

DECADES OF RESEARCH

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**Research Development and Ethical Review Sub Committee (2008)
Faculty of Agriculture, University of Peradeniya**

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Forward

The Faculty of Agriculture of University of Peradeniya has been in the forefront in agricultural research since its inception in 1948. The pioneers of the faculty at the initial days strived hard to conduct research irrespective of constraints they faced with resource limitations, both human and physical. However, they contributed to the generation of new knowledge in agriculture at the time when country was importing most of its food requirement. While engaging in teaching and research, they took initiatives to develop infrastructure and other facilities at the Faculty by acquiring research farms and securing foreign assistance. We owe our gratitude to those who took these initial steps, sustained the development and guided young staff to develop the research culture of the Faculty during last 60 years.

This book is an attempt to traverse through the path followed during this period indicating initiatives at the beginning, the developments (research) that took place, highlights of some of the major findings and what we do at present. The research highlights are categorized under specialized areas of each department. It was a very difficult task to limit the number of pages since the research output from the academic staff from 8 departments of the faculty has been substantial. However, we tried our best to communicate some of the highlights of research over this period while restricting the length of the document in order to make it attractive to a wider audience. For the same reason, an effort was made to reduce the scientific details and jargon as far as possible.

The challenge of writing this book was taken by the members of the Research Development and Ethical Review (ReDERC) Sub-Committee of the Faculty of Agriculture in year 2008 when the Committee deliberated on its possible contribution to the series of events planned to commemorate the 60 years of higher education of the Faculty of Agriculture. The ReDERC wishes to acknowledge Prof. B. Marambe, Dean, Faculty of Agriculture for continuous encouragement, Prof R.O Thattil, Director, Research and International Relations of the University of Peradeniya for accepting to go through the final draft of the report and Mr Ajith Angamma of the Faculty of Agriculture for designing the cover page.

Research Development and Ethical Review Sub-Committee

Faculty of Agriculture

October 2008

Message from the Dean of Faculty of Agriculture

I take the pleasure and pride to send this message on the occasion that we celebrate 60 years of University education in agriculture in Sri Lanka, an event that only the Faculty of Agriculture at University of Peradeniya can celebrate. The event organized to recognize and felicitate our long-standing partners in February 2008, bringing in the state, private sector, and non-governmental organizations while soliciting their support was the kick-off event of a series of activities planned for the year. The island-wide quiz program conducted for school children with a view to popularize the B.Sc. Agricultural Technology and Management (B.Sc. AgTech&Mgt) and the B.Sc. Food Science and Technology (B.Sc. FST) degrees, documenting the historical development of the Faculty that led to the publication of “60-years of Higher Education in Agriculture”, documenting and publishing the evolution of the curriculum offered by the Faculty as “Curriculum in Retrospect 1948-2008”, documenting and publishing the outstanding research activities carried out by the Faculty during the past 60 years, and the “Agriculture Exhibition” held at Peradeniya marking the grand finale of events are some highlights to listed here.

It is needless to state how and why research become important to academia. However, being the pioneer in agriculture education in universities of Sri Lanka, it is our prime duty to demonstrate how the research work carried out by the Faculty has contributed to national and international development agenda. Being a country with the primary focus on an agricultural economy, Sri Lanka has invested significantly on improving university education in agriculture. The returns to this investment have not only been in the form of producing high quality graduates who are undoubtedly all-rounders meeting any challenge in the society, we have also come up with innovations. Well-thought out research programs, financially supported by national and international granting agencies, have led to this success, especially contributing to the economic development of the country.

This effort is to create awareness among all stakeholders in the society of our achievements as research outcomes during a period of 60-years (1948-2008). With a modest beginning, the Faculty has come a long way, providing enough substance through research that have benefitted the country at large. This publication is another feather in our cap, where we have documented the research outcomes with confidence and will prove the society how the stage has been set over a period of six decades to support the agricultural development in the future. We are proud of our multidisciplinary achievements, and we will continue to excel in all spheres in the field of agriculture, and contributing to science and to the socio-economic development of Sri Lanka and the globe.

Professor Buddhi Marambe
Dean/Faculty of Agriculture
October 2008

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CHAPTER 1: RESEARCH CONDUCTED BY

Department of Agricultural Biology

*Compiled by
Dr. (Ms) D.M. De Costa*

Introduction

History of research initiated and conducted by the academia of the Department of Agricultural Biology dates back to the beginning of the Faculty of Agriculture at the University of Peradeniya. Since the inception of the Department of Agricultural Biology in 1973 and even before as separate divisions of Zoology and Agricultural Botany which were affiliations of the Faculty of Agriculture, internationally and locally-funded research had been part and parcel of the academia of this department. The wide spectrum of disciplines that the Department of Agricultural Biology (later with the amalgamation of the two divisions) explores in the spheres of Biology and Agricultural Sciences and the enthusiasm of the staff members paved the way for inculcating a research culture in this department. Major fields of research conducted by the Department of Agricultural Biology are Entomology, Plant Pathology and Microbiology, Genetics and Plant Breeding, Plant Physiology, Molecular Biology and Biotechnology and Plant Systematics. Most of these research projects provided opportunities for undergraduates, postgraduates and academic staff members of the Department to have research collaborations with the Department of Agriculture, National Research Institutes and private sector companies in Sri Lanka. Moreover, some of the research projects allowed the members of the Department to get the exposure to international research culture and also to share research expertise with international scientists/authorities through collaboration with international universities and research institutes. Given below are some of the major landmarks of the journey of research followed by members of the Department of Agricultural Biology.

Entomology

Research projects carried out in the field of Entomology were under main themes of Apiculture, Botanical Pesticides, Natural enemies of pest insects, Microbials in pest control and insect taxonomy. Some of these projects were carried out in

collaboration with the Department of Agriculture, Tea Research Institute, Coconut Research Institute, Sugarcane Research Institute, Agriculture Faculties of other universities and private sector organizations. These research projects were funded by local funding agencies such as Sri Lanka Council for Agricultural Research Policy (CARP), National Science Foundation (NSF), Postgraduate Institute of Agriculture (PGIA) and the University of Peradeniya research grants as well as international funding agencies.

The first recorded internationally-funded research project of the department was in collaboration with the Department of Agriculture, Sri Lanka. Prof. B.A. Baptist, Reader in Agricultural Biology, who was then a member of the Division of Zoology, Faculty of Agriculture pioneered this research project which was funded by the Canadian Government (CIDA). The long term objective of the project was to uplift the research and development activities of the Department of Agriculture on Bee Keeping. Development/designing of efficient, economical and user-friendly bee boxes, multiplication of bee colonies, and popularization of bee keeping among the public were the primary objectives of this project. A pilot project was centered around the Bandarawela area. Later, in addition to the above research objectives, the bee keeping research team worked with a German Scientist named Prof. N. Koeniger of University of Frankfurt, Germany on population and behavioural studies of indigenous populations of *Apis* species (i.e. *bambara*, *debara*, *kanameemessa*). This is considered as the first taxonomical and ecological study conducted in Sri Lanka on these insect species and it is a piece of research work still referred to by many scientists in the field of bee keeping. Research on bee keeping created a huge popularity among the public. The effort by the pioneering scientists and the need of the country was well understood by the government. As a result, a special research station on bee keeping was established at Bindunuwewa, Bandarawela by the Department of Agriculture to continue research and developmental activities on bee keeping. Even after the completion of the CIDA-funded project, research on bee keeping was continued by Prof. Baptist in the Faculty of Agriculture due to his everlasting desire in the field of bee keeping. Following in the footsteps of Prof. Baptist, bee keeping related research is still being continued in the Department of Agricultural Biology in collaboration with Bindunuwewa research station.

As alternatives to synthetic chemical control, insecticidal compounds were extracted from various local plant species, *Azadirachta indica*, *Lantana camara*, *Tridax procumbans*, *Eucalyptus* sp. etc. and were tested against stored product insect pests with very effective results. Moreover, research carried out on natural enemies of insect pests includes identification and evaluations on effectiveness of parasitoids and predators of pest species such as Cabbage caterpillar complex, Whiteflies, Vegetable leaf miners, Cucurbit fruit flies, Aphids and mealy bugs. These research projects generated very valuable information on many natural enemy species native to Sri Lanka. Research projects in the field of entomopathogenic microbes paved way to isolate, identify and laboratory and

field testing of *Bacillus thuringiensis* strains effective in mosquito control and fungal strains of *Metarhizium* sp. on rice and vegetable pests.

Taxonomic work on Leafhopper species in Sri Lanka resulted in the identification of few new records in addition to evaluations on already recorded species. Development of Identification keys has been carried out for some pests of Mushroom, Leafminers of the Genus *Liriomyza*, Leafhoppers and some Coccinellids.

Plant Pathology and Microbiology

Research on Plant Pathology and Microbiology has focused on diverse aspects of the effects of biotic and abiotic factors on crop production, yield performance and also on environmental processes. Hence, applied and basic research on Bacteriology, Mycology, Virology and Nematology are of high significance within this field of research.

The largest internationally-funded research project to the Department of Agricultural Biology was funded by the Belgian government in collaboration with the Catholic University Leven to work on Biological Nitrogen Fixation. The project lasted a long period, from 1978 to 1986 until the Belgian research team shifted to the Institute of Fundamental Studies, Hantana. The Department gained numerous financial, equipment and research assistance through this project. We had resident-Belgian scientists working in the project in the Department. The project funded for vehicles and also to establish a well-equipped analytical laboratory. The project provided funds for a Ph.D. degree to a newly-recruited staff member of the department and also for the completion of five M.Phil. degrees. Moreover, all the technical staff attached to the department during that period were trained in Catholic University Leven, Belgium by the financial assistance provided by the same university. Several short duration visits of the staff members were also supported by the project.

Staff members of the Department of Agricultural Biology have been awarded grants by international funding agencies such as USAID, USA, International Foundation for Science (IFS), Sweden, International Centre for Genetic Engineering and Biotechnology (ICGEB), Italy to conduct research on a range of research disciplines, namely Microbiology, Plant Pathology, Postharvest Pathology and Molecular Plant Pathology.

Loss of the quality of crop yield due to plant pathogens is as equally-threatening as the quantitative losses caused by them to the final yield. When contaminated with the final yield, certain fungal pathogens produce mycotoxins thereby, reducing the quality of crop yield and leading into health hazards to humans and animals. Mycotoxins with a special emphasis on Aflatoxin contaminations in rice consumed by Sri Lankans were elucidated by a six-year project funded by the IFS, Sweden. The findings of this project had direct interactions on the rice processing methods that had been practiced in Sri Lanka. As a result of the findings, Rice

Processing Research and Development Centre in collaboration with Paddy Marketing Board introduced improved-parboiling and milling techniques.

Research on Plant Pathology has focused mainly on the determination of etiology of unknown (newly-emerged) plant diseases, host-pathogen interactions and disease management. *Fusarium* wilt of Carnation, *Alternaria* blight of Carnation, Foot rot of *Capsicum*, Crown gall of Kapok, Rust of Citronella and Lemon grass, Little leaf disease of Pepper and Chillie, Sugarcane white leaf disease are some of the example on which such investigations have been carried out.

Use of fungicides for the control of plant pathogenic fungi and their hazardous effects on the environment are well known. As a possible option to mitigate these environmental hazards, potential use of indigenous microorganisms, naturally dwelling on plant surfaces is being investigated. Presently, control of postharvest pathogens of tropical fruits by biological control agents and elucidation of molecular mechanisms related to the antagonism of those biological control agents are being investigated under the financial assistance of IFS, Sweden and NSF, Sri Lanka. Promising bacterial antagonist (identified as *Burkholderia spinosa*) which was originally-isolated from the fruit peel of banana has been identified for its desirable features as a potential biological control agent. Desirable features of the antagonist bacterium needed for commercial use are being investigated. A detailed study on the anthracnose pathosystem which is responsible for causing an economically-important postharvest disease of banana (i.e. anthracnose) has been studied both at organism and molecular levels. This research project was commended by the National Science Awards in 2008.

With the financial assistance of CARP, a research project was conducted to screen indigenous microbial antagonists for the control of rice sheath blight, a serious biotic factor contributing to high yield losses in collaboration with Rice Research and Development Institute, Batalagoda. Two bacterial (i.e. *Bacillus megaterium* and *Bacillus subtilis*) and a fungal (i.e. *Aspergillus niger*) antagonists were identified as potential biological control agents against sheath blight under field conditions. Based on these findings, presently a talc-based formulation of these three microbial antagonists is being tested for field efficiency at the Rice Research Station of the Department of Agriculture at Labuduwa,

Bacteriophage therapy has become an attractive and effective biological control option to control bacterial pathogens infecting economically-important plants. A NSF funded grant is presently exploring the potential bacteriophage antagonists for the control of bacterial wilt disease of Solanaceae crops.

Research on soybean diseases and winged bean diseases were funded by world food programme and FAO respectively. These researches identified the diseases of those crops when grown under Sri Lankan conditions and the causal organisms of those diseases. Moreover, with the financial assistance provided by USAID programme, serological research on biological nitrogen fixation was established in the Department.

Aquatic Microbiology and water quality analysis is another important theme of research in need at present in Sri Lanka. Residues of herbicides (Paraquat) on lowland rice fields have been studied in detail. COMPASS, is a collaborative research programme, funded by the Netherlands, to determine the etiology of chronic renal failure prevalent among farm families in the North Central Province of Sri Lanka. Conclusive evidence for the association of elevated dietary Cadmium originating from agricultural inputs has been established. Presently, a team of researchers is working in collaboration with University of Hawaii and Chicago, USA to determine a suitable biomarker for early disease diagnosis. Bioinformatics aspects of the project have yielded good software programmes that could be used in clinical diagnostics in hospitals.

Genetics and Plant Breeding

Research in genetics and breeding began in the early 1980s with the introduction of quantitative genetic methods in breeding programmes. For the first time in Sri Lanka, genetic designs were used to produce new varieties as well as to estimate hybrid vigour and to predict the performance of new inbred lines. This was carried out with the local rice varieties as a collaborative research programme including the Department of Agricultural Biology, Rice Research and Development Institute, Batalagoda and the Department of Applied Genetics, University of Birmingham, UK. The research was funded by Overseas Development Agency (ODA), UK.

In the early 1990s, an extensive breeding programme was initiated to produce superior new hybrids of silkworms in order to produce high yields of better quality silk. This programme was carried out in collaboration with the Silkworm Breeding Station at Nillambe. For the first time in Sri Lanka, new hybrids of silkworms were produced using genetic designs. These hybrids were tested in farmers' field conditions and were found to be far superior in silk yield and silk quality than those that were available in 1990s.

Moreover, in the early 1990s, a collaborative breeding programme was conducted at the Sugarcane Research Institute at Uda Walawe, again using genetic designs to produce new varieties of sugarcane. Mutation breeding was also used to produce new types of rice and ornamental plants. Molecular characterization experience was also used for the first time in Sri Lanka to establish a molecular laboratory at Uda Walawe, to characterize the sugarcane germplasm, which was done successfully and published in 1999.

For the first time in Sri Lanka, in 1992, genetic designs and methods were used to produce new inbred varieties of tomatoes far superior to those that were used in Sri Lanka in early 1990s. This breeding programme was carried out in collaboration with the Department of Applied Genetics, University of Birmingham, UK and Ceylon Tobacco Company (CTC), Kalagedihena (presently Serendib Hort, Ltd.). This programme was funded by CTC.

Plant Physiology

A number of local and international funding agencies have also supported the Department members for the conduct of research pertaining to the influence of factors on the physiology of plants. These included the investigations on carbon compartmentalization and source-sink relationships of plant species of agricultural and economic significance and also studies on the effect of moisture stress and drought resistance of plant species such as rice, chillie, corn and sugarcane.

Investigations on the feasibility of using hydroponics for horticultural and medicinal crops were another sphere of study. Significant research was also conducted on the effect of environmental influence on physiological parameters of plants of export significance. Research on the factors influencing the internal browning of pineapple for export was a major piece of research in this category. Recommendations of practical significance were made at the completion of the study. Another area of research where many studies were conducted was the investigation on the use of *in vitro* techniques as a tool in plant physiology for plant improvement.

Molecular Biology and Biotechnology

Research in the field of Molecular Biology and Biotechnology in Sri Lanka were pioneered by the Department of Agricultural Biology. Department of Agricultural Biology established a molecular biology laboratory in early 1980's and carried out pioneering research activities in biotechnology in Sri Lanka with the financial support from CARP. Construction of transgenic rice plants and ornamental plants against insect pests using *Agrobacterium*-mediated transformation and crop improvement through genetic manipulation are some of the biotechnological research areas that were initially focused on by the Department of Agricultural Biology.

From 1992 to 1994, through an international fellowship programme funded by the Rockefeller Foundation, USA, a research programme in Rice Biotechnology was initiated in Sri Lanka, using local rice material. This programme was carried out at the University of Liverpool, UK and at the Texas A&M University, USA. Many DNA Fingerprinting techniques including RFLP, RAPDs and SSR markers were used to characterize the local rice material as well as to attempt to find molecular markers for important QTLs in a Marker Assisted Selection programme. Molecular breeding techniques were used for the first time in Sri Lanka in producing new hybrid and pure line varieties of tomato and chilli. Through the use of Asian Development Bank funds, new varieties of tomato hybrids specially bred for dry zone conditions were produced using both molecular and classical breeding techniques. This is the first time that hybrid varieties were produced in Sri Lanka. Publications based on this research won several awards at the PGIA Congress, 2004.

Molecular breeding techniques were also used to produce new tomato hybrids superior for fruit quality traits, new superior chilli hybrids and new varieties of brinjal hybrids. This research was funded by a grant from CARP for producing local vegetable hybrids based on national priorities. The best hybrids were then extended to produce superior inbred lines of both chilli and tomato. Moreover, attempts on flower breeding were initiated with the Royal Botanical Gardens, Peradeniya including colchipoideity and mutation breeding of *Gymnostachium* and molecular characterization of six species of *Exacum* (Binara) which is presently underway.

With the research conducted in National Institute of Agrobiological Research (NIAR), Japan in 1993, a RAPD- based classification was suggested for the Asiatic *Vigna* species. Then with the sponsorship of Japan International Research Center for Agricultural Sciences (JIRCAS), Tsukuba, Japan, three salinity related genes for rice were cloned during 1997-1998 using physical screening and gene expression studies. This work was later continued to assess salinity status of 72 important rice varieties obtained from Rice Research and Development Center, Batalagoda where their phylogenetic relationships were also studied.

Molecular mechanisms of salt tolerance are being investigated with the help of an ICGEB funded grant which is a collaborative research project with the Department of Crop Science, Faculty of Agriculture.

Here is a brief description of an ongoing research based on industrial biotechnology which is funded by the NSF. *Aspergillus oryzae* has been used for production of food grade amylase and many types of fermented food products in bio-industries. A research project is being conducted to characterize a locally-isolated strain of *A. oryzae* by rDNA technologies to compare its fermentation efficiency with presently available commercial strains.

Plant Systematics

In latter part of 1980's isozyme analyses were used to characterize several rice varieties and wild rice species. Morphological characterization has been conducted in collaboration with the Plant Genetic Resources Center (PGRC), Gannoruwa on Maize, *Solanum* and Mulberry cultivar/species. Moreover, the sex determination of *Carica papaya*, initially isozymes were tried and subsequently a collaborative research project successfully completed with Fruit Crops Research and Development Center (FCRDC), Department of Agriculture, Sri Lanka identified three primers suitable in differentiating male, female and hermaphrodite flowers.

Quite a lot of research work has been carried out in the Department of Agricultural Biology in the field of molecular characterization of some of agriculturally- and economically- important plants in Sri Lanka. These projects include, morphological, biochemical and genetic characterization of medicinal plants, genetical and biochemical characterization of *Rhizobium* nodulating legumes of Sri Lanka and screening their nitrogen fixing efficiencies. Moreover,

molecular characterization has been done for some consumer-preferred and traditional rice varieties in Sri Lanka. Furthermore, molecular characterization was also carried out in *Munronia pinnata*, a very useful medicinal plant as well as in local banana species.

Research that has been conducted in the Department of Agricultural Biology over the years has facilitated the introduction of novel research disciplines such as Biotechnology, Cytogenetics, Molecular Biology, Glycobiology, Proteomics and Bioinformatics to the Department while contributing to the development of its research infrastructure. Findings of these research projects have been published in a wide range of local and international peer-reviewed journals. Moreover, these research projects have produced valuable findings and provided recommendations to the relevant research institutes and authorities for implementation. Another positive impact of the research conducted by the Department has been the contribution to human resource development of the country by producing skilled research scientists in various fields of study.

CHAPTER 2: RESEARCH CONDUCTED BY

Department of Agricultural Economics and Business Management

Compiled by
Dr. L. H. P. Gunaratne

Introduction

The socio-economic research activities of the Faculty of Agriculture commenced with the establishment of the Division of Agricultural Economics in 1956. The first international link of the division was with the Agricultural Development Council (ADC), New York, (then named as the Council on Economic and Cultural Affairs). This link promoted research in the rural social sciences by providing financial support for staff participation at international conferences and seminars. Since then, a series of international collaborative research activities was implemented. One of the landmark events amongst these activities was the organization of the First Near-east South Asia Agricultural Credit Seminar in 1961 at the University of Ceylon, Peradeniya, with the co-sponsorship of the International Cooperation Administration (ICA), Washington D.C., and the United States Agency for International Development (USAID). With this activity, the division was able to hold number of conferences, seminars and workshops with the international support. The Division was also able to get financial support from the Agricultural Development Council (ADC), New York to establish the Agricultural Economics Research unit of the Faculty of Agriculture. With the recognition of the importance of the role of agricultural economics by the development administrators, the Agricultural Economics Research Unit was consulted to carryout socio-economic studies for different development projects in the country.

The establishment of the Department of Agricultural Economics and Farm Management in 1972 further strengthened the research activities of the social sciences of Agriculture. The research agenda at the department broadened its horizons to new areas such as Production Economics and Agricultural Marketing parallel with the developments of the Faculty. The research activities of the department were promptly supported by the new recruitments to the Department and returning of young academics after completion of their postgraduate degrees. Although the department had undergone several changes during these period (i.e., branch out into two departments: Agricultural Extension

and Agricultural Economics, and then renamed as Agricultural Economics and Business Management), it continued as a leading player in strengthening the agricultural and allied sector in Sri Lanka by providing the necessary socio-economics inputs.

The Department has been involved in a variety of research and outreach activities in applied and agricultural economics, and business management through extensively developed local and international collaborations. The local sponsors include the National Science Foundation (NSF), the Council for Agricultural Research Policy (CARP), the Ministry of Environment and Natural Resources, the Ministry of Consumer Affairs and Trade, the Ministry of Agriculture and Livestock Development, Center for Womens' Research, Center for Poverty Analysis and Sri Lankan offices of the World Bank, the ADB, the FAO, the UNDP, the International Fund for Agricultural Development, GTZ, NORAD, DANIDA and EU. The members of the department have won a number of international competitive research grants from Environment and Economy Program for South East Asia (EEPSEA), South Asian Network for Development and Environment Economics (SANDEE), ETH/Zurich, the International Development Research Centre (IDRC), the Department of International Development (DFID-UK), the Poverty Reduction and Environmental Management (PREM) programme of the Institute of Environmental Studies, the Netherlands. International Food Research Institute (IFPRI), International Livestock Research Institute (ILRI), the Hewlett Foundation, and the Asia Pacific Trade Research Network (ARTNeT) are some of the international/regional research networks that have provided financial assistance over the past decade. Some of the studies were conducted in collaboration with foreign universities such as University of Guelph, University of Warwick, Stirling University, Virjie University in Amsterdam, University of Western Ontario, Purdue University, and Saga University. Most of these links are facilitated and coordinated by the Agribusiness Centre, which is the research and outreach arm of the department that maintains close links with the rapidly growing industrial sector by multi-disciplinary applied research.

The research areas of the department can be broadly grouped into the following themes: Resource and Environmental Economics, Development Economics, Production Economics, Agricultural Marketing and Marketing Management, International Trade, Entrepreneurship and Agribusiness. The output of these research studies are discussed under each of these themes.

Resource and Environmental Economics

The members of the department are pioneers in research on Resource and Environmental Economics in the country. The overall aim of the research studies carried out in this area by the department was to incorporate economic thinking into the decision making process in environmental management, specifically economy-wide policies. This effort was rooted in all academic activities including teaching, research and outreach.

The studies on Environment and Natural Resource Economics cover the broad areas of economics of common property resource (CPR) management, environmental valuation and use of participatory approaches in handling environmental issues. The studies conducted on common property resource (CPR) management highlighted the importance of the CPR management in village economy and the impact of excessive use of CPR on resource mismanagement. Another group of studies provided the insights into the economic-environment linkages of shifting cultivation of forested areas in Hambantota and Moneragala districts. A research project funded by the South Asian Network on Development and Environmental Economics (SANDEE) examined the implications of point source pollution due to cement production in Puttlam district and estimated the associated health costs.

