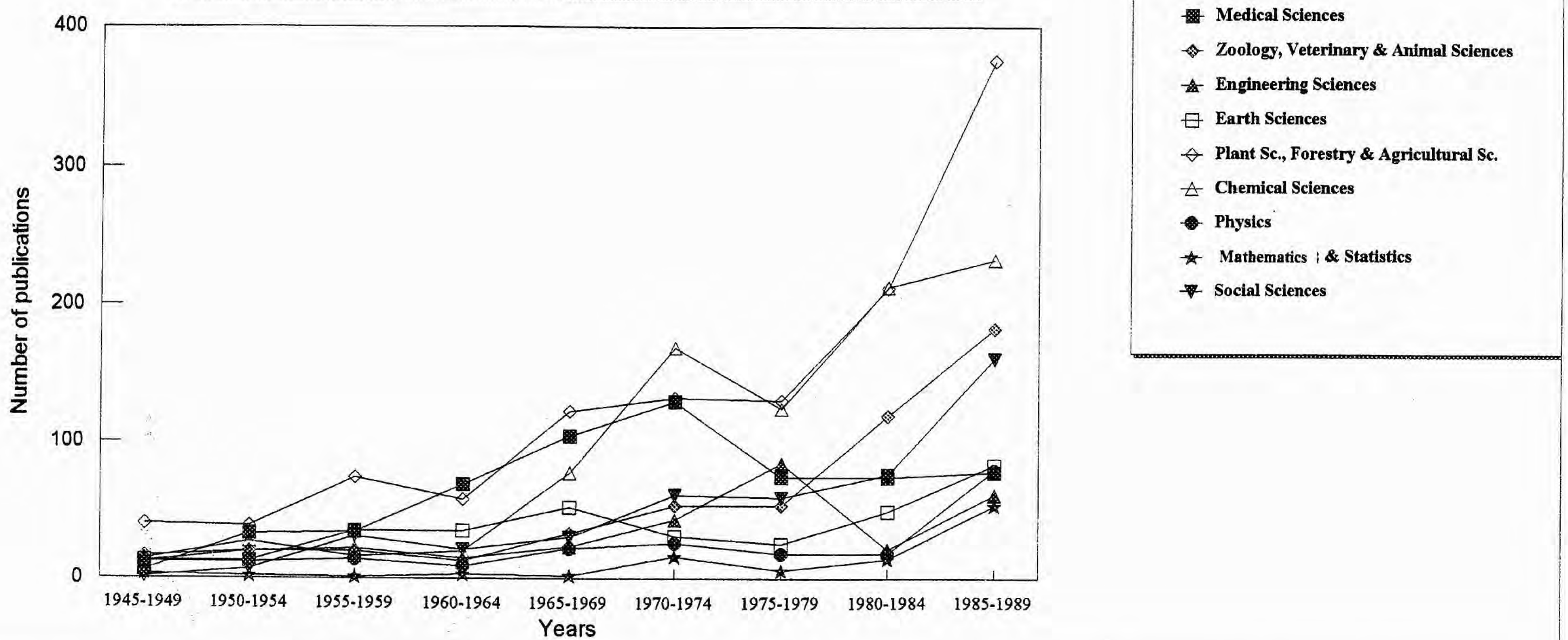
Under this scheme, 'grants awarded for research annually were monitored by Statutory Working Committees comprising of recognised scientists appointed by the Minister in charge of Scientific Affairs, on the advice of the Board of Management. These Committees were also responsible for evaluating the final reports submitted by the recipients of research grants.

Table 2.2 Number of Scientific Communications Read at the Annual Sessions of SLAAS (1945 to 1989), by Discipline and Time Periods

	1945 - 1949	1950 - 1954	1955 - 1959	1960 - 1964	1965 - 1969	1970 - 1974	1975 - 1979	1980 - 1984	1985 - 1989	Total
Medical Sciences	6	33	34	69	104	129	74	74	78	601
Dental Sciences	-	1	1	1	1	1	5	14	6	30
Zoology, Veterinary & Animal Sciences	16	20	20	13	33	53	53	119	183	510
Engineering Sciences	12	20	22	15	23	43	84	21	61	301
Architecture & Surveying	0	0	0	0	3	4	2	1	2	12
Earth Sciences	13	13	35	35	52	31	25	49	83	336
Plant Sc. Forestry & Agricultural Sciences	40	39	74	56	122	132	130	212	376	1183
Environmental Sciences	0	1	0	0	4	2	1	7	5	20
Chemical Sciences	14	27	16	20	77	169	124	213	233	693
Physics	12	12	14	9	22	26	16	16	79	210
Mathematics & Statistics	3	2	1	3	2	16	6	14	53	100
Social Sciences	1	7	31	21	30	61	59	76	161	447

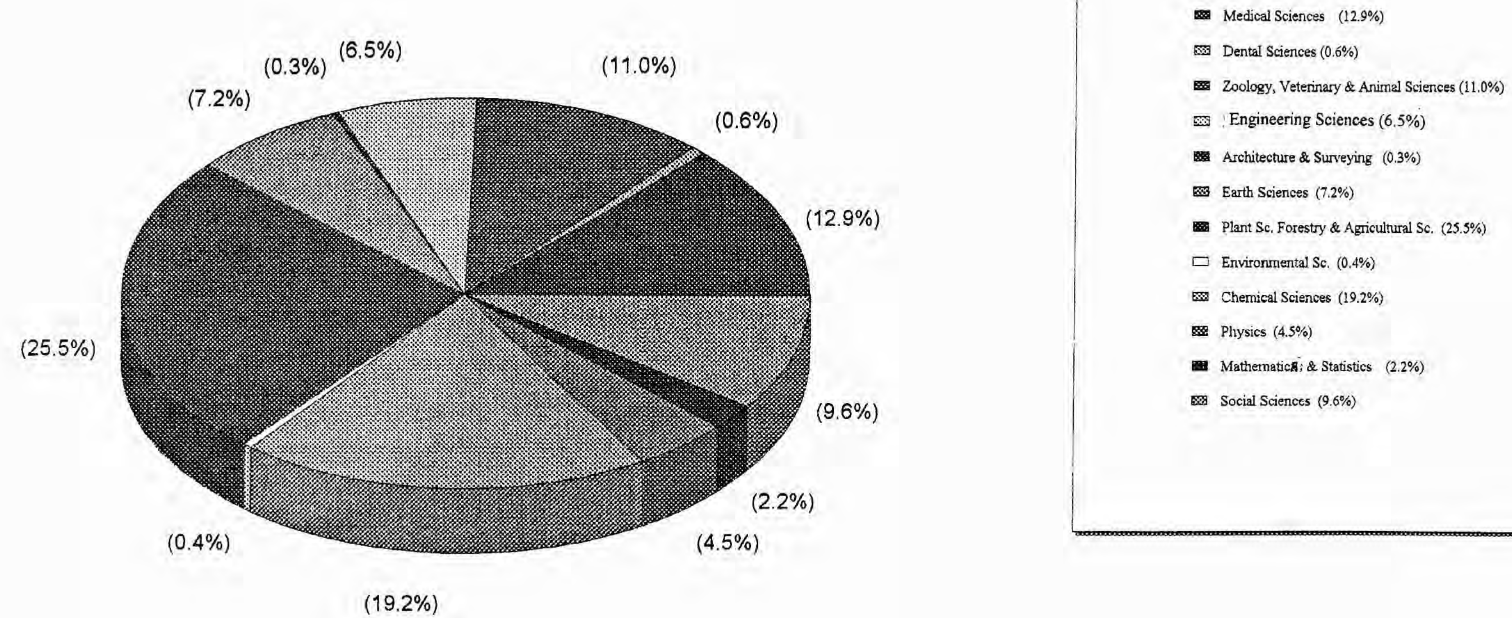
Source: SLAAS Proceedings 1945 to 1989

Figure 2.2: Discipline-wise Growth Pattern of Papers Read at SLAAS Annual Session



[Dental Sciences, Architecture & Surveying and Environmental Sciences are excluded]

Figure 2.3 Scientific Communications Read at the Annual Sessions of SLAAS from 1945 to 1989



Source of Information: Proceedings of the Annual Sessions of the Sri Lanka Association for the Advancement of Science, 1945 to 1989.

In awarding research grants, the National Science Council and its successor the Natural Resources, Energy and Science Authority had as their main objectives, (a) of providing opportunities for Sri Lankan scientists to engage in both applied and curiosity-oriented "expedient basic" research in any field of science, (b) the enhancement of research capability, both of the recipient and of his laboratory, (c) providing opportunities for promising young scientists to obtain postgraduate degrees and to be in productive employment and (d) offering an opportunity for foreign trained Sri Lankan scientists to re-orient towards the national research needs of the country (74). Accordingly, in evaluating research output, consideration had to be given to the extent to which the primary objectives have been achieved, which includes not only assessing intrinsic scientific merit of the findings, but also enumerating the postgraduate degrees awarded to personnel associated with the project.

The data summarized in Table 2.3 illustrates the productivity of the research grants scheme in terms of postgraduate degrees awarded, and the number of scientific publications produced by recipients of such grants. It is significant to note that during the 22 year history (1970 - 1992) of this research grants scheme a total of 207 Masters degrees and 33 Doctoral degrees had been awarded to young scientists, who had taken up research assistantship in the 585 research projects completed during this period.

On the basis of expenditure involved in these research grants, the overall cost of producing a postgraduate degree (refer row 8 of Table 2.3) during the period 1970-1992 was computed. The costs have been found to range from about Rs. 39,000/= for biological sciences to about Rs. 54,000/= for agricultural and chemical sciences, which even under Sri Lankan conditions are very modest. The costs include expenditure on equipment, consumables, travel, living allowances of the research student and any other labour costs, but does not include the costs of bench space and payments to supervisors. These figures show that at least in terms of human resource development, the research grants scheme had been highly profitable and productive.

The research grants scheme also resulted in the release of 327 scientific publications of which a little under 50 percent were in internationally recognized refereed journals. This is indeed a reflection of the quality of work done by Sri Lankan scientists. It is significant to note that 51 percent of scientific papers contributed to international journals and 26 percent of papers contributed to local journals came from chemical science grants. Sri Lankan chemists had consistently demonstrated their desire for basic type of research, relating mainly to geochemistry, natural products chemistry and electrochemistry, for which international links were also inevitable. This also meant better access to the prestigious journals in the fields of chemical sciences, a factor which may have determined the greater success of chemists in receiving the patronage of such journals.

Table 2.3 Output of the NARESA Research Grants Scheme in Terms of Postgraduate degrees and Scientific Publications 1970 -1992

Subject Area / Parameters	Agri. & Animal Husbandry	Biological Sc.	Chemical Sc.	Medical & Vet. Sc.	Physical & Eng. Sc.	Social Sc.
No. of completed grants	74	112	122	118	49	110
Total expenditure (Rs.10x^3)	4565	5744	9781	5582	2482	1666
Expenditure on equipment (Rs.10x^3)	473	311	640	319	231	0
Percentage spent on equipment	10.4	5.4	6.5	5.7	9.3	0
Master's degrees	12	47	45	31	14	58
Doctorates	01	03	09	14	03	02
P.G. degrees as a percentage of the No. of grants	17.6	47.6	44.3	38.1	34.7	55.5
Overall cost of a postgraduate degree (Rs.)	53728	39270	52639	46181	50120	4550
Publications in international journals	08	18	78	19	27	3
Publications in local journals	19	27	43	39	08	38
Scientific Communications	24	67	192	59	22	8

Source: De Silva, M.A.T., (1993) Natural Resources, Energy and Science Authority 1968-1993: *A Historical Narration To Commemorate The Twenty-Fifth Anniversary*, NARESA, Colombo. pp 24-29.

2.4 Commercialization of Research Findings

The Research and Development Process discussed in Section 2.1 featured the core activities in the research system. It illustrated the manner in which the deployment of specific basic resources leads ultimately to a set of outputs which could be assessed for quality and quantity, but stop short of an assessment of the utility value of these findings or outputs. This is because the R & D process invariably comes to an end with the findings on the laboratory bench, which is essentially the establishment of technical feasibility of a technique or technology.