The research work on valuation of environmental goods and services were conducted at the department with the view of incorporating those values into development policy analysis and decision making. The assessment of the recreational value of the Peradeniya Botanical Garden is undoubtedly the first such study carried out in Sri Lanka. The study made a significant policy impact, and the administration of the Royal Botanic Gardens implemented some of the main recommendations of this study. A similar approach was used to estimate the economic value of other recreational sites such as the Pinnawala Elephant Orphanage and the Bopath Ella. A considerable number of valuation studies have been carried out using contingent valuation and choice modeling techniques. Findings of these environmental valuation studies provided a scientific justification of the sustainable development by taking into consideration of the development and conservation trade-offs.

Among the other studies conducted in the area of environmental economics, assessing the value of irrigation water and assessing the applicability of economic instruments for environmental management received significant support from external agencies. The research agenda of the department further include environmental policy research primarily on market based instruments for environmental management. The economics of biodiversity conservation, soil conservation, watershed management and protected area management have been addressed by the researchers in the department. The other areas of research include forest resource management on policy analysis and strategies for financing conservation as well as the role of valuation in environment management and proposing economic means for conservation. Natural resource economics research has also been extended to the peripherals of water resource economics, forest economics and energy economics.

The nexus between poverty and environment was comprehensively studied in the context of the human-elephant conflict in the North-western province using spatial analysis and choice modeling. The study identified that without the cooperation of the rural poor the expected conservation benefits cannot be obtained as crop damage was the most serious concern of the people. A financial transfer mechanism was proposed based on the willingness to accept

compensation for crop damages and the urban willingness to pay for the conservation. In an extension of the same study, an insurance scheme for elephant damages was introduced with the collaboration of an insurance company.

The participatory concepts and approaches for successful coastal zone management were displayed by using a case study conducted in the Batticaloa lagoon. The stakeholder analysis exercise carried out in this study showed the importance of mobilizing and empowering fishermen as primary stakeholders is a key to the success of developing sustainable livelihood amongst the coastal community. In a similar study, impact of salinity on paddy production and its economic control was investigated in Mahaweli system H. The research recommended that farmers be encouraged to practice drainage improvements through subsidies and training. The findings were useful to the irrigation agency to make policies and initiate action for sustainable irrigation management. A study that investigated the scale effects of irrigation on paddy production and welfare of farmers in major, medium and minor irrigation systems in Anuradhapura district revealed that the major irrigation system had no scale advantage but used more inputs compared to medium irrigation systems. Poor access to water leads to under utilization of land in minor irrigation system. The role of Irrigation Department and Agrarian Service Department in strengthening farmer organization in rehabilitation work was emphasized. To gain advantage of high price of paddy, a marketing oriented production by small-scale farmers has been recommended.

A study on soil conservation practices adopted by potato farmers in Nuwara Eliya district found that a farmers who follow poor level of soil conservation, obtained short-term high income but low income in the long run. Expansion of land extent and clear land ownership enhanced the choice of a good level of soil conservation. Similarly a study was conducted on economics of non-timber forest products in the rural economy and its implications for forestry conservation policy for Sri Lanka in Sinharaja forest. A comprehensive study funded by EEPSEA identified the appropriate policy options to conserve natural forests in Sri Lanka. The department has contributed to advancement of the frontier of knowledge in some areas such as economics of non-timber forest products used by local communities. The department members have been involved in a number of environment impact assessment activities for integrating economics into the development projects.

The department members have worked closely with the Ministry of Environment and Natural Resources, the Forest Department and the Department of Wildlife Conservation in developing national policies. Based on the research output produced by the department staff, the Sri Lanka Forestry Sector Master Plan Revision set new standards and proved to be successful in implementation. The staff in the department assisted to build capacity in Environmental Economics research in the South Asian region through the involvement in SANDEE research and training activities. Video documentaries have been produced to disseminate the findings of some of the studies. Similarly, a number of stakeholder workshops

and press conferences were held to pass the essential messages to the target audiences. Upon following up the evolution of environmental policy and management strategies in Sri Lanka over a period of two decades, the department feels that policy makers, managers and the nation now recognizes the need to conserve the environment and natural resources on economic reasoning, and seek economic strategies to conserve.

Development Economics

Most of the studies conducted in the last decade in the department either directly or indirectly incorporated developmental challenges like poverty, malnutrition and gender. Poverty assessments were conducted using monetary measures, nutritional status of young children and multi-dimensional indices. Identification of the key determinants of poverty and malnutrition was one of the main focus areas of some of the studies. Furthermore, the impacts of various trade and domestic policies such as taxes and subsidies on poverty were examined. Consumption patterns of food with special reference to protein-calorie nutrition to measure the variation of calorie-protein ratio among rural, urban and estate sectors were estimated using a time series models.

A number of studies have been carried out to determine the importance of women in agriculture and global impacts on them. These include impact of the WTO on women workers in Sri Lanka, role of the poverty alleviation programmes in empowering women, role of mothers in alleviating child malnutrition and the role of women in spice cultivation.

The departmental expertise is always sought by the public, NGOs and the corporate sector in the designing, implementation and monitoring stages of development projects. A number of projects that involved economic analysis were conducted by the staff. Village Irrigation Rehabilitation project (VIRP) in the early 1980's and Medium Irrigation Rehabilitation (MIRP) project in 1990's were mainly related to the evaluation of the irrigation project benefits to the paddy and subsidiary crop farmers in the dry zone districts of and wet zone districts of Sri Lanka. The methodology involved comparison of the project parameters with and without project in the selected small and medium scale irrigation projects operated by Ministry of Irrigation. Another study based on extended cost benefit analysis and ecological capital value of rubber in the Kalutara district mainly concentrated on the carbon sequestration of rubber cultivation. Dendro thermal energy use potential in Organic tea in Haputale and Haldummulla divisional secretariat divisions in the Badulla District was analyzed using extended benefit cost analysis. The economic analysis results showed that the Dendro thermal energy had an overall benefit. These results also show that there can be a good level of increase in soil conservation and soil fertility by conserving bio diversity with the Dendro thermal fuel wood supply. Immediate economic benefits and the protection of soil and water can go hand in hand especially when enhanced by collective action.

Production Economics

Given the fact of a decline in the sectoral contribution of agriculture to the national economy, identification of key issues such as cost of production and the generation of viable solutions are of paramount importance. In this context, the economics of agricultural production and food consumption were subjected to the analysis by the researchers in the department. The research themes include cost of production, economics of integrated farming and other production systems, and productivity and efficiency analysis.

The department members have conducted a numerous studies on the economics of the staple food crop including production and marketing. Cost of production and maintenance of comparative advantage in paddy production was investigated in Anurahdapura and Kurunegala districts. Strengthening farmer organizations for efficient irrigation management, own seed paddy production, safe effective use of agro-chemicals, reduction in post-harvest loss and market orientation were proposed. An empirical study was carried out on the fertilizer subsidy impact on paddy cultivation in the Minipe scheme. They found that paddy yield had not significantly increased and it discouraged organic manure use among paddy farmers.

The economics of integrated farming was also focussed at the department. A village level study was done to determine the economics of paddy–subsidiary crop-livestock based farming systems in dry zone districts. A similar study was done in the Mahaweli B and C settlement schemes. A study on the cattle-buffalo rearing systems exist in the intermediate dry zone highlighted the importance of the livestock based system in the village economies as a source of farm income as well as in input in paddy production. Risk and consumer attitudes towards safety of poultry products were examined to measure consumer responses to different levels of safety standards in the poultry industry. Recently economics of traditional rice cultivation was investigated and the results revealed that under low input rainfed systems traditional varieties provide the similar net income thus providing signals to promote tradition systems under poor resource situations.

A research study supported by EU with the collaboration of the Institute of Aquaculture, University of Stirling used participatory community appraisals to identify target and reference sites for studying the effects of agrochemical when applied in multi-use aquatic systems. Identification of worse case scenarios in terms of pesticide application and entry routes, socioeconomic aspects of pesticide application, cropping practices and income generation/livelihood activities of the farmers in Mahaweli System H were made. The relationship of pesticide application verses socioeconomic status, land ownership, irrigation water availability was also researched into. The final aim of the research was to develop a decision support system for farmers, agriculture extension officers, pesticide regulators and marketers. In another collaborative research project carried out with Institute of Aquaculture, University of Stirling/CARE International Sri Lanka and the University of Newcastle, UK themed Fish in Irrigation Systems Technology (FIRST) the feasibility of promoting inland fisheries (food fish)

production for the benefit of the poor communities in the dry zone of Sri Lanka, both in minor and major irrigation systems were explored. The policy implications drawn from this study were adopted by the CARE International in their rural development projects carried out in the dry zone of Sri Lanka.

The department is considered as a centre for productivity and efficiency analysis. Different total factor productivity measurements as well as deterministic and stochastic efficiency analysis were carried for different production systems, including shrimp farming systems, small holder tea and rubber production systems, rice production in Mahaweli H system, potato production and buffalo production system. The analysis was extended to profit analysis of rubber and tea production. In all these studies, technical and profit efficiency of production systems were examined to define the index of efficiency and to identify the sources of inefficiency.

Major findings of the research were published locally and internationally in the form of journal articles, books, monographs, reports, abstracts and conference proceedings and hence created awareness among the general public, policymakers academics and researchers in the area.

Agricultural Marketing and Marketing Management

Agricultural marketing and Marketing Management are two of the core areas of Agricultural Economics and Business Management. The recent studies at the department dealt with the new frontiers of marketing such as supply chain analysis.

Among the early studies, a study on cooperative marketing is noteworthy. In this study the role of cooperative marketing in improving the village economy was investigated. The research highlighted the structure of the cooperative marketing system, its capacity to serve the consumers and producers in the village economy, its limitations and the policies required to improve the cooperative marketing system to compete with private trade.

The demand and supply of rice and the impact of policy implications on the rice economy was studied using an econometric simulation model to forecast the changes in the domestic rice production and imports of rice and wheat flour under different scenarios in the changes in exogenous variables affecting demand and supply of rice. The seasonal variation of wholesale and retail price of rice in Colombo market was also examined using an econometric time series model. The market information system existing for agricultural producers in Sri Lanka and its effectiveness in reducing the price spread between retail and farm gate were also investigated in another study. Similarly the consumption patterns for subsidiary food crops such as green gram, cowpea and ground nut in Sri Lanka were studied using a time series econometric model. The results calculated the own price elasticities, cross price elasticities and income elasticity. The consumption

patterns for sugar was researched to determine the own price, cross price and income elasticity. Area supply response study was carried out for other field crops considering yield risk and price risk in the Mahaweli H system.

The impacts of the different marketing policies such as the producer subsidy and storage and distribution of paddy /rice on the competitiveness of Paddy Marketing Board (PMB) and private trade in paddy in the dry zone surplus districts were studied. The results showed that the competitiveness of PMB was lacking due to ineffectiveness of the producer price formula and the poor capital and other constraints faced by PMB. The welfare effects of government intervention in rice marketing were determined using an econometric modeling approach from which the consumer and producer surpluses were estimated for Sri Lanka.

The study on export demand elasticities for coconut and coconut by products provided the information on the global competitiveness of the Sri Lankan coconut industry with other major world producers such as the Philippines. A similar study was done to determine the export demand elasticity for the tea industry in Sri Lanka taking into consideration the world exports and imports of tea. The export demand elasticities for rubber were calculated in a time series modeling approach. The other studies in this line include the patterns of expenditure on cooking oils of urban consumers in Colombo, willingness to pay for a fee-based extension service by tea smallholders, impact of nutritional labeling on consumer buying behavior and market potentials and willingness-to-pay for selected organic vegetables. The study aimed to examine the extent to which supermarkets have contributed in increasing the wellbeing of small holders, efficiency and effectiveness of food marketing and the improvement of quality and safety standard of the products sold at supermarkets. It assessed whether the emergence of supermarkets have actually contributed to the improvement of the welfare of various segments in the society including producers, consumers and other retailers. This study was funded by the International Food Policy Research Institute (IFPRI).

The marketing studies were not limited to food crops. In livestock marketing, the household consumption of milk, milk products, meat and meat products in the coconut triangle of Sri Lanka were investigated to determine elasticity measures. Supply response studies in egg production were done in measuring the supply elasticities among egg producers in the country. A similar study yielded the import shares of milk and milk products and their implications for the Sri Lankan economy due to changes in world price of milk.

The above studies were published as journal articles, reports and conference proceedings and hence created awareness among the general public, academics and researchers in the areas. The findings of the studies have been presented at various local and international conferences which were attended by policy makers at various levels, academics, and researchers. The studies were heavily used in undergraduate and graduate teaching by the academic staff members of the department.

International Trade

The department initiated its research studies on assessing economic impacts of international trade in the mid-nineties. The initial studies conducted in this area focused on quantifying the economic impacts of import liberalization on the agricultural sub-sectors in Sri Lanka particularly on rice, other field crops, coconut, dairy using conventional welfare measures. Subsequently, broader issues, i.e., effects of globalization on the Sri Lankan economy were examined. Moving with the global trends, the emphasis was shifted to assessing the effects of regionalization on the South Asian economies in the recent past. The studies also addressed the impacts of trade on poverty, inequality and environmental degradation. Together with trade related issues, various issues related to agricultural markets such as state interventions in agricultural marketing, effects of market power exercised by various groups on the functioning of the markets, and the growth of food retail stores and their effects on supply chains have been investigated. Such issues were examined in markets for paddy, rice, tea, milk, vegetables, chicken, indigenous animals etc. Furthermore, issues related to agricultural production ranging from individual farm efficiencies to public investment in agricultural research have been examined for tradable commodities.

One of the key findings of the studies conducted was that, although the impacts of trade are contextual, they are not as adverse as perceived by the general public. Increased international trade not only would improve economic growth, but also help in narrowing down income inequalities and gender disparities, and reducing malnutrition and environmental degradation, if appropriately planned.

Studies have been conducted to analyze the impacts of globalization on agriculture with a special emphasis on the tea industry of Sri Lanka. In this respect, some studies have addressed how industries could achieve a competitive edge over others where a main focus has been given to the supply chain analysis. Supply chain coordination and its impact on performance, and the use of organizational design features in purchasing are some of the issues addressed.

The findings of these were published as journal articles, research reports, conference proceedings and newspaper articles. In addition, these have been presented at various local and international conferences which were attended by policy makers and academics.

Entrepreneurship

Through research carried out in entrepreneurship, the researchers in the department were able to uncover the dynamics of socio-economic success and failure of rural paddy farmers which in turn enabled unveiling the diversity of entrepreneurial processes adopted by such farmers in Mahaweli systems, despite an apparent uniformity in paddy farming activities. The study successfully demonstrated how pure business and management theories could be used in

researching agricultural related problems. At the undergraduate and postgraduate levels, the department members have guided to carry out innumerable studies on entrepreneurship related to Small and Medium Scale Enterprises with special emphasis on women entrepreneurship.

An island-wide research study on women entrepreneurship funded by International Labour Organization (ILO) was conducted to assess the opportunities available to women and the constraints faced by them and to draw policy implications related to women entrepreneurship development. The recommendations were subsequently adopted by the ILO in their women Entrepreneurship development activities.

In recent years, the tendency has been to reduce types of motivations for starting a new business to two forms, opportunity and necessity, where opportunity is associated more with developed country contexts and necessity is associated with developing country contexts. In collaboration with the University of Stirling, research on entrepreneurship among Scottish farmers and their motivation to start up and diversify businesses was done. Subsequently the findings were compared and contrasted with the findings of research conducted in Sri Lanka to draw parallels. Another research was also carried out on similar lines in collaboration with the University of Edinburgh, UK and the Makerere University Business School, Uganda. The results of both the studies showed that entrepreneurs have a complex range of motives to start businesses which are a blend of “push” (i.e. necessity) and “pull” (i.e. opportunity), not purely one or the other. Overall most entrepreneurs are initially motivated by the need to make a living and to improve their circumstances, but the success of entrepreneurs is dependent upon the presence or absence of opportunity driven motives immaterial of their country of residence. Findings of the research conducted in collaboration with the University of Edinburgh and Makerere University of Uganda also confirmed the above findings.

The department has hosted a series of studies that assess the service quality. One such study carried out in collaboration with the ESSSP (a development project funded by the GTZ) and the Ministry of Public Administration in order to investigate the quality of services delivered by DS secretariats as perceived by the employees and customers. The willingness of the customers to pay for an improved service delivery was also investigated into. Similar studies conducted focussed, service quality of health sector and airports.

Agribusiness

Agribusiness management receives a key position in the department’s research agenda. At the undergraduate and post-graduate level studies have been conducted on agribusiness management in areas such as analysis of changing food consumption patterns and their implications on agribusiness in Sri Lanka, shift share analysis of Sri Lanka’s export sector performance and export credit insurance in Sri Lanka in promoting exports.

A number of studies were carried out to assess the business orientation of farmers. The findings of these studies revealed that about 15% of the Sri Lankan farmers are market orientated whereas the rest of the farming population is production orientated to varying degrees and engaged in routine practices, making them more vulnerable to the market realities, necessitating the extension and support services to adopt more market oriented approaches.

CHAPTER 3: RESEARCH CONDUCTED BY

Department of Agricultural Engineering

Compiled by

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Introduction

The research in Agricultural Engineering commenced at the Faculty of Agriculture much before the establishment of the Department in 1975. In early 50s, the question of research in a division of one lecturer, one technical assistant, a carpenter, tractor operator and labourer, where around 20 hours of face- to-face teaching was involved, is difficult to visualize. Attempts were made to conduct some studies that were relevant to the needs of the country at that time. The first 2- wheel tractor played a significant role in this. It was a time when a farmer intending to use a 2-wheel tractor, had to buy 3 machines- one to work in the field, one in the repair shop, and one on the road from the repair shop to field! This first 2-wheel tractor (Merry tiller) was such a machine. It was tested and several far-reaching changes were made including the replacement of a more suitable engine. The work on this machine did make some contribution to the development of the “Landmaster” which at one time was very popular. At that time (1956/60) the poultry industry was in its infancy and promised to be a good commercial proposition. The Agricultural Engineering Division developed simple feeders, waterers and other equipments for small scale poultry farmers, in addition to designing pre-fabricated 2-storey laying houses which a local firm (setrac) commercialized using pressure treated low-grade timber. Other projects included the development of criteria for loose-housing of dairy cattle. Thus, although no earth shattering discoveries come out of the division, nor papers worthy of publication in foreign journals, the division was able, in spite of the lack of facilities and staff, to make some small contribution to agricultural development. Through foreign aid sources, the division had acquired rainfall recorders, water stage recorders and other meteorological equipment to conduct basic hydrologic studies in the field of soil and water conservation.

A sustained research programme has commenced since 1975 with the establishment of the Department of Agricultural Engineering complemented by PhD qualified academic staff, new building and other resources. Over the years

more equipments was procured from donor agencies, such as USAID, ODA, JICA and from the annual allocations made by the University Grant Commission. Commencement of postgraduate research with the establishment of Board of study in Agricultural Engineering at the Postgraduate Institute of Agriculture has made it mandatory for the academic staff to engage in long-term research programmes.

The following sections briefly describe the research work carried out by the academic staff of the Department of Agricultural Engineering since the establishment of Agricultural Engineering in 1975. The research areas were categorized in to irrigation water Management, watershed management, water pollution and waste water management, GIS and remote sensing, post-harvest technology, farm power and machinery and instrumentation. Some of these studies are undertaken in collaboration with public and private institutions and foreign universities. Most of these studies are being conducted as research projects of the postgraduate and undergraduate students who specialized in Agriculture Engineering.

Irrigation water management

More emphasis on irrigation water management research was made as a result of demand created by the down stream area development activities under the accelerated Mahaweli development programme. The Department staff has been involved in irrigation water management research in almost all the Mahaweli Systems in the area of hydrology, irrigation agronomy, irrigation system design, irrigation water management and drainage. The irrigation agronomy research studies covered the responses of number of major non-rice crops to different moisture regimes. Furrow, basin, and raised beds systems were tested for major soil types in the dry zone in order to provide recommendations on steam size, time of irrigation, width of raised beds, basin size etc. New irrigation technologies, such as drip and sprinkler systems were tested under varying soil and crop types. Local drip units were fabricated and tested against imported ones as far back in 1980s.

Multidisciplinary research approach was one of the unique features of water management research conducted by the department. Technical aspects of studies were complemented with social-economic inputs in order to capture the realities on the ground. This approach was adopted in all irrigation management studies from village tanks to system level studies.

Basic research has also been carried out in late 1980s on large diameter agro-wells when this technology was introduced by the Agricultural Development Authority as a pilot project with 200 wells. About one hundred professionals were trained in this technology by the Department staff through two residential workshops conducted in 1989 and 1990 which contributed to the rapid expansion of agro-wells in the country in the following decade.

Research on agricultural drainage was conducted simultaneously with irrigation research in order to facilitate the crop diversification, because poor drainage was considered as one of the constraints to expand the extent under the non-rice crops. The initial research on agricultural drainage on system H provided basic guidelines for drainage designs followed by process studies on drainage in Mahaweli System C. More sophisticated, sub-surface drainage systems were designed and adopted in early 1990s in Mahaweli system B which is much more prone to water logging compared to rest of the Mahaweli systems. DRAINMOD, a simulation model to predict water table level and groundwater recharge was validated with field data obtained at Mahaweli system B.

These research findings were disseminated through publications, workshops and training programmes. Many residential short courses were conducted for higher level officials, who had at least a basic degree, so that they could make use of this new knowledge. Middle level officials at the system level have been trained using more simplified training materials, which could be also used for farmers training, in order to facilitate the adoption at the farm level.

Watershed management

While research in the downstream areas was focused on irrigation and drainage, hydrology and soil erosion research have been conducted in the up-stream areas, especially the upper Mahaweli watershed. Hydrological processes under different land use types, mainly natural forest, plantation forests, grasslands, were studied in detail in order to obtain information on the effect of land use changes on stream flow. This research has been carried out at in major agro-ecological zones starting from Horton plains down to Mahaweli system H in the dry zone. Hydrological models were validated with the information acquired from this basic research studies so that such models could be used to find impact of land use changes at a given location. Use of GIS and remote sensing techniques also complemented this work carried out by the Department. These studies were conducted in collaboration with Institute of Hydrology of the UK.

Soil erosion research has commenced at the Department in 1976s with the construction of standard runoff plots at Meewatura farm. Since then different aspects of basic soil erosion research on erosivity and erodibility have been carried out. The erosivity map for Sri Lanka was prepared, erodibility of few wetzone soil types were estimated and soil erosion under different land cover has been measured. This plot size research has been extended to watershed scale using improved instrumentation and the results obtained were used to develop and validate computer simulation models, especially for the upper Mahaweli Watershed.

The findings of watershed management research have contributed to the development of Forestry Sector Master Plan and Protected Area Network of Sri Lanka. The findings of soil erosion research have been used in designing foreign

funded watershed management project in order to make interventions at individual farm fields as well at watershed scale.

Remote sensing and GIS

Remote Sensing is an important spatial data source which provides useful data and information for agriculture related research and applications. The Geographical Information Systems (GIS) are important tools that can be effectively used in mapping and in analyzing spatial data in decision making in agriculture. The Department of Agricultural Engineering identified the usefulness of remote sensing and Geographical Information Systems and associated disciplines in agricultural resource management in general and in the field of agricultural engineering in particular in early 1990s. With this understanding, it introduced this discipline into the undergraduate and postgraduate curricula in mid nineties. However, the use of remote sensing and GIS in soil erosion related studies by the Department staff dated back to 1989 where remote sensing and GIS has been used in soil erosion assessment in Hanguranketha area. With time, the research activities using remote sensing and GIS were developed rapidly. Most of the studies are related to water resources management at catchment scale and have attempted to study the land use changes in the upper Mahaweli catchment area using multi temporal remotely sensed data and to relate these land use changes with soil erosion and reservoir sedimentation, hydrological changes and water quality. Wetlands are important ecosystems that contribute to water quality and quantity at the catchment scale. Changes in important wetland ecosystems in the western province as a result of urbanization and industrial development have also been focused in our research activities.

Small tank cascades play an important role in dry zone agriculture. However, due to various natural and man made reasons, the productivity of these tank cascades are deteriorating rapidly. Studies have been conducted to identify the changes in the tank cascade systems and to relate it with land use changes in the tank catchments with remotely sensed data.

Remote sensing and GIS related research is not only focused on water but also in yield predictions and food security analysis and mapping. A study was conducted to identify the relationship between satellite derived biomass indices with tea yield in selected mid and up country tea plantations. These yield predictions are important to get a general estimate of tea yield under good and adverse weather conditions. It may be helpful to identify the areas with low yields to find reasons and to apply rectifications.

Pollution and Waste water management

Due to rapid rural and urban development in Sri Lanka, point and non-point source of water pollution have been drastically increased. Release of untreated wastewater into natural environment creates series of environmental problems

affecting the eco system and livelihood of the people. One of the main reasons is lack of knowledge and know-how on economically and environmentally viable wastewater treatment system. Constructed wetlands have been used for treating wastewater as a cost-effective and environmental friendly system. However, the design, operation and maintenance criteria of constructed wetland have to be optimized to suit local situation since the performance are location specific. Growth performance of selected plants and pollutant removal have to be investigated at different design, operation and maintenance conditions to understand the functional processes in more detail and to formulate the management guidelines for using constructed wetlands in Sri Lanka where the climatic condition is very conducive for biological transformation.