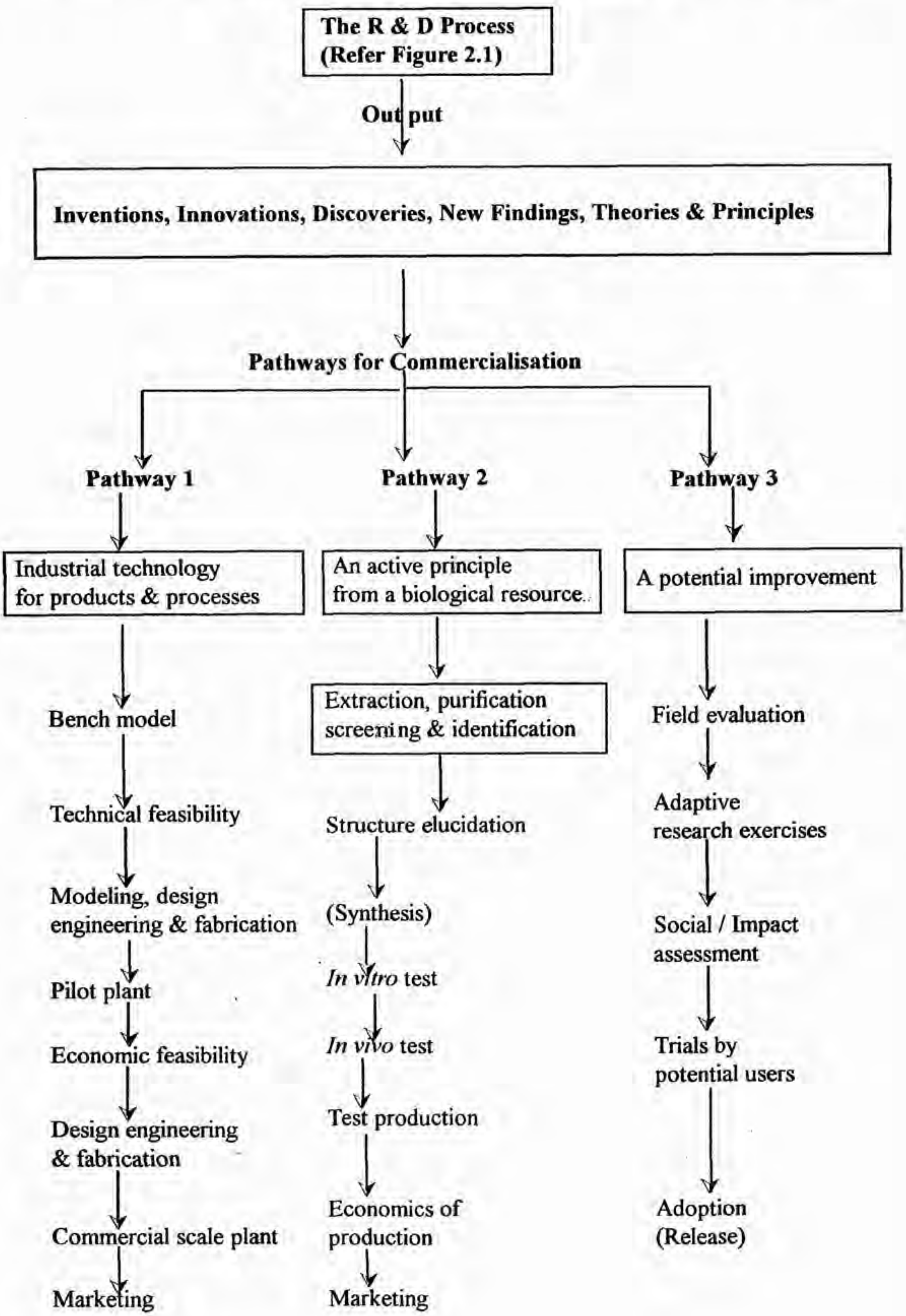
It was mentioned in Section 2.2 that in the case of inventions and innovations, less complex procedures could be devised to compute the monetary benefits, if and when such inventions and innovations become a tool or component in an economic activity. Evidently the more important and final aspect of scientific research should be the mechanism by which any new finding could be popularized and marketed. Figure 2.4 shows the final phase of research operations, which is the development and marketing of a new product or process technology. In this flow chart three common pathways are illustrated, although many others are possible. The development and marketing process obviously has to proceed through a number of stages, and may take several years before the fruits of research labour are realized. Thus even if laboratory studies do not pose any serious problems, the experimental development work to scale-up, demonstrate and transfer a technically feasible procedure, calls for high degree of co-ordination in the skills of design engineering, techno-economics and extension.

In a small developing country such as Sri Lanka, with a shortage of skilled manpower and limited financial resources, such an exercise seems formidable. It is estimated that scaling up of a bench model to a pilot plant, and testing its economic feasibility, could cost anything up to 10 times the total cost expended for bench research. This is indeed a serious constraint to commercializing of research findings. A further aspect is the lack of entrepreneurship in the country, due mainly to the small and uneconomic internal market. The risk factor appears inflated when the internal market is small and unsound, and this constitutes a serious disincentive for entrepreneurship.

Despite these debilities, over the years Sri Lankan scientists have been able to make substantial contributions to new technological developments, which have been adopted locally as well as in other countries.

Sri Lanka has had a long history of work in the field of natural products. During the late 1950's interest in natural products research gained momentum, and by the late 1960's several teams of chemists and botanists entered the field, resulting in a spurt of activity. Several of these research centres though engaged in different areas of natural products chemistry, developed into centres of excellence. It was thus not surprising that one of the bigger groups, which had been highly productive and active over a period of about 25 years, should receive the highest scientific award in the country in 1986, the "Presidential Award for Scientific Achievements". There are also many other Sri Lankan scientists who have won prestigious international awards for research in natural products chemistry. It is in the shadow of these achievements, and in the context of rich and voluminous body of new knowledge produced by

Figure 2.4: THE FOLLOW THROUGH FLOW CHART FROM R & D TO COMMERCIALISATION OF RESEARCH



natural products researchers, that a special study was initiated to investigate constraints in commercialization of research findings in this area of activity.

2.4.1 Constraints in Commercialization of Research Findings in Natural Products Chemistry - A Case Study

During the past few decades Sri Lankan scientists are estimated to have screened more than 1000 species of plants for various classes of biologically important secondary metabolites such as alkaloids, steroids, terpenoids, plant phenols and pheromones. In about 50 species of higher plants, active principles and commercially useful natural products have been investigated. Although Sri Lankan researchers have been in the frontier of natural products chemistry, in the past their general thrust in research had been to widen the horizons of knowledge on the range and character of plant and animal metabolites, rather than to exploit the exquisite and unique qualities of these constituents in commercial terms. However, in recent times with the accumulation of knowledge in active ingredients, especially of those which have been traditionally identified with specific medicinal value, and the availability of new analytical tools and screening techniques, researchers have turned to pharmacognosy.

The search for biologically active constituents in materials of plant and animal origin involve chemical and physio-chemical analytical processes, broadly referred to as screening. During the initial phase of the screening of materials for biological activity, a laborious process involving extraction, fractionation, isolation, purification and identification takes place. Sophisticated instrumentation now facilitates fairly quick identification of the biologically active principles. However, most biologically active ingredients are present only in minute quantities, and hence demand a high degree of attention and care in the isolation process. A well known example is the extraction of the anti-leukaemia alkaloid vincristine which is known to be present only to the extent of 20 mg per metric ton of the dried leaves of *Catharanthus roseus*. This would mean that to obtain one gram of vincristine, one would have to work with 50 tonnes of leaf materials (75).

Natural products chemists seeking to isolate and identify active principles in biological material are also often frustrated by the difficulty of confirming the structure and biological activity of the isolates. Currently easily applicable techniques are available mainly for the determination of antibiotic and anti-cancer activity. The limited availability of simple bio-assay facilities in Sri Lanka have been a limiting factor in developing marketable products. Most of the laboratories have facilities for *in vitro* assays, but only some limited and less precise facilities for *in vivo* assays. The range of *in vivo* assays are not only limited, but are also short of the rigorous conditions necessary for determining the specificity of activity. As a result of this situation much effort is dissipated in dealing with physiologically inert natural products.

Currently many of the likely active ingredients are forwarded to reputed international laboratories for structural determination and identification of the specificity in activity. This procedure is beset with hazards. There have been numerous instances of the loss in transit of material prepared with great care and attention. Sometimes even if the material finally reaches the reference laboratory safely, there is no guarantee that it will receive the attention that is required to get an accurate finding. Thirdly, the final interpretation of the results leaves some element of doubt in the minds of the researcher as to the completeness and truthfulness of the interpretation.

Some Sri Lankan natural products chemists carry out studies in collaboration with well known multi-national pharmaceutical corporations, which assist them with funds for research, and access for high precision and broad spectrum screening in their reference laboratories. Although many potentially responsive extractants produced by these scientists have been screened by these pharmaceutical laboratories, thus far the results have been frustratingly negative. Here again researchers are somewhat confused and concerned about the results provided, since the interpretations are often unintelligible or vague. There is some doubt all the time, as to whether some vital information is not truthfully revealed in the interpretation of such results. However, the third world scientist has no choice in this situation, but to continue with his toils hoping for better times.

In a recent study, a group of researchers from the University of Peradeniya discovered that the yield of a plant ecdysteroid could be obtained in yields more than 6-fold greater than the procedure currently used. This phytoecdysteroid, well known to be active against the larvae of the European corn borer *Ostrinia nabilis*, was also found to be active against the groundnut aphid. It also had moderate insecticidal and spermicidal activity(76). The researchers demonstrated that this active principle could be produced according to required specifications at one sixth the current (1989) price which was marketed by a Swiss firm at 13.00 Sw.Fr. per milligram, and by an American Company at US $ 12.00 per milligram.

Accordingly the University researchers invited quotations from well known British, German, Swiss and American drug firms for the sale of this constituent. Strangely however, none of these firms showed any interest in the purchase of this active steroid from the cheaper source, possibly because they had already linked up with prestigious laboratories to purchase it at predetermined prices(77) .

This is an example where scaling-up or pilot plant studies were not of any concern, yet the effort of these researchers to market a process technology in the international market was aborted by circumstances beyond their control. Thus regardless of the quality of research, developing country scientists face many impediments in trying to commercialize a new found product or process technology.

CHAPTER 3

PLANNING, MONITORING AND EVALUATION OF RESEARCH IN THE NATIONAL RESEARCH NETWORK

3.1 Prioritization of Research

The escalating costs of research and dwindling resources, have in recent times forced research managers to find means of optimizing resource utilization. One of the major efforts towards this end has been the identification and intensification of research in specific priority areas. It has been conceived that by setting priorities for R and D, specific plans and policies could be evolved, thereby facilitating optimal distribution of resources. Traditionally resource allocations have not been determined by the expected returns, or for that matter, even by any pre-determined societal needs. On the other hand certain institutions, for example the plantation research institutes, which depended on a cess collection from exports(and in one case on imports), received financial allocations based on export (or import)values of products derived from the crops served by these institutions. In general such allocations were largely unrelated to the scope of R and D required. Thus until recently, plantation research institutes were not constrained by financial deficits, and therefore the scope of their research programmes were very much fashioned to match the expected flow of finances. Research planning now takes a more precise form mainly to facilitate deployment of resources to areas which are likely to produce more attractive and visible returns on investment on the short run.

Prioritization of research has generally been an institutional activity, where the Head of the institution with the advice and guidance of project leaders, potential beneficiaries, senior managers and policy makers in the respective ministries set out the specific areas for research and development. More recently, as seen in the National Agricultural Research System (NARS), an attempt has been made for an hierarchical priority setting scheme in which the primary focus is on crops and commodities rather than on specific grey areas. Thus for example under crop prioritization, the Department of Agriculture has, in it's work plan for 1993-1997(78) categorized crops into four priority groups as follows.

Group I	**Group II**	**Group III**	**Group IV**
Banana	Bean	Apple	Bittergourd
Chilli	Brinjal	Avocado	Broccoli
Citrus	Cabbage	Beet	Cauliflower
Mango	Capsicum	Black gram	Guava
Mungbean	Cassava	Carrot	Knokhol
Pigeonpea	Cowpea	Chickpea	Leek
Potato	Durian	Cocoyam	Lettuce
Rice	Grape	Cucumber	Lufta
Sweet potato	Groundnut	Garlic	Me
Tomato	Kurakkan	Gherkin	Raddish
Maize	Ginger	Snakegourd	Sunflower
	Mushroom	Innala	Turnip
	Okra	Jak	

Onion	Leafy vegetables
Papaya	Mangosteen
Passion fruit	Melon
Pineapple	Pear
Rambuttan	Pumpkin
Sesame	Wood apple
Soyabean	

The scale of research activities to be carried out under the above four groups is expected to be as indicated below:

Group I - Very high priority crops

Varietal development (High), cultural practices (High), pest and disease management, cropping systems, use of machinery in planting, growing, harvesting and seed processing, post harvest technology development, value addition, adaptive research.

Group II - High priority crops

Varietal development (Medium), cultural practices (Medium), pest and disease management, cropping systems, post harvest technology development, value addition, adaptive research.

Group III - Medium priority crops, but possibly having regional priority

Varietal development (Low), cultural practices (Low), management of major pests, adaptive research.

Group IV - Low priority crops

Varietal development (Low), adaptive research.

The four priority groupings had been arrived at by consensus after consideration of the following factors.

(a) Present areas under cultivation and likely extent in the future and value of crops to growers, processors and consumers

(b) Magnitude of researchable problems whose solutions seem possible technically.

(c) Research findings that can be adopted by clients and which will provide significant benefits (78).

Apart from the above, special attention had been given to those crops that have export potential, or those that can competitively substitute current imports.

The Council for Agricultural Research Policy (CARP) which has as one of it's primary functions to advise the Government on matters pertaining to agricultural research policy, also instituted a research prioritization exercise based on commodities and crops. This was carried out in two distinct steps. The first step involved the definition of the national agricultural development strategy in terms of selected objectives, and indicating their relative importance by assigning a weight to each of them. Five objectives were selected and weights were assigned to each of them as follows:-

1.	Income and employment generation	-	30%
2.	Generation of foreign exchange	-	24%
3.	Economic efficiency	-	18%
4.	Satisfaction of future domestic demand	-	18%
5.	Satisfaction of nutritional requirements of low income groups	-	10%

The second step was to assess and prioritize the commodities on the basis of their capacity to contribute to the attainment of the development objectives identified. Accordingly commodities were grouped into three priority classes. However, the database and methodology were considered inadequately sensitive to rank the commodities. Therefore the listing of the commodities within the three priority groups was done in alphabetical order as follows:-

Priority Group I : Banana, coconut, dairy cattle, fish, forest products, pepper, poultry, rice, rubber, sugar and tea

Priority Group II: Black gram, cashew, chilli, cinnamon, cocoa, coffee, cowpea, gherkin, gingelly, grape, green gram, goat, maize, mango, manioc, passionfruit, pineapple and potato

Priority Group III: Bean, cardamom, citrus, clove, groundnut, kurrakkan, onion, papaw, pigeon pea, soyabean, sweet potato and tomato.

The Veterinary Research Institute (VRI) in late 1992 carried out a prioritization exercise for seven categories of commodities (cattle, poultry, buffalo, goat, swine, rabbit, sheep) and eight categories of non-commodities (economics, marketing, farming systems, extension, processing, equipment, environmental issues, animal by - products). Apart from utilizing the CARP's priority listing, and the listing prepared by the Department of Animal Production and Health, VRI evolved its own scheme for this exercise. The mechanism for this study was as follows:

(a) All shades of interest groups sat in discipline-based groups with a leader.

(b) Each species was taken up separately.

(c) In each group, a facilitator introduced each research area.

(d) The group leader appraised all participants objectively.

(e) The subject was then open for discussion.

(f) Each group scored individually, with the scoring done by discussion and consensus

(g) Scores were aggregated and averaged.

(h) Priority status was then determined using the scores obtained (79)

The scoring procedure involved three criteria and three events. The three criteria were as follows.

- **Potential benefits from research** : Here consideration was given to the present knowledge and productivity level, expected enhancement of knowledge or productivity, expected contribution of research towards overall productivity, examination of present position in relation to set targets and the consideration of the intensity and volume of work required to achieve the final objective.

- **Applicability to Sri Lanka** : Here consideration was given to the scope of applicability or market, extent of import substitution (if any), assessment of demand for findings or product, the capacity of Sri Lanka to reap the benefits, and the possibilities of income generation to the organisation.

- **Feasibility** : Here assessment was made of the capacity to achieve objectives, the availability of the required manpower, skills and infrastructure, and the technical achievability of objective.

The three levels of scoring were: low (0-33 marks), medium (34-66 marks) and high (67-100 marks).

The VRI conducted two workshops under this prioritization exercise and came up with the following priority ratings.

Commodity (or industry) ratings

First	**Second**	**Third**	**Fourth**
Dairy cattle	Drought cattle	Beef cattle	Quails
Dairy buffalo	Diary goat	Sheep (meat)	Meat buffalo
Draught buffalo	Swine	Duck	Horse
Layer chicken	Turkey	Elephant	Meat goat
Broiler chicken	Inland fish		
Village poultry			

Non-commodity or multi-commodity ratings

First	Second	Third
Farming systems	Extension	Equipment
Economics	Technology transfer	Animal by-products
Marketing	Environmental issues	
Product development		

In order to determine the usefulness or otherwise of their prioritization exercise, a comparison was carried out between it's final outcome and the distribution of current (1992) ongoing research projects (80). The data summarized below in Table 3.1 show that on a species basis, the distribution of high priority research is almost identical to the distribution of on-going research projects of 1992. On the other hand, on a discipline-wise basis (Table 3.2), there is a significant deviation, with nutrition decreasing and farming systems increasing sharply. Thus the prioritization exercise has fairly convincingly demonstrated the need for a re-assessment and re-adjustment of V.R.I's research focus in the future, when the Institute also expects to assume autonomous status.

Table 3.1 Comparison of Species - wise Distribution of Projects

	Poultry	Cattle & Buffalo	Goats	Others
On-going R & D projects (1992)(As % of total)	33	50	6	11
Prioritized research areas (as % of total high priority areas)	32.2	58.1	9.7	-

Table 3.2 Comparison of Discipline -wise Distribution of Projects

	Breeding	Nutrition	Diseases	Farming Systems/ Management	Others
On-going R & D projects(1992) (As % of total)	13	32	39	3	13
Prioritized research areas (as % of total high priority areas)	16.1	22.5	35.5	22.5	3.2

It is relevant to mention that the Department of Agriculture as well as the V.R.I, followed up the initial crop/ industry based priorization process with a search for thrust areas for research within each commodity. Project identification was thus to be determined by the thrust areas of research.

Apart from commodity - based research there are many other areas of research which are not specific for a crop, but cross- disciplinary as well as cross - commodity. Such factor research components also need to be prioritized.

These include the following types:

- Farming systems	- Technology transfer
- Economics	- Animal by products
- Marketing	- Land and water management
- Product development	- Soils, water and climate
- Farm machinery	- Weed science
- Extension	- Biotechnology
- Environmental issues	- Germplasm conservation

Priority setting exercises of a similar nature initiated by the plantation crop research institutes, directed mainly to determine the thrust areas for research.

All these activities seem to show the emerging trend to devise new mechanisms to optimize the deployment of scarce resources, by focussing attention on priority areas for research.

3.2 Identification of Research Projects

As much as prioritization of research was an in-house activity, identification of specific themes for research has often been the choice of individual researchers. The research process of Sri Lanka like most other developing countries, is fashioned to be a continuous unending activity, often devoid of expediency; except in circumstances such as an epidemic, or when there is a threat of an unknown disease. Hence the formulation of a "bankable" research proposal, cannot be expected to be a particular requirement for approval and funding. The field survey initiated during 1992-1993, and described in section 2.3.1 of this report investigated aspects of research planning, and choice of projects for funding in the National Research System (NRS). It is obvious that public research demands a consultative process for identification of researchable themes. Since there was no evidence of the existence of any specific guidelines for such a consultative mechanism, the study attempted to see whether any one or more of the following approaches were made use of by research leaders for project identification:

- Preparation of programmes on personal preferences
- Planning in consultation with colleagues within the division
- Inviting suggestions or proposals from members of the division
- Use of in-house seminars or workshops
- Directions given by higher authorities (top down)
- Other alternative procedures

The responses to this questionnaire are summarized in Table 3.3. The results are composited under three major sectoral categories to abbreviate and facilitate readability. As expected there was no uniform approach to project identification. In some instances more than one procedure had been employed by these sectional heads, and as a result when data are weighted as percentages, the institutional totals exceed 100. It is clear from this study that personal preferences and internal consultations were the preferred methods for planning of research. The inference here is that the final choice of projects if at all could have been only marginally influenced by sources outside the confines of the division.

The data summarized in Table 3.4 shows the manner in which research proposals are evaluated and selected in scientific research institutes. The results clearly point to the fact that national priorities and institutional objectives were the key guiding principles for evaluation and selection of research proposals.

Institutional objectives are undoubtedly a reflection of national priorities. The fact that the research system involuntarily orients itself to these objectives indicates in no uncertain terms that the State is the most important client. Therefore whatever the manner in which the priorities for research are set, the research system will respond to the needs of this client. Obviously the research system continues to be played by the vestiges of an inflexible neo-colonial culture of research that seems to be both pervasive and perpetual.

Now while the State may in all good faith be acting on behalf of an identified public beneficiary, there is no gurantee that national priorities are synonymous with priorities of the public beneficiary. There is also no gurantee that the State could be adequately sensitized to the variety of demands and priorities of these beneficiaries. In fact this is one of the major defects in the research planning mechanism of the National Research System. The consistent failures in recent times, both in the agricultural and industrial sectors, to respond to the needs of their true stakeholders - the users and consumers, could be attributed to this constraint. It is also evident from the observations of this survey (see Table 3.4), that issues such as technical feasibility, profitability and even user preferences had not received the deserved ranking in the evaluation processes of project proposals.

The field survey also looked at the character of research performed by the public sector research organisations. Table 3.5 summarizes the type of research performed by these institutes, expressed as a measure of the time spent by researchers in the course of their work. As would be expected, on an overall basis, over 60 percent of the researchers time is spent on applied research. However, surprisingly, over 20 percent of the research time is also spent on basic research.

What is seen here is a significant depature from the situation that prevailed during 1985 when the basic research component was less than 10 percent, the applied research component was 72 percent and experimental development component was 18 percent in terms of resource allocations (13). The definition of the term basic research here is in conformity with that given in section 2.1 of this treatise.

Table 3.3 Mechanisms for Planning of Research Programmes in the NRS as Indicated by Team Leaders (field survey 1992-1993)

Criteria	Agricultural Research *		Medical & Veterinary Research **		Industrial & Construction Research***		Overall Percentage
	Responding team Leaders	As percentage of total (79)	Responding team leaders	As percentage of total (18)	Responding team leaders	As percentage of total (29)	
1. Prepare ones own programme	32	40.5	5	27.8	7	24.1	30.8
2. Plan in consultation with colleagues in the section	28	35.4	8	44.4	11	37.9	39.2
3. Invite proposals from members of the section	6	7.6	3	16.7	1	3.5	9.3
4. Through in - house seminars	1	1.3	0	0	1	3.5	1.6
5. Directions by higher authorities	7	8.9	1	5.6	4	13.8	9.4
6. Other	4	5.1	1	5.6	5	17.2	9.3

* CRI,TRI, RRI, CARI, RARC (Bombuwela), RBRS & ARTI
** MRI & VRI
*** CISIR, NBRO

Note : Figures in parenthesis give the total number of team leaders responding.

Table 3.4 Basis for Selection of Projects by Project Leaders in the NRS. Weightage for marks given by respondents - expressed as percentages (field survey 1992-1993)

Criteria	Agricultural Research * (81)	Medical & Veterinary Research ** (16)	Industrial & Construction Research *** (31)	Overall Percentage
1. Relevance to objectives of the organisation	28.3	28.5	28.5	28.4
2. National needs & Priorities	39.7	37.5	36.0	37.7
3. Technical feasibility	8.0	24.5	13.5	15.3
4. Expected profitability in solving the problem	4.1	2.0	5.5	3.9
5. Short gestation period	2.0	2.0	2.0	2.0
6. Consumer / User preference	8.3	3.5	9.0	6.9
7. Crisis demand	8.0	0.5	4.0	4.2
8. Prestige value	0.6	0	0.5	0.4
9. Other	1.3	1.0	1.0	1.1

* CRI, TRI, RRI, CARI, RARC (Bombuwela), RBRS & ARTI

** MRI & VRI

*** CISIR, NBRO

Note : Figures in parenthesis give the total number of team leaders responding.

Table 3.5 - Project Leaders Perceptions of the Character of Research Performed by the Team. Expressed as percentage of time devoted by team members (field survey 1992-1993)

	Type of Research	Agricultural Research *	Medical & Veterinary Research *	Industrial & Construction Research ***	Overall Percentage
1	Basic Research	19.2	21.6	23.5	21.4
2	Applied Research	62.4	70.0	43.9	58.8
3	Experimental Development	14.9	7.4	15.7	12.7
4	Pilot Plant Research	2.9	1.1	14.5	6.2

* CRI,TRI, RRI, CARI, RARC (Bombuwela), RBRS & ARTI
** MRI & VRI
*** CISIR, NBRO

The observation made here has an interesting parallel to what was seen in the Western World during the 1960's and 1970's. Although by the 1980's, the balance in the character of research in these countries shifted, with both basic and applied research components decreasing in favour of experimental development (13). The question that may be posed is, are we retracing the evolutionary phases of the western model of science planning and policy making, and if so, are we on the correct pathway in the context of our own national goals and priorities?

3.3 Methods of Monitoring and Evaluation of Research Activities

Many different schemes are available for mid-stream monitoring and evaluation of research activities. For a national evaluation process, there are a number of issues to be considered. Among these the following are the most relevant:

- What are the objectives of the study?
- What were the components to be undertaken during the particular phase?
- What were the resources required for this phase, and were these resources available in time?
- Has the researcher been able to carry out the planned activities?
- If so what were the results and preliminary findings?
- Has there been a shortfall or delay, and if so, for what reasons?
- Are the preliminary observations consistent with the results obtained so far, and can the progress be considered acceptable within the framework of achievable goals?
- Is there a necessity to revise the strategy or work plan, and/or is there a need to carry out additional experimental studies?
- What were the constraints faced by the researcher?
- Was the expenditure incurred, commensurate with the planned outlay for the particular phase?
- With due consideration for any debilities and omissions, and within the framework of the researchers scientific environment, can the performance be considered adequate in terms of quality, quantity and usefulness?

The above issues can be set out appropriately in a reporting format to enable the researcher and the evaluator to focus attention on the principles and criteria for the mid-term progress review.

Experience has shown that while the researcher is not always inclined to provide evidence in respect of all these issues for one reason or other, the evaluators are sometimes disinclined to be objective in their assessments. It is not infrequent to find researchers complaining that they cannot afford to waste time on preparing mid term reports. Occasionally however, researchers do not wish to divulge important findings until a publication is ready for release. But more often researchers tend to fall behind time, and find that there is nothing worthwhile to report. Evaluators on the other hand being senior scientists do not find it adequately rewarding to devote much time on such progress review reports, unless the findings are likely to enrich their own knowledge of the subject. Many senior scientists however, value the recognition bestowed on them by being invited to serve on monitoring and evaluation committees.

As part of the current investigation, an effort was made to review the methods and mechanisms employed by the NRS to monitor and evaluate the progress of research. The data summarized in Table 3.6 shows how sectional heads and project leaders have attempted to monitor and evaluate the progress of research projects. The responses clearly indicate that none of the research institutes have a clearly defined mechanism for this activity. It may appear that team leaders opt for different alternative methods to review progress of research. But the more likely inference is that there is no in-built capacity, to set in motion a research monitoring process. Obviously even where monitoring committees or peer evaluation processes operate, the assessments seem to be based on the subjective judgements of the evaluators.

3.4 Quality and Performance

There are many factors that could influence quality and performance in research, and these will undoubtedly be related to the nature of problems to be addressed and the approach employed to achieve the prescribed goals.

It is well known that the relevance and importance of a research finding in the national context gives no guarantee for its acceptance by an international journal for publication. International journals generally tend to accept work that have a regional or global significance, or work that is of a fundamental character. Although in the past, higher recognition was given to work that had been published in a reputed international journal, today there is a visible trend to give equal or even higher weightage to scientific work that have a significant bearing on a national issue. Here therefore, a quality judgement is made on the basis of relevance of research findings to a national problem, rather than to its intrinsic scientific elegance.

There are other measures for quality assessment. These included methods for quantifying a research achievement in terms of its social significance, its potential impact, its expected monetary returns, and in some cases, its expectation in influencing market trends, eg. in assuming a role in import substitution or import competition.

Generally quality assessments could be done by one of the following methods;

(a) by reference to a peer for a peer evaluation
(b) By reference to a special evaluation committee
(c) By computing the volume and usefulness of the published material
(d) By use of cost-benefit evaluation or impact assessment techniques

Table 3.6 - Methods Adopted by Team Leaders of the NRS to Monitor Progress of Research Projects(field survey 1992 -1993)

Criteria		Agricultural Research*		Medical and Veterinary Research**		Industrial and construction Research***		
		Responding team leaders	As per-cent age of total (87)	Responding team leaders	As per-cent age of total (19)	Responding team leaders	As per-cent age of total (29)	Overall Percentage
1.	Use of check list	14	16.1	4	21.1	4	13.8	17.0
2.	Use of a point system	1	1.2	0	0	2	6.9	2.7
3.	Rank order score	3	3.5	1	5.3	1	3.5	4.1
4.	Reference to evaluating committees or referees	25	28.7	6	31.6	9	31.0	30.4
5.	By no. of scientific publications and communications	21	24.1	4	21.1	8	27.6	24.3
6.	Combination of above methods	25	28.7	3	15.8	11	37.9	27.5
7.	Others	28	32.2	6	31.6	14	48.3	37.4

* - CRI, TRI, RRI, CARI, RARC (Bombuwela), RBRS & ARTI
** - MRI & VRI
*** - CISIR & NBRO

Note : Figures in paranthesis give the total number of team leaders responding.

When a research output had led to a new product or process technology, then it could be subjected to an appropriately modified "Absolute Efficiency Test", as set out by the United Nations Industrial Development Organization (UNIDO) for development projects (81, 82). A test case in the use of such a modified procedure in evaluating an inter-country collaborative R & D programme has been reported (83).