Media plays a major role in the hydraulics in the constructed wetlands. In order to reduce clogging and for rapid establishment of plants, coconut coir was introduced as the media in the constructed wetlands. Hydraulic has been improved and the nitrate removal increased up to 100% for diluted leachate discharged from municipal solid waste dumping sites.

Studies were conducted to identify wetland plant species that have the potential to be used in constructed wetlands under tropical conditions and to identify optimum plant management conditions viable to tropical regions. *Scirpus grossus* has great potential to remove pollutants and was found to be a viable plant species for domestic wastewater treatment which has not being thoroughly investigated previously under tropical conditions. Harvesting is suggested as sustainable plant management option. A secondary benefit is the possibility of utilizing this harvested plant material for cottage industries such as matting, weaving, and medicinal applications—a potential income source.

An integrated system of emergent plants (*Scirpus grossus*) and submergent plants (*Hydrilla verticillata* in a subsequent channel) was also investigated. The submergent plant subsystem improved removal of nutrients that survived the emergent subsystem operated at low hydraulic retention times. The significant improvement in effluent quality following treatment by the submergent plant system indicates the value of incorporating such plants in wetland systems.

Plant growth performance study was conducted to find the optimum plant growth in terms of pollutant removal for harvesting because harvesting is considered as a vital management practice in constructed wetlands to maintain the performance and avoid recycling of the pollutant within the system. A model was developed for *Scirpus grossus* for treatment of lechate.

Phytoremediation measures to control agricultural pollution at farm level are being carried out in intensively cultivated areas in Nuwara Eliya using Water Cress - *Nasturtium officinale*, and Arum Lily - *Zantedeschia aethiopica* plants) including assessment of health and socio-economic impacts of agricultural pollution. This research is carried out with the involvement of the farmers, health officials and environmental officers at the Urban Development Authority.

The research associated with water quality in the past has been concentrated on physical aspects such as sediment loads carried by the stream flow as a result of soil erosion. Emergence of eutrophication due to nutrient pollution (chemical aspects of water quality) due to intensive agriculture was investigated from 1990s onward. The recent water quality issues in the upper watersheds due to fecal contamination (biological water quality) have prompted the department to embark on water supply and sanitation research. A comprehensive, long-term research programme has been launched to address this latest issue with a foreign funded project.

In addition to the traditional way of disseminating the results of these studies through publications, the findings have been used to train industrialists, government officials of line ministries, school teachers and students. The staff has also designed constructed wetlands to process waste generated from industrial units.

Energy and waste management

The field of energy and waste management became an important subject in the late 1970's. The early attempts were on biogas productions and solar dryers. The latter was studied in greater detail and led to a thesis research in utilizing solar roof in tea factories. Soon it was felt that there were technological problems as well as changes in emphasis with fossil fuel usage as we have been constantly reminded over number of decades. The technical problems were not apparent, particularly with biogas productions in single reactor systems, like Chinese and Indian types that were researched and promoted. The research on biogas was halted to gain experience and background knowledge while thermal systems of pyrolysis and gasification became the main focus of research. A multi-product pyrolyser was one of the outcomes of a doctoral research. The study focused on a very early attempt to prevent atmospheric pollution from burning straw. It provided an avenue to examine advantages and disadvantages of char in rejuvenating nutrient depleted soils. It revealed that char provides a very large specific surface for ion exchanges coupled with increased microbial activities, leading to nitrogen fixation. Looking at the 'chena' farmers more closely it could very well be said that they not only enjoyed the benefits of char but a reservoir of organic mass, 'the roots' of the felled trees. However, such systems were not sustainable with the increase in population. Nevertheless, the lessons learnt in researching into slash and burn, chena farming systems needed to be transformed to a modernized approach. In the mean time, the Green Revolution (GR) became the bastion of inorganic fertilizer use, but it was at the expense of exploiting fossil fuel to produce the miracle substances of GR.

In the middle eighties, environmental problems became more visible with number of reservoirs showing signs of algae blooms and thus reservoir capacities getting less, although Mahaweli scheme provided ample water for replenishing the depletions. Excess use of inorganic fertilizer was recognized as one of the major

causes. The research on charcoal became a useful tool to conduct trials on developing a slow release fertilizer to reduce pollution and fossil fuel usage while enhancing productivity. It led to a patent on char coated urea. It was a very efficient technique in reducing the use of inorganic nitrogen to less than 10%, thus a 90% saving. Unfortunately, it was not promoted, since the fertilizer trading companies were not impressed with the results.

With the experience gained in trying to commercialize the research findings and in pursuing the fertility requirements in tropical soils, it was recognized that Municipal Solid Wastes (MSW) could be converted to aerobic compost. In view of the growing crisis in managing MSW, an attempt was made in 1994 to fabricate a low cost reactor. It was a self funded project and soon became a reality in 1998, a patent was obtained.

The results were commercialized with World Bank funding through the MEIP project, backed by the UDA and a private company. A 4tonne/day unit that was built at Meewathura Farm was upgraded to 8tonnes/day of mixed MSW. The findings were disseminated and a UDA funded project was formulated to build three units at Mawenella, Dambulla (with Kandalama Hotel as the operator) and Kalutara (operated by the Kalutara Urban Council). The one at University of Peradeniya was operated for more than three years during which the operations were self-sustained and good quality, high temperature 'thermophilic' compost was sold to A Baur & Co. They are still sure of the market potential for thermophilic compost, since degradation rates are very low, providing the humic acids in slow doses for mobilizing the nutrients in tropical soils. It was a lesson learnt from the 'chena' cultivators.

The Solid Waste Management Research Unit (SWRMU) of the Department was selected among number of universities that had applied for the project on "Sustainable Solid Waste Landfill Management in Asia". It is a sub-project of the Asian Regional Research Programme on Environmental Technologies (ARRPET). The project was coordinated by the Asian Institute of Technology (AIT) and funded by the Swedish International Development Cooperation Agency (Sida). It had two phases of research over a period of seven years from 2001 to 2008. They were both laboratory level investigations and field level, ranging from waste characterization to a test cell.

In the first phase of the project, landfill pre-treatment technologies were experimented and developed to suite different conditions of use from small local authorities to large scale commercialized systems. The findings are being applied in different parts of the country. A reactor using anaerobic digester technologies is being developed to feed on domestic wastes for replacing large proportion of LP gas use in urban dwellings. In contrast, large scale landfill bioreactor technology was developed to produce electricity from methane. It is the flagship technology of the SWMRU that has been developed to use local materials and produce gas at affordable prices. The development process took considerable time and effort to understand the behaviour of landfills and dumpsites under wet tropical conditions.

The developed landfill bioreactor technology that can be made into small biocells, can overcome the present failures of liner systems to prevent pollution. The problem of breaching of High Density Polyethylene (HDPE) liners was overcome with a live biofilter of a composite design consisting clay soil –waste polyethylene –clay soil, having only a total thickness of 150mm. Its novelty can be attributed to natural attenuation of polluting liquid substance of ‘leachate’ to give pure water. The mechanism of this filtration, control system of leachate recirculation along with natural formation of specific reactions zones within the landfill body provides ideal conditions to produce valuable methane gas, effectively making these biocells waste to energy (WTE) units. It is predicted that biocells will produce gas over a period of three years and it could be the fastest turn-around-time so far reported for mining the wastes. The mass and energy balance studies of both raw and mined wastes indicates that combustibles of both biodegradable and non-degradable materials can be made into Residual Derived Fuel (RDF) for producing electricity. The Kandy Municipal Council recognising the value of these findings has appointed CRES of PGIA as the consultants to implement the project “Rehabilitation of Gohagoda Dumpsite and Development of Integrated Solid Waste Management System for the KMC”.

Post harvest Technology

Crop drying is a widely practiced operation in agro-processing in the country. Various types of designs which depend on thermal energy from variety of sources are available for crop drying. Many of these dryers require improvements in spatial uniformity of drying and low power consumption in cases where electricity is used for blower mechanisms. Since drying is a function of flow rate and temperature of air stream, it was intended to develop a dryer which is capable of producing evenly distributed velocity throughout the drying chamber. The engineering model which was tested for its performance showed promising conditions in distribution of air velocities. One such successful application was the fabricated dryer coupled with solar air heaters for drying herbs in Hambantota District,

Paddy husk has been a popular source of thermal energy for domestic and small scale industrial applications due to its availability in abundance. The present technology of paddy husk furnace used in the said applications requires improvements in thermal efficiencies. Paddy husk which is packed in cylindrical shape is burnt from the opening about the centre axis. Hence, with continued combustion, the diameter of the inner surface increases causing more material being burnt. Therefore, as the thermal energy supply increases regulation of combustion process is required. The presently available technology does not provide adequate control measures for regulation of combustion process or thermal energy supply. A study was conducted to design fuel blocks made of paddy husk facilitating combustion on a uniform surface area. The experiment included selection of suitable bonding agent for making paddy husk blocks and studying of combustion characteristics of them in a simple furnace. Tests on leaf

extract of *Neolitsea cassia* (“Dawul Kurudu”) and *Neolitsea fuscata* (“Kudu Dawula”) indicated strong bonding with husk particles. Uniform combustion of the surface where fire started continued until the last moment at which the wall arrangement collapsed. In addition to the uniform heat energy supply throughout the burning, higher thermal efficiency was observed with complete and slow combustion of material.

Rice processing industry in Sri Lanka has been contributing to ground water pollution as a result of disposing water which is used for soaking of paddy. Continued soaking of paddy for about 3 days causes inferior quality in rice leading to water pollution. Spray soaking of paddy was tested as an alternative method and was found successful. Spraying of water at intervals reduced the water consumption and pollution while producing better quality rice compared to the process of continued soaking in tanks.

Fruits from trees such as woodapple, tamarind and *Beli* are available in abundance during the seasons in many parts of the country but underutilized due to unavailability of technology for processing. The ripened fruits of these crops are characterized by thick pulp, fibre and seeds. As a result of low moisture content in fruit at this stage, extraction of pulp is difficult and requires special mechanisms which consume high energy. A centrifugal mechanism which operates at high speed was designed and tested for its performance in pulp extraction from fruits of these crops.

Experiments were conducted on low cost fruits and vegetables storage structures and a patent was awarded for the Design of a Green Fridge Suitable for Small-Scale Vegetable Stalls. The Institute of Postharvest Technology (IPHT) was granted permission to provide this technology to required people. Later, the same technology was used to develop a banana ripening chamber using charcoal and cement structure. The technology was introduced to Cargills supermarket chain as a student research project. Interesting results were drawn from another experiment conducted to prevent banana splitting. This problem is extremely serious with *Kolikuttu* fruits and laboratory level experiments were very successful and the technology will be patented very soon.

Another research problem on production of white copra at small scale level was raised by the Coconut Research Institute (CRI), Coconut Cultivation Board (CCB) and Sarvodaya Economic Development Services (Gte) Ltd. Findings were published in international and local journals and news letters. Training programmes were also conducted for selected farmer groups in Puttalama and Kurunegala districts.

In the recent past, attention was paid on the application of cleaner production principles in agro-processing industries. Those requests were also received from the industries as the CEA started the implementation of environmental regulations strictly during past few years. Technologies were developed on mobilization of phosphate available in Eppawala Rock Phosphate (ERP) using pineapple peel waste and potential use of whey in pospho-compost

manufacturing. A Joint Patent was applied for the technique developed for pineapple waste. One company has already agreed to use the technology in future.

Quality preservation waste minimization techniques for agricultural produce will be the main research theme even for the future. However, these studies will be linked to cleaner production and lifecycle analysis with special reference to energy issues in postharvest operations. Development of a domestic scale coconut grinding and emulsifying machine and development of a commercial level banana ripening room to minimize fruit splitting are ongoing research projects. Research related to bio-fuel development will be the other area of interest for coming years.

Instrumentation

Research in electronics and instrumentation applications were initiated in 1990s with the development of a water level sensor for water management in irrigation canals. This work was followed by research in the area of digital image processing. Some of the work such as the development of a new RH sensor where the action of human hair and the strain gauges were combined earned a patent. Detection of groundwater table using Seismic Waves generated through locally fabricated instruments was also developed.

Even though there were many projects of small scale on development of various sensors and measuring techniques, no attempt could be made beyond imparting the research experience to the students, towards taking them to commercial level as there was no significant demand in the country for such instruments to make such efforts profitable. However, image processing related research together with the collaboration of the personnel from the Coconut Research Institute (CRI), has led to the development of a software for identifying and counting mites in coconuts using microscopic images which has supported the research and development work there. Another very significant achievement was the development of the sand separator for made tea through collaborative work with the Tea Research Institute (TRI). This was successful as a research prototype, and was tested at the tea factory in Ratnapura that belongs to the TRI. The development has been patented, and after many years of trying different options to proceed towards a commercial model, a research grant has been awarded by CARP to carry out further developments towards a commercial model.

Two other major achievements were the development of a Turbidimeter and the development of a Seismic sensor with a digital display. The Turbidimeter is wanted by many researchers due to its low cost, and portability. The Seismic sensor with a digital display is considered to be a unique combination of ideas, and is being patented. This is expected to be useful in many applications including underground explorations, and other applications where measurement and display of earth-borne shock waves is useful.

CHAPTER 4: RESEARCH CONDUCTED BY

Department of Agricultural Extension

Compiled by
Dr. J. A. S. De Silva

Introduction

Agricultural extension as a part of the program of instruction at the Faculty of Agriculture dates back to 1974 when it was introduced by Dr. A.T Mosher, who had by then retired as the President of ADC, as a component of the subject in farm management and agricultural extension in the then Department of Agricultural Economics and Farm Management. However, research in agricultural extension formed a part of the research activities undertaken by the Agricultural Economics Research Unit set up in the late sixties with the Agricultural Development Council (ADC) assistance with the arrival of Dr. Rainer Schickele, formerly Head of the Agriculture Division of the Food and Agriculture Organization as a Visiting Professor. The government was then engaged in a large program to rehabilitate the major irrigation schemes. A collaborative agreement was entered into with the Land Commissioner's Department and the Department of Agriculture to carry out bench-mark surveys of the major irrigation schemes, with a view to evaluating the special projects program of the government. The Elahera Colonization Scheme was the first to be surveyed in 1967 and this was followed by a survey of nine major colonization schemes, viz. Minneriya, Galoya, Padaviya, Allai, Iranamadu, Minipe, Hakwatuna Oya, Rajangana and Mahavillachchiya. The most significant feature was the involvement of the Faculty students in carrying out the surveys. They came face to face with the realities of farming as a way of life and as a business and this helped to dispel, at least to a great extent, the earlier criticisms of "blackboard agriculture". Dr. Schickele left on the expiry of his contract in the early seventies, but the Agricultural Economics Research unit continued with its activities. The Elahera Scheme was resurveyed and bench-mark studies of further 6 irrigation schemes carried out. These included Nachchaduwa, Usgala Siyambalangamuwa, Kandalama, Giritale, Kaudulla and Kantalai.

The importance of Rural Sociology as a component of Agricultural Extension was well realized and on the expiry of Dr. Mosher's term of office, ADC assisted in bringing over Dr. Nancy Waxler to develop this field of study. Assistance was

sought from various foreign organizations to develop the teaching and research program and place it on a firm foundation. The Department was fortunate in getting the services of Prof. P. Von Blanckerburg of the Technical University of West Berlin as a visiting professor in agricultural extension. He was of great assistance to the Department staff in conducting research on the training and visit system of agricultural extension and publishing a monograph.

The Department was re-named as the Department of Agricultural Economics and Extension in 1983. The name change reflected the changing importance and thrust in the social sciences as we attempted to direct agricultural production and development to meet the social needs of the country to be supported by appropriate research and outreach activities. An Audio-Visual (AV) unit was set up in 1984 and the valuable VHS video production and editing system, audio recording and duplicating system, still photography unit and graphic art equipment received under the AED project were installed. The AV Unit assisted in preparation of several videotapes regarding the cultivation of crops and rearing of animals. Further, video-recorded several seminars and workshops conducted by the Faculty.

The Research Unit was re-activated through a grant of approximately 75000 Canadian dollars received from the International Development Research Centre, Canada. Research work of applied nature increased substantially with many Departmental members working on projects such as the Small Holder Rubber Rehabilitation Project, Village Irrigation Rehabilitation Project, Major Irrigation Rehabilitation Project, and Integrated Rural Development Project. These projects helped create employment of a temporary nature for several agriculture and other graduates, and more importantly provided opportunities for them and the staff members with valuable field experience.

In order to cater to the needs of the specialized courses in the new curriculum and the postgraduate level training, in 1996 the Department was separated into two, namely the Department of Agricultural Economics and the Department of Agricultural Extension. Agricultural Extension has developed a distinct disciplinary and professional identity in the world and also in the country. In fact in 1990 the Sri Lanka Agricultural Extension Association was formed in which some Departmental members served as office bearers. The research areas of the Department of Agricultural Extension include agricultural extension approaches, agricultural education, rural sociology including gender issues, communication, adoption of innovations and organizational management.

Agricultural Extension Approaches

Extension approaches in the main agricultural sub-sectors have been changing from time to time. Several studies were conducted to assess the different systems and to propose changes for improving these extension approaches. The problems related to extension – research linkages and issues related to their organizational and health aspects have been studied not only in the food crop sector of the

Department of Agriculture but also in several non-governmental extension rural development agencies.

With the decimation of field level extension professional and the development of information communication technology (ICT) the extension services are depending more and more on the use of mass media for the transfer of agricultural technology. However, the conventional formats of mass media programs may not be equally effective in disseminating technical messages to farming communities. Therefore, a series of research studies were conducted to evaluate different media formats such as interactive drama and interactive multi media CD ROMs. Using the findings the docu-drama and interactive multimedia formats have been developed by government, non-government and private sector extension organizations and are being used in some of their communication campaigns. Innovative methods of using video programs to evaluate selected farming technologies such as ergonomics of tea pluckers and improved plucking baskets were also developed and tested successfully.

Irrigation water management requires a substantial extension inputs to make sure that the farmers adopt various management systems. The extension needs related to water management have been studied and published extensively. Demonstrations are the most commonly used extension method adopted by most organizations promoting improved field practices. Care International used agricultural demonstrations extensively in its agricultural development projects and the studies conducted jointly has resulted in improving the arrangements used by Care in designing and implementing agricultural demonstrations. Coconut Research Institute of Sri Lanka implemented a new extension approach called Persuasive extension program. It was evaluated jointly and suggestions for further improvements made.

Traditional systems of environment management and medicinal and food preparations are increasingly becoming popular owing to their sustainable nature of natural resource use. Studies have been conducted to identify the extension needs of the medicinal plants industry. The studies conducted in Sinharaja peripheral villages have revealed that a great deal of traditional knowledge is being lost due to non-transfer of the knowledge and technology from the parents to their children. With the assistance of over 30 traditional medicinal practitioners, the methods of medicinal preparations using Sinharaja plants and other natural resources have been documented.

Agricultural Education

Curriculum development

The staff of the Department has been involved in major curriculum development activities within the University and in other organizations in Sri Lanka as well as in the region. Apart from the common undergraduate curriculum development activities, the staff members of the Department were collectively involved in the

development of two new very successful postgraduate degree programmes in the areas of Organizational Management and Developmental Communication. The members have also assisted the Coconut Development Training Centre, Lunuwila in the preparation of training material related to extension methodologies, the National Institute of Plantation Management, University of Sabaragamuwa in designing computer related courses and Ministry of Agriculture and Marine Resources of the Republic of Maldives in preparation of curricula for certificate courses in agriculture, at individual levels.

Technical guides

The members have contributed to the development of material to be used by both students and public. They have contributed to the Handbook on Survey Design and Analysis for University students and a technical guide to assist in the writing of dissertations. Different guides in Sinhala, mainly for extension officers and farmers, have also been produced in the areas of tea plucking, tea pruning, and soil conservation.

Training

Apart from coordination and contribution to numerous training activities, the members have also contributed to this area by dissemination of knowledge related to training on areas such as outreach activities, skill development, and training in participatory extension methods at regional, Provincial, and University level conferences. The staff has also prepared plans for training in large scale national level projects such as the Participatory Forestry Project.

Computer Based Learning Resources

Ensuring effective pluralistic information flows between farmers and various stakeholders involved in agriculture is identified as one of the major challenges ahead of agricultural extension in the present world. Recognizing the farmers' need for information and appropriate learning methods thus shifting from direct one-way technology transfer systems to a demand driven or a negotiated system through which farmers and rural communities determine their own information needs become really important.

To meet these challenges the Department has initiated research on developing computer based learning resources. Basically there are three types of resources:

- Interactive multimedia CDs to disseminate agricultural information
- Decision Support Systems
- Computer Based Learning Material used in undergraduate education

Interactive multimedia CD ROMS which include video clips, photographs, diagrams, sound, animations and text together in an interactive manner are found to be an effective means of information dissemination to an intended audience. These IMM CDs were developed, in collaboration with the Audio Visual Center of the Department of Agriculture, using software program called Macro-Media Director arranging the content into electronic book which facilitate user interaction to a great extent. These CDs were based on selected crops such as Anthurium, Orchid, Gerbera,

Mushroom etc and are presently used at Cyber Extension Units to disseminate information to farmers.

Information at the right time at the right place is crucial for management, in terms of decision making. It has been identified as an important resource thus managers are supposed to manage information just as managing other resources. The Department has contributed an array of research outputs related to information management over the past years. These information management systems were widely known as Decision Support Systems (DSS) and were basically meant for agriculture community development and management. 'VegInfo' is a Beta Version of an information and decision support system for 25 vegetables developed by the Department in collaboration with Horticultural Development & Research Institute of the Department of Agriculture. "Mahaweli Flora" yet another Information System on plants in Mahaweli areas which is developed for Natural Resources Management Services (Pvt.) Ltd. of Mahaweli Authority of Sri Lanka. There were many other systems to support project monitoring and evaluation, human resource management, project management, performance assessment etc.

Recent trends in education have promoted learner centered educational approaches which involve active independent learning by the students. This has created a demand for supplementary self-learning material of high quality. Computer based interactive self-learning materials could be an ideal substitute to strengthen traditional class room based learning allowing great deal of user-control in a flexible learning environment. The Department has initiated producing computer based learning materials for two subjects, that are coming under the new curriculum of the Faculty of Agriculture, using commonly used software i.e. MS PowerPoint. These products will act as models for future computer based learning materials in other courses.

Rural / Sociology

Rural sociology is a field of sociology associated with the study of social life in non-metropolitan areas. It is the scientific study of social arrangements and behavior amongst people distanced from points of concentrated population or economic activity. Strengthened by the individual and collaborative contributions of economists, extensionist and sociologists, the Department excels in sociological research, teaching and outreach focusing in three interrelated areas: agriculture and irrigation; evaluation / impact assessment of development projects and socio-economic studies. These are embedded in a wide range of issues related to the sociology of agriculture, irrigation and rural society, impact assessments, participatory community development, socio-economic studies, baseline studies and socio-economic evaluations. These studies are conducted as social research, consultancies or evaluations at national, regional, and international level.

In Sri Lanka rural areas are largely agriculture based. Almost all the lands depend on irrigation at least in one of the major cultivation seasons. Therefore, rural community faces a range of specific issues and challenges with regard to sociological aspects

of agricultural activities and irrigation. Having understood the importance of exploring such sociological aspects many researches, projects and socio-economic studies have been conducted. These cover village irrigation rehabilitation, food security and minor tank development and its impact on livelihoods of rural households in Sri Lanka. Besides, socio- economic studies on village irrigation schemes and rehabilitation of irrigation schemes have been identified as key areas for improvement and therefore many studies have been conducted in several districts of Sri Lanka. Moreover, study of knowledge, attitude, cooking methods and consumption or household utilization of crops; shifting cultivation stabilization; use of traditional knowledge for crop management; status, problems, potentials, needs and recommendations for improvement of grains, vegetables, fruits and industrial crop sectors; socio-cultural factors on industrialization and agricultural development in Sri Lanka and drawing attention towards ecological-anthropological study on socio-cultural aspects behind promoting different crop management aspects are perceived to be central to researches undertaken in rural agricultural sector, with the aim of sustaining agriculture based livelihoods and lives of rural communities.

The socio-economic studies conducted in Sinharaja peripheral villages have highlighted the rapid loss of the unique traditional knowledge systems related to local medicinal and food preparation systems using Sinharaja plants. They have also revealed that the tea cultivation has completely changed the sustainable traditional systems of forest usage pattern. The qualitative and time series studies in the same tea plots of the selected sample of small holders were done and assessment of soil fertility, pests and diseases, weed growth and agronomic operations were closely monitored. It was revealed that the productivity is declining fast imposing threats for clearing up more and more forest land.

The long term studies in the Sinharaja peripheral villages have been published. The traditional knowledge on food and medicinal preparations has been documented. The villagers were further advised on how to overcome their problems and improve the productivity. Based on the research findings, a special comprehensive field training program was designed especially for the tea small holders in the area. A special advisory booklet was also published and distributed among many villagers. A series of special training programs including field demonstrations, mini exhibition and a series of presentations were also conducted in three central locations around the Sinharaja periphery, in consultation with the tea extension staff of the area. More than 500 tea growers from several villages participated in these programs. In addition, a video documentary titled "Sinharaja Life in Transition" was produced to highlight the traditional systems of forest use and the changing lifestyles of the villagers with the expansion of tea cultivation. It was shown to several national and international audiences and also broadcast on the national television. The outcomes of such socio-economic studies are highly significant and community development aspects are of immense use for community awareness.

The human-elephant conflict study undertaken by a group of scientists from three faculties in the University of Peradeniya is one of the most comprehensive studies undertaken so far on this important issue. A new scientific method was developed to classify the conflict level and the total area of the South-Western Wildlife Region (Anuradhapura, Kurunegala and Puttlam districts). This is evidence where conflict resolution approaches were worked out for betterment of certain communities where it is highly felt.

Going beyond sociological aspects of rural community, livelihood enhancements, conflict resolution and agriculture, some common but important sociological issues and problems have been addressed. Except for lack of education and unemployment, many youth problems are associated with issues related to love and sex. Since developing countries including Sri Lanka are promoting sex phobic cultures, it demands answers to overcome existing situation. Research studies carried out on youth, sex, love and sexual risks have been able to address these to certain acceptable level. These research findings were disseminated through publications, workshops and training programs.

The evaluation studies including baseline studies, participatory rural appraisals mid-term and final evaluations undertaken on behalf of many national development projects implemented by both government and non-government organizations have contributed in their successful designing and implementation bringing benefits to rural communities. Socio-economic evaluation of projects such as village irrigation rehabilitation, integrated rural development, second agricultural extension, integrated food security, dry zone agricultural development and tea estate assistance are some of the major studies undertaken. Besides, impact assessments of farmer trainings, minor tank development programme and regional economic advancement projects had also been done by the academic staff of the Department.

Communication

Development communication

Department of Agricultural Extension has conducted a variety of research work on communication viz: development, interpersonal and mass communication. A study on assessing the role of research managers as communicators gives insight on the role of development communication in transmitting the latest findings to facilitate development. Research and development studies and action research in development communication have resulted in the development of two interactive drama formats which can be used in creating awareness and changing negative attitudes towards the development interventions. The evaluation of different video formats has helped in identifying suitable formats such as docu-drama and docu-features. Some of these video programs were broadcasted over the national television.

Interpersonal and Mass Communication

Department has conducted research extensively on interpersonal and mass communication. A research study on patterns of communication among Sri Lankan youth regarding love, sex and associated risks and a similar study conducted among University students reveal the effectiveness of communication in improving their behaviour. In another study, the role of interpersonal communication in the adoption process has been discussed.

There are many research studies on the use of communication channels. In one such study the relationship of use of communication channels to both personal and situational factors and adoption of paddy varieties among farmers in the Vaddakachchi village of Iranamadu Special Project, Sri Lanka has been assessed in 1979. The relationship of use of communication channels to personal and situational factors and adoption of paddy varieties has been assessed in the same year. Use of mass communication channels by farmers for obtaining information on high yielding varieties of paddy has been the subject of study in another contemporary research study.

The study on farmers' listening behaviour to agricultural radio programmes in a major irrigation scheme in Sri Lanka has tried to facilitate the effectiveness of radio programmes in disseminating information among the farming community. Another study on farmers' perceptions of the usefulness of publications and farm radio programs of the Department of Agriculture has tried to enrich the usage of communication channels by the public sector institutions. A recent case study conducted at Mahailuppallama area on farmer preferences over different communication channels to receive agricultural information has tried to assess the effectiveness of different communication channels in delivering the latest information among the dry zone farming community. The advent of novel communication channels and the change of farmer behavioural patterns increase the timeliness of such research.

Adoption of Innovations

Research is of no use unless the findings in the form of innovations are effectively utilized or adopted by the relevant stakeholders to bring about pre-determined desired changes. Enhancement of knowledge, favourable attitude and development of the necessary skills serve as the pre-requisites for the adoption of innovations. Many research studies have been conducted in the Department by the staff either individually or as a team and also along with undergraduate and postgraduate students on the factors affecting the adoption of innovations in agriculture and allied fields. Some of the important studies conducted in the Department are described below.

Rice being the staple food plays a prominent role to ensure the food security in Sri Lanka. Increasing rice production and achieving self sufficiency is an important aspect of agricultural policy of the country. Various studies were conducted to

examine the factors related to the adoption of recommended agronomic practices in rice cultivation. A gap between knowledge and adoption of practices was observed indicating that knowledge was necessary but not sufficient to encourage farmers to adopt the recommended practices. Although the farmers were generally knowledgeable, availability of good quality inputs in time and in the required places had been a limiting factor. Also, some of the recommendations regarding the agricultural practices were found to be not suitable to the resource-poor small farmers in the domestic food crop sector.

Similar studies were conducted with respect to other field crops. Chemical pesticides are heavily used to control pests and diseases in the cultivation of other field crops such as chillies, onions and vegetables. The consumers also had been interested in purchasing pest free vegetables rather than pesticide free vegetables although in the recent past there had been a reversal of this trend especially among the middle and upper class people. Studies were conducted focusing on the hazards associated with the spraying of pesticides to chilli, brinjal and other vegetables, and the factors associated with the use of protective measures by agro-pesticide applicators as well as the health problems experienced by them. It was clearly demonstrated that the non-use of protective measures was significantly related to the intensity of health problems experienced by the agro-pesticide applicators. Consequently safe use of pesticides and use of integrated pest management practices to reduce the ill effects of pesticides to both applicators and consumers among farmers in the Mahaweli area were examined.

Another strategy to increase agricultural production is to bring in additional lands under cultivation. In this regard, research was conducted in the development of alternative agricultural strategies for abandoned paddy lands in the urbanized areas of Gampaha district, ways of stabilizing shifting cultivation in Lao People's Republic and in the establishment of home gardens by households through school nursery programs in Trincomalee district. Findings of these studies were implemented through various projects both in Sri Lanka and abroad yielding positive results. Similarly, problems associated with the adoption of farming practices of the out-grower farmers of the Sri Lankan sugar industry were also investigated and compared with the settler farmers in the same industry.

Research activities of the Department on the adoption of innovations were not only restricted to the domestic food crop sector but also included the export oriented plantation sector covering crops such as tea, rubber and coconut. The adoption of recommended technology by tea small holders and the ergonomics of harvesting tea in the high elevations of tea plantations were analysed resulting in useable recommendations.

The major findings of the above studies have been published as undergraduate research reports, postgraduate theses, journal articles and monographs. The findings have also been communicated to the policy makers through various seminars resulting in the formulation and implementation of various development

projects. Based on the research findings, a series of field training programs were conducted for the farmers with the objective of encouraging them to adopt the recommended innovations by enhancing their knowledge, changing their attitudes and developing the necessary skills.

Organizational Management

Being a forefront institution in higher education in agriculture, one strategic move of the Faculty of Agriculture was to introduce organizational management into its first trimester based curriculum in 1991. The challenge was given to the Department. The mandate was to teach and conduct research in areas such as basic concepts and common social problems in organizations; Human Resource Management (HRM) procedures and techniques for enterprise development; types of communication in organizations; improving effectiveness and efficiency of the organizations; role of a leader and a team member; skills for good interpersonal relationship with work groups, etc. Although specialized staff members were not available at that time, the Department staff was basically involved in the 'science' and 'art' of management such as sociology, psychology, communication, etc. and has had vast experience in working with various public, private, and non-governmental sector organizations.

At present, the Department has a fairly strong human resource base as a result of recruitment of a few staff members from related fields. Since the area and the staff are fairly new to the department, the research output is still at its early stages. Nevertheless, the Department recognizes organizational management as a thrust area that it would continue to enhance its teaching and research capabilities in the future. The department is involving in conducting research in the areas such as Management Information Systems (MIS), Managing and Developing Human Resources (HRM and HRD), organizational culture, managing small and medium enterprises, innovation, management strategy, marketing, and public relations.

The impact of socio-cultural factors on the development of small and medium enterprises in Sri Lanka has been investigated. The effect of various socio-cultural institutions such as education, family, religion, caste, ethnicity, and social class has been found significant on the establishment, development, and sustainability of small and medium enterprises in Sri Lanka. Apart from the national culture, the impact of organizational culture has also been studied. One focal area is to determine how organizational culture affects the innovation in Sri Lankan food processing industry. Strategic orientation for product innovation in food processing industry has also been studied. Five dimensions in organizational culture namely, open system focus, pioneering nature, pragmatic approach, futuristic time orientation, and optimistic view of employees are found as closely associated with product innovation. It has also revealed that product innovation is closely correlated with a higher degree of growth, diversity and proactive strategic choices, research and development expenditure, technological

modernization, staff competencies, and continuous external links. However, the organizational culture and strategic orientation, which derive from the national culture, of many food processing firms in Sri Lanka, have been found hindering product innovation. These cultural values and strategic orientations should be changed if the firms want to innovate and survive in this competitive global market.

As part of the development activities the staff has developed, and also guided students in the development of computer based information systems. These have been in the areas of examination information, vegetable information and decision support for production planning, crop project analysis by banks, project monitoring of NGOs, human resource information for a food production division of a leading company, and performance appraisal in a private company. Computer based information systems developed by postgraduate students have also been used to assist in the production of a rubber based product, and export processes in the foliage sector.

In addition, the Department has also been involved in research on marketing. The research areas include internal marketing practices in Sri Lankan organizations; the influence of branding in the consumer buying decision of milk powder; the factors influencing marketing of life insurance in Sri Lanka; and potentials and problems in market integration of small scale floriculture industry in Colombo. Some other areas that the Department is involved include public relations practices adopted by non-formal education units of provincial departments of education and socio-cultural barriers for group work in Sri Lankan workplaces.

These research activities are expected to help the readers, particularly those in management research and practical management of public, private, and non-governmental organizations in Sri Lanka, to view culture, strategy, marketing, and public relations as important factors behind successful management of the organizations. The Department is very much involved in disseminating these research findings in international and national fora. Among them, sharing of this knowledge with micro, small and medium scale entrepreneurs through training programs in various parts of the island including the Central, Western, Uva, and Eastern provinces has been an important contribution to national and regional development of the country.

CHAPTER 5: RESEARCH CONDUCTED BY

Department of Animal Science

Compiled by
Prof. (Ms) S. Premaratne

Introduction

The Department of Animal Science was established in 1968 to teach all aspects of animal production to the undergraduate students. At present, the teaching and research activities are carried out by well trained and well qualified 19 permanent academic staff members. The Department has 7 Laboratories (General Laboratory, Nutrition, Physiology, Aquaculture, Meat Science, Dairy Science, and Reproductive Endocrinology and Animal Biotechnology); a Livestock-Fish Integrated Farm and Animal Units. Of the laboratories belonging to the Department, the Animal Nutrition Laboratory is equipped to conduct feed analysis and is supported by an animal experimental (Metabolic) unit. An Arboretum (Forage Demonstration Unit) consisting of most available forages is also located in the Department premises for demonstration purposes. The Physiology Laboratory has facilities for blood metabolite analysis, semen evaluation and radio immuno – assay work. Facilities for immunology, endocrinology and biotechnology also are present in the Reproductive, Endocrinology and Animal Biotechnology laboratory. The Dairy and Meat Product Technology laboratories and Aquaculture laboratory along with Fish Ponds and Hatchery are used for research and training in respective areas. The Computer Laboratory of the Department provides facilities for teaching and research primarily in Animal Genetics and Breeding. These laboratories are used at maximum capacity for undergraduate and postgraduate training along with farmer training, while a number of active research programmes are also ongoing.

The Mawela Livestock Field Station (located about 1.5km from the Department Premises) is maintained as a model farm to demonstrate Livestock – Bio energy – Fish Integration System. The total extent of the farm is 100 ha, while pasture and fodder have been established in about 30 ha. The Mawela Livestock Field Station maintains a limited number of animals (temperate and tropical cattle breeds, buffaloes, goats, sheep, swine, rabbits, ducks and geese) for teaching and research purposes. In addition, a micro-livestock unit inclusive of guinea pigs, peacock, elk, spotted deer, crocodiles, jungle fowls, and porcupine and wild pigs has been

established recently. The poultry production unit located at the Department premises maintains over 2000 birds, inclusive of layer and broiler chicken, turkey, guinea fowls , quails, pigeons, with a breed museum and a hatchery. The wide genetic diversity conserved within each animal unit has made the Department to possess the best animal production training establishment in the country. While the cattle, buffalo, goat, rabbit, duck, aquaculture, piggery, and micro - livestock units are housed at Uda Peradeniya farm, the main poultry units and fish breeding units are located at the main premises of the Department. In addition, the farm also houses a mini- slaughter house which is routinely used for processing of poultry and pigs and occasionally for goats.

Further to these facilities available at the Department, students and staff members of the Department make use of the common facilities available at the Agriculture Biotechnology Centre and maintain strong collaborations with various other national institutes such as the Department of Animal Production and Health, National Livestock Development Board, Milk Industries Lanka Company Limited, National Aquatic Resource and Development Agency, National Aquatic Development Authority, Veterinary Research Institute, Faculty of Veterinary Medicine and Animal Science, Coconut Research Institute and Provincial Ministries as well.

The Department has active research programmes in the areas of Animal Nutrition, Forage Science, Animal Physiology, Endocrinology, Animal Reproduction, Animal Biotechnology, Animal Genetics & Breeding, Dairy Science & Technology, Meat Science & Technology, Fisheries Management & Aquaculture, Farming Systems, Wild Life Management and Animal Behavior & Welfare.

The primary thrust of these research programmes are to cater to the needs of the Livestock – Fisheries and Wild-Life Sectors and livestock based industries of Sri Lanka. Members of the Department have received a number of research grants on different fields of Animal Science from international and national donor agencies such as Council for Agriculture Research Policy (CARP) , Sri Lanka; National Science Foundation (NSF), Sri Lanka; International Atomic Energy Authority, (IAEA) Vienna; International Foundation for Science (IFS) (Sweden); JICA, International livestock Research Institute (ILRI), Kenya; United State Agency for International Development Agency, USA; European Economic Community (EEC) etc.

Forage Science and Ruminant Nutrition

Forage Science research in the Department of Animal Science was started in 1960's. Initial studies were concentrated on the effect of nitrogen fertilization on the yield, digestibility and nutritive value of forages, effect of frequency and intensity of defoliation on yield and quality of forages, molybdenum supplementation and liming on acid soils on the growth, nitrogen fixation and nutrient utilization in legumes, ensiling characteristics of tropical silages, nutritive value of fodder legumes and soil, plant and animal interactions .These research were carried out with the minimum availability of laboratory facilities. Major

thrust was on the exploitation of new feed bases for better animal use. These include exploration of new feed resources, upgrading, conservation and processing of forages as an animal feed.

Feeding and management of forage is very important in obtaining quality forage which determines the yield and composition of milk in dairy animals as well as the profit in dairy farming. Therefore, studies were conducted to find out the effect of nitrogen fertilization and intensity and frequency of defoliation on yield and chemical composition and feeding value of tropical grasses. Inclusion of nitrogen increased the yield and quality of grasses. However cost benefit ratio has to be calculated before applying higher levels of nitrogen to tropical forages. According to research conducted by the Department, frequency of defoliation for tropical pastures and fodders were around 30 days and 60 days, respectively.

Launching of a text book on "*Thruna saha Ranila Wagawa*" (Grass and legume cultivation and management in Sri Lanka) in Sinhala is to be used in Agriculture students in schools and, training sessions for field officers and farmers. In addition, "Grassland Profile of Sri Lanka" was developed and published with the FAO so that interested personnel could get the information through the web.

Being a tropical country, Sri Lanka experiences wet and dry weather during the year, so feed scarcity is a problem during the drought period. Therefore, experiments were conducted to preserve the excess forage produced during the wet season for later use. Therefore, ensiling characteristics and nutritive value of different tropical grasses as affected by growth stage and additives were studied. According to the results, fermentation of tropical grasses was mainly due to acetic acid fermentation rather than lactic acid which were the common acid produced in temperate grasses. Inclusion of additives such as coconut poonac, rice polish and molasses greatly improved the quality of tropical grass silage. Silo can be opened and fed to animals after 45 to 60 days of ensiling.

Land availability to grow forage is a problem in Sri Lanka at the moment especially in the saline soils in the coastal waterlogged area. Therefore, research was carried out to select the forages for waterlogged saline soils as an animal feed. Forages were identified and selected and, yield and nutritive value of some of the selected forages were measured in this study. Palatability studies were also conducted with buffaloes using some of the selected varieties grown in saline soils.

Buffalo and goat are ruminant animals that can consume poor quality feeds and, live under harsh environmental conditions while producing milk and meat. However, feeding and management could improve the production of these animals using the available feed resources. Therefore, systems of supplementary feeding for buffaloes and goats in Sri Lanka were done using fodders and available feeds. Rations were formulated with available feed resources for different groups of animals according to their nutrient requirements and cost of production of rations.

Straw and fodder based supplementation for buffaloes were also studied. According to results, buffaloes can be reared on straw based diets when

supplemented with urea, fodder legumes and minerals without having any problems. According to the results of the collaborative research with Wageningen Agricultural University, quality of rice straw can be increased with urea supplementation (2kg of urea dissolved in 100kg of water and applied to 100kg of straw just before feeding) or with urea-ammonia treatment (4kg of urea dissolved in 100kg of water and applied to 100kg of straw and ensiled for 7 days before feeding).

Several studies were also conducted to find out the constraints and opportunities on small scale livestock production in different agro-climatic conditions in Sri Lanka. The results of these studies demonstrate that the real constraints on livestock production can only be understood when livestock production is considered in the context of the overall household economy. The availability of labor for livestock production depends, at least partly, on the employment opportunities and the income that can be obtained from dairying. If other employment opportunities increase and the price for milk remain low, farmers may be even less inclined to spend time in rearing cattle. On the other hand, if milk prices increase, more farmers may become interested in dairy farming. The extent to which this could lead to higher milk production in the area depends on the availability of forage to feed more animals, and on the dairying as a form of employment generating only a low income. Although it is a great importance for households who cannot benefit from financially more rewarding employment, it is not very attractive for those who can.

One of the breakthroughs that were made was characterization of nitrogen fractions in common feeds and their behavior in the rumen and the gut. Such feed bases include natural grasses, legumes, agricultural by products and some agro-industrial wastes. In such feed bases, estimation and mitigation of anti nutrients components such as tannins, mimosins, lignin and saponins were considered. Manipulation of rumen environment to optimize the rumen microbial activity to enhance the nutrient utilization through interventions such as maintenance of rumen ammonia level through nitrogen supplementation using UMMB, urea, and animal excreta (poultry litter and manure) were also studied.

Feeding strategies in feeding livestock by introduction, formulation and using UMMB made a breakthrough in the dairy feeding system. This supplementation improved the growth, lactation yield and quality of milk, age at puberty, calving interval and conception rate. This was even extensively used by the small holder dairy farmers and accepted as a successful supplement by the state and the private sector today. In addition internal parasites were controlled by using the same technique as UMMB by incorporating synthetic or herbal local antihelmintic agents into the block. Even though the response was good this technology was not well accepted due to many differences of opinion.

Current research on forage and nutrition include studies on development of a leaf meal block as an animal feed, Investigation on low cost feeds and feeding strategies for high production and reproductive efficiencies, Methods to alleviate poverty through improved livestock production, Adaptation of better

management practices to enhance the natural resource utilization and minimizing environmental pollution, Conservation of natural resources and improving the living standards of the community through eco-agro tourism, Feeds and feeding of livestock and Livestock production systems.

Environment is threatened due to the global warming with green house gasses released by the livestock through enteric fermentation and manure management systems. Many studies have been conducted to minimize the methane emission through enteric fermentation and manure management. In addition studies were also conducted to conserve the nutrients from manure during storage through leaching and volatilization at the small holder conditions, using absorbents and paving.

The outcome of the collaborative research on forages and animal nutrition have been communicated at the discussions on policy planning and development of action plans at various statutory bodies of various ministries including Ministry of Livestock Development and Ministry of Forestry and Wildlife. Most of the research was published in text books, advisory leaflets, field manuals, field books, extension booklets and journals.

Monogastric Animal Nutrition

Poultry sub sector represents the major part of monogastric animal production in Sri Lanka. During the past few decades, the poultry industry showed a fast growth and today it has become the most developed livestock sector in Sri Lanka. Therefore the feeding and nutrition of poultry, especially chicken, must be given due attention in order to sustain the industry. It is well known that poultry feed is very expensive in Sri Lanka which makes about 70 - 80 % of the total production cost. This is mainly due to the dependency on imported feed raw materials and poor feed efficiency. Research activities in monogastric nutrition in the past in general were therefore focused to address this problem. Until late 1980's, emphasis was given to evaluate locally available feed raw materials for poultry in order to facilitate increased local feed production. The last two decades can be recognized as an era emphasized on feed additives.

Since the main components of poultry feeds are maize, soybean meal and fish meal, research priorities at the beginning were to evaluate alternatives to those raw materials. Many studies have been carried out to evaluate the feeding value of cassava, sweet potato, jack seeds, colocasia corms, tamarind seeds, avocado seeds, rubber seeds, coconut poonac, rice bran/polish; broken rice, used coconut scrapings, sugar cane by-products, brewer's by-products, silk worm pupae and various other non-traditional feeds and agro-industrial by-products. If not a complete information on their nutritive values, at least the information on their proximate composition, deleterious factors, processing requirements and suitable levels of inclusion in diets are today available and published on these raw materials.

As a result of the studies conducted on locally available feed raw materials, some of the products could be incorporated into compounded animal feeds produced by local feed millers. Coconut poonac and rice milling by-products are today used as important components of commercial animal feeds. At the beginning, the usage of rice bran/polish was limited to a small fraction of the production. However, they are now fully utilized by commercial feed manufacturers and therefore there is absolutely no surplus in the country. In fact there are market shortages of these by-products during off seasons.

During late 1970's, rubber seed meal was produced locally and utilized for commercial feed manufacturing by state owned Ceylon Oils and Fats Corporation. During the same time, used coconut scrapings were collected and used as a feed raw material by them. After privatization of the corporation, this practice was changed and importation of raw materials was preferred by neglecting these valuable resources. Today the country is facing a feed crisis and has realized the importance of producing feed raw materials locally. Nevertheless, small scale self-feed mixers utilize certain amount of local feed raw materials in their feed formulae.

After 1980's, more emphasis was given to studies on feed additives as they were recognized as a primary tool in improving feed efficiency, especially with low quality feeds. With the restrictions imposed worldwide on the usage of antimicrobial and hormonal growth promoters, scientists were challenged to find alternatives. The situation was common to Sri Lanka as well. Therefore, investigations were carried out to evaluate the efficacy of various substances, locally available as well as imported, in improving feed efficiency and thereby animal performance. Western world was success in using biotechnological tools to produce new generation of feed additives including digestive enzymes, probiotics and prebiotics. Studies were carried out locally to evaluate such feed additives under local conditions. Today almost all feed millers in Sri Lanka use enzymes, probiotics and prebiotics in producing compounded animal feeds. Advancing further, the staff have started evaluating locally available herbs/spices as alternatives to traditional antimicrobial feed additives and found some of the products contain strong antimicrobial activities and therefore can be used as alternatives to antibiotics. Turmeric root powder is one of such products. Findings of these investigations are published but the information is not yet translated to practice.

Livestock based Farming Systems and Livestock Economics

Crop and livestock farming and non farm employment are the sources of income for rural farming households in Sri Lanka. Livestock keeping due to its versatility and low risk attributes has gained popularity and in most instances makes a significant contribution to rural livelihood. However, cropping which provides the staple food is popular among farming families. Therefore, success of related policies and adaptation of new technologies at farm level depends on number of

factors that may not directly relate to livestock. The Department of Animal Science recognized the necessity of considering farming as a whole, and livestock husbandry as an activity of a total household system in a broader perspective. As a result, livestock economics and farming systems have been included in undergraduate study programme in early 2000's. The initial research focused on characterization of livestock farming systems and it was extended to study nutrient recycling, socio-economics and technical efficiency of dairy cattle farming systems. Data on the economic analysis of dairy production systems showed low profit margins as a result of low farm-gate price of milk, low productivity and high cost of production. During relatively short period of operation, a number of projects have been conducted in collaboration with national and international institutions. Among them "the appraisal of the Sri Lankan dairy sector", jointly conducted with International Livestock Research Institute (ILRI) and Ministry of Livestock Development and Estate Infrastructure of the Sri Lankan Government was a significant contribution and paved the way to understand the opportunities and constraints and resulted in the formulation of viable policies to boost the dairy industry of the country.

Formulation of economical feed rations for poultry, pigs and ruminants has been a popular area of research conducted by the department since inception. Inclusion of non-traditional feedstuff was suggested to reduce the feed cost. In 1980's, under the straw utilization project funded by the Netherlands government, cost effectiveness of urea-ammonia treated rice straw based feeds for ruminants were investigated. Later studies revealed that inclusion of urea-molasses multi-nutrient blocks in ruminant rations can effectively cut down the feed cost.

Members of the department have spearheaded the knowledge and research needs on various aspects of systems research both nationally and internationally. Some of the major outputs of such activities include: a text book on 'Introduction to Agricultural System Studies'; setting up of crop-livestock model farms at the Mahaberithanna training centre (MLDC/NLDB); studies related to mid/up country and coconut based crop livestock systems; nutrient resource management and cycling; economics of dairying in the upcountry estate and village based systems; urban dairy farming in major cities in Sri Lanka; role of earthworms in farming; and the dairy village concept.