On the other hand performance in research can be assessed in terms of adequacy and expediency in dealing with a research problem, by an evaluation of achievements against a specified time frame. Thus for example, it may be possible to measure the rate and volume of technology generated to meet an identified goal. Generally such measurements in research are rare. One has also to give consideration to the fact that the final outcome of research can take either a positive or negative turn in the testing of a scientific hypothesis, in which case either result is equally significant.

A good example of adequacy and expediency in research performance is the development of the new improved varieties (NIV) of rice in the 1970's which rapidly replaced the old improved varieties (OIV), virtually meeting the targets of production anticipated by the Government in its investment plans for the period. The technology developed during the period 1960 to about 1975 to increase rice production, has been widely considered as gratifyingly adequate (84). However, since then the national rice production average (and yields per ha) has levelled out and remained stagnant, considered to be partly due to the slowing down in the rate of technology generation in rice. These observations have led to the inference that the rate of technology generation in this field had been inadequate during this period (84).

In the field survey that was carried out, an attempt was made to determine the conditions promoting good quality work in the NRS. The data summarized in Table 3.7 indicates how the team leaders perceived this problem. There is some degree of consistency in the observations of the team leaders in all disciplines with 35 percent agreeing that persuasive advice and guidance was a significant approach, and 22 percent agreeing that providing good facilities was a condition for promoting good quality work. Surprisingly, awards, honours and promotions as well as provision of regular training opportunities did not figure prominently in these team leaders perception of conditions conducive for good quality work.

In order to investigate this point further, the survey sought to determine the causes that limit researchers from giving their best. Table 3.8 shows how research leaders perceived of the constraints that limit good performances by researchers. It is unfortunate that despite of an assurance that strict confidentiality will be maintained in this field survey, only about 45 percent of the sample population responded to this particular question. The data here seems to indicate that a diversity of issues are responsible for incapacitating researchers from doing what they possibly could do better. One may note here that domestic problems and lack of motivation have figured prominently as causative factors, both of which are possibly not of any concern in developed countries.

Finally the field study directed its attention to enumerate the success rate of research efforts. Table 3.9 shows the level of success in carrying out research activities in the respective institutions.

Table 3.7 Team Leaders Perception of Conditions Promoting Good Quality Research. Weightage for marks given by respondents - expressed as percentages (field survey 1992 - 1993)

	Criteria	Agricultural Research* (17)	Medical & Veterinary Research ** (18)	Industiral & Construction Research *** (28)	Overall Percentage
1.	Persuasive advice and guidance	37.4	29.0	32.0	32.8
2.	Recommendations for awards, honours & promotions	9.1	7.0	12.0	9.4
3.	Providing best possible facilities	24.3	25.0	18.0	22.4
4.	Providing regular training programmes	7.4	9.5	9.5	8.8
5.	Solving conflicts	3.7	6.0	4.0	4.6
6.	Consideration in respect of social problems	6.6	13.5	6.5	8.9
7.	Promoting curiosity - oriented research	9.1	9.5	9.5	9.4
8.	Others	2.6	0	8.5	3.7

* - CRI, TRI, RRI, CARI, RARC (Bombuwela), RBRS & ARTI
** - MRI & VRI
*** - CISIR & NBRO

Note : Figures in parenthesis give the total number of team leaders responding.

Table 3.8 Team Leaders Perception of Constraints Limiting Performance of Researchers. Weightage for marks given by respondents - expressed as percentages

	Constraints	Agricultural Research * (34)	Medical & Veterinary Research ** (13)	Industrial & Construction Research ***(13)	Overall Percentage
1.	Lack of interest	9.3	6.0	5.5	6.9
2.	Lack of motivation	13.0	5.7	36.0	18.2
3.	Incapacity of some members	5.4	0	5.0	3.5
4.	Not upto required academic level	9.1	10.5	5.0	8.2
5.	Low educational standards	5.0	2.5	0.5	2.7
6.	Dissatisfaction	16.7	7.9	11.0	11.9
7.	Domestic problems	13.0	17.4	21.5	17.3
8.	Lack of rewards and recognition for achievement	10.3	23.2	9.5	14.3
9.	Internal conflicts	3.6	9.7	2.5	5.3
10.	Others	14.0	17.5	3.5	11.7

* - CRI, TRI, RRI, CARI, RARC (Bombuwela), RBRS & ARTI

** - MRI & VRI, *** - CISIR & NBRO

Table 3.9 - The Rate of Success in Meeting Research Targets as seen by Team Leaders. Expressed as weighted sectoral percentages (field survey 1992 - 1993)

Success Rate	Agricultural Research * (79)	Medical and Veterinary Research ***(19)	Industrial and Construction Research*** (27)	Overall Percentage
100 percent	11.2	0	8.4	6.5
75 percent	66.2	47.8	72.3	62
50 Percent	20.0	31.7	19.5	23.7
25 Percent	2.1	5.0	0	2.4
Less than 25 percent	0	15.6	0	5.2

* - CRI, TRI, RRI, CARI, RARC (Bombuwela), RBRS & ARTI
** - MRI & VRI
*** - CISIR & NBRO

Note : Figures in parenthesis give the total number of team leaders responding.

Sixty four percent of the team leaders claim that they have been able to achieve a success rate of 75 percent, while another 22 percent claim a success rate of 50 percent. Thus on the whole it would appear that 86 percent of the team leaders have been able to see a success rate exceeding 50 percent, which by global standards could be considered very satisfactory.

The success of a research project is seen only as a satisfactory completion of the project leading to a new finding. It does not necessarily mean that the final result is a marketable product or process. This is clearly evident from data in Table 2.1 obtained from the same study, which shows the number of inventions, innovations and patents achieved by researchers of the NRS during 1985 & 1989.

3.5 Resume of Findings

In concluding this chapter, the noteworthy observations and issues in the NRS may be summarized as follows:-

* The increasing need to sharpen the focus and intensification of research effort has in recent years induced most research organisations to develop modalities for prioritization of research. This has been clearly evident in the National Agricultural Research System, where elaborate procedures have been employed simultaneously by the Council for Agricultural Research Policy and the major R & D organisations. However, this prioritization effort has been only on a commodity basis, and must proceed deeper down to the critical themes and thrust areas. Such thrust areas will obviously demand team effort and multi-disciplinary approaches, rather than discipline-wise exploratory work meant to increase the body of useful knowledge.

* The field survey has clearly demonstrated the absence of a uniform or clearly defined approach to identification of research projects. Individual preferences and internal consultations within research divisions were the preferred methods for project identification, indicating that research themes were hardly influenced by anyone outside the confines of the division.

* The guiding principles for evaluating a research proposal appear to be its relevance to national priorities and institutional objectives, indicating that the State (or employer) is the major client. The State obviously acts on behalf of an identified public beneficiary (user and consumer), though there is no guarantee that this client is adequately equipped to identify the variety of problems for which solutions and new technologies are sought by such beneficiaries. In fact this has been identified as a major defect in the research planning mechanism of the agricultural research system (84).

* The character of research in the early 1990's shows a striking deviation from the trends seen in the mid 1980's, with the resources devoted by researchers for applied research dropping from 72 percent in 1985 to 60 percent in 1992, and the resources deployed for basic research increasing from 10 percent in 1985 to 20 percent in 1992.

* There was no evidence to indicate that any of the research organisations subjected to this study, had a clearly defined mechanism for monitoring and evaluating the progress of research.

* Although the team leaders had different thoughts on factors promoting good research, there was some constancy across the sectors, with 35 percent agreeing that persuasive advice and guidance was a significant approach, and 22 percent agreeing that providing good facilities was a contributory factor to promoting good quality work. Surprisingly, rewards as well as regular training opportunities did not figure prominently in the team leaders perception of conditions conducive for research.

* The field survey indicated that a diversity of issues affect the performance of researchers, though domestic problems and lack of motivation have been the most important causative factors.

* Finally, despite of a variety of constraints, defects and deficiencies in the NRS, more than 80 percent of the team leaders claimed a success rate of over 50 percent, which by global standard could be considered very satisfactory.

CHAPTER 4

ISSUES AND OPPORTUNITIES FOR WOMEN IN R & D

4.1 The Gender Issues in Science and Technology

The past several decades have witnessed an unprecedented change of attitudes towards gender delineation. This is not because of the fact that even in the traditional sheltered domestic environment, unpaid family work could no longer be ignored, but because of the recognition, that given equal opportunities, women could be equal to or even more productive than men, at least in certain spheres of economic activities. There is no doubt that the main thrust towards gender equality stems from the change in the educational opportunities world over. Sri Lanka in particular may be considered a leader in this paradigm of change, resulting from the far-sighted and revolutionary educational reforms introduced during the early phase of the post-colonial period. In fact by the 1980's, almost four decades after the introduction of free education, school enrollment increased by 300 percent; in the wake of which science education also took a foothold in rural Sri Lanka.

It is significant to note that female literacy rate increased from 67.3 percent in 1963 to 86.2 percent in 1996, and currently about half of the school going population is female.

However it has been pointed out that more girls opt for social sciences, and more boys for the hard sciences (85). There is no specific evidence to indicate that this disparity is by compulsion. Yet as has been pointed out, the phenomenon of "gender role stereotyping", that is quite obvious in the curricula of secondary schools, where feminine-type subjects such as home economics, needlework, weaving etc., are reserved for girls, while carpentry, woodwork, metal work etc. are reserved for boys, tends to promote the choice of such disciplines (85). Fashioning the thought process in this manner also tends to sustain the socio-cultural inhibitions, preventing young women from breaking away from traditional vocations.

Sri Lanka has however, a unique record in gender equality. In fact it stands well above most South Asian countries, and can be considered a trail blazer in some fields.

There are however, a few obvious short falls in gender equality, and this is in the manual wage labour, where female workers are paid lesser wages than their male counterparts.

Although better educational opportunities and increasing literacy rates have provided leverage towards gender equality, a more fundamental issue may be the conviction and the overriding influence of the revered teachings of religious leaders. The philosophy of Buddhism, adhered to by a majority of the people of Sri Lanka however, takes great pride in the emancipation of women, and in fact, themes such as maternal love and the dignity of womanhood continues to be popular topics in religious discussions and discourses.

It is significant to note that the year 1920, marked the entry of women to scientific professions, with medical education taking the lead and opening the doors for woman professionals in this field. The first woman science graduate is said to have qualified from the then University of

Ceylon in 1945, and the first woman engineer had qualified in 1958 (86). The changing dimension of women in tertiary education is evident from the fact that University enrollments for science, medicine, engineering, architecture, and agriculture increased from 350 (30.76 percent) during 1975-1976 to 861 (35.77 percent) during 1985 - 1986, and to 1408 (34.67 percent) during 1994 - 1995.

4.2 A Field Study of Women in Research

As an important appendage to the study on constraints to research, a parallel field investigation was initiated to examine the gender issues concerning professionals involved in scientific research. It was projected to be an Island-wide investigation of women in scientific research, with population and other baseline data drawn from a human resource database developed at NARESA in 1990. The database contained information on approximately 80 percent of persons involved in fulltime as well as part-time research in Sri Lanka, outside the North-East troubled zone. The database also did not include the small number of researchers attached to private sector organizations.

The NARESA database provided the basic information necessary to identify a suitable sample. Any missing data were obtained either by contacting the respective heads of divisions, or from the annual reports. Accordingly 170 female scientists comprising approximately 50 percent of the population of women researchers, and representing the major disciplines, were selected for the field survey. The study was limited to researchers in hard sciences and comprised essentially of those associated with bench research.

A questionnaire which had a pre-survey pilot test run and amended subsequently, was administered to this sample. However, despite much effort by the survey team, only 102 (or 60 percent) of these researchers responded to the questionnaire. The questionnaire consisted of 19 questions, which could be grouped into about four categories. The first lot of four questions were meant to obtain the civil and professional status of the respondents. The second set of four questions provided information on the working environment, while the third set of four questions sought to determine the professional qualities and occupational constraints faced by women researchers. The next set of five questions focussed on gender-specific hazards faced by female researchers engaged in full time or part time research, and finally the last question was meant to get an indication of their productivity in the profession.

The data in table 4.1 summarizes the professional and civil status of respondents in the sample. At a first glance it is clear that within this sample of female researchers, 35 percent were in the field of agriculture, 29 percent in the field of medical and veterinary sciences, 21 percent were in natural sciences, and 7 percent in marine and freshwater biology. The data also shows that about 25 percent of researchers in the sample were senior scientists, functioning either as heads of departments or as university professors. The others were at the middle management level. There were no obvious differences amongst the major discipline groups. It may be noted that except in the medical and veterinary sciences sector, where about 60 percent of the researchers had male bosses, in the other subject areas, generally over 80 percent of the women had male supervisors. It is presumed that with increasing numbers of young females entering the medical and veterinary professions, correspondingly increasing numbers appear to opt for research careers, and consequently an increasing number reach the top positions in research.

Table 4.2 shows the frequency distribution of the sample of researchers in respect of age and discipline. It is inevitable that a third of the sample comprises researchers in agricultural sciences. More than 55 percent of the women researchers in the sample are in the age group 30 to 40 years.

Table 4.3 shows the methods employed by women researchers in selecting research projects in different disciplines. Here one sees a significant deviation from the views expressed by sectional heads (see Table 3.3). While over 50 percent of women researchers claimed that research programmes are prepared by themselves, only about 30 percent of sectional heads claimed that research projects are prepared by themselves. Again only 9 percent of sectional heads as against 33 percent of women researchers agree that research projects are decided by higher authorities.

Table 4.4 gives the indicative criteria for selection of research projects by women researchers. The views expressed by these researchers correspond reasonably closely with views expressed by sectional heads (see table 3.4), with the majority agreeing that the determining factor for the choice of research themes, was the relevance to objectives of the research station. This again highlights the conceptual fallacy of the State acting as client, staking a claim to represent the true voice of the farmer or the user of the research findings.

The data summarized in Tables 4.5 and 4.6 analyses the constraints and impediments faced by female researchers in their working environment. The data in Table 4.5 shows how external inhibitions have affected the work norms of these researchers. Within all disciplines, the most pressing issue had been the inadequacy of facilities for research. A similar observation was seen in the study involving sectional heads and project leaders as illustrated by the data given in Table 3.7.