Animal Physiology, Endocrinology and Animal Reproduction

Although, the field of Animal Science (called as Animal Husbandry in early stages) remained as a major component in the teaching, research and extension programmes carried out by the Faculty of Agriculture since its inception, until 1960's the research in the broad field of Animal Physiology could not be effectively strengthened. This was primarily due to limited availability of human and physical resources rather than lack of interest or importance paid by the Department.

During initial stages, a number of research studies were carried out under the leadership and collaboration of the academic staff of the Department of Animal Science to investigate the status of reproduction and production performance (growth, milk yield) of different farm animal species, very specially of cattle, buffalo, sheep and goats with the objective of establishing the indices of reproduction and production under Sri Lankan conditions to lay the necessary foundation for subsequent research. Most of the investigations concentrated on examining the performance of farm animals reared in the government farms, which had stocks of imported cattle and buffalo as well as the first generation of cross bred animals. Few studies investigated the local animals and their performance. The findings of these investigations along with findings of research carried out by the researchers in the government Departments, Research Institute and the Division of Veterinary Science of the University revealed that the status of reproduction and production performance of the domesticated farm animals in the country required substantial improvement. Thus, the need for research on possible interventions to improve the production and reproduction performance of these animals was evident. Although studies on the status of reproduction and production of farm animals continued during the subsequent period, it was these initial findings which laid the foundation for physiology research.

With the recruitment of an academic staff member, research in the field of animal physiology took a positive turn from the late 1960's. Most of the research studies were emphasized on improving male and female reproduction performance. Recognition of artificial insemination as an approach for genetic improvement of domesticated farm animals and the establishment of Regional Artificial Insemination stations in the country by the government would have influenced those research. Laboratory facilities were developed for semen analysis in the 1970's. A number of studies were carried out on evaluating the characteristics of semen, alternative methods of semen preservation, and the suitability of different diluents for semen preservation under field conditions using buffalo and cattle. Studies on the reproductive patterns and behavior of these species followed next. The Department maintained a stock of research animals, while collaboration was secured from the researchers serving at the Government Breeding Stations, Departments, as well as the Division of Veterinary Science of the University. The findings of these researches were published both locally and internationally, and used for further research focusing on refinement of procedures.

During the late 1970's the Departmental Physiology laboratory was improved to equip with the facilities for conducting radioimmunoassay to quantify hormones especially progesterone. Research studies extended to incorporate female reproduction. Being cognizant of the importance of advancing the age at puberty, and reducing postpartum anoestrus period for improving reproduction performance in female farm animals, research were conducted on the effectiveness of using prostaglandins and progesterone releasing intra vaginal device in estrus synchronization of buffalo and cattle. Further studies on superovulatory response of buffalo heifers to hormonal treatments, the use of

progesterone releasing device to overcome postpartum anoestrus of dairy buffalo cows and hormonal induction of lactation in buffalo heifers and cows were carried out. The findings of these researches have been used to refine the protocols used for super ovulation, and induction of estrus and lactation of farm animals under research conditions subsequently, which have progressed to the present.

With the recruitment of another staff member for the field of Animal Environmental Physiology in 1979, research in animal physiology was extended to encompass animal environmental physiology in the 1980's and 1990's. Research to investigate further aspects on reproduction was also continued based on findings of previous research conducted by the department and elsewhere. Effect of thermal environmental factors and supplemental light on the ovarian and pituitary hormonal profiles, physiological parameters, behavior, growth, puberty, milk production and reproduction performance of cattle, buffalo, poultry and rabbits were investigated. Beneficial effects of supplemental light in inducing puberty in buffalo, stimulating growth in broilers and rabbits were established. Physiological responses of cattle and buffalo to diurnal changes of ambient conditions were compared and threshold body temperatures for diverse integrated physiological responses were established. Effect of thermal stress on growth, lactation and reproduction performance of cattle and buffalo were investigated. A suitable cooling method to alleviate thermal stress in these animals was established and its beneficial effects on production performance were proven. Upon publication of the findings, this cooling method is being used for alleviating heat stress in buffalo at several locations in Sri Lanka.

In the late 1980's another staff member was recruited, while in the 1990's the facilities for blood metabolite determination was developed in the Physiology Laboratory. Research extended to investigate the environment nutrition and management interactions on physiology of farm animals. Effect of supplementary nutrition on the growth, blood metabolites, production and reproduction performance of cattle and buffalo were investigated. The relationships among these parameters were analyzed. Reproduction research extended to investigate the approaches for improving conception rate. Interrelationships among environmental, physiological and managerial parameters at insemination on conception rate of cattle and buffalo were studied. Threshold body temperatures, and suitable time range for insemination to improve conception rate of cattle and buffalo under local conditions were revealed. Physiology research further extended to include aspects of management such as frequency of milking and phenotypic characteristics on milk yield of cattle and buffalo.

In the 2000's the facilities for conducting research on molecular biology and animal biotechnology including enzyme immunoassay, in vitro maturation and fertilization of oocytes, and embryo transfer were developed. Studies on super ovulation and embryo transfer of laboratory animals were conducted successfully. The established hormonal regimes serve as the foundation for embryo transfer research in laboratory animals. Studies on Reproductive endocrinology and biotechnology in the female, conservation and Improvement of scientific

knowledge of traditional Indigenous Veterinary Medicine in Sri Lanka and, conservation of Sri Lanka elephants are also some priority area of research under consideration. To determine the role of endocrine/paracrine/autocrine factors in the regulation of optimal environment for sperm transport and capacitating, oocyte pickup, final maturation and transport, fertilization, early embryonic development and passage several studies have been carried out and some other studies are in progress. Overall findings of the research provided knowledge on the local modulation of oviductal environment and insight into the mechanisms by which the reproductive process is regulated within the oviduct. This will greatly improve the basic understanding of the control mechanism of the oviduct, insight about the factors that negatively influence the fertilization process and contribute to ectopic pregnancy, and help to develop therapeutic strategies to treat these disorders, and thus can be efficiently utilized to improve the fertility in domesticated animals as well as in human.

With respect to the Conservation of Sri Lanka elephants, techniques are identified to breed them at the time of maximum fertility, by determining the time of ovulation in relation to the changes in blood hormone parameters, physical changes and vaginal cytology. The knowledge gained will help the wild life conservationists, reproductive biologists and policy makers to plan future conservation strategies to save the Asian elephant from extinction. Thus, the survival of this culturally important subspecies of Asian elephants can be ensured. Moreover, the status of elephant's inhabitant to different areas of the Sri Lanka will be Identified, and characterized (Phenotypically and genetically) in order to understand the population structure to provide a better guide to conservation strategies of this highly endangered animal.

With the increasing interest on the use of non invasive techniques for determining hormonal profiles around the globe, in the mid 2000 physiology research further extended to investigate the potential of using non invasive techniques to establish reproductive hormonal profiles in Sri Lankan elephants with the collaboration of the Pinnawala Elephant Orphanage and Sandiago Zoo, USA. The methodologies developed could be used to apply for other species as well.

Research grants secured from local and international funding agencies including the University, UGC, SAREC, NARESA, IAEA, VPI&SU, and Sandiago Zoo have made these research studies possible.

Animal Genetics and Breeding

One of the key areas of research that the Department of Animal Science has been involved in is Genetics and Breeding of farm animals. The main research focus during 1980s was performance evaluation of indigenous animals and their crosses with improved exotic breeds. The growth and reproductive performance of indigenous pigs and their crosses with exotic breeds have been evaluated. The effects of sire and dam breeds have been estimated and recommendations have been drawn in planning cross breeding programs of indigenous pigs with exotic

breeds. Prediction of growth of indigenous, exotic and crossbred pigs also has been carried out during this period. Performance evaluation of indigenous sheep under traditional production system of northern part of the country was another interesting research project completed during the same period.

The main constraint in genetic improvement of farm animals in the country is paucity of proper genetic evaluation and selection programs at all the levels of respective industries. Genetic evaluation procedures require prior information on genetic parameter estimates in livestock populations. Therefore, estimation of genetic parameters of the predominant farm animal species, namely cattle, buffaloes, swine, poultry, and goats has been the main focus of research in the Department during the last decade. Progeny testing of dairy bulls in upcountry region is a most recent effort in this endeavor. This has been a collaborative effort with Department of Animal Production and Health in the Ministry of Livestock Development. At present the staffs of the Department utilize their expertise and outcome of their research in contributing to the national efforts in field level animal identification, animal recording, performance recording and progeny testing scheme development in dairy cattle.

Effectiveness of crossbreeding programs and hybrid vigour associated with swine, dairy cattle, goats and buffaloes have been determined using information in state livestock farms. The findings are used in designing breeding programs for state farms that belong to National Livestock Development Board and Department of Animal Production and Health. Defining the reproductive lifespan of dairy cattle is a controversial issue in commercial level dairy farm operations even in developed world. Incorporation of extended lactations in redefining the 'productive life' in evaluating commercial dairy cattle is one of the attempts taken to help solving the above problem. The present USDA national genetic evaluations of dairy cattle conducted in the United States with respect to trait Productive Life are based on the methodology developed by the scientists in the Department of Animal Science (during their overseas leave). Prediction of growth and reproduction parameters is also important in selecting animals for breeding. First ever genetic parameter estimation based on the mixed model methodology (Average Information Restricted Maximum Likelihood procedures) for Asian buffaloes was conducted by the scientists in the Department of Animal Science in 1998 in collaboration with Obihiro University, Japan. Lactation curve modeling for cattle and buffaloes including Holsteins in the USA, and growth curve modeling of goats are two of the present research themes of the department. Captive breeding of endemic and endangered fish species and crossbreeding experiments carried out with Carp species by the Department are described under the category of Aquaculture.

Sustainable utilization of indigenous farm animal genetic resources (FAnGR) is a priority research area in the world. The first molecular characterization of indigenous genetic resources by the members of Department was carried out in 1985 using protein polymorphism in collaboration of group of scientists from Tokyo University, Nagoya University and Kyoto University of Japan. Recently, diversity analysis of indigenous farm animals populations including cattle, swine,

chicken, goat and sheep have been commenced using DNA markers such as micro satellite and single nucleotide polymorphism (SNP).

The outcome of the collaborative research on animal breeding have been communicated at the discussions on policy planning and development of action plans at various statutory bodies of various ministries including Ministry of Livestock Development (including National Animal Breeding Committee, National Swine Development Committee, Tender Boards on purchasing exotic semen for artificial insemination) and Ministry of Forestry and Wildlife, in which the staff of the Department of Animal Science are official members.

The knowledge gained through the physiology and breeding research have been communicated to livestock farmers, students and teachers of Agriculture through various workshops and training programs organized by Sri Lanka Association of Animal Production, Alumni Association of Faculty of Agriculture, University of Peradeniya etc. The Secretariats of those national associations are located at the Department of Animal Science and the staffs of the Department have been holding the key positions since inception of those Associations.

The research activities undertaken so far is of national interest and also important to provide information to the global effort in conservation and evaluation of farm animal genetic resources. Information generated by the research done so far have been compiled and made available to the public in various ways, as research articles, workshops, training programs, web pages and interactive CDs. This information has been used in many instances in revising National Animal Breeding Policy, developing breeding programs at field levels.

Contribution of members of the department towards the national development activities is a continuous process. The research findings and other expertise of the members have been communicated in revisions of National Animal Breeding Policy, development of breeding programs for state farms, preparation of addendum for the Framework for Action on Biodiversity Conservation in Sri Lanka, documentation of State of Animal Genetic Resources in Sri Lanka. Present international collaborations with respect to animal breeding research include International Livestock Research Institute, International Atomic Energy Authority, Animal Improvement Programs Laboratory of United States Department of Agriculture, Virginia Polytechnic Institute and State University and Iowa State University, USA.

Dairy Science & Technology

One of the major issues confronting the local dairy industry is clean milk production and subsequent low temperature preservation of milk. Since microbiological quality of locally produced raw milk is unsatisfactory, strategies are required to mitigate the above mentioned limitation. In this respect the establishment of optimum conditions, modalities and mechanisms to preserve raw/fresh milk at room temperature in order to avoid deterioration of the keeping

quality especially within remote areas by employing lactoperoxidase system through research conducted in different agro-climatic zones under field conditions.

In order to inculcate good milking practices among the farming community a video documentary on clean milk production and milk hygiene was prepared both in Sinhala and Tamil to be used in dairy development and extension services in rural agricultural sector and plantation sector in Sri Lanka.

The quality and the shelf-life of indigenous fermented milk product, deekiri (curd) is a crucial issue in the local buffalo curd industry. In order to improve the quality of the product and to minimize the defects in the product, research were carried out on isolation and characterization of microorganisms contained in the cow and buffalo starter cultures employed in different parts of Sri Lanka.

One of the major issues confronting the local dairy industry is, when compared with the competitive dairy industries of the country from which milk products are imported, the cost of milk production. In order to address this issue a comprehensive research programme, encompassing the five major Agro Ecological zones relevant to livestock industry was carried out to analyze all the aspects of cost of production of milk, constraints faced by the dairy farmers and the fluctuation of milk collection within the annual weather patterns including the cropping patterns to determine the factors and the trends present within the Sri Lankan dairy sector. The valuable findings were utilized in policy formulations in dairy sector and determination of farm gate price of raw milk.

A critical feature in the local horticultural sector is the underutilization of horticultural produce especially fruits which is produced seasonally as gluts. In addressing this timely problem and also to link the dairy and the horticultural sector in the local agro industry, product development research was conducted to incorporate abundantly and seasonally available produce including export oriented produce in fermented milk products, frozen desserts and fluid milk.

Research and development of novel dairy products with health benefits through incorporation of probiotics, prebiotics and horticultural produce including herbal extracts are also in the priority list of the department. As current research initiatives, isolation and characterization of probiotics from native Sri Lankan populations to be used as starter cultures in the local dairy industry is under way.

Meat Science & Technology

One of the global concerns about consumption of meat and eggs is the composition of fat and their effects on human health especially the cardiovascular system. Addressing this issue research studies were directed to investigate the effect of locally available herbs including velvet beans, spices and prebiotic compounds from various plant sources on lipid metabolism and the resulting serum lipid profiles in chicken, rat and guinea pig laboratory animal models.

Furthermore, herbal sausages and formed meat products were developed in order to provide health benefits to consumers.

It is a common fact that slaughterhouse by-products are discarded as wastes currently. In order to mitigate this problem including the pollution, studies were directed to develop pet food especially for the local pedigreed companion animals. In addition another attempt in the direction of utilization and upgrading of some of the slaughterhouse by-products for human consumption was carried out.

To establish the utility value of indigenous cattle, buffalo, goat and poultry for meat production, analysis of their carcass and meat quality was achieved through investigations. Research and development activities towards new meat products were carried out by using locally available binding materials, natural tenderizers and ingredients containing compounds which contribute health benefits and antioxidative properties. As an attempt to add value to meat produced by low income generating rural sector farming community, fancy meat products were developed for the high in market. Furthermore, as an effort in value addition, fish sauce was developed using freshwater fish, small underutilized marine fish, by-catch and off cuts from tuna processing factories. Similarly oyster sauce was developed by underutilized mollusks available in Sri Lanka through accelerated digestion processes by incorporating locally available horticultural produce which contain proteolytic enzymes.

HACCP quality management systems were established in three leading broiler chicken manufacturers in the island as an effort to improve the product quality and safety. Development of marinated ready to cook or ready to eat products was carried out to cater for customers who are inclined on convenience and fast food. Research on natural food additives especially of natural coloring agents for sausages and meat products were investigated for the local meat industry.

In addition, consultation services are being provided to five major meat packing plants in the island. Launching of a monograph on broiler processing in Sinhala language is to be used in training sessions for field officers and farmers. Similarly a text book on "Havun Palanaya (Rabbit Management) was launched to popularize the rabbit farming among rural farming community in Sri Lanka as to increase the meat consumption.

Representation of the three members of the academic staff in the National Committee on Livestock, Aquaculture and Fisheries of CARP (Council for Agricultural Research Policy) and formulating the section on animal products, processing, their economics and marketing for Research Priorities in Livestock Aquaculture and Fisheries for the period of 2007-2011. One member of the staff served as the Commissioner General of Livestock under the Ministry of Agriculture & Livestock Development. The same member represented the review committee appointed by the Ministry of Agriculture to reorganize and revise the Advanced Level (G.C.E. A/L) agriculture syllabus. In addition, two staff members are

committee members of the different committees in related to formulating standards for meat products under Sri Lanka Standard Institute.

Fisheries Management & Aquaculture based Farming Systems

Introduction of Fisheries to Agriculture curriculum was the development of an aquaculture based integrated farm at Mawela, Uda Peradeniya in early 1980's. The inclusion of fisheries into agriculture curriculum was done in 1991 thereafter. This became another subject area in the field of Animal Science and both undergraduate as well as postgraduate research in different areas of fisheries commenced by 1980's.

Livestock-fish Integrated Systems

The basic research knowledge in pond fish culture from the field experiments were performed at the Faculty of Agriculture. The basal application rate, supplementary fertilizer rate as well as stocking densities for different livestock-fish integrated systems were determined. These results are being used not only in Sri Lanka, but in other parts of the world as well. This research work was sponsored by the International Foundation for Science, Sweden.

Rice-Fish Integrated Systems

Once again, rice –fish integrated farming system research was initiated at the Faculty of Agriculture for the first time in Sri Lanka. Use of organic manure for such systems has been published for the first time in the world from these experimental series. The application rates of fertilizer as a basal application as well as supplementary fertilizer were determined together with culturing of different table-fish as well as ornamental fish species. These experiments revealed that in Sri Lanka rice-fish integration is suitable for post-larval culture up to fry stage as well as fry to fingerling stage when table-fish are being cultured. In addition for ornamental fish culture, this method is suitable for both fish breeding as well as for growing of different stages of fish having suitable characteristics. The use of a pond-refuge at the centre was found to be the best. Rice-fish integration with the application of organic fertilizer is being practiced in different areas of Sri Lanka today. This research was funded by CARP, Sri Lanka.

Shrimp Farming

A significant number of research papers were published on shrimp farming, which indicated the effect of constructing farms in the inter-tidal zone by destroying invaluable mangrove resources. The ill-effects of such unscientific culture systems are clearly shown today due to the prevalent disease problems and the present poor status of the industry. Though the government has spent billions to remedy the situation, an improvement is not within the near future.

Breeding of endemic fish species

In Sri Lanka, all the endemic freshwater fish species are endangered. Hence a series of experiments were commenced with CARP and NARESA to determine the reasons as well as methods of artificially breeding these fish species. Results revealed that guppy (*Poecilia reticulata*) is also responsible for the removal of endemic fish from natural habitats and hence it is an invasive fish in Sri Lanka. In addition, endemic fish of Sri Lanka possess better adaptability to remove mosquito larvae and hence the use of guppy by anti-malaria campaign is incorrect. The effect of tea plantations on the endangered fish species was determined through experiments performed at Ginigathhena and therefore different strategies were recommended for the conservation of these invaluable fish species. A significant number of these endemic fish were artificially bred for the first time in Sri Lanka and these research results have been published. With the support of NARESA, a series of experiments are being carried out at present to artificially breed some of these fish species.

Breeding of Table-fish species

For the semi-artificial breeding of common carp, the suitability of polythene strips and the suitability of different plant materials, which are easily available, were determined through research, which have been published at different forums. The effect of rainfall and other different physico-chemical parameters of major-carp breeding have been determined, which are useful for the Ministry of Fisheries. Research has also been conducted to find out the suitable technique for breeding of fish and fish seed production at desired varieties/traits of culture fish species under domesticated conditions. Comparisons were made on the effect of two different inducing agents s-GnRH and LHRHa used for spawning of Catla and Rohu, Indian Carps species in Dambulla Fish Breeding Station in 2006/07. Main objective of the study was to identify the suitable inducing agent as well as the effective dosage for two different species of Catla and Rohu fish seed production with induced spawning under Sri Lankan condition. According to the results, most suitable steroid was identified as s-GnRH for both species. Effective dosage of s-GnRH and LHRHa for females were 0.5mg/kg and 30 µg/kg while 0.3mg/kg and 15 µg/kg for males.

At present two different research studies are being conducted at CIC Agri Businesses, Dambulla and Regional Resources Development Authority, North Western Province respectively for Ultrasound Enhanced Masculinization of Nile Tilapia, *Oreochromis niloticus* with immersion Protocol and Production of Asian Sea Bass, *Lates calcarifer* seeds under domesticated condition in Sri Lanka. These researches will generate the most suitable hormone concentration required to produce "all male Tilapia population" in Sri Lanka and, the production of required Asian Sea Bass seeds within Sri Lanka for the enhancement of Asian Sea Bass culture.

Ornamental Fisheries Development

Over thousand farmers in different areas of Sri Lanka were provided with a 2-day Residential Training programme during the past 10 years on different aspects of ornamental fish farming systems. The necessary knowledge on the preparation of a feed using locally available feed ingredients for ornamental fish (as well as shrimps) was imparted to these farmers. It is useful to note that most of these farmers are performing well and a significant number of Agriculture Graduates are in the fisheries industry today. With the assistance of different Provincial Ministries, formation of Co-operative Societies for the Ornamental Fish farmers is being successfully carried out. This is to link the producers with the exporters.

Development of Villages having fisheries facilities

A Model (Rapid Rural Implementation Model) was introduced through research done by centering Dambulla reservoir, which was sponsored by REAP, Matale. Through this programme, a few villages were developed and this Model is used even today for undergraduate as well as post graduate teaching. It is interesting to note that the villages are performing extremely well and the system is sustainable. University graduates were involved in this work.

Fish Processing Research

Different traditional fish processing methods are being developed and with the assistance of Provincial Ministries, steps are being taken to popularize them in different parts of the country.

Animal Behavior and Welfare

There is no doubt that the public interest in welfare of animal during the past two decades had been increased, where consumers are concerned not only with characteristics such as the nutritive content of animal products, but also want assurances that food animals are raised in humane conditions and receive humane treatment during handling and slaughter. The field of Animal Behavior and Welfare is one of the most recent additions to the various disciplines within the Department of Animal Science to address those issues related to the behavior and welfare of animals under our management, and is in the early stage of establishing research in this field.

The main objective underlying the research program in animal behavior is, to advance the basic understanding of behavior of animals with an ultimate aim of putting that knowledge into practice in order to improve the productivity and the quality of life of our agricultural animal species. Ongoing research projects in this field at the moment includes “The effect of different colors of light on welfare, behavior and performance of broilers under tropical environment”, “Assessing present welfare status of farm animals in Sri Lanka” and “Identifying welfare aspects of castration in piglings under Sri Lankan conditions.

CHAPTER 6: RESEARCH CONDUCTED BY

Department of Crop Science

Compiled by

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Introduction

The Department of Crop Science has been engaging in research relating to the agronomy of crops for over half a decade from 1959, although in the early days the availability of only a very few staff members limited both the scope and volume of the research output. In those early days, the Faculty had very meager facilities in terms of land, laboratory and other resources. The laboratories were very poorly equipped and mainly designed for conducting practical classes for undergraduates. Under those conditions, the options available for staff research were field trials to study crop responses to various agronomic practices such as varieties, plant density and fertilizer application. The earliest research was on rice fertilization, testing the levels of NPK for rice grown in the Ramanathan paddy field located within the University premises, on a paddy land which belonged to the Faculty. The involvement of the staff and students in rice research is worthy of mention as all the field operations, data collection and analysis were handled by the students. The program on rice research continued for many years and later shifted to weed research in paddy. From the early days the involvement of the private sector was very prominent, especially in weed research. The private industries not only supplied the herbicide materials but also provided the funds for research. In these trials various new formulations of herbicides were tested against recommendations of the Department of Agriculture. Eventually these trials led to the introduction of new herbicides for rice weed control.

Of the vegetable crops the most popular test crop was the green bean, and a series of plant density trials were conducted over several years in the premises of the Faculty on a land currently used by the Animal Science Department. These trials led to important findings on the correct spacing for various bean varieties. It was from these research projects that the first research publications of the Faculty were recorded. In the next decade many of the young staff returned after receiving postgraduate degrees from overseas universities. Their input to research was tremendous in that new dimensions were introduced to better understand the factors causing variations in crop yield. These were laborious field experiments

on growth analysis of crops, yet many staff and students were keen on involvement due to their novelty. The main crops tested included soybean, maize, rice and several vegetable crops such as potato and soybean. In the late 1970's with the advent of the fertilizer crisis, many field trials were conducted with slow release urea based fertilizers for the first time in the country, under the auspices of the East West Center of the University of Hawaii. Later, during the early 1980s the INSOY programme, funded by USAID commenced. It was a joint effort of the Department of Agriculture, the Faculty of Agriculture and the University of Illinois, USA. Under this programme several varieties of soybean were introduced and field tested at various locations of the dry zone. This programme opened avenues for the staff of the department to undertake not only field research but also studies on post harvest technologies. Out of this programme the faculty staff received training in crop experimentation, laying of field trials, data collection and analyses and interpretation of results. As a consequence of this faculty research staff members were able to publish many research articles in referred journals. It was also during this project phase that the Department and the Faculty made viable joint programmes for research. Recognizing the faculty strengths in research, the USAID also made provision for staff to travel aboard to attend workshops and conferences organized by the International Rice Research Institute, Philippines.

After acquiring farm lands at Dodangolla in the intermediate zone and Mahailuppallama in the dry zone, the research agenda was expanded and the staff involvement became more prominent. Under the Farm Forestry Programme sponsored by the Winrock International in 1985, intercropping was the main theme of research of many members of the Crop Science staff. Most of these trials were conducted at the Dodangolla farm and over seven years of the project period a significant contribution to intercropping research was made. These studies included nitrogen dynamics using slow release fertilizers and isotopes. Intercropping systems involving maize and soybean and other pulses were also developed to produce adequate maize for the livestock industry and pulses for human consumption. The maintenance of soil fertility was another objective of these trials. This combination of intercrops are still grown by the farmers of the dry zone. The farm forestry programme sponsored by Winrock International brought in another important feature to agricultural education in the faculty and the department. This was the importance of networking with other research and educational institutes. It became very clear to members of the department, that networking is an effective, low cost means of exchanging information among partners. This project initiated the National Multipurpose Tree Research Networks (MPTS) in different regional countries and the Sri Lankan MPTS Network, was based at the Department of Crop Science. The regional MPTS networks constituting 6 other regional member countries contributed immensely to the development of intercropping research. The MPTS network became popular not only among the local scientists but also among others in the region who were involved in multipurpose tree research. The MPTS Network was able to conduct annual workshops on current themes to educate the scientists and the general

public on the importance of conserving and sustainable use of these valuable tree species. The National MPTS Network also produced a number of publications including a series of workshop proceedings on themes of current importance to the agricultural sector. Many of the other regional partners have abandoned their in-country MPTS network while the national MPTS Network is yet continuing with its own funding to this date. Agroforestry and forestry related research expanded, staff were trained in the related specific subject areas and laboratories were equipped through the ODA funded forestry project in the 1990's.

Another important milestone of the department was its link with the Multiple Cropping Project of the Department of Agriculture which was sponsored by USAID. The concept of this project was that tropical countries like Sri Lanka having conditions favorable for crop growth year round should embark on multiple cropping for enhancing food production and increasing farmer incomes. Although this was not a new concept for Sri Lanka having experienced the sustainability of the year round vegetable cropping of the Nuwara Eliya farmers, it introduced many new concepts for maximizing resources in agricultural production. Multistory cropping, relay cropping and other related techniques of intercropping were introduced and all these concepts were added to the B.Sc Agriculture curriculum.

The research in the department diversified over time, as staff qualified in different fields assumed senior positions. Some research projects have demonstrated the use of several new experimental methodologies for the first (and only) time in Sri Lanka. The use of carbon dioxide enrichment technology to study the impacts of climate change on plants, the use of thermal methods (i.e. thermal dissipation probes and sapflow gauges) to study transpiration and water use of trees, use of hemispherical photography to measure radiation interception by a complex natural forest canopy, study nutrient cycling dynamics of labeled fertilizer using tree injection technologies, and investigation of health properties (antioxidant and glycemic index etc.) of agricultural products are such examples.

Plant biodiversity became a prominent research area in the recent past and the contribution to national biodiversity conservation and utilization has been substantial. The development of agroforestry systems with international collaboration with the World Agroforestry Centre, Kenya is yet an on going project, involving several departments such as Forestry and Agriculture and Environment. This impressive contribution is evident from the many publications on this subject. Another special area is the development of intensive agriculture production systems under controlled environments; it is evident that the expertise in the department outnumber those in any other organization working on crop science in Sri Lanka. The intensification of Agricultural production is an important field due to limited land availability for agricultural expansion and to involve the youth in agriculture, paving the way to efficient production systems. Studies on climate change; a topic of enormous importance for the future is yet another research area given importance by the department. There has been considerable interest in biotechnology and related technologies such as tissue culture in recent years. The

faculty staff has been successful in developing protocols for rapid multiplication of various floriculture and horticultural crops. The members of the staff of this department has not only conducted research, but their research findings have been embedded in valuable local /international scientific journals and texts that could be used by the students of agriculture and the agricultural practitioners.

A detailed account of specific research carried out and contributions made locally and internationally under major disciplines of the Department namely; agronomy, horticulture, plantation crops, agroforestry, and biometry are presented below:

Field Crops

The principal focus and aim of field crop research has been to investigate, quantify and understand the physiological basis of plant responses to different agronomic management practices and various soil and environmental factors (i.e. water availability, nutrient, elevated carbon dioxide and temperature, salinity etc..) on different types of crops such as cereals, legumes, tuber crops and condiments etc.. They also cover a wide range of plant species including field, horticultural and plantation crops and natural plant species.

As water is the major resource limiting increased production of annual crops in the dry and intermediate zones of Sri Lanka, a considerable amount of research have been conducted to determine irrigation regimes that would maximize yield per unit of water used. The work covered a wide range of crops such as rice, maize, grain legumes (green gram, soybean and groundnut), and chilli. Crop water relations, which is directly relevant to investigations on drought resistance, involved screening of genotypes based on the measurements of stomatal conductance, chlorophyll fluorescence, osmotic adjustments, drying cycle, and sap flow using advanced technologies (in collaboration with relevant Research Institutes). These technologies enabled identification of the key environmental and plant factors that control the transpiration process in these crops. In order to increase crop production in water-limited, drought-prone environments that are found in Sri Lanka, cultivars and genotypes especially in rice, sugarcane, coconut and tomato that are resistant to drought have been identified through research conducted by members of the department.

It is now firmly established that the global climate is changing because of increasing concentrations of greenhouse gases in the atmosphere. The major aspects of climate change that will affect plants (including agricultural crops) are increasing concentrations of atmospheric carbon dioxide, increasing air temperatures and increased frequency of drought. Therefore, it is imperative that research is conducted to determine the impacts of the above aspects of climate change on the major food crops. In collaboration with the Rice Research and Development Institute, Batalagoda, a pioneering research in Sri Lanka on the effects of elevated atmospheric carbon dioxide and temperature on rice has been conducted. In these experiments, CO₂ enrichment using open top chamber technology was used for the first time in Sri Lanka. A large number of rice

varieties in the Sri Lankan rice germplasm were screened for their response to elevated atmospheric carbon dioxide. As a result, varieties with greater than 100% yield increase in response to a 200 ppm increase in atmospheric carbon dioxide were identified. In addition to rice, the response to elevated carbon dioxide was quantified for other crops such as maize, finger millet, sorghum, soybean, green gram, tea and coconut and for forest tree species.

Similarly, response of the Sri Lanka rice germplasm to increasing air temperature is being investigated and quantified at present. The work on drought resistance of rice and other agricultural crops as described earlier addresses the need to develop crop varieties that are suitable for water-limited environments that might occur more frequently under a changed climate in the future.

Increasing salinity in arable lands is a problem that is increasing in significance, both in Sri Lanka and elsewhere. Current on-going research focuses on screening a wide range of varieties from the Sri Lankan rice germplasm for their resistance to salinity in different phases of salt stress development and agronomic management improvements to minimize salinity impacts. These research projects also focus on identification of physiological mechanisms and candidate genes that confer salt resistance in rice. Research has also been conducted on the physiological mechanisms of salt resistance in green gram. A technique to screen a large number of green gram genotypes for salt resistance has been developed and using this technique, relatively salt resistant cultivars and breeding lines have been identified.

In addition to research based on experimental work, research has also focused on simulation modeling which enables prediction of crop performance using simulations based on quantified responses of different crop processes to their controlling factors. Through simulation modeling, impacts of climate change (i.e. increasing atmospheric carbon dioxide and increasing temperature) on rice yields in the dry zone of Sri Lanka have been predicted. A detailed analysis of long-term (140 years data) temperature and rainfall data from different agro-climatic zones of Sri Lanka has demonstrated that climate change has in fact taken place during the last 1 ½ centuries.

The research undertaken on other food crops has also been impressive. In collaboration with the International Potato Center regional office in India, sweet potato germplasm has been screened for adaptability in diverse environmental conditions. Key results have been the usefulness and adaptability of the newly introduced orange fleshed varieties. Other programs on potato in collaboration with the Department of Agriculture have resulted in the development of hydroponic and aeroponic systems for the growth and development of seed tubers.

Horticulture

The Department of Crop Science has been carrying out horticultural research under commodity groups, ornamental plants, fruits and vegetables. The broad research objectives are; (I) Expansion of the understanding of the scientific basis of crop growth and (II) Advancement of the production and postharvest technologies of horticultural crops and commodities.

The research areas covered during last few decades can be categorized into; (i) germplasm evaluation and crop improvement (ii) growth media and plant propagation (iii) plant nutrition and hydroponics (iv) management of environmental stress (v) plant growth manipulation and (vi) postharvest quality management.

The horticultural research is conducted mostly as a series of research projects, funded by state, private and NGO based national and international funding agencies. National Science Foundation (NSF), Sri Lanka Council of Agricultural Research Policy (CARP), National Research Council (NRC), US-Aid program UNDP and Overseas Development Administration of the British Government (ODA) are some of the main funding organizations. The research programs are collaborated by other departments of the Faculty, agriculture and plant science departments of other universities, the Department of Agriculture (DOA), ITI, IFS, and a number of private sector enterprises and individual farmers. Most of these research projects are conducted as student projects, giving them opportunities for upgrading their research skills in undergraduate as well as postgraduate programs under horticultural disciplines.

The research conducted under germplasm evaluation in vegetable crops cover three main greenhouse vegetables, tomato (*Lycopersicon esculentus*), bell pepper (*Capsicum annum*) and cucumber (*Cucumis sativas*). In addition, testing some of the newly released vegetable varieties in comparison with the conventional varieties has been done for tomato, bitter gourds and ridged gourds (thumba karavila). Selection of wild species with respect to ornamental value and their subsequent development have been conducted in *Stachytarpheta spp*, *Hemidesmus indicus*, *Osbeckia octandra*, *Muraya paniculata*, *Plumbago indica* and *Chlorodenran pinnata*.

Meanwhile, use of biotechnological tools on propagation and crop improvements have been done for selected ornamental and fruit crop species using the facilities of the Crop Science Department and biotechnology center of the University. Some of these research lines have shown promising results and perfection of micropropagation protocols for neem, banana, pineapple, anthurium, orchids, gerbera, *Cordyline*, *Scindapsus*, *Aspleneium* and *Munronia* have been carried out and are available for public use. Also, micropropagation with cost effective methods has been introduced to the general public as a result of staff research efforts and several tissue culture laboratories have been established at domestic level. Furthermore, a regeneration procedure through somatic embryogenesis and transfer of gai gene which is a gibberellic acid inhibitor that produces a dwarf

phenotype have been conducted in collaboration with the Agriculture Biotechnology Centre. As dwarf plant architecture is popular as an ornamental character a few wild plants, *Stachytarpheta spp*, *Hemidesmus indicus*, *Osbekica octandra* and *Plumbago indica* have been exposed to gene transfer.

Growth media and plant propagation is an area with many research records. Starting with growth media, various trials have been conducted to identify the performances of various agricultural by-products and other natural materials as potential growth media for nurseries as well as hydroponics systems. As a result, coir dust, sand, paddy husk and in appropriate ratios have been identified for vegetable nurseries and the drip irrigated grow-bag culture. Similar work has been performed for selecting media for Anthuriums, orchids, roses and various foliage ornamentals. In addition some research has been done to compare different sterilization techniques and fertigation methods for growth media to be used in the containerized transplant production.

Research on growth media has been combined with the research on developing appropriate protocols for conventional as well as modern propagation techniques mainly for fruit crops and other herbaceous and woody plants to be used in indoor decorations and landscape designs. For example, rambutan, neem, garcinia, ebony and satin wood have been successfully micropropagated.

Plant nutrition and hydroponics is one of the main research areas that come under protected culture or high-tech horticulture in the world today. Although various materials and methods have been developed for high-input agriculture in other countries, due to unavailability, high cost and various other reasons, they cannot be practiced in the same form under less-intensive technology and tropical climates in Sri Lanka. Therefore, a series of research projects were conducted to test different hydroponics systems and fertigation methods basically for major greenhouse vegetable crops. Drip-fertigated grow-bag system has been identified for most crops based on comparatively high growth and yields. The weaknesses in common complete fertilizer sources, proper methods of dilution, proper fertigation procedures and scheduling, establishment of decisive factors for pH and EC controls and growth-stage based variations in nutrient balances are some of the main research work done for vegetable crops. Circulation of excess nutrient solution and weather based EC adjustments have been identified as the best strategy for cost-effectiveness in drip-fertigated grow-bag culture. Most of these research projects were carried along with the greenhouse environment and stress control research series.

Environmental stress is a major decisive factor for plant productivity in greenhouse crops. Therefore, several fact-finding surveys and data recording, followed by designing of experiments were conducted collaboratively to develop greenhouse structures and new cooling strategies. Venlo-type greenhouses, use of adjustable ridge vents, fully open side vents, wind direction based vent positioning, up-sizing of top-vents and enlarging mesh-sizes in net-covered side vents have been tested successfully for improving natural ventilation based greenhouse cooling. Other cooling options such as forced-air intake or exhaust

ventilation, the use of convection tubes, use of thermal covers, misting etc, have also been tested on an individual basis or in combination. Hence, a significant progress has been made in this line of research which can be directly utilized by the production sector. Research facilities have been established or upgraded in farmer fields and the university experimental station with external funding sources for conducting these research projects. Meanwhile, the observations made on plant growth, plant physiology and pest and disease incidence etc. during the course of this research series provide a good data base for future improvements in environmental stress control in greenhouse crops.

Manipulation of the plant growth by mechanical (training and pruning) or chemical (growth regulation) means is very essential for horticultural species, particularly for fruits and ornamental plants. Different plant training methods, staking or trellising methods for greenhouse vegetable species is one of the main achievements in this area of research. Furthermore, use of growth regulators for changing the canopy architecture, promoting or delaying flowering, as root inductors are some of the others.

Improvements in post-harvest technology of horticultural commodities have gained enormous attention of the research groups during the last few years due to the demand from the export oriented production and marketing sub-sectors. Therefore, this area of research is at a distinctive position within the horticultural research program of the Department. Covering all three groups of commodities, the post harvest research projects have developed low-cost technologies for extending the shelf-life without significant deteriorations in the commodity and its major quality attributes. Correct harvesting operations, cleaning and sorting methods, hygienic handling, use of proper packaging materials, controlled atmospheric storage and commodity treatments are the range of technological approaches followed in this regard. Many cut flower species, foliage ornamentals, tropical fruit crops and vegetables crops have undergone these improvements. Most of the research have been done in collaborative institutions in recent times, because of the availability of advanced research facilities for post-harvest research. Horticultural Research Institute, Department of Agriculture, Gannoruwa, Botanic gardens Peradeniya, Industrial Technological Institute, Colombo and a few private export nurseries of ornamental plants have been the major collaborators for such studies.

In addition to above mentioned major research categories, significant work records can be noticed in some minor research lines which deal with furtherance of the understanding of the scientific basis in specific areas of plant science. Studies on development physiology, detailed plant nutritional aspects, crop breeding, host-pathogen relationships in plant protection are a few examples of such research lines.

The research findings of the horticultural research programs have been basically documented in the form of project reports and student thesis. Significant findings have been published in different forms, targeting different groups of knowledge seekers. For example, dissemination of the knowledge gained in specific areas of

science and technology has been disseminated to the scientific community through scientific publications and presentations while the readily practicable findings have been included in the adaptive research programs or in the extension material such as books, popular articles, training materials, bulletins, interactive CDs etc. The developments made and the experiences gained in these research programs could also be seen from the residential short courses, conducted annually for middle level officials, private sector entrepreneurs and for farming communities.

The resultant improvements of the subject matter knowledge, research skills and the experience in team work etc. during these research and developmental programs can be considered as the basis of the constantly growing success of the researchers, co-workers and the research students in terms of their academic or professional status as well as contributions to the national and the global developments in varying degrees.

Agroforestry, Forestry, Biodiversity, Underutilized Fruit Trees and Medicinal Plants

There has been renewed interest, from 1980s onwards, both locally and globally, in Agroforestry as a sustainable crop production and land management practice. However, apart from the traditional agroforestry systems such as multi-layered home gardens and shifting cultivation, many of the newly-developed and introduced agroforestry systems and practices have not been widely adopted by the farmers. This section briefly describes the research work carried out by the academic staff of the Department of Crop Science on Agroforestry, Forestry and Multipurpose Trees, Biodiversity, Underutilized Fruit Trees and medicinal plants. The research areas can be categorized into (i) evaluation of genetic resources of forest and agroforestry trees, underutilized fruit trees and medicinal plants; (ii) agroforestry system research; (iii) biodiversity assessments; (iv) natural forest management, (v) silvicultural aspects of forest and agroforestry trees; and (vi) agronomic practices on medicinal plants. Some of these research studies have been undertaken in collaboration with foreign institutes (Overseas Development Administration-ODA, International Atomic Energy Agency (IAEA), International Council for Research in Agroforestry (ICRAF) presently known as World Agroforestry Centre) and Universities (Oxford, Bangor, Goettingen, Guelph), and public sector (Ministries of Agriculture and Environment and Natural Resources, Sri Lanka Council for Agricultural Research Policy-CARP, Department of Agriculture-DOA, Forest Department, Tea Research Institute-TRI, Coconut Research Institute-TRI, Rubber Research Institute-RRI), private sector institutions and NGOs. Most of these studies are being conducted as research projects of the undergraduate and postgraduate students.

Long-term research programmes to determine the degree of resource competition (which is believed to be a primary reason for the poor adoption of many newly-developed agroforestry systems and practices) in contour hedgerow

intercropping systems, which was one of the newly-introduced agroforestry systems) have been conducted.

For example, research was focused on two specific contour hedgerow intercropping systems, one involving a perennial crop (i.e. tea) and others involving a range of annual crops (i.e. maize and grain legumes). The experiments tested a range of potential hedgerow tree species in combination with the above-mentioned agricultural crops. It was clearly shown that hedgerows exerted significant competition for essential growth resources (i.e. water, nutrients and light) resulting in significant yield reductions in the agricultural crops. However, it was also shown that the competition exerted differed for different hedgerow tree species and those with minimum competition could be identified.

In addition to resource competition, these research programmes also quantified the many beneficial effects of contour hedgerows such as soil fertility improvement and erosion control through detailed measurements. In-depth studies were conducted on decomposition and nutrient release characteristics of hedgerow prunings from a range of tree species under different climatic and soil conditions. Nutrient dynamic study carried out by injecting ¹⁵N fertilizer to the tree component in alley cropping systems, exhibited how the labeled N translocated and partitioned within the tree and the recovery by subsequent cropping species. These research programmes enabled a holistic understanding of the biophysical processes operating in hedgerow intercropping systems involving important cash crops of Sri Lanka.

Under the theme of genetic resources, emphasis has been given to establishment of provenance trials, evaluation and selection of forest and agroforest trees species (*Gliricidia sepium*, *Leucaena leucocephala*, *Azadiracta indica* (Neem), *Artocarpus heterophyllus* (Jackfruit), *Calliandra calothyrsus*), underutilized fruit trees (*Aegle marmelos* (Bael fruit), *Phyllanthus emblica* (Nelli), *Annona muricata* (Soursop) and other *Annona* species, *Tamarindus indica* (Tamarind), *Garcinia quaesita* (Goraka). Genetic variation of these species have been identified and new provenances/cultivars have been tested and selected (i.e. in Beli fruit, Nelli, *Gliricidia* etc.). Parallel to genetic improvement research on forest and agroforestry trees, basic research on species reproductive biology, seed germination and propagation, and certain important health properties have also been conducted for many fruit species. The Department has made significant contributions to network tree domestication activities in fruit and timber trees and medicinal plants in Sri Lanka in collaboration with ICRAF and CARP.

Basic research on agroforestry system and other types of land use evaluation and development has been carried out by members of the Department since late 1980s in collaboration with the Forest Department and other faculties of the University of Peradeniya. Improvement of overall physical, chemical and biological properties of soil and other protective and productive roles of Kandyan forest gardens that were established on degraded lands were estimated.

Kandyan Forest Gardens (KFGs) form a complex ecosystem which has many similarities to a natural forest. It also contains valuable timber, food and spice tree species. Because of the presence of a significant density of deep-rooted tree species, KFGs could extract substantial amounts of water from the soil. Water use of different tree species representing different vertical layers of the canopy structure of a KFG has been quantified. For the first time in Forestry research in Sri Lanka, sap flow sensors to quantify the transpiration rates of tree species have been used. Using this advanced technology, contributions from different vertical layers of a KFG to its overall water use were estimated. Using advanced micro-climatic instrumentation, the control of tree transpiration by incident solar radiation, air temperature, vapour pressure deficit and soil water availability were quantified.

The department also conducted research on participatory rural appraisal and diagnosis and design analysis, establishment of knowledge based systems and system improvement research on homegardens in collaboration with ICRAF. Socio economics of surrounding communities of forests and their impacts on forests were another research area in the Department. The Department was also involved with evaluation of community and participatory forestry research programs of the Forest Department.

Research on silvicultural aspects have been conducted in relation to optimum tree density and silvicultural treatments including thinning, pruning and harvesting in Eucalypts, Neem, Gmelina and Teak. The initial research on silvicultural treatments of forest trees was followed by development of specific yield functions for assessment of standing timber volumes.

Research on biodiversity includes assessment of forest biodiversity and agrobiodiversity in agricultural landscapes. The Department in collaboration with the Royal Botanical Gardens initiated assessment and domestication of Pteridophyte biodiversity of Sri Lanka which is one of the neglected areas in the biodiversity research in Sri Lanka. The findings of biodiversity research on Pteridophytes have contributed to identification of new species (i.e. *Cyathea srilankensis* Ranil) and rediscovery of several species after 50 years and enhance conservation policies of Pteridophytes. In addition, pioneering research on assessment of effect of alien invasive species such as *Myroxylon balsamum* and *Swietenia macrophylla* on forest biodiversity has been carried out. Assessment of non timber forest products (NTFPs) was also done by the members of the department.

Agronomic practices of medicinal plants are important in conservation and utilization of medicinal plants. Agronomic requirements of *Andrographis paniculata*, *Boerhavia diffusa*, *Solanum virginianum* and *Evolvulus alsinoides* have been investigated and better practices were identified. Further, the problems and prospects of cultivation of medicinal plants, their propagation and seed germination requirements have also been identified for *Cassia senna* (Senehekola), *Vallariana mooni* (Lanka Thuwarala) and *Trachyspermum roxburghianum* (Asamodagam).

The Department has undertaken a research programme to quantify the carbon sequestration capacity of different forest types (both natural and plantation) of Sri Lanka. Different methodologies have been used to quantify carbon sequestration of natural and plantation forests. Carbon sequestration by a complex multi-species natural forest is being estimated by quantifying its radiation interception and conversion, and satellite image techniques. Hemispherical photography was used for the first time in Sri Lanka to quantify radiation interception by a complex natural forest canopy. Image analysis of hemispherical photographs also enabled a detailed quantification of the canopy structure and the understorey light environment of wet evergreen forests at Sinharaja, Kanneliya and Knuckles. Carbon sequestration by plantation forests is being quantified using the standard methodology of using the dimensions of the tree trunk. The Department also made contribution to assessment of tree resources outside forests in collaboration with Department of Agricultural Engineering and Forest Department. The response to elevated carbon dioxide was also quantified for forest and agroforest tree species.

Understanding the physiological basis of survival, establishment and growth of different plant species in this complex environment presents an extremely stimulating challenge to a Plant Physiologist. Hence, the Department has conducted research on the physiology of a range of tree species found in wet evergreen forests of Sri Lanka. Photosynthesis, stomatal mechanics and water relations of these different species have been the primary focus of these studies. While a complete understanding of this complex ecosystem and its component species requires a much greater research effort, research has provided data on basic ecophysiological processes on several plants species for the first time. Also, through these physiological investigations, research has been able to provide plausible explanations to the invasive behavior of some of the plant species that are found in the wet evergreen forests of Sri Lanka.

Plantation Crop Production of Tea, Rubber, Coconut and Export Agricultural Crops

Plantation Crop Production has been considered as one of the five major areas of teaching and research at the Department of Crop Science. The research on plantation crop production and related areas at the Department of Crop Science dates back almost to the time of establishment of the faculty. Over the years these research investigations have made immense contribution to the progress of the industry. A large proportion of these studies have been conducted as undergraduates and postgraduates research projects. Three types of research collaboration is evident when considering the past history of research projects on Plantation Crops at the Department of Crop science. They are given below.

Collaborations with Government Research Institutes

A large proportion of the research projects have been conducted as collaborative projects with state sector Research Institutes including Tea Research Institute

(Talawakele and Ratnapura), Rubber Research Institute (Agalawatta), Coconut Research Institute (Lunuwila) and Export Agricultural Crops Research Station (Matale and other sub stations). These long-established research links have resulted in sharing of experience and skills, laboratory facilities, manpower and many more benefits to the Department as well as to those research institutions.