Strangely researchers in the field of agricultural sciences concur with this view, despite of the fact that a massive World Bank funded project (Agricultural Research Project), designed to strengthen the physical and human resource capability in agricultural research had been in operation since early 1986. Obviously the Agricultural Research Project (ARP) has not been able to meet its targeted objectives of satisfying the scientists, technical and social needs, for which it was partially designed. An Interim Review of the project by the World Bank in mid 1994, pinpoints the conceptual and operational defects of the ARP, which have contributed to its poor impact in enhancing research capability in the agricultural sector(87).

Other constraints include domestic problems, and the absence of recognition and rewards for work.

Data in Table 4.6 shows how personality issues and sour human relations can affect the research environment of female scientists.

It is a common observation that in the case of working women, the social background and status of the employee, or that of her husband tends to draw reactions from fellow workers. For instance, if the husband is a prominent politician or a high official, there tends to be an over-awed reaction from her fellow workers. This reaction can have a facilitating or a debilitating effect both mentally and physically.

Although in case of women scientists too this phenomenon is seen, the effect is not as marked as one would expect. This may be partly because of their wider exposure in society, and partly because of their higher intellectual capacity to understand and cope up with human conflicts and relationships.

It is also significant that women scientists associated with bench research, are not only the least concerned about working long hours, but also face no serious objections from their husbands, although family commitments seem to affect them to some degree. Obviously, it reflects the common understanding that scientific research especially experimental research, cannot be confined to the usual fixed working hours.

In relation to overnight stays too, female researchers find no constraints or inhibitions, though most of them find family bonds and responsibilities too important to be ignored.

The survey also sought to find out whether sex discrimination existed in their profession. The initial response indicated that only about a third of the population subjected to this study had experienced sex discrimination in their working environment.

Table 4.7 shows the frequency distribution and type of discrimination alleged to have been faced by those researchers who have experienced sex discrimination. In all disciplines, the researchers complaining of sex discrimination, have found the behaviour pattern of the opposite sex often objectionable.

It has to be realized however, that complaints of sex discrimination can sometimes turn out to be illusive thinking or even caused by psychological conditions. In such cirumstances any action by the opposite sex, whether in good faith or otherwise, could be construed to reflect sex discrimination.

Thus for instance, a project leader for genuine safety reasons, may prefer to offer a field visit to a male researcher instead of a female researcher. The latter within her own perception may sometimes resent such a decision, and construe the project leader's action as unwarranted. Since such possibilities are likely to occur, complaints of sex discrimination must be viewed with sympathy and caution.

Finally, how does one rate the productivity and performance of female researchers, in relation to their fields of research? The Survey on Women in Research and Development, sought to examine this aspect purely from the point of view of the relative outputs of research papers, during the course of their research careers. The research publications were classified into three categories, namely, (a) papers published in journals, (b) short communications, and (c) unpublished or published reports.

Summarized data in respect of each category are presented in Tables 4.8 (a), 4.8 (b), and 4.8 (c).

The data in Table 4.8 (a) provides information on the output of research publications in relation to age class and scientific discipline. This data indicate that scientists in aquatic biology were the most productive, accounting for nearly 11 papers per researcher. Agricultural sciences, industry and natural sciences come next in that order of importance. Another significant relationship is the influence of age on productivity. The frequency distribution shows that the most productive period in the career of a female researcher is during 26 to 30 years of age, when on an average, each researcher has been able to account for nearly 15 publications. This productivity rate decreases progressively upto the 45th year of age, after which there is a sharp drop until the age of retirement (55 years). The latter observation however, must be viewed with caution, as the sample of those over 51 years of age was not only small in size, but also represented only one discipline (medical and veterinary sciences).

The data summarized in Table 4.8 (b) provides information on the output of communications by female researchers in relation to age class and scientific discipline. It is clear that the output of communications in relation to disciplines follow the same pattern as for scientific publications, with researchers in aquatic biology being the most productive. The effect of age on productivity also showed a similar trend in respect of those under 50 years of age. Here again reflecting the limitations discussed in the previous paragraph, the small sample of scientists in the over 50 years age class had shown pronounced productivity in their scientific discipline. The data summarized in Table 4.8 (c) on the output of scientific reports by female researchers, follow a similar pattern to those of the two previous tables, although the productivity of researchers in aquatic biology is even more pronounced here. The relationship between age of researchers and research output again follows a trend similar to those in the two previous sets of data.

In general it can be said that regardless of the type of written material produced by women scientists as research outputs, the productivity trends follow a similar trend with scientists in aquatic biology being the most productive, and the newer recruits (i.e. those under 30 years of age) being more productive than their older colleagues.

In summarizing the findings of the Survey on Women in Research, the following observations are reported:

* Although it was planned to employ a sample size of approximately 50 percent of the population of women researchers in all disciplines of the hard sciences, the overall response was only a little more than 25 percent of the population. The sample however, was representative of a cross section of the major discipline classes (viz Agriculture, Medical and Veterinary, Natural Sciences, Marine and Freshwater Biology and Industry).

* 25 percent of the sample were senior scientists, others were at the middle management level. Except in the medical and veterinary sciences, where about 60 percent had male

supervisors, in all other disciplines, over 80 percent of female researchers had male superiors. Over 55 percent of this sample of researchers were in the 30 to 40 years age group.

* Over 50 percent of these scientists claimed that research programmes were prepared by themselves, and only 33 percent said that research programmes were decided by higher authorities.

* Majority of researchers agreed with the view that the determinant factors for the selection of research programmes were the specified objectives of the organisation and the development objectives of the State. Only a few claimed that the needs of the farmer or of the user of technology had an overriding effect on officially proclaimed objectives.

* One-third of the researchers found that lack of facilities was a major factor inhibiting research performance. The agricultural sector which benefitted from a massive World Bank funded project to enhance physical and institutional capability, also continued to be plagued by this deficiency. Female researchers were also affected by domestic burdens, and a lack of appreciation and rewards for their contributions.

* Personality issues, including the standing of their spouses or parents, which tends to affect the working environment, especially of women in general, did not figure prominently as a matter of much concern among women scientists. This observation is attributed partly to their wider exposure in society, and partly to the higher intellectual capacity to understand and cope up with diverse human relationships.

* Women researchers also generally had no major difficulties in working long hours and staying overnight for research related activities. This reflects the greater understanding of the professional demands of female researchers, by their spouses and parents.

* About a third of the researchers claimed some form of harassment, which was attributed to sex discrimination.

* Finally the productivity of women researchers as measured by various categories of publications, show firstly that researchers in aquatic biology were consistently the most productive. Secondly, among age classes, the age group of 26 to 30 years had been the most productive recording on average of about 15 research papers in journals, 8.5 communications, and nearly 7 reports (which may or may not be published documents), per researcher.

Table 4.1 - Professional and Civil Status of a Sample of Women Researchers in the NRS (Number of respondents 101)

	Dept/Sectional Heads[1]	O.I.C./ Professors[1]	Snr Research Off./Snr Lecturers[1]	Research Officer/ Lecturers[1]	Number Married[2]	Researchers With Children[2]	Women Researchers with Male Bosses[2]
Agricultural Sciences (35)	7	1	13	14	82	74	94
Medical & Veterinary Sciences (29)	8	2	5	14	83	66	59
Natural Sciences (21)	3	1	13	4	81	71	90
Marine & Fresh Water Biology (7)	1	-	2	4	86	86	71
Industry (9)	2	2	3	2	78	67	88
Overall Percentage	21	6	36	38	82	73	80

1. Figures given are the actual numbers.
2. Figures expressed as percentages.

Note: Figures in parentheses are the number of respondents

Table 4.2 - Distribution of Women Researchers by Age Group and Discipline (Sample responding 98)

Age Group(Yrs)	Agricultural Sciences	Medical & Vet Sc.	Natural Sciences	Aquatic Biology	Industry	Total
26-30	2	7	1	1	0	11
31-35	8	7	7	2	2	26
36-40	9	6	8	2	4	29
41-45	11	2	2	1	3	19
46-50	3	4	2	1	0	10
Over 51	0	2	1	0	0	3
Total	33	28	21	7	9	98

Table 4.3 - Methods of Selecting Research Projects by Women Researchers (Overall trends within disciplines expressed as percentages) (Sample responding 99)

	Agric. Sc. (35)	Medical & Vet Sc. (29)	Natural Sc. (21)	Aquatic Biology (7)	Industry (17)	Overall Average
Prepare ones own programme	46	34	90	43	57	54
As directed by higher authorities	29	34	-	43	29	33
By discussion with colleagues	14	28	10	14	14	16
Others	12	-	-	-	-	12

Note: Figures in paranthesis give the number of researchers responding.

Table 4.4 - Criteria for Selection of Research Projects by Women Researchers (Weightage as overall percentage of marks given by respondents)(Sample responding 63)

Criteria	Agric. Sc. (20)	Medical & Vet Sc. (23)	Natural Sc. (9)	Aquatic Biology (6)	Industry (6)	Overall
Relevance to objectives	45	45	49	51	29	44
Duration of project	9	4	-	3	4	4
Time constraints and working hours	3	1	7	5	3	5
Technical feasibility	25	24	24	33	50	31
Nature of work involved (eg Lab vs field)	8	10	5	2	2	5
Personnel involved in the project	5	9	-	1	5	4
Short gestation period	-	-	-	1	4	-
Social factors	-	-	-	-	-	-
Others	3	-	-	-	-	-

Note: Figures in paranthesis indicate the actual number of researchers responding.

Table 4.5 Factors Inhibiting Research Performances of Women Researchers (Weighted overall percentage of marks given by respondents)(Number of respondents 75)

Type of problem	Agric. Sc. (25)	Medical & Vet. Sc. (27)	Natural Sc. (12)	Aquatic Biology (5)	Industry (6)	Overall %
No constraints	21	18	14	3	35	18
Non co-operation of supervisors	8	6	-	4	4	4
Non co-operation of colleagues	3	4	-	-	2	2
Non co-operation of subordinate staff	3	4	1	-	-	1
Domestic problems	7	14	15	40	13	18
Internal conflicts	8	2	6	-	8	5
Inhibitions due to religious beliefs	2	-	-	-	-	-
Social restrictions	-	4	-	-	-	1
Non availability of facilities	31	34	40	28	33	33
Non-recognition and non rewarding nature of work	6	8	10	22	5	12
Dissatisfaction	7	3	-	1	-	2
Sex discrimination	-	3	2	-	-	1
Others	-	-	11	-	-	2

Note: Figures in parenthesis give the number of researchers responding.

Table 4.6 Impediments Affecting Working Environment of Women Researchers

Type of Constraint	Agric. Sc. (31)	Medical & Vet. Sc. (24)	Natural Sc. (14)	Aquatic Biology (8)	Industry (9)
1. Social background of researchers affecting fellow workers*	17	28	24	14	-
2. Social background of parents/husbands of researchers* affecting attitudes of fellow workers	9	28	14	-	-
3. Social background of parents/husbands affecting ones own performance*	9	21	14	14	-
4. Researchers who have no problem in working after/long hours**	41	42	50	20	25
5. Family commitments preventing working after/long hours**	37	37	26	59	33
6. Inadequacy of transport facilities preventing working after/long hours**	12	21	11	14	23
7. Isolation and loneliness preventing working after/long hours**	8	14	14	7	9
8. No objections for overnight stay during out-door work**	45	44	52	45	68
9. Objections by parents/guardians/warden for overnight stays**	4	12	3	7	5
10. Objections by spouse for overnight stay**	1	7	-	-	-
11. Personal dislike for overnight stays due to social inhibitions**	5	10	-	7	4
12. Personal dislike for overnight stays due to family commitments**	35	25	48	36	23

Note: Figures in parenthesis give the number of researchers responding.
* Data given in rows 1 to 3 shows the number responding as a percentage of the total number responding.
** Data in rows 4 to 12 represent weighted overall percentages of marks given by respondents.

Table 4.7- Instances where Sex Discrimination has been Experienced by Female Researchers (Frequency and type of discrimination)

Type of Discrimination	Agric. Sc. (13)	Medical & Vet. Sc. (13)	Natural Sc. (8)	Aquatic Biology (2)	Industry (1)
Promotions or filling of vacancies	6	6	2	-	-
Training programmes,foreign and local	6	3	3	1	1
Assignment of tasks	8	7	4	1	-
Behaviour of colleagues/ subordinates/superiors	7	13	6	2	1

Figures in parenthesis give the number of researchers who have experienced discrimination.

Table 4.8(a) - Number of Publications by Age Group and Discipline (upto end of 1991)

Age Group(yrs)	Agricultural Sciences	Med.& Vet. Sciences	Natural Sciences	Aquatic Biology	Industry	Total	Per Researcher
26 - 30	74	32	37	17	0	160	14.6
31 - 35	80	39	41	19	8	187	7.2
36 - 40	61	15	29	31	26	162	5.6
41 - 45	35	11	18	6	24	94	5.0
46 - 50	4	5	3	3	0	15	1.5
Over 51	0	5	0	0	0	5	0.6
Total	254	107	128	76	58	623	
Per Researcher	7.7	3.8	6.1	10.9	6.4		

Table 4.8(b) - Number of Communications by Age Group and Discipline (upto end of 1991)

Age Group(yrs)	Agricultural Sciences	Med.& Vet. Sciences	Natural Sciences	Aquatic Biology	Industry	Total	Per Researcher
26 - 30	39	31	15	8	0	93	8.5
31 - 35	38	45	19	22	12	136	5.2
36 - 40	37	10	28	19	23	117	4.0
41 - 45	5	9	5	5	14	38	2.0
46 - 50	0	5	1	0	0	6	0.6
Over 51	0	23	0	0	0	23	7.7
Total	119	123	68	54	49	413	
Per Researcher	3.6	4.4	3.2	7.7	5.4		

Table 4.8(c) - Number of Reports by Age Group and Discipline (upto end of 1991)

Age Group(yrs)	Agricultural Sciences	Med.& Vet. Sciences	Natural Sciences	Aquatic Biology	Industry	Total	Per Researcher
26 - 30	49	4	8	14	0	75	6.8
31 - 35	46	9	12	23	4	94	3.6
36 - 40	39	5	11	32	12	99	3.4
41 - 45	5	5	0	17	11	38	2.0
46 - 50	0	1	1	2	0	4	0.4
Over 51	0	4	0	0	0	4	1.3
Total	139	28	32	88	27	314	
Per Researcher	4.2	1.0	1.5	12.6	3.0		

CHAPTER 5

RESOURCE STRUCTURE OF THE NATIONAL RESEARCH SYSTEM

5.1 Constituents of the National Research System (NRS)

The historical process for institutionalisation of scientific research in Ṣri Lanka has been dealt with in the introductory chapter of this treatise. This study deals almost exclusively with constraints and issues concerning disciplines in hard sciences. Therefore only casual references have been made to research activities in other disciplines, such as sociology, anthropology, economics etc. The current institutional network of the National Research System (NRS) of Sri Lanka could be broadly set out in the following manner:

[A] The National Agricultural Research System (NARS)

(i) ***Non-plantation crop sector***

- Commodity research institutes, regional agricultural research and development centres and the supporting centres of the Department of Agriculture.
- Department of Export Agriculture

(ii) ***Plantation crop sector***

- Tea Research Institute
- Rubber Research Institute
- Coconut Research Institute
- Sugarcane Research Institute

(iii) ***Marine, coastal and freshwater resources***

- National Aquatic Resources Research and Development Agency
- Bio-science departments of the universities
- Fisheries Biology Division of the University of Ruhuna.