Collaborations with Regional Plantation Companies

In addition to projects with government research institutes, the Department of Crop Science has developed strong research links with Regional Plantation Companies, mainly Pussellawa, Bogawantalawa, Lalan, Kahawatta, Kelani Valley, Maskeliya and Talawakele Plantation Companies. This has enabled the Department to undertake research directly with the industry and also understand their immediate problems.

Research collaborations with NGOs and other projects

Department members also have carried out research projects on tea industry, worker welfare and delivery of Government services to estates in collaboration with Non-Governmental Organizations such as CARE and Sarvodaya, and Donor Funded National Projects under the ministry of Plantation Industries and other related Ministries.

All these studies have transferred some important knowledge for the advancement of the industry and also provided a wealth of experience, knowledge and skills for staff and undergraduates who conducted these projects. These collaborative research projects have yielded a large body of new knowledge and have contributed to adaptation of cultivation practices and confirmation of existing practices. Therefore, the knowledge base of plantation crops has improved. For example, research on rubber (in collaboration with the Rubber Research Institute) includes a detailed investigation of the feasibility of early commencement of tapping and thereby increasing the profitability for the growers. This study also included an in-depth analysis of yield components, canopy photosynthesis and related physiological parameters of three contrasting rubber clones under different tapping systems. Current research on rubber also includes a programme aimed at identifying high yielding rubber genotypes at the seedling stage by relating their early growth and physiological parameters to yield at the mature stage. Detail investigation of impacts of climate variation on latex production and identification of clones that are more tolerant to light level fluctuation and extreme weather events have been carried out in collaboration with Rubber research institute of Sri Lanka.

Research on coconut (in collaboration with the Coconut Research Institute) has included the use of the compensation heat pulse methodology to quantify the sap flow in different coconut genotypes under different climatic and soil conditions. This has enabled identification of factors that control the water use of coconut. Research has also been conducted to identify drought resistant genotypes in coconut and to quantify its response to elevated atmospheric carbon dioxide.

From the total undergraduate research of about 1300, around 320 research projects have been conducted in the areas of Growth, yield and quality aspects, Physiology aspects and Crop improvement, nursery and propagation, crop & field management, replanting, soil fertility and moisture management, fertilizer management, weed management, Cropping systems (Crop diversification, intercropping, and agro-forestry), Fuel-wood usage, shade & support trees management, smallholding sectors, organic methods, product processing, health properties of products and worker welfare related studies of plantation crops under the guidance and supervision of staff of the Department of Crop Science. Research on tea crop has received very high priority, as it is the main plantation crop identified in the undergraduate curricula. Physiological basis of high yielding tea clones, drymatter portioning under different management conditions, sustainable land management, rapid methods of propagation of tea in nurseries in reducing time required to raise healthy plants for field establishment, categorization of tea fields based yield and identification of specific management measures, climate variation on clonal responses and identification of superior clones; improvement of harvesting, handling and processing efficiencies were some of the important research areas. Many local and international research grants had provided the financial support for these research projects. This will give a fair reflection of volume and type of research areas covered by the Department and also expertise available at the department.

Further, members of the department have involved in research on forestry and agroforestry covering topics such as firewood trees, timber trees and multipurpose trees, Kandyan and other homegardens and agroforestry models involving plantation crops. These projects have immense bearing on Plantation Crop Production and have contributed in many ways to the advancement of management and knowledge base related to plantation crops.

Also there were many postgraduate research projects conducted on plantation crops leading to PhD, M.Phil and MSc degrees at the Postgraduate Institute of Agriculture, University of Peradeniya under the supervision of staff of the Department of Crop Science.

These collaborations also assisted the researchers at the department to join hands with other senior scientists in the country to perform important research projects. Findings of these studies have been disseminated to the industry by the department and also by those research institutes involved. These research studies have also made significant contributions to the improvement of the quality of undergraduate teaching on plantation crop production at the Department of Crop Science.

Weed Science

The research in the field of weed science carried out by the Department of Crop Science has focused on all aspects of this important field of study. The main thrust areas include the general aspects of weed biology and ecology and weed control,

and more specific areas of allelopathy, crop-weed competition, distribution and control of invasive alien plants, herbicide-resistant weeds, and eco-physiology of parasitic weeds. Both agricultural and natural ecosystems have been the areas of interest in these studies.

The major research grants received in support of the above projects are; Ecology of tropical weeds in food legumes (VLIR Project, Universty of Gent, Belgium), Herbicide-resistant weeds in tea lands and Propanil-resistant *Echinochloa crus-galli* in rice fields of Sri Lanka (CIC Agrochemicals, Lankem Ceylon Ltd., Heyley's Agrochemicals, and BASF-Finlays Pvt. Ltd., Sri Lanka), Screening of novel herbicides for weed control in different crops (CIC Agrochemicals, Lankem Ceylon Ltd., A. Baur Co. Ltd., Heyley's Agrochemicals, Mackwoods Ltd., Harrisons Pvt. Ltd., Opex Agrochemicals, and BASF-Finlays Pvt. Ltd., Sri Lanka), Eco-physiological Studies on the invasive behaviour of *Cuscuta* spp. In Sri Lanka and their impact on host plants (National Science Foundation (NSF), Sri Lanka), Stabilization of the banks of the Colombo-Katunayake Highway Development Project using commonly known weeds (Keannagm-Daewoo, Korea), Study of Distribution, growth and development of *Mimosa pigra*: an alien invasive plant in Sri Lanka (National Research Council, Sri Lanka), Screening potential biocontrol agents for the control of *Ligustrum robustum* subsp. *Walkeri* to be released in French Reunion Island (Government of France and CABI-Bioscience, UK), Survey on Farmer Practices in Weed Control in Rice (Zeneca Agrochemicals, UK) and Herbicide resistance in rice weeds (Eiselen Stiftung, Germany)

The activities carried out by the Department of Crop Science in the field of weed science, in collaboration with many state and private sector organizations, have led to the identification of the presence of *Mimosa pigra*, propanil-resistant *Echinochloa crus-galli*, paraquat-resistant *Erigeron sumatrensis* and *Crassocephalum crepidioides*, and the presence of *Cuscuta campestris* as a major parasitic weed in Sri Lanka. All these were the first such incidents reported in Sri Lanka.

The outcome of these projects has led to the introduction of novel herbicides and integrated techniques to combat herbicide-resistant weeds under different crops, and implementation of inter-ministerial and inter-departmental action plans to tackle problems associated with invasive alien plants in Sri Lanka.

Statistics

The Department Staff involved in teaching Statistics have done many research projects encompassing diverse areas where application of Statistics solved many of the problems. The Z – score use in selecting students to the universities was formulated by one of our staff members. The methodology used in Coordinated Rice Varietals Trials to recommend rice varieties (CRVT) were derived by two of our staff members.

Our members have helped government Institutes in solving many problems using Statistical methodology (E.g.: Intrsectoral Study on Education and Health conducted by National Education Commission). Indices to quantify biodiversity, new models to describe rainfall variability, handling overdispersion in categorical data, optimum plot size for various crops, new spacing trials (E.g. 3-way parallel row systematic designs), new approaches in experimental designs such as single palm plot for tree crop experiments, were worked out by the members responsible for teaching Statistics in the Department. They have also helped in forecasting the national yield of crops such as rice and maize.

The staff has also helped members of other faculties in their research projects which were essentially multidisciplinary in nature. They have also ventured into agroforestry/ forestry where problems such as 'best' sampling method have been researched. Research methodologies in Food Science and Technology were another area where staff has contributed a lot. Some research grants have also been obtained by the staff members in the areas of modelling multivariate time series and multiple nutrient fertilizer response modelling.

CHAPTER 7: RESEARCH CONDUCTED BY

Department of Food Science

Compiled by

Dr. (Ms) B. E. P. Mendis

Introduction

Universities being National Institutions for generation and dissemination of knowledge, research forms one of the three major activities within the University culture. The Department of Food Science & Technology, right from its inception focused on research needs in the development of infrastructure and securing of facilities and funds. In a developing tropical country, with agriculture as the life line of the nation, food production and food processing, including preservation contribute much to the national economy through production for export and local consumption. The Department of Food Science & Technology planned its research agenda with emphasis on product development, food safety and human nutrition as key areas taking the national needs into consideration. The activities in the above three areas require a host of support activities such as food analysis for quality, safety and nutritional assessments, sensory assessments for product acceptance, and adherence to international food standards falling in line with globalized marketing control principles and global trade agreements. The current staff capacity developed over the years with 11 members having postgraduate qualifications from several developed countries, experienced in all the major sub-disciplines in food science & technology, forms a team capable of carrying out meaningful multidisciplinary research. Within the major research disciplines, research activities in the following wide areas have been progressing in the department during the last 22 years.

- a) Product development based on local agricultural raw materials leading to novel foods.
- b) Assuring food safety through chemical and microbiological investigations on market foods and interacting with the industry to modify the processes to ensure food safety.
- c) Assessment of nutritional quality of foods and their impact on human health.

The findings and the knowledge gained through research by the academics and the students in the department have provided mechanism to enter into formal and informal links with the research institutes in the tea and coconut sectors, the large private sector industries and with researchers abroad having common interests. In research, most links with industries emerge as need-based and demand-driven activities rather than planned and documented processes. In the need-based, demand-driven approach of the food industry, the individual researchers of recognition in the department are approached by the private and the public sector seeking for solutions to their problems. The policy of the department throughout has been to take up a proactive approach, where academics identify the problems in the food industry through scientific observations and interactions. The academics next gather existing research data based on global approaches to cater to the needs of the industries combined with appropriate research. This approach has opened the way for the department to serve as a hub of excellence, encouraging the industry to approach the academics for know-how, trouble shooting and guidance to be competitive globally.

The research output in the department could be viewed best based on the major findings, products developed and patents obtained. The academic nature of research in universities compels examination of the research publications by the academics and the students as a major evaluation criterion. The publications provide a yardstick to recognize the potential of the academia in meeting research demand of the society. Outside the area of peer reviewed publications, there is much information generated through product development and research by the undergraduate and postgraduate students which serve as seeds to be picked by the food industry for conversion into processes. It is hard to quantify or list all these. However, some of the major research outputs in the department are discussed below.

Aflatoxins in foods

Contamination of foods by fungi producing the carcinogenic compound aflatoxins is a major food safety problem in the tropical countries. In Sri Lanka, the three major crops affected are copra, peanuts and maize. Research on aflatoxins has established a mechanism to remove aflatoxins in coconut oil commercially by a solar detoxification process, which was patented. The researchers in the Faculty were able to recognize the origin of aflatoxin problems in peanut locally, interact at the market and processing points through assistance of the local food regulatory authorities and educate the small scale peanut processing industry in the Central Province on methods to eliminate contamination.

This research has generated two postgraduate degrees, a patent, more than 25 research publications in cited journals, invitations to write a chapter to a book published by CRC Press, Boca Raton, Florida in 1991, a review article to a prestigious journal in USA, and the General Research Committee award of the Sri Lanka Association for the Advancement of Science for the “Most outstanding

research Contribution to Sri Lankan Science in 1992. The researchers engaged in animal experiments in this project also won the Hector C. Perera Award for the outstanding clinical communication presented at the 42nd Scientific Session of the Sri Lanka Veterinary Association in 1991.

Currently the research interests have been extended to examine the presence of aflatoxins in local milk by applying more sophisticated analytical techniques. The researchers have been successful in identifying the origin of the contamination, to an industrial raw material used as cattle feed and suggest means to avoid contamination problems. The research team was able to conduct several awareness programs for small scale milk producers living in the Central Province on clean milk production. The programs were mediated by the Feed Registrar of the Department of Animal Production & Health in the Central Province. The research team will continue to extend its' findings to educate farmers.

Fermented beverages

Research on alcoholic fermentation is of high industrial significance. The research carried out on fermentation of toddy (local palm wine) provided an in depth understanding of the biochemical nature of the fermentation process, the characteristics of the yeasts engaged naturally in fermentation and their contribution to sensory properties of the end products. Extension of this work to distillation of alcohols opened new avenues of product development. Of nearly 200 yeast cultures isolated in this project a culture designated Y11 was found to carry highly desirable fermentation characteristics and was deposited in the National Yeast Culture collection in UK. It is now available to be purchased. The research also opened up development of new beverages based on addition of judicious concentrations of spice extracts to give a variety of flavours to the distilled product arrack, which was picked up by the distilleries industry in Sri Lanka. The research produced two MPhil degrees, more than 20 research publications, and an invitation to write a chapter to a book printed by Marcel Dekker Inc, Washington and a book for the Natural Resources, Energy and Science Authority of Sri Lanka in their education publication series in 1986. The Institute of Chemistry, Ceylon awarded the Gold Medal of the Institute of Chemistry for outstanding research contributions in the field of Chemistry in 1993.

The interest in fermentation research in the department continued into identification of appropriate fungi and yeast for rice wine fermentations, an industry that could make use of the excess rice production in the country to generate additional income. A surplus of rice in the country was experienced a couple of years ago and the scientists were requested to come out with measures for utilization the excess. Conversion of rice starch into fermentable sugars could open up an avenue for producing alcoholic beverages. The most challenging aspect of such work was to isolate a fungus for breaking down starch into sufficient quantities of fermentable sugars. A strain of *Aspergillus oryzae* was isolated and used for producing koji. Rice starch was converted to fermentable

sugars, which were converted to alcohol by yeast species isolated from coconut and palmairah saps. Rice wine produced in this process possessed toddy odour. Fruits such as sapodilla, uguessa and dan were used either to mask the toddy odour or to incorporate antioxidant properties and pleasing colour to rice wine or both. The fruit incorporated rice wine was found to possess pleasing sensory properties and about 10% ethanol. However, this technology was not transferred particularly to abide by the regulations enforced under “Mathata Thitha” by His Excellency the President of Sri Lanka. The isolated strain of *Aspergillus oryzae* was made available to a group of researchers, who attempt to make bio fuel using manioc starch.

Strengthening the cashew processing industry

The cashew processing industry was suffering due to low quality of processed kernels arising from defects generated in processing thus limiting export opportunities. The research in this area led to new protocols for handling fresh cashew during deshelling and redesigning of the drier used locally. The redesigned drier operating at low cost was established at a cooperative society and the women groups engaged in deshelling the cashew nuts manually were educated with the new technology strengthening the small industrial sector to generate an exportable quality product. The work is a significant contribution to the small industry sector in Sri Lanka. The research led to a PhD degree of a student at PGIA and 3 publications.

Polycyclic aromatic hydrocarbons in foods

The safety of smoke cured foods has become a much debated issue due to the carcinogenic nature of the compounds deposited from smoke on the foods, especially the benzopyran and its closely related compounds. In Sri Lanka, smoke curing is practiced in large scale in the coconut industry and in production of Maldive fish. A group of researchers from the Tropical Products Institute and University of Greenwich in UK invited the department to participate in a multidisciplinary research project involving six countries. The research generated identity on the types of polycyclic aromatic hydrocarbons (PAH) produced from coconut shell and other part of the coconut plant used as fuel, the conditions under which they are generated and mechanisms to minimize their production and eliminate the PAH from coconut oil. The research also yielded very valuable information on generation of PAH due to high heat of the coconut oil expellers and the important characteristics of the non-PAH components in the smoke in suppressing the growth of aflatoxin producing moulds on coconuts at industrial level and in laboratory experimental cultures. This research was carried out on collaboration with the University of Greenwich, UK, and the Institute of Fundamental studies, Sri Lanka resulted in generation of data to gain three research degrees for the team in Sri Lanka. The recipients of the degrees were from Institute of Fundamental Studies (MPhil from University of Greenwich),

Faculty of Engineering at University of Peradeniya (PhD from University of Portugal) and a postgraduate student (MPhil from PGIA). The work generated many publications and an international symposium in Sri Lanka. The research was recognized by awarding the National Award for Agriculture Research, Council for Agricultural Research Policy and Ministry of Agriculture in 1999. The senior scientist of the group was invited to write a chapter to a book published by science publishers Jodhpur, India in 2003.

The research findings of this project resulted in the Department of Food Science & Technology working with the Coconut Research Institute to redesign the “Ceylon Copra Kiln” to operate on charcoal powder and establish pilot kiln effectively for demonstration to the industry. This work contributing directly to the coconut industry was recognized with the Sri Lanka National Science & Technology Award 2007 in the area of Quality Improvements of Products, Processes and Services.

The department also collaborated in a project with the department of Agricultural engineering in designing a rotary copra drier which led to a MPhil degree

Acrylamide in fast foods

Acrylamide, recognized as a probable carcinogen is produced during frying of food material at high temperature. An ongoing research monitors the acrylamide levels of different types of fried foods sold at fast food stores. Researchers have extended their work to study the changes in acrylamide levels in repeated usage of oil for frying which is practiced in most of Sri Lankan restaurants.

Histamine formation in fish

Undesirable health effects associated with consumption of fish and fish products is a major consumer concern. This project examined the extent of histamine contamination in fish and fish products, the microorganisms engaged in production of histamine and means to minimize histamine contamination. The research highlighted the importance of “Goraka” in preventing histamine accumulation in fish. The research team collaborated with National Aquatic Research Agency. The research yielded a PhD degree and the contribution of this project to science in Sri Lanka was recognized by a merit award of the National Science Foundation to the team in 1999.

Considering the possible health implications of histamine from tuna (Balaya) fish the research was extended to human subjects exposed to histamine through consumption of fish in a canteen. The examination of blood samples of the subjects and the food for histamines revealed the safe levels of histamine that could be tolerated in foods. This work led to a Masters degree at PGIA and the work was published.

Fungal spoilage of dry-fish

Dry-fish is much sort after by Sri Lankans as a source of proteins and as well as a delicacy by most sectors of the population. The high salt concentrations in dry-fish do not allow bacterial spoilage. However, the fungal growth cannot be ruled out. Examination of salt tolerant fungi isolated from dry-fish and study of the growth characteristic of the organisms in laboratory cultures and on dry-fish revealed the desirable concentrations of minimum salt concentrations and permissible maximum moisture concentrations required to keep the dry-fish free of fungal growth. The work was published internationally and the research led to a Masters degree at PGIA.

Listeria monocytogenes in food

Listeria is a more recently recognized pathogenic bacteria capable of leading to miscarriages during pregnancies among other toxic effects. A survey in foods in Sri Lanka revealed that the organism is present predominantly in fresh milk and cheese. Some of the more useful findings related to this organism, include the ability of fermentation of milk to curd and yoghurt to suppress the growth of Listeria, the ability of the organism to survive pasteurization process of milk when present in high populations and suppression of it by hydrogen peroxide. Cheese carrying sodium chloride as a component provides an advantage for this microorganism to grow into large populations in the absence of competitive organisms. This work led to a MPhil degree at PGIA and the results were published nationally and presented at international symposia.

Heavy metals and other toxic components in food

Contamination of food by heavy metals arising from absorption from soil rich in heavy metals and also accumulation of heavy metals in animal tissues exposed to high concentrations in animal feeds are problems of concern in food safety. The students working in the department for postgraduate degrees examined a variety of yams and tuber crops and edible animal tissues for probable presence of toxic levels of metals. The research revealed absence of heavy metals beyond acceptance levels in the foods examined. However some animal tissues such as brain appeared to carry recognizable concentrations of molybdenum. The research findings were published internationally.

Packaging for desiccated coconuts

Desiccated coconut is a major source of foreign exchange to Sri Lanka. In the past desiccated coconut for export were bulk packed in multilayer craft paper bags. The research on the permeability of the bags to moisture under different relative humidity conditions for long durations simulating shipping indicated that the desiccated coconut could reach unsafe moisture concentrations during transit and

the initial moisture content is critical. The study also revealed the moisture absorption of desiccated coconut packed in different types of laminated packages when subjected to simulating conditions experimentally could avoid contamination problem by the time the products reach markets abroad. The work was published locally and made available to the coconut industry. Later this information helped the Coconut Development Authority to identify cause of some of the problems associated with desiccated coconut exports when the buyers complained of contaminations. The work was published. The desiccated coconut is now packed in laminated bags.

Iron contamination of spices during grinding

Spices are ground industrially in mills containing two soft iron tooth wheels rotating against each other. Examination of spice powders in the market showed presence of paramagnetic iron particles. The highest concentrations of iron powder were observed in turmeric. However, the iron present in the form of ferric does not contribute to nutritional quality or safety of foods. The work was published.

Use of formalin to preserve fish

Formalin has been observed to be used as a preservative for fresh fish, especially when ice is not available. This study carried out with the Food regulatory Laboratory in the Kandy Municipality revealed the types of fish commonly preserved using this unpermitted method. The study also showed that some types of fish naturally contain low levels of formalin generated in their bodies and as such the reports on formalin in fish need to be interpreted cautiously in taking regulatory actions.

Quality of bottled water

The microbiological and chemical qualities of bottled water produced by all the industries in Sri Lanka were examined. All industries met the microbiological requirements in water. There was one industry bottling water of very low pH. The researcher visited the industry, identified the cause of low pH and provided guidance to avoid the problem.

Potato and banana chips

Potato chips are imported and sold at a high price. Imported varieties of potatoes are used for producing chips locally as all the local varieties are not suitable for chipping due to high sugar content, which causes development of an unacceptable colour in the chips. Suitability of local potato varieties for chipping was studied and recommendations were made to the Potato Research Institute,

Seethaeliya. Moreover, measures for improving the color of chips produced using local potato varieties containing undesirable quantities of sugars were identified. Hot water blanching for 1 min with 200 ppm potassium metabisulphite improved the colour of chips processed using potato varieties containing undesirable quantities of sugar. Small scale producers were assisted in identifying measures for improving the sensory quality of potato and manioc chips, which are more popular now than imported potato chips due to low price of the former.

The cultivar 'Kolikuttu' is very unique due to its characteristic flavour and is preferred over other banana cultivars. However, this cultivar, being the most perishable among banana cultivars, contributes to the highest percentage postharvest loss of banana. As overripe 'Kolikuttu' banana cannot be used for any food application, banana chips were developed using them. These banana chips are highly acceptable in terms of sensory attributes such as colour, flavour, aroma etc and thus can replace sugar based snacks that may have many health implications if consumed frequently. Though banana chips are very popular as a snack in many countries, they are still not produced in Sri Lanka on commercial scales.

Modified atmosphere packaging

Oyster mushroom needs packaging due to its high perishable nature. Polypropylene (PP) was the most widely used material for packaging oyster mushroom. Shelf life of oyster mushroom packaged in PP was limited to a couple of days as high barrier properties of the material to oxygen and water vapour caused onset of anaerobiosis and accumulation of moisture. The former contributed to off-odour development and the predominant odour perceived upon opening the package was the odour of acetone. The latter caused fogging inside the package. Devising a modified atmosphere system using a packaging material more suitable than PP was a timely need to extend the postharvest life of oyster mushroom. Linear low density polyethylene (0.015 mm thickness) was found to be more suitable than PP for packaging oyster mushroom. These findings led to replace PP with Low density polyethylene, thereby extending the postharvest life of mushroom, which is currently practiced in Sri Lanka. Shelf life of mushroom packaged in LLDPE containing 3g of magnesium oxide as a carbon dioxide scavenger was found to be 5 days at $27\pm 2^{\circ}\text{C}$ at $82\pm 3\%$ RH and 12 days at $8\pm 1^{\circ}\text{C}$ at $70\pm 2\%$ RH.

Kolikuttu is one of the most popular cultivars of banana due to its pleasing aroma and taste. This cultivar has a good export potential if ripening can be delayed by at least three weeks as it takes such time for sea freighting. It was revealed that Kolikuttu banana can be packaged in low density polyethylene (0.075 mm thickness) and stored at 14°C and 94% RH for 24 days without ripening. Storage life could be further extended up to 30 days by using potassium permanganate in LDPE bags. Under similar conditions green life of Kolikuttu banana can be extended up to 20 days at room temperature. This technology is particularly

important in countries where cold storage is not readily available. Modified atmosphere packaging of 'Pollock' avocado in LDPE (0.05 mm) with ethylene scavengers could extend the postharvest life up to 29 days. Under similar conditions, postharvest life of 'Karuthacolomban' mango could be extended up to 21 days.

The findings of these studies and technologies developed on active modified atmosphere packaging are being applied on other perishables too at the Institute of Postharvest Technology, Anuradhapura.

Instant soup

The society is getting more and more health conscious particularly due to globalization. However, the time they can spend on preparing a balanced diet is getting shorter and shorter particularly due to privatization, which demands longer working hours. Easy-to-prepare food products or instant products are popular among consumers with busy lifestyles. Instant soup is one of the products that has attracted these consumers. However, most instant soup mixtures contain monosodium glutamate (MSG), which is a known nerve poison. Moreover, use of MSG has been questioned by consumers all over the world due to probable adverse effects on health. Some people develop allergy symptoms on consumption of very minute quantities of MSG. As the food industry is in search of alternative flavour potentiators, an instant vegetable soup mix with no MSG was developed, which was comparable to those containing MSG. This technology has reached the producers through the "Vidatha" programme run by the Ministry of Science & technology.