(iv) ***Veterinary and animal sciences sector***

- Veterinary Research Institute
- Faculty of Veterinary Science and Animal Health of the University of Peradeniya
- Agriculture faculties of universities

(v) ***Forestry sector***

- Research Division of the Forest Department
- Bio-science departments of the Universities of Colombo, Peradeniya and the Open University.

(vi) ***Academic sector***

- Agriculture and bio-science faculties of universities
- Postgraduate Institute of Agriculture.

(vii) ***Others***

- Hector Kobbekaduwa Agrarian Research and Training Institute
- Farm Mechanisation Research Centre
- Institute of Fundamental Studies
- Food Technology Research Centre

[B] Industrial and Technological Research System

- Ceylon Institute of Scientific and Industrial Research
- National Engineering Research and Development Centre
- National Building Research Organisation
- Rubber Research Institute
- University of Moratuwa
- Engineering Faculty of the University of Peradeniya

[C] Natural Products Research System

- Bandaranayake Memorial Ayurvedic Research Institute
- Chemistry and bio-science departments of universities
- Ceylon Institute of Scientific and Industrial Research
- Institute of Indigenous Medicine
- Medical Research Institute

[D] Medical Research System

- Medical Research Institute
- Medical faculties of universities

[E] Frontier Science Research System

- Institute of Fundamental Studies
- Arthur C. Clarke Centre for Modern Technologies
- Universities

Aside of this main network of public sector research organisations, where bench research - or research in hard science disciplines are undertaken, there are a number of in-house research units within the state-run statutory organisations, and in some of the large private sector business enterprises. Although public sector research is largely funded by the government's consolidated fund, supplementary funding is also provided by the Natural Resources, Energy and Science Authority (NARESA), the Council for Agricultural Research Policy (CARP) and the Atomic Energy Authority (AEA), through assistance received from local and foreign sources. Limited support has also been made available for very specific research projects by the Export

Development Board. A small non-profit making voluntary organisation known as "Vidyartha" - The Centre for Science, Technology and Social Change, has disbursed small grants for themes on philosophy of science.

5.2 The Organisation of the National Agricultural Research System

The National Agricultural Research System is the largest research network in the country. This is clearly evident from the large number of constituents participating in this network. As will be evident later more than 50 percent of all resources deployed in the National Research System are directed towards NARS. Therefore, an understanding of its complex organisational features is important, and warrants a special place in any review of research in Sri Lanka. The discussion that follows focuses on the structural features of mandated institutes of NARS.

Non-plantation Crop Research

Within the NARS, the Department of Agriculture (DOA) has the widest web of research units, and thus has a pivotal role to play.

During the evolutionary process in the development of the DOA, there was a realisation in the 1960's, that a strong indigenous research culture should be built and nurtured to enable the Department to respond to the needs of domestic agriculture. The need to cater to the regional requirements in agriculture, led to the decentralisation of the research thrust into eight agro-ecological zones, classified on the basis of elevation, topography, rainfall, temperature and soils (88). These zones were served by 8 Regional Agricultural Research Centres (RARC), each of which was also supported by several outreach experimental stations. By 1976, through the early work on soil classes, and the subsequent studies on rainfall probability confidence limits in relation to moisture demands of crops, further refinements were made in the classification of zones (88). These studies led to the identification and mapping out of 24 new agro-ecological zones. Most of these new zones are now served by smaller Agricultural Research Stations (ARS).

Thus the infrastructural base up to 1977 comprised eight Regional Agricultural Research Centres (RARC) situated at Peradeniya, Maha Illuppallama, Karadiyan Aru, Angunakolapelessa, Bandarawela, Makandura, Bombuwela and Kilinochchi. In addition to these were the three specialized units, the Central Rice Breeding Station, Batalagoda, the Farm Mechanization Research Centre, Maha Illuppallama and the Land and Water Management Research Centre, Peradeniya. To these main centres 18 peripheral experimental stations (ARS) were attached.

After 1977 some significant institutional changes were introduced. These included the addition of the Plant Genetic Resources Centre, the Aralaganwila RARC to cater to irrigated agriculture in systems B and C of the Mahaweli Diversion Programme, and the Adaptive Research Service comprising 24 Adaptive Research Units (ARU) for conducting on-farm trials.

The progressive enhancing of infrastructural needs was obviously necessary to meet the new challenges in irrigated and rain-fed agricultural systems in the emerging scene for high productivity and profitability.

As a result of these developments, an institutional framework for scientific research as illustrated in Figure 5.1 came into existence in the DOA by the mid 1980's.

Figure 5.1 Organisational Structure of the Research Division of the Department of Agriculture upto December 1993

Director of Agriculture

Research Division

Plant Genetic Resources Centre ⟷ Central Rice Breeding Station, Batalagoda

Land and Water Management Research Centre, Peradeniya ⟷ Farm Mechanization Research Centre, Maha Illuppallama

RARC's

RARC's	ARS	ARU's
- Kilinochchi →	Thirunelveli Paranthan Murunkan →	Kilinochchi, Mannar Vavuniya, Thirunelveli Mulaitivu
- Maha Illuppallama →		Anuradhapura Polonnaruwa
- Karadian Aru →		Batticaloa Malwatta Kantalai
- Angunakolapelessa →	Ambalantota →	Telijjawila Ambalantota
- Bandarawela →	Sita Eliya Rahangala Bibile Moneragala →	Sita Eliya Rahangala Nuwara Eliya Moneragala
- Makandura →	Vanthavillu Kalpitiya →	Walpita Wariyapola Tabbowa
- Bombuwela →	Bentota Labuduwa →	Kalutara Homagama Labuduwa

| - Peradeniya → Pussellawa → Wagolla
                                                   Kundasale
| - Aralaganwila → Girandurukotte

This centrally managed organisational structure remained intact till December 1993. It was however, recognised that this hierarchical research management and implementation framework had several drawbacks of which the following were considered to be the most serious:

(a) The discreet manner in which the technical divisions were structured left little room for an integrated approach to realize an end product in research.

(b) Segregation of research, technology transfer, economics and plant protection, seeking top-down approach to packaging of technologies tended to attain unrealistic goals.

(c) The technology generation and dissemination process being disjointed, failed to bring home a holistic answer to the problems of the clients.

(d) In the absence of a direct link between researcher and his client, there was no guarantee that the problems of the latter were heard in the true perspective by the researcher.

(e) The rigidity with which the hierarchical links functioned within the DOA, left no room for the researcher to respond to direct requests from growers.

Accordingly, effective from first January 1994 a major shake-up of the DOA was carried out, resulting in a partial decentralization of the technical, administrative and financial functions, together with a divestiture of research mandate in three commodity centred research institutes. In this process, the Central Agricultural Research Institute at Peradeniya was assigned the R and D responsibilities in respect of fruit crops, vegetables, root and tuber crops, ornamental plants and plants of medicinal value, and redesignated as the Horticultural Research and Development Institute (HORDI). The Regional Research Centre at Maha Illuppallama was assigned the R and D responsibility for other field crops, comprising condiments, coarse grains, grain legumes and oil seeds, and was named the Field Crops Research and Development Institute (FCRDI), and the Central Rice Breeding Station at Batalagoda was assigned the totality of R and D work on rice, and re-named Rice Research and Development Institute (RRDI).

Each of these three institutes was headed by a director, and assisted by two deputy directors ; one for research and the other for extension. These institutes were also assigned one or more Regional Agricultural Research Centres, re-named as Regional Agricultural Research and Development Centres (RARDCs), as well as a number of experimental sub-stations (ARS) and adaptive research units (ARU). The main institutes were semi-autonomous in their technical functions. The regional research facilities as well as their smaller sub-stations maintained line administrative responsibilities with their respective commodity research institutes, and were also very often linked laterally on technical matters to other research stations, in order to serve regional needs.

The organisational arrangements for the three commodity research institutes which came into existence in January 1994 may be set out as in Figure 5.2.

Figure 5.2 Organisational Structures of the Three Research Institutes of the Department of Agriculture during January 1994 to December 1995

[A] **HORDI**

Head Office, Peradeniya

- RARDC Makandura
  - Kalpitiya ARS
  - Vanathavillu ARS
  - Wariyapola ARU
  - Tabbowa ARS
  - Inginimitiya ARU
  - Walpita ARU
  - Walpita Farm
- RARDC Bandarawela
  - Nuwara Eliya ARS
  - Rahangala ARS
  - Moneragala ARS
  - Bibile ARU
  - Bibile Farm
  - Muthukandiya ARU
  - Pallekelle ARU
- Others
  - Gannoruwa Unit 11 Farm
  - Wagolla ARU
  - Eraminigolla ARS
  - Tibbotumulla ARU
  - Ambatenna ARU
  - Kundasale ARU

[B] **FCRDI**

Head Office; Maha Illuppallama

- RARDC Angunakolapelessa
  - Weerawila ARS
- RARDC Aralaganwila
  - Girandurukotte ARS
- RARDC Kilinochchi
  - Kilinochchi ARS
  - Thinnevely ARS
- Others
  - Anuradhapura ARU
  - Polonnaruwa ARU

[C] **RRDI**

Head Office, Batalagoda

- RARDC - Bombuwela
  - Bentota ARS
  - Labuduwa ARS
  - Pelmadulla ARS
  - Homagama ARU
  - Horana Farm
- Others
  - Ambalantota ARS
  - Telijjawila ARS
  - Paranthan ARS

How has this re-structuring process of the DOA affected the overall research environment and performance? An operation of this magnitude would obviously necessitate a comprehensive situation analysis of issues, constraints and opportunities, and an implementation strategy for the proposed plan of action. Except for a few consultancy reports there was no evidence of such pre-planning investigations. Several studies undertaken under the auspicies of the Council for Agricultural Research Policy (CARP), indicated that this strategic mission was almost devoid of a vision or a goal(84,87).

The initiative and urgency for the re-organisation was undoubtedly the repeated failures of research to salvage an ailing farming community. The urgency for action has been generally considered to be purely political expediency in the context of an on-coming parliamentary election.

The situation that resulted from this restructuring activity is clearly evident from the following references made in a study undertaken by CARP, with World Bank assistance, a few months after the first changes were effected.

"Although it seems too early to comment on the adequacy of the new approaches to eliminate these shortcomings (of DOA), it was perfectly clear that 10 months after the re-structuring initiative, the research and extension processes seem to be in a state of disarray " (84).

The report then goes on to state:

"We have to observe that the research institutes are at this moment characterized by a sense of bewilderment - some researchers are visibly happy, others confused or dispirited. In part this is the consequence of the re-structuring of the DOA which has been undertaken this year. It has given the three DOA institutes that we examined an independence of function without an independence of circumstances. The dismantling and re-assembling have been only partial, and the institutions suffer from the confusion of a dual orientation" (84).

The disorganisation that resulted from the re-organisation process evidently now needed a second hard look. This however, had to await the outcome of the parliamentary and other elections,that were scheduled for 1994. The new government that was installed needed adequate time to review the complex situation, and during this period several interim adjustments had to be made which included a partial decentralisation of accounting functions, and restoring to some extent, the link between research and extension. Finally on 1st January 1996 a new organisational framework came into existence in which the entire network of research units of DOA was reconstituted into 9 decentralized semi-autonomous stations, comprising the 3 original research and development institutes (HORDI, RRDI, FCRDI) and the six RARDC's which now assume a new identity. The organisation of the research network of the Department of Agriculture as of 1st January 1996 can be depicted as in Figure 5.3. That in fact was the situation at the time this study was concluded.

Figure 5.3 Organisational Structures of Institutes of the Department of Agriculture after January 1996

[A] Horticultural Research and Development Institute (HORDI)

Head Office: Gannoruwa

- ARU
  - Kundasale
  - Matale
  - Wagolla
- Horticultural farms
  - Eraminigolla
  - Ambatenna

[B] Rice Research and Development Institute (RRDI)

Head Office: Batalagoda

ARS

- Ambalantota Paddy Research Station

[C] Field Crops Research and Development Institute (FCRDI)

Head Office: Maha Illuppallama

- ARS
  - Anuradhapura
- ARU
  - Polonnaruwa

[D] Regional Agricultural Research and Development Centre, Angunukolapelessa

Head Office : Angunukolapelessa Research Centre

- ARU
  - Telijjiawila
  - Weerawila
- Reserach Farm
  - Weerapana

[E] Regional Agricultural Research and Development Centre, Aralaganwila

Head Office : Aralaganwila Research Centre

ARS

- Girandurukotte

[F] Regional Agricultural Research and Development Centre, Bandarawela

Head Office : Bandarawela Research Centre

ARS
- Rahangala
- Sita Eliya
- Bibile
- Moneragala

ARU
- Muthukandiya

[G] Regional Agricultural Research and Development Centre, Bombuwela

Head Office : Bombuwela Research Centre

ARS
- Bentota
- Labuduwa
- Horana
- Homagama

ARU
- Pelmadulla

[H] Regional Agricultural Research and Development Centre, Makandura

Head Office : Makandura Research Centre

ARS
- Wanathavillu
- Kalpitiya
- Walpita
- Pasyala
- Inginimitiya

ARU
- Wariyapola
- Tabbowa

[I] Regional Agricultural Research and Development Centre, Kilinochchi

Head Office: Kilinochchi Research Centre

ARS
- Thinnaveli
- Paranthan
- Batticaloa

ARU
- Vavuniya
- Murunkan
- Mulaitivu

The Department of Export Agriculture (DEA) was established in 1973, to meet the ever increasing demand for spices, cocoa and coffee. Subsequently, the DEA was entrusted with improving the productivity and quality of cinnamon, cocoa, coffee, pepper, cardamom, clove, nutmeg, citronella, lemon grass and a few others such as vanilla, betel and arecanut. Unlike the Department of Agriculture, DEA dealt with politically less sensitive field crops and was therefore said to have been spared of a reshuffle (84). The general layout of the research network of the Department of Export Agriculture may be depicted as follows:

Department of Export Agriculture

Head Office: Peradeniya

↓

Main Laboratory Complex Matale

↓

Specialized sub-stations
- Gammaduwa, Cardamom Res.Sta.
- Mapalana, Cinnamon Res.Sta.
- Narammala, Betel and Inter-cropping Res.Sta.

Research sub-stations
- Kundasale
- Delpitiya- Nilambe

Plantation Crop Research

The institutional framework for plantation sector research comprises, the Tea, Rubber, Coconut and Sugarcane Research Institutes. Of these the Tea Research Institute (TRI), the Rubber Research Institute (RRI) and the Coconut Research Institute (CRI) have a long history of active scientific work, with a well established research framework and an extensive research network.

The Sugarcane Research Institute (SRI) is a relatively new organisation and comprises the head office based in Colombo, and a fairly extensive laboratory complex at Uda Walawe.

CRI has the largest number of substations, of which three function as field stations, three others are isolated seed gardens, and one is an adaptive research farm. The organisational framework of the TRI, RRI and CRI are depicted below:

Figure 5.4 The Organization of the Tea, Rubber and Coconut Research Institutes

TRI Talawakele

↓

Research Substations
- Hantane
- Ratnapura
- Passara

Advisory Centres
- Kottawa
- Deniyaya

RRI Agalawatta

Decentralized Research Divisions
- Ratmalana
- Nivitigalakelle

Advisory Sub-station
- Kuruwita

CRI Bandirippuwa

Field Res. Stations
- Ratmalagara
- Pothukulama
- Walpita

Seed Gardens
- Ambekelle
- Makandura
- Maduru Oya

Adaptive Research Centre
- Nattandiya

Marine, Coastal and Freshwater Resources Research

The National Aquatic Resources Research and Development Agency (NARA) established in 1981 is the main organisation responsible for scientific investigations on the aquatic resources of Sri Lanka. Its main activities include resource surveys and investigations on offshore, coastal and inshore fishery, prawn fishery, coral reef management, ornamental fishery, fish technology development, geology, geophysical and hydrographic surveys and coastal environmental management. NARA's research network consists of a central laboratory complex and four substations as shown below:

National Aquatic Resources, Research and Development Agency (NARA)
Central Laboratory Complex:
Crow Island, Mattakkuliya

Regional Research Centres
- Trincomalee
- Kalpitiya
- Kadolkele

Field Stations
- Kapparatota

Veterinary and Animal Sciences Research

Research on livestock is handled by the Veterinary Research Institute (VRI), established in 1967. It functions under the Department of Animal Production and Health, and its central laboratory is situated in Gannoruwa, Peradeniya. The seven scientific divisions of the VRI are well equipped to handle a wide variety of laboratory and field investigations on domesticated animals. The organization of its research network can be depicted as follows:

Department of Animal Production and Health
Veterinary Research Institute
Central Laboratory Complex - Gannoruwa

Central Poultry Research Centre, Kundasale	Experimental farm Gannoruwa	National Poultry Development Centre, Polgolla.

One of the features of veterinary research in Sri Lanka, is the close links and collaboration with the Faculty of Veterinary Medicine and Animal Science, and the Faculty of Agriculture of the University of Peradeniya. Situated in close proximity to each other, this "triumvirate" forms a strong network in veterinary research.

Forestry Research

Forestry research is undertaken by the Research Division of the Forest Department (FD) which was established in 1937 as the Silviculture Research Unit. The small research facility consists of a laboratory unit at Kumbalpola and a sub-station at Agaratenna, co-ordinated from the Head office of the Forest Department in Colombo by the Deputy Conservator of Forests (Research). The FD however has a number of field stations in which observational studies are undertaken.

During the past two decades, with substantial support from foreign funding agencies, forestry research spread-eagled, bringing in a large number of research organisations and institutions into a forestry research network. The Forestry Sector Master Plan - 1995 (90) had identified at least 40 such agencies involved in forestry-related research.

Other Agriculture-Related Research Organisations

In the non-plantation crop sector, the only other mandated research organizations are the Farm Mechanisation Research Centre (FMRC) situated at Maha Illuppallama, the Hector Kobbekaduwa Agrarian Research & Training Institute (HARTI) in Colombo and the Food Technology Research Centre (FTRC) at Peradeniya.

As the name implies, the FMRC's main research thrust is to develop low cost equipment and machinery to facilitate cultivation, harvesting and processing in small and medium scale farming systems. It has no sub-stations as such, but engages in field operations in collaboration with clients (farmers) and relevant state agencies.

The HARTI's main research directions are in market surveys, and socio-economic studies pertaining to agricultural and agrarian issues.

5.3 The Other Constituent Members of NRS

Outside the NARS are the other constituents of the National Research System. Some of these organisations fall within the purview of the Ministry of Science and Technology. These include the CISIR, NARESA, NERD Centre, the Arthur C.

Clarke Centre for Modern Technologies, and the Atomic Energy Authority. There are two other organisations within this Ministry, which are not directly associated with scientific research, *viz* the Meteorology Department and the Computer and Information Technology Council.

In early 1994, on the basis of a report prepared by a task force constituted by the Ministry of Science and Technology, preparations were made to re-structure the institutions within this Ministry.

Accordingly, by a Bill to provide for the Development of Science and Technology in Sri Lanka, it was proposed to repeal the Acts that constituted NARESA, the Computer Information Technology Council, the CISIR and the Arthur C Clarke Centre for Modern Technologies, and in their place, a National Science Foundation, a Council for Information Technology, the Industrial Technology Institute and the Arthur C Clarke Institute for Modern Technologies were to be created. Apart from these organisations, it was also proposed that an apex organisation known as the National Science and Technology Commission should be created. The Bill though controversial in its fundamentals, was enacted by Parliament, and was to be immediately implemented. However, due to various logistic difficulties, implementation of this activity had to be postponed until the Parliamentary and Presidential elections were concluded.

Unlike the research units of the National Agricultural Research System, the other organisations of NRS do not in most instances have regionalized research facilities of a permanent nature, although they may institute outreach research facilities for specific field investigations whenever the need arise.

The other units of the National Research System are the Medical Research Institute, the Bandaranayake Memorial Ayurvedic Research Institute and the National Building Research Organisation, which are instituted under different ministries responsible for health, indigenous medicine and house construction respectively. They provide the scientific and technological back-up services to the institutions of these ministries.

While the Institute of Fundamental Studies and the Arthur C. Clarke Centre for Modern Technologies are associated with fundamental and frontier science research, the universities perform basic and academic research in a wide spectrum of disciplines. But the more important role of the university system is the generation of a high calibre human resource to sustain the vigour and ingenuity of the NRS.

5.4 Resource Deployment in the NRS

As a prelude to a critical examination of scientific capability in Sri Lanka, the National Academy of Sciences in collaboration with the Natural Resources, Energy & Science Authority initiated a study in April 1992 to examine the resources deployed in the science and technology sector of the country. The initial phase of the study was a listing of all governmental, para-statal and non-governmental institutions considered to indulge in scientific, technical, and science and technology related activities. Accordingly some 296 institutions were listed to be subjected to this study. The study essentially consisted of a survey based on a questionnaire, addressed to the chief executives of the respective institutions. Learning from previous experiences, it was decided that, (a) the questionnaire should be simple, comprehensible and short, and (b) the assistance and influence of the senior members of the Academy should be employed to the maximum possible, to collect data and information, within their areas of operation. The latter expectation however, was only partially realized.The questionnaire was structured to extract largely two categories of information, namely

(a) The number of scientific and technical personnel in gainful employment by end of 1990.

(b) The financial resources devoted to research and development during 1990.

Although the University of Jaffna and the Eastern University did respond, the Northern and Eastern Provinces could be covered only partially. On the whole it was estimated that in relation to scientific and technical (S and T) human resource potential, the survey had reached a success rate of about 75 percent. On the other hand, the survey was estimated to have covered over 95 per cent of expenditure devoted to research and development (R and D). The results of this survey are discussed below.

5.5 The Human Resource Capacity

The survey covered economically active scientific and technical personnel, but excluded the secondary school science teachers and medical personnel not directly associated with scientific research and related activities. A number of medical institutions (hospitals) have responded, and although some of the medical officers in these institutions may have carried out research surveys on community medicine and primary health care, the specific aspects of research have not been indicated in their responses to the questionnaire. The data summarized in Table 5.1 compares the S & T human resource structure of 1985 with that of 1990. However, it has to be borne in mind that the Northern and Eastern Provinces have been covered only partially in the 1990 survey.

Previous studies have shown that scientific and technical manpower employment in scientific institutions, inclusive of architects, medical scientists and social scientists, had steadily increased with an annual growth rate of about 10 percent from 4567 in 1978 to 8253 in 1985 (13).

Table 5.1 - Economically Active S & T Personnel by Major Class and Sex in 1985 and 1990

Sex	1985*			1990		
	Scien-tists	Engi-neers	Medical Scientists	Scien-tists	Engi-neers	Medical Scientists
Male	2802	4165	244	1434	2564	191
Female	640	315	133	456	181	111
Total	3442	4480	377	1890	2745	302

**Sri Lanka Science and Technology Indicators Part 1: Organizational Structures and the Status of National Efforts in Science and Technology* - S. Liyanage and M.A.T. de Silva (1987) NARESA, Colombo.

Excluding these three categories, the number of economically active S and T personnel in 1985 was 7922. Thus even if the Northern and Eastern Provinces were to contribute another 25 percent, to the human resource pool of 4635 enumerated in 1990, there could still be a significant negative growth rate of about 5.4 percent per annum from 1985 to 1990.

It is believed that this trend was due to, (a) the closure of the institutions of higher education for nearly two years in the late 1980's, and (b) the displacement and massive migration of educated youth following the turmoil in the North and South of Sri Lanka during 1983 to 1989.

Tables 5.2, 5.3 and 5.4 show the distribution of scientists and engineers according to sex, qualifications, sector of performance and age group.

Table 5.2 Scientists and Engineers by Sex and Qualifications in 1990

Qualifications	Males	Females	Total 1990	Total 1985
Ph.D.	485	87	572	417
M.Sc./MPhil	618	105	723	808
Postgraduate - Diploma	150	5	155	225
Degree only	1774	365	2139	4906
Professional Qualifications only	971	75	1046	1566
Total	3998	637	4635	7922

Table 5.3 Scientists and Engineers by Sector and Sex in 1990

Sector	Males	Females	Total
Government	1037	198	1235
Para-statal	622	47	669
Higher Education	1028	320	1348
Private	430	26	456
Not Identified	881	46	927
Total	3998	637	4635

Table 5.4 Scientists and Engineers According to Age class and Sex in 1990

Age class	Male	Female	Total
Less than 30 yrs.	211	53	264
31-35 yrs	609	121	730
36-40 yrs.	458	48	506
41-45 yrs.	369	38	407
46-50 yrs.	299	15	314
51-55 yrs.	182	5	187
Over 55 yrs.	203	1	204
Not identified	1667	356	2023
Total	3998	637	4635

It is interesting to note that despite of the general decline in the pool of economically active S and T personnel, the number of persons with doctoral degrees had increased from 417 in 1985 to 572 in 1990. On the other hand the number of personnel in all other educational categories had dropped during this period.

The data for 1985 show that among economically active scientists and engineers, the number employed in the private sector was about 9.1 percent (13). The present study shows (table 5.3) that while the total employed in the private sector had declined from 724 to 456, in relative terms, the proportion in the private sector employment had increased to 9.8 percent in 1990.

Table 5.4 shows the age distribution of scientists and engineers in 1990. Although in about 40 percent of the individuals, the age had not been specified, among the balance, the under 30 years age group makes up about 10 percent, the 30 to 40-year category about 47 percent, the 40 to 50-year group about 27 percent, and the over 50-year group about 15 percent. On the other hand in 1985, the under 30-year age group was about 21 percent, the 30 to 40-year group about 49 percent, the 40 to 50-year category about 19 percent and the over 50-year group about 10 percent.

The current data therefore indicates a decline in the younger age category of scientists and engineers compared to 1985, and an increase in numbers in the over 40-year age class. These observations are clearly not in conflict with the assumptions attributed to the general decline in the pool of S and T personnel in Sri Lanka.

5.5 Financial Resources for Research and the Index of State Sponsorship for Research

The total financial commitment for R and D in 1989 was Rs. 474 million, and in 1990 it was Rs. 447 million. Financial allocations in 1989 and 1990 therefore record an increase from Rs. 257 million allocated in 1984, though the amount for 1990 was less than that for 1989 (13). However, in real terms this increase had been only from Rs. 78 million in 1984 (at constant 1975 prices), to Rs. 216 million in 1989 and to Rs. 166 million in 1990, at constant 1982 prices. This would mean that the funds allocated for research in 1990 was almost 25 per cent less than in 1989 in real terms.

Data summarized in Table 5.5 shows the relative contributions of the state sector and the private sector to the national research and development effort of the country.

Table 5.5 Gross National Expenditure on R and D (at market prices) by Source of Funding (x '000)

Source	1984		1989		1990	
	R & D Exp.	As %	R & D Exp.	As %	R & D Exp.	As %
State	239,409	93	414,837	85.6	438,846	98
Private	17,390	7	59,558	14.4	8,770	2
Total	256,799	100	474,396	100	447,616	100

The above figures show that although there was an apparent increase in the contribution of the private sector to research in 1989, there was a sharp drop in 1990. It has to be noted that this substantial increase in 1989 was entirely due to a massive commitment (of Rs. 50 million) by a single multi-national firm for a specific short term adaptive research activity. If this figure is deducted from the total private sector allocation in 1989, one would observe a clear progressive decline in private sector participation in local research during these two years.

Tables 5.6 and 5.7 indicate the manner in which the Gross National Expenditure on Research had been allocated in 1990, compared to 1984.