Dehydration

Dehydration of oyster mushroom is commercially practiced to extend the shelf life of highly perishable mushroom. Rubbery flavour and brownish colour were some problems encountered by the processors. It is a common practice to blanch raw materials in hot water before drying and use of sodium metabisulphite to improve the colour of dehydrated products by arresting browning reactions. Blanching treatment can accelerate the browning reactions particularly due to tissue injury. Use of sulphur dioxide has drawn attention of the medical personal due to its side effects. Attempts were made to establish blanching conditions and to find alternatives to sulphur dioxide. It was revealed that oyster mushroom can be dehydrated at 45°C for 5 h after immersing the torn mushroom in 0.05% sodium bicarbonate for one min. This treatment resulted in dehydrated mushroom with no rubbery flavour and with appealing colour. Dehydration products often fail in the market due to use of packaging materials unsuitable for such products. It is imperative that the water activity of the dried products be kept below 0.6 during storage. Aluminium laminates and meatlized films are the best options. Dehydrated mushroom can be packaged in pouches made of aluminium foil

laminated with low density polyethylene for 9 months at room temperature without considerable changes in water activity and sensory quality attributes. Similarly, technologies were developed on dehydration of jakfruits, brinjals, onions, banana blossoms, leeks and bitter gourds. These technologies were made available to small scale food processors.

Information collected on changes of water activity when dehydrated products are packaged in aluminium laminates and metalized films were made available free of charge to Warna Pvt., Ltd., Ratmalana, who provided packaging materials free of charge for research work, to help them identifying suitable materials for food processors.

Artificial ripening

Fruits are harvested before ripening and transported to wholesale and retail markets. It is a common practice to ripen the fruits artificially to make ripening faster and obtain uniformly ripened fruits. In the developed countries artificial ripening is achieved by using ethylene gas, which is an expensive process. Though use of calcium carbide is banned in Sri Lanka and an alternative has been identified its use continues. As commercial grade calcium carbide is reported to contain phosphorous hydride and arsenic hydride, which could cause health hazards, recommendations on the method of application to prevent contact of the fruits with calcium carbide were made to the fruit handlers. They were educated on the importance of taking precautions to prevent contact of calcium carbide with fruits. Most importantly, the problems associated with sprinkling calcium carbide on fruits with bare hands were pointed out.

Food & Nutrition

The early research on food and nutrition was aimed at examination of nutritional quality of winged bean and on mechanisms to make winged bean products available in a ready to consume form locally. The research carried out as split programs led to two PhD degrees from the Virginia Polytechnic Institute and Penn State University in USA for academic staff members. This work expanded later into examination of nutritional properties of other locally important crops. With staff in the department qualifying in examining the nutritional problems from a food point of view, much research was focused on assessment of nutritional status of various population groups in Sri Lanka with a view to recognize areas needing intense attention. The current research focuses on more interactive study of humans for improving their health status identifying functional food components. They include focus on glycaemic index of local foods as a means of addressing diabetes related issues and understanding desirable fatty acid profiles in humans through food based interactions.

The research on glycemic index of local foods including traditional varieties of rice and finger millet as a means of addressing diabetes associated issues attracted

much scientific interest. The findings were published in scientific journals. The findings are now used to assist food producers to establish GI symbol in their food products. Currently the researchers collaborate with the University of Sydney. The project has received a research grant of Rs 3.6 million from the Council for Agricultural research policy to study the Glycemic responses of different traditional and improved varieties of rice. The department also received a NSF (National Science Foundation) grant of Rs.1 million to develop a dietetic software tool for Sri Lankan Health care institutions. The department has commenced research on cholesterol lowering ability of Avocado based food drink in human subjects.

The department was also engaged in a study with academics from the Faculty of Medicine to understand the role of modifying local fat consumption through balance of coconut oil and sesame oil. The findings were published internationally and received national recognition through the Presidential award scheme for publications in cited journals.

Health promoting compounds of tropical fruits: occurrence and processing effects

The department is currently investigating the development and application of new processing technologies or optimize the potential health promoting compounds in tropical fruit juices and juice based products. This study is carried out with collaboration of the Product Design & Quality Management group of the Wageningen University, the Netherlands.

Health promoting compounds of mango, pineapple, papaya and selected local fruits are analyzed to investigate the effect of pre-treatments, pulp separation techniques, thermal treatment and other processing techniques. The research would identify the critical processing step/s in-depth (laboratory /pilot scale) to develop new process technologies as alternatives to the existing process techniques. Production process of Ready-to-drink fruit juices, concentrated juices, and canned products (pieces in fruit juices/syrups) are currently under investigation. Modeling of the changes of health promoting compounds will be conducted. The information of this project is important for nutritional labeling, product and process design of tropical fruit products.

CHAPTER 8: RESEARCH CONDUCTED BY

Department of Soil Science

Compiled by
Dr. (Ms) S. P. Indraratne

Introduction

Soil Science has been taught in University of Peradeniya since the inception of higher education in agriculture under then Department of Agriculture and Veterinary Medicine. The research activities dedicated to Soil Science progressed slowly until the establishment of Department of Agricultural Chemistry in 1973. The members who taught soil science during this time such as Prof. F.S.C. Kalpage, Prof. M.W. Thanabadu, and Dr. L.G.G. Yapa contributed significantly to the soil science related research conducted in the Faculty of Agriculture. With the recruitment of new members trained in different disciplines in soil science the teaching and research programs further expanded and a fully fledged Department dedicated for Soil Science was established in 1986. Being the only Department having more than 30 years of experience in teaching and research in Soil Science in the higher education system in Sri Lanka, the Department is heavily involved with capacity building and providing consultancy and advisory services to regulatory and policy making bodies of Sri Lanka. At present the Department of Soil Science is responsible for teaching and conducting research pertaining to the broad areas of Soils, Plant Nutrition and environmental aspects related Soil Science at undergraduate and postgraduate levels. Soil Science discipline is taught at the core programmes B.Sc. in Agricultural Technology and Management (Ag.Tech.&Mgt.) and B.Sc. in Animal Science and Fisheries as well as in the advanced module of Soil and Environment of Ag.Tech.&Mgt. degree. Courses of the core program for the B.Sc. in Ag.Tech.&Mgt. are designed to build up the knowledge progressively starting from Soil Formation to Soil Management. The advanced module in Soil and Environment is designed to address environmental issues providing an in-depth knowledge on soil as a natural resource and theoretical aspects that are essential to develop the technologies to accomplish sustainable land management.

The present and past academic staff at the Department of Soil Science has contributed significantly to the development in Soil Science discipline both locally

as well as globally. In brief, research on Agricultural Chemistry and Soil Pedology started at a very early stage. Research conducted during 1960 to 1980 addressed rice production, fertilizer use, nutrition of tea, rubber, oil palm, grasslands, soil fertility and management, and agricultural development. Distinct research areas related to different disciplines of soil science emerged and evolved since late 1980's. Accordingly fundamental and applied research on soil chemistry, soil fertility, soil physics, soil microbiology, soil mineralogy, soil taxonomy and mapping and land-use planning has evolved under the leadership of the academic staff of the Department in many instances with the collaborations of local and foreign scientists and institutions. Some examples of financial sources that supported research activities during last two decade are National Science Foundation of Sri Lanka, National Research Council of Sri Lanka, Sri Lanka Council for Agriculture Research Policy, Ministries align with Environment and Agriculture in Sri Lanka, International Foundation for Science, Food and Agriculture Organization of the United Nations, University Development Corporation of Belgium, Queen Elizabeth scholarship program of University of Winnipeg of Canada, Canadian Soil Science Society and University of Peradeniya of Sri Lanka. Therefore, the research conducted at the Department of Soil Science always stayed in line with national development goals and global trends in soil and environmental science research.

The members of the Department have been serving in various capacities such as principal investigators, team leaders, co-investigators or collaborators in multidisciplinary research projects that seek to address nationally or internationally important issues. The support from the University Grants Commission and University of Peradeniya, equipment donations by Japan International Cooperation Agency (JAICA), and numerous research grants received by the academic staff members helped to develop resource base at the Department over the years. At present the Department host five research laboratories dedicated to soil microbiology, molecular biology, soil physics, soil and environmental chemistry and soil fertility, and geo-spatial analyses. In addition a teaching laboratory is available in the Department to facilitate undergraduate teaching and research activities. The laboratories are equipped with basic and advanced instruments necessary to conduct research.

The undergraduate teaching and research has been benefited by the strong research culture maintained by the Department. For instance each year a number of undergraduate students volunteer in research activities, cultivating analytical skills, technical competencies, civic values, and communication skills among many other benefits. Further, most of the students in the advance module of soil and environment join the ongoing research programs in the Department to conduct their final year research projects. Undergraduate students get to interact with postgraduate research students working in research laboratories of the Department leading to mutual benefits for both parties. The research conducted by the members of the Department has been acknowledged in different forums and the members authored a large number of publications in peer reviewed local

and international journals, books and book chapters contributing to the dissemination of knowledge.

When reviewing the research conducted by the academic staff of the Department of Soil Science during past 70 years, two broad areas of research could be identified; namely, studies on soil properties aiming to improve, enhance and to reclaim those, and studies on environmental aspects of soil science mainly aiming on potential and possible mitigation measures of soil degradation due to the use of agro-chemicals and different agricultural practices. In this chapter key findings of some research projects coming under these two categories are summarized.

Studies on Soil Properties

Soil Physical Properties

The soil water retention parameters needed for irrigation planning, soil hydraulic properties used as input parameters for simulation of soil water and solute movement has been characterized for major Sri Lankan soils by the department staff. The wet and dry soil aggregate stability which could be used as an indicator of soil erodibility has been measured and documented. Suitability of equipments as Time Domain Reflectometers and Guelph Permeameters were evaluated for their use in tropical soils.

Formation of a hard pan in sub soils layers is a major limitation for plant root penetrations. One of the studies came up with a critical bulk density of 1.45 Mg m³ for root penetration for legumes and further found that the rice roots were able to penetrate compacted Alfisols.

Soil morphology and classification

Staff of the Department of Soil Science pioneered many soil taxonomy related studies at numerous stages of classifying soils of Sri Lanka. Studies on tropical soils, their classification, fertility and management were conducted in 1960's. Later on characterization of ill-drained soils of the wet-zone, understanding the Montane Soils in Sri Lanka were conducted during the 1970's. After 1994, soil classification studies got a major swing towards classifying the soils in Sri Lanka according to the soil taxonomy guidelines given by the United States Department of Agriculture (USDA). The leadership for characterizing and classification of Wet, Intermediate and Dry zone soils of Sri Lanka, mapping them and development of a digital soil data base for Sri Lankan soils during last three decades was provided by the departmental staff. Recently, the soils in the Northern and Eastern regions of Sri Lanka were characterized and mapped by the staff of the Department of Soil Science.

Soil Chemical properties and fertility studies

Investigations on soil chemical properties, redox behaviors in soils, development of multi-nutrient extractants for chemical analysis, evaluation of extractants for Zinc and Copper in paddy soils, validating Effective Cation Exchange Capacity

measurements for Sri Lankan soils, development of a nitrification Inhibitor, development of a Key for potassium fertilizer application to tea grown soils of Sri Lanka based on soil mineralogy, introduction of new sequential extraction method for soil organic matter fractionation, validation of sequential extraction method for soil phosphorous fractionation, selection of the best suitable, economical analytical procedure to assess S-availability in tea grown soils and establishment of baseline concentrations of selected potentially toxic trace elements in some soils in the dry zone were the major contributions to soil chemistry.

A series of greenhouse and field studies at Aralaganwila to assess potassium uptake by corn revealed that moisture stress could overcome by adding potassium to soils. In addition, legumes and black gram could overcome deleterious effects caused by the water logging conditions, and potassium uptake by rice supplied in the form of organic manures was higher under flooded conditions compared to saturated soil.

Outcomes of studies leading to improvement in soil fertility included the findings of 15N mineral transformation to organic forms, nitrogen and phosphorus mineralization, distribution of nitrogen forms in Sri Lankan Soils and phosphorus availability in Sandy Regosols due to addition of organic and chemical fertilizers.

Soil fertility evaluations and nutrient availability studies were conducted using different methodologies. Soils collected from 32 locations of Sri Lanka representing different Agro-ecological zones were evaluated for their fertility status. The tested soils indicated widespread deficiencies in macro, secondary and micronutrients. Fertilizer recommendations for individual soils can be formulated by analyzing soils for available nutrients and conducting sorption studies. Identification of nutrient disorders and toxicities in plants followed by soil nutrient studies provided the basic data for many fertilizer recommendations. Nutrient requirements were assessed based on fixation ability of nutrients by soils. After considering results of all these studies, fertilizer recommendations were formulated for rice, vegetables and fruit crops based on the site-specific approach. Comparisons of different Nitrogen fertilizers, appropriate use of organic materials, establishment of fertilizer recommendations through Variety Adaptation Trials, and development of a Key for potassium fertilizer application to tea grown soils of Sri Lanka, made significant contributions for soil fertility improvements.

Studies of nitrogen, phosphorous, potassium and sulfur dynamics in soils helped to understand availabilities of those nutrients for plant growth. Additional studies were conducted to assess the potassium uptake by rice, mustard and corn under greenhouse and field conditions from fertilizers and manures. The results revealed that potassium uptake by rice is either promoted or suppressed by the presence of magnesium. Assessing a variety of fodder and pasture for the nutrient availability has revealed that Guinea and Gliricidia contains nutrients adequate for the dairy cattle.

In order to bring low-productive lands under successful crop production and to improve or maintain the productivity of present agricultural fields, is vital to

address soil fertility issues, which are site specific. Therefore, the soil characters leading to poor crop performance could be different from field to field. Site-specific Beneficial Management Practices (BMPs), as opposed to 'blanket' applications of fertilizers, helped to overcome soil-based productivity constraints in upland cropping systems. These BMPs included formulation of site specific fertilizer recommendations and the use of rock powder and carbon rich organic materials such as biochar and mixture of cattle manure and sawdust to enhance soil nutrient availability and soil carbon sequestration facilitating long-term soil fertility. Biochar is being considered as an organic soil amendment that can be effectively used in integrated soil fertility management approach. Under Sri Lankan conditions, application of synthetic fertilizers along with biochar has decreased soil acidity, increased nutrient availability, improved soil physical properties and enhanced soil carbon pool and crop yields. In addition to organic and synthetic fertilizers, the use of rock powder as soil amendment to improve soil fertility status.

The department is conducting number of research projects to evaluate the potential uses of biochar produced from crop residues to increase soil organic carbon reserves and enhance soil fertility parameters. Research so far completed have confirmed that application of corn cob waste biochar helps to reduce soil organic C mineralization, particularly in acidic Ultisol. Biochar increases the pH buffer capacity in acidic soils and increases P availability in soil. Moreover, corn cob wastes biochar plus chemical fertilizers help to improve growth of corn plants when compared to the conventional fertilizer applications. The department also successful in developing a slow release N fertilizer using biochar and urea.

For the first time in the rice research in Sri Lanka, the scientists in the Department in collaboration with the Rice Research and Development Institute, Batalegoda and the International Plant Nutrition Institute were able to modify a web-based nutrient management tool for rice cultivation in Sri Lanka. The modified version is under field investigations currently.

Soil Microbiological studies

Changes were identified in the diversity of soil microorganisms in intensively cultivated uplands and wetland paddy soils collected from Dry zone and up country Wet Zone. Diversity indicated that total microbial communities differed among soil types and also between rhizosphere of about 20 improved and traditional rice varieties. Rhizosphere is comprised with a variety of plant growth promoting bacteria. Fungi and bacteria have been formulated into inoculants that decompose rice straw under field conditions which promotes fast plant growth.

A research confirmed that triple super phosphate fertilizers imported to Sri Lanka could be partially replaced by Eppawela rock phosphate added along with bacterial inoculants to rice and obtain comparable yields. Inoculants of

mycorrhizal fungi, nitrogen fixing bacteria and phosphorous solubilizing bacteria were successfully developed for nutrient management in rice, pole beans, carrot, leeks, maize and red onions. Several inoculants are made available to enhance decomposition of fresh rice straw and to solubilize Eppawela rock phosphate. A culture collection comprising of several hundreds of these bacteria and fungi characterized for beneficial traits and identified to the species level is available with the Department. Some of these isolates were documented under the list of indigenous flora of Sri Lanka published in the issue on Natural Resources of Sri Lanka by the ministry of Environment and Renewable Energy.

In addition to the studies on plant growth promoting microorganisms, the Department research on the role of microorganisms in the flow or resources in the environment. Nitrification is a main transformation governing pool sizes of NH_4^+ and NO_3^- in soil. A study was conducted to determine the ability of rice to suppress nitrification using ten rice varieties. It was found that some rice varieties have the potential to suppress nitrification. Further rice varieties respond differently to different plant available nitrogen forms in the root zone with some varieties performing better under NH_4^+ rich condition and some performing best under mixed supply of NH_4^+ and NO_3^- . Research for the development of botanical nitrification inhibitors in order to enhance fertilizer nitrogen use efficiency in vegetable production systems is ongoing at present.

A study on the diversity of bacteria and fungi in forest soils analyzed using a metagenomic approach revealed very high richness of species that has not been accounted previously using culture based analytical approaches. For instance the dryzone forest soils had less abundance and less diversity of fungi compared to wetzone forest soils according to culture based analysis. But the molecular studies revealed that the abundance and diversity of fungi is higher in the soils collected from dryzone forest compared to the wet zone forest with significant proportion of unculturable fungi in both systems. Further studies on diversity and ecology of soil microorganisms using molecular techniques are being carried out in the Department.

Soil Mineralogical studies

Identification of major clay minerals presents in Wet, Dry and Intermediate zone soils of Sri Lanka and their contributions to soil properties were reported. The studies are conducted on Organo-mineral complexes formed in soils which are responsible for the enrichment of C pool. Differences in stabilities of organo-mineral complexes found in Sri Lankan soils are directly related to the type of clay minerals contributing to the formation of the complexes, i.e. montmorillonitic-organo complexes being more stable than kaolinitic-organo complexes. Furthermore, clay mineralogical studies in Sri Lanka revealed that the presence of smectite clays in significant quantities contributes for the cracking of the earthen dams in Dry zone.

Digital Soil Mapping and Proximal soil sensing

Digital soil mapping and proximal soil sensing are novel research domains of Soil Science. The Department of soil science initiated researches in these domains while gradually developing its research capacities. Digital soil maps depicting the short-scale variability of key soil properties such as plant nutrient concentrations, soil texture, pH and EC have been developed for selected areas representing great soil groups, reddish brown earth, low humic gley soils, red yellow podzolic soils and red latosols. Geostatistical analysis of soil information revealed the presence of a structured spatial variability of these soils and such spatial information are essential for precision agriculture activities, site-specific soil nutrient management, process based land use planning and environmental modelling. Further digital soil mapping techniques such as univariate ordinary kriging and multivariate regression kriging, co-kriging and artificial neural network predictions have been found to be useful in construction of detailed soil maps using environmental covariates such as elevation, primary and secondary topographic attributes, precipitation, temperature and land use.

Proximal soil sensing is one of the frequently used techniques to generate ancillary information for digital mapping of soil properties and classes. Potentials of a variety of proximal soil sensing techniques are being tested worldwide for accurate and cost-effective mapping of soil resource. The acquisition of the state-of-art DuEM1S proximal soil sensor through the research project “Implementing Novel Technologies for the Spatial Inventory of Soil Quality” funded by the University Development Cooperation, Belgium allowed the researchers to initiate researches on proximal soil sensing. During last years, the potential of soil proximal sensing for mapping of soil properties such as soil texture, salinity and concentrations of K and P has been investigated. Promising potentials of proximal soil sensing for mapping of soil texture and salinity/sodicity in the intermediate and dry zones have been shown. A part of the soil map of the Dodangolla Experimental Farm has been upgraded by using proximal soil sensing. Further, nutrient management zones for paddy have been delineated using proximal soil sensing.

Environmental Aspects of Soil Science

Soil degradation due to agricultural related practices and other anthropogenic activities has been the focus of research by many staff of the Department, especially during last ten years. Addition of different types of compost as a fertilizer has been practiced for a long time. Staff has contributed for the development of standards for composts and organic products in Sri Lanka. Preparation of guidelines for waste water irrigation and development of a Nitrification Inhibitor have contributed significantly to the environmental related research studies. Many pesticide adsorption and leaching studies were carried out by the Department. Potential risk areas of groundwater contamination with selected pesticides were identified for the wet zone of Sri Lanka. Mechanism of

atrazine sorption to the clay minerals were identified as the hydrophobic interactions with organic compound surfaces, H-bonding and ionic bonding with clay-mineral surfaces.

A larger fraction of bacteria, fungi and micorrhizae of intensively cultivated soils show resistance to heavy metals and pesticides whereas sensitive organisms have been excluded resulting in a narrow biodiversity. Development of antibiotic resistance and its spread in the environment is a crucial global health concern at present. The use of untreated poultry manure in agriculture could spread antibiotic resistance determinants exerting threats to ecosystem and human health. A study conducted in the Department found that poultry litter and manure contained antibiotic resistant bacteria. Both intensively vegetable cultivated soils and uncultivated soils from Nuwara Eliya region contained antibiotic resistant bacteria. The history of exposure to poultry manure significantly affected the response of soil microorganisms to new inputs of poultry manure and antibiotics. Further the study indicated that antibiotic resistant bacteria were among those colonizing *Daucus carota* roots. Variability in antibiotic resistance traits among the tested isolates from poultry litter/ manure and soils is suggestive of high diversity among antibiotic resistance bacteria in each environment.

Application of more than recommended levels of fertilizers to intensively cultivated cropping systems was a major environmental concern of recent past. Studies were conducted on plant nutrient contamination of shallow-ground water in intensive vegetable gardens of Nuwara Eliya and groundwater quality of three Agro-ecological zones of Sri Lanka.

The accumulation of potentially toxic trace elements such as Cd, Pb and As in soils, is a great concern to food quality and human health. Analyses of organic manure for these elements indicated that the concentrations of the elements did not exceed the maximum permissible levels recommended by the Sri Lankan Standard Institute for compost. Related studies in intensively cultivated fields indicated that these elements could accumulate in agricultural soils with time. Although no alarming levels of the trace elements were reported in soils, increasing trends of concentrations of trace elements were recorded in agricultural fields. The potential bioavailability of Pb and Cd in vegetable growing soils in the up-county region was higher compared to that in the forest soils in the region. .

Remediation of polluted soils with trace elements using naturally available materials is an economical and environmental friendly practice. Eppawala Rock Phosphate and Sri Lankan Dolomitic Limestone possessed high adsorption capacity for Zn, Cu and Cd. Apatite- and dolomite-soil mixtures convert Zn, Cu and Cd into less bioavailable forms indicating their potential for the remediation of heavy metal contamination. Nano oxides of Al and Ti and compost pellets could be used to reduce bio-available forms of Cd, Pb and Zn in contaminated soils. Furthermore, long-term cattle manure applied soils showed metal enrichments and high correlations between extracted P and metals.

Many researches have applied geo-spatial data analysis techniques for environmental studies. Maps of trace elements within a dry zone mapping unit have been developed. Digital Mapping of trace elements in the wet zone soils is being conducted through research funding from the National Research Council. Further, presently mapping of soil organic carbon stocks and Phosphorus stocks are being conducted at sub-catchment scale. This study attempts to quantify the dynamics of P and C stocks under different land uses. The researchers of the Department of Soil Science produced the first national map of soil carbon stocks. This work was published in the Geoderma Journal.

More than 75 years have passed since the introduction of fertilizers for plant nutrient management in Sri Lanka but the use efficiency of these fertilizers remains less than 50 %. This has led to numerous on-farm and off-farm socio-economic as well as environmental issues. Therefore, there is a great need of continuing research on soil fertility and plant nutrition management plans. Findings of such research will help to reduce virtual costs on recovering from environmental and health issues created due to agricultural pollutants. The Department is presently engaged in research in collaboration with government institutions including Department of Agriculture to develop mechanisms to improve nutrient use efficiency of agricultural systems. Most of the projects have taken a multidisciplinary approach acknowledging the nature of complexities of problems seeking to address in reality. Further, research projects are being carried out to generate information required to develop regulations and policies to ensure sustainability of the environment and mitigate contamination of soil, environment and food-chain with potential contaminants due to agricultural practices.

The support given by the present and former Heads and the academic staff of the Department in compiling this document is acknowledged.

Postface

Compilation of the contribution to agriculture research of academia of the Faculty of Agriculture of University of Peradeniya was first initiated by the Research Development and Ethical Review committee-2008 of the Faculty at the event of celebrating the 60 years agricultural higher education of the country in the year 2008, the very year the Faculty celebrated its 60 year jubilee. Forward of this book clearly indicates that the objective of this initiative was to record the sailing path of the agriculture research lead by the academia of the Faculty of Agriculture, University of Peradeniya for the 60 year period from 1948 to 2008. Thus, this compendium presents foot prints of the staff of the Faculty in the national agriculture research arena for six decades up to 2008.

Ten years later of the first compilation, the Faculty Research Committee (2016-2018) of the Faculty of Agriculture is pleased to launch this compendium as the Volume 1, along with the Volume 2, which compiles the research achievements and contribution of the academia of the Faculty of agriculture during the last decade, from 2009 – 2018. We acknowledge very much the efforts of the Research Development and Ethical Review committee, 2008, and then dean of the Faculty for their initiative for this worthy endeavor. The corporation extended by all Heads of Department in verifying the information recorded in this compilation is highly appreciated by the Faculty Research Committee.

Faculty Research Committee (FRC) 2016-2018

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