Table 5.6 Gross National Expenditure on R and D by Economic Sectors (in x 'ooo)

Economic Sector	1984*		1989		1990	
	Total R & D Exp.	As %	Total R & D Exp.	As %	Total R & D Exp.	As %
Agri.& Animal Husbandry	131,906	51.4	233,364	49.2	258,561	57.8
Forestry & Fishery	12,715	5.0	13,386	2.8	12,968	2.9
Industry	41,833	16.3	148,121	31.2	101,057	22.5
Other	70,345	27.3	79,523	16.8	75,031	16.8
Total	256,799	100	474,396	100	447,616	100

*Liyanage, S and De Silva, M.A.T. (1987). *Sri Lanka Science and Technology Indicators*, Part I, NARESA, Colombo.

The data in Table 5.6 shows a significant change in the structure of research funding in Sri Lanka, with a clear shift towards industry, where the research expenditure had increased from 16 percent of the gross national expenditure on research in 1984 to 31 per cent in 1989. However, the vital forestry and fishery sector had experienced an unexpected drop. Agriculture and animal husbandry has continued to enjoy the major share of GERD.

Table 5.7 Gross National Expenditure on R and D by Sector of Performance (in x '000)

Sector Performance	1984*		1989		1990	
	Total R & D Exp.	As %	Total R & D Exp.	As %	Total R & D Exp.	As %
General Services	216,343	84	379,203	79.9	339,138	75.8
Productive	24,318	10	60,907	12.8	74,410	16.6
Higher Educational	16,138	6	34,286	7.3	34,068	7.6
Total	256,799	100	474,396	100	447,616	100

*Liyanage, S and De Silva, M.A.T. (1987), *Sri Lanka Science and Technology Indicators*, Part I, NARESA, Colombo

The data in table 5.7 shows a welcome shift in research expenditure, with the Productive Sector attracting more support at the expense of the General Service Sector. This would obviously indicate that the research outlook and direction are now straying away from the previous routine towards the more innovative strategic scenario. Although the governments policy on industrialisation is well focused and substantially attractive for investment, its outlook on science, technology and the academia have been considered to be grossly inadequate in relation to industrial development. In these circumstances it is doubtful if the current shift in research effort would be adequately aggressive to enhance the competitive edge of local industrial products to a point, that will enable these goods to increase their market share in international trade.

Table 5.8 Growth of R and D Expenditure in Sri Lanka

Year	Expenditure at current costs (x 10^6)	Expenditure at constant prices (x10^6)	Research expenditure as percentage of GDP
1975	45.1	45.1*	0.20
1983	218	77.4*	0.19
1984	257	77.9*	0.18
1989	474	224**	0.18
1990	434	129**	0.13

* At 1975 prices

** At 1982 prices

A depressing feature is the continuous decline of research effort during the past two decades. Thus as evident from Table 5.8, the Gross National Expenditure on Research and Development (GERD), as a percentage of GDP has declined from 0.20 percent in 1975, to 0.19 percent in 1983, to 0.18 percent in 1984 and to 0.13 percent in 1990.

It is true that like transnational corporations, the major local enterprises, which depend fully on imported state of the art, turn-key technologies, may not be unduly concerned about such a decline in indigenous research capacity. Nevertheless it is clear, that an industrial super-structure projected towards a range of generic as well as emerging technologies, cannot be sustained on a declining academic and scientific profile that has characterized Sri Lanka during the past few decades.

CHAPTER 6

SUMMARY AND CONCLUSIONS

This study was initiated to investigate the influence of physical, organizational, environmental and sociological constraints on the process and outcome of scientific research in Sri Lanka. The ground situation in respect of these issues was examined through a number of surveys and case studies, which were designed to bring out both generic and specific problems that hinder the progress of research.

The introductory chapter deals with the epoch-making events in the institutionalization history of scientific research in Sri Lanka. It also traces milestones in achievements of scientific inquiry and discovery over the past 150 years or so, during which a western model of scientific culture had been progressively and completely indigenized and assimilated. It is against this eventful history of scientific development that the current framework and environment for research is being reviewed.

The research process has been made to resemble a production system in which a set of inputs go-through a manipulative process, within what may be described as the "research system". The initial output of this process is "new knowledge", which manifests itself, or get moulded into a semi-finished or finished product.

The quantity and quality of these outputs then determine the productivity as well as adequacy of research in the sector. The current study (Chapter 2) demonstrates some of the better known as well as new approaches for the measurement of productivity, and ventures out further to illustrate hypothetical procedures to measure the illusive accountability factor in scientific research. The application of this technique using data from 234 completed research grants, awarded and administered by the former National Science Council of Sri Lanka and its successor the Natural Resources Energy & Science Authority of Sri Lanka, is discussed. The method has been used to illustrate the "rates of return" on investments in scientific research.

The classical approach to measure productivity, is through counts of published or communicated research material. In the current study, several such counts have also been taken to measure productivity of Sri Lankan scientists.

The first of these was through a questionnaire administered to sectional heads and project leaders in all applied research organizations of the country. The second was through an analysis of papers communicated or presented at the annual sessions of the country's premier scientific association, the Sri Lanka Association for the Advancement of Science (SLAAS) during the period 1945 to 1989.

The third count was made using data from 585 completed research grants awarded by the National Science Council of Sri Lanka, and its successor the Natural Resources, Energy and Science Authority of Sri Lanka during the period 1970 to 1992.

The first study showed that during a five year period (1985-1989), the average annual output of publications in refereed journals ranged from 21 for the Rubber Research Institute to zero at the Hector Kobbekaduwa Agrarian Research and Training Institute. It seems unfortunate that commercialization of research findings, as evident from the number of inventions, innovations and adaptations, had taken a back seat during this period, leading to the assumption that research policies and the research system, had not been fine tuned to generate a utilisable finished product.

The results of the second survey shows that during a period of 45 years, a total of 4643 papers had been presented at the annual sessions of SLAAS, at an overall average rate of 101 papers per annum. In terms of intensity, plant sciences, forestry and agriculture had been the most profound, contributing more than 25 percent of all papers read at the annual sessions of SLAAS. The growth in productivity shows a fairly consistent trend, with a first peak during early 1970's, followed by a decline in the 1980's, and finally a steep increase during the second half of the last decade. However, despite a shift in state policy towards industrial development since 1977, technology related disciplines such as engineering sciences, physics and earth sciences have shown only a modest growth in scientific activity.

The third study indicated that NARESA's research grants scheme had led to the production of 327 scientific publications during the period 1970 to 1992, of which a little under 50 percent were in internationally recognized refereed journals. A significant finding in this study was that, 57 percent of scientific papers contributed to international journals, and 26 percent of papers contributed to local journals came from the grants awarded for research in chemical sciences.

Another measure of productivity is the award of postgraduate degrees to researchers involved in a research programme. A postgraduate degree award can be regarded as a finished product that has evolved from the core pool of new knowledge. The NARESA research grants scheme provides a useful base to measure this output component in research. The data available shows that during the period under consideration, a total of 207 masters degrees and 33 doctoral degrees had been awarded to young scientists as a result of the NARESA research grants scheme. Adopting a benefit - cost computation procedure for 234 completed research grants awarded by NARESA, it has been possible to show that rates of return ranging from 12.5 percent to 16.2 percent per annum have been achieved. The study has also shown that the overall cost of producing a postgraduate degree (MPhil) during the period 1970 to 1992 ranged from Rs 39,900/= for biological sciences to about Rs. 54,000/= for agriculture and chemical sciences.

There are many impediments in the commercialization of research findings, even where techno-economic feasibility has been convincingly demonstrated. Firstly, in the case of an industrial product or process, there is the necessity to scale-up the bench model to a pilot plant. This is a very costly exercise often requiring a variety of expertise including mathematical modelling, design engineering, fabrication and techno-economics, apart from elements of hardware and testing equipment.

In Chapter 2, a case study on efforts to commercialize a discovery in natural products chemistry is presented to highlight some of the impediments faced by chemists researching on natural products. It has been shown that even in a situation where a cost effective finished product of international quality standard could be developed, penetration into the global markets can be thwarted due to the existence of long term international contractual agreements.

Priority setting in research has been a relatively new phenomenon in research. During the past two decades research managers have witnessed an ever increasing contraction of expendable resources for research. The initial reaction to this situation is to find measures for optimizing resource utilisation; and one feasible approach for this is to evolve criteria to prioritize research.In Chapter three, the efforts to prioritize research in the National Agricultural Research System are discussed. A feature of these exercises is the consistent effort to prioritize commodities rather than researchable issues.

An extensive survey of research organizations in relation to operations and management of research have led to the following observations.

* In the absence of any guidelines for a consultative process for prioritization of research, project leaders have adopted a heterogenous mix of procedures for identification of research problems.

* Personal preferences, and limited internal consultations were the most common approaches for project identification.

* National priorities and institutional objectives were the key guiding principles in choice of projects, indicating that the State was the most important client.

* Resource allocation for research was not dependent on the bankable features of research proposals.

* There is no evidence to indicate that the demands of the State (as the client), also reflects the specific needs of the real public beneficiary. The consistent failure of the NRS to satisfy the needs of real users and consumers, is thus attributed to this deficiency.

* The time devoted to basic research had shown a significant shift from less than 10 percent in 1985 to over 20 percent during 1992 to 1993

* There was no evidence of an in-built process, capacity or even a time frame for monitoring of research in any of the organizations studied.

* According to the perceptions of research leaders persuasive advice and good research facilities were the key factors promoting good research. However, surprisingly, awards, honors and promotions as well as regular training opportunities did not figure prominently as conditions conducive for good quality research.

* Lack of motivation and domestic problems are seen as factors incapacitating researchers from doing better quality work.

The issues concerning women in scientific research was examined (Chapter 4) through a separate survey in which a sample representing about 25 percent of the entire population of female researchers in hard sciences were involved.

Around 25 percent of this sample of women researchers were senior scientists, who were either heads of scientific divisions or university professors. The key findings from this field survey are as follows:

* Over 50 percent of these researchers agreed that research programmes were prepared by them, and only 9 percent said that directions came from higher authorities.

* Majority of the women researchers agreed with the conclusions of the sectional heads (of the earlier survey), that the determinant factor for choice of a project was the relevance to institutional or national objectives.

* Majority of women researchers also agreed with sectional heads when they claimed that inadequacy of facilities was the major constraint affecting research performance.

* Personality issues such as the social background and status of spouse had no adverse or sour effects on the research environment of female scientists.

* Women researchers were also not the least concerned about working long hours or travelling long distances for field investigations, although family commitments were seen to affect them to some degree.

* About a third of the sample claimed to have experienced some form of sex discrimination.

* Productivity of women researchers in terms of research publications indicated that the most productive period in their careers was during 26 to 30 years of age, when on an average 15 publications per person had been generated. This productivity rate declines progressively upto about 45 years of age, after which there is a sharp drop until retirement at 55 years of age.

* The most productive female researchers were those in the fields of aquatic biology. Agricultural sciences, industry and natural science were next in that order of importance.

Finally, in Chapter Five the constitution and deployment of resources in the National Research System is analyzed.The spectrum of public sector organizations participating in the NRS are discussed in this chapter, giving a special place for the NARS, which constitutes the biggest research network in the country. Since institutions have evolved independently under a variety of circumstances, there is no uniformity in their structure and organizational frameworks. Each research organization had experienced fluctuating fortunes in respect of the capacity to deliver the goods. However, there is no evidence that the diversity of organizational frameworks in these institutions had any significant impact on their performances. This would also mean that there are no indicative criteria to conclude that any particular structure was better than another.

A survey instituted during 1991 to 1992 to examine the deployment of human and financial resources have led to the following observations:

* The pool of skilled scientific and technical personnel which increased from 4567 in 1978 to 8253 in 1985 at an average annual growth rate of 10 percent, has witnessed a drop to 4635 in 1990, indicating a negative growth rate of 5.4 percent per annum, during this latter period.

  This decline is attributed to a closure of institutions of higher education for nearly two years, and the displacement of educated youth following the ethnic turmoil in the north and south of Sri Lanka.

* Despite the general decline in the pool of economically active science and technology personnel, the persons with doctoral degrees had increased from 417 in 1985 to 572 in 1990.

* The proportion of scientists and engineers employed in the private sector was 9.1 percent in 1985. Although in terms of numbers, private sector employment had dropped from 724 persons in 1985 to 456 persons in 1990, in relative terms the proportion in the private sector had increased to 9.8 percent in 1990.

* The proportion of S and T personnel in the under 30 years of age category had declined from 21 percent in 1985 to 10 percent in 1990, while in the over 40 years of age category the proportion had increased from 29 percent in 1985 to 42 percent in 1990.

* The financial commitment for R and D had increased from Rs 257 million in 1984 to Rs 474 million in 1989 and declined to Rs 447 million in 1990. However in real terms, the trend had been from Rs 78 million in 1984 (at constant 1975 prices), to Rs 216 million and Rs 166 million for 1989 and 1990 respectively at constant 1982 prices.

* The private sector contribution to research increased from 7 percent in 1984 to 14.4 percent in 1989, and then dropped sharply to 2 percent in 1990. However, the increase noted in 1989, was entirely due to the contribution of Rs 50 million made by one multinational firm for a specific short term adaptive research activity.

* Agricultural research continues to enjoy a major share of the Gross National Expenditure on Research, receiving 51.4 percent in 1984, 49.2 percent in 1989 and 57.8 percent in 1990.

* Significantly the contribution to industry had increased from 16 percent in 1984 to 31 percent in 1989, although it had again dropped to 22.5 percent in 1990.

* A gratifying shift in emphasis is also seen in R and D expenditure, in relation to sector of performance, with the contribution to productive sector increasing from 10 percent in 1984 to 12.8 percent in 1989 and to 16.6 percent in 1990.

* Finally the GERD as a percentage of GDP is seen to have dramatically dropped from 0.20 percent in 1975 to 0.19 percent in 1983, to 0.18 percent in 1984, and to 0.13 percent in 1990.

The results of this survey are undoubtly disheartening. Resource allocations have continued to narrow down, yet the expectations from the research system continue to remain high - these two aspects are incompatible. Sri Lanka aspires to be an industrialized nation, but can the country sustain an industrial super- structure with a substantially weak, scientific and technological base? This is an issue which deserves the urgent consideration of all concerned. There is no doubt, that given adequate resources and facilities, Sri Lanka can attain a degree of scientific excellence and capacity to be able to absorb and sustain the technological needs of an industrialized nation.

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