AGROFORESTRY FOR SUSTAINABLE DEVELOPMENT IN SRI LANKA

Contributions to a three-day Participatory Training Course

Editors

P. A. Huxley
D. M. S. H. K. Ranasinghe

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Contributions to a three-day Participatory Training Course

Organised by
The Forestry Unit, University of Jayewardenapura
with the support of The Sri Lanka Foundation Institute.

September 9-11, 1994.
At The Sri Lanka Foundation Institute, Colombo, Sri Lanka.

Editors

P.A. Huxley
D.M.S.H.K. Ranasinghe

Huxley, P. A., Ranasinghe, D. M. S. H. K. ***Agroforestry for sustainable development in Sri Lanka: Contributions to a three-day Participatory Training Course.***

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Cover illustrations by Jaquelien Chapman.
Front, Kandy Homegarden, Sri Lanka;
Back, Sloping Agricultural Land Technology (SALT).

Published, 1996, by the University of Wales, Bangor, and University of Sri Jayewardenapura.

Printed by The Basingstoke Press (75) Limited, UK.
Text prepared by Fountain Renewable Resources Limited.

ISBN 0-904567-81-8

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Foreword

A three-day participatory training course was held on Agroforestry for Sustainable Development in Sri Lanka as part of the ODA-funded Link Project between the University of Sri Jayewardenapura (USJ) and the University of Wales, Bangor. The course was organised by Dr. Hemanthi Ranasinghe, Head of the Forestry Unit[†] , USJ, and held at the Sri Lanka Foundation Institute in Colombo.

There is a need to increase awareness about agroforestry and the role that this technology can play in the sustainable development of Sri Lanka's land resource, so the training course was a timely initiative. It also enabled those with some experience in agroforestry to exchange ideas and discuss future needs. There were over 60 participants; not only scientists representing Sri Lanka's leading organisations involved in natural resources, such as the major universities, Government departments and research institutions, but also those from development boards, policy units, environmental organisations and other NGOs, private companies, newspapers and banks, who very often need to be aware of issues involved in agroforestry, but who rarely get invited to such meetings.

The training course consisted of a series of presentations on a wide range of topics, followed by open sessions during which the participants formed small working groups to discuss recommendations for improving agroforestry practices in Sri Lanka. Leading national scientists were invited to present overviews of specific historical and present-day agroforestry practices in which Sri Lanka is so rich. Focus was given to multiple cropping under coconuts, the role of agroforestry in watershed management and traditional tank systems which incorporate animals into agroforestry systems. There was also a presentation from the Neosynthesis Research Centre on current research on Analog Forests, and a video was shown on Sloping Agricultural Land Technology (SALT); a narrative of which is included in this volume. The presentations made by the national scientists were linked together by a series given by Dr. Peter Huxley on some of the underlying issues involved in

† Now a Department

agroforestry research and practice in general. Dr. Huxley was formerly Director of Research Development at ICRAF.

Since the decision to publish the presentations was only made after the meeting was concluded, the editors, Dr. Peter Huxley and Dr. Hemanthi Ranasinghe, have, where it has not been possible to obtain full papers, compiled this volume from authors' drafts, and from the rough notes of the Working Groups. The style and content of individual contributions have been retained as far as possible.

The volume reflects the current status of agroforestry in Sri Lanka, and offers comments and suggestions about its future role. Thus, it will be of use, not only to those who attended the meeting, but to all Government officials, researchers, practitioners, policy makers, administrators and students who recognise the opportunities that both traditional and modern agroforestry techniques can offer to the sustainable development of Sri Lanka.

Joanne Wainwright
November, 1996

Acknowledgements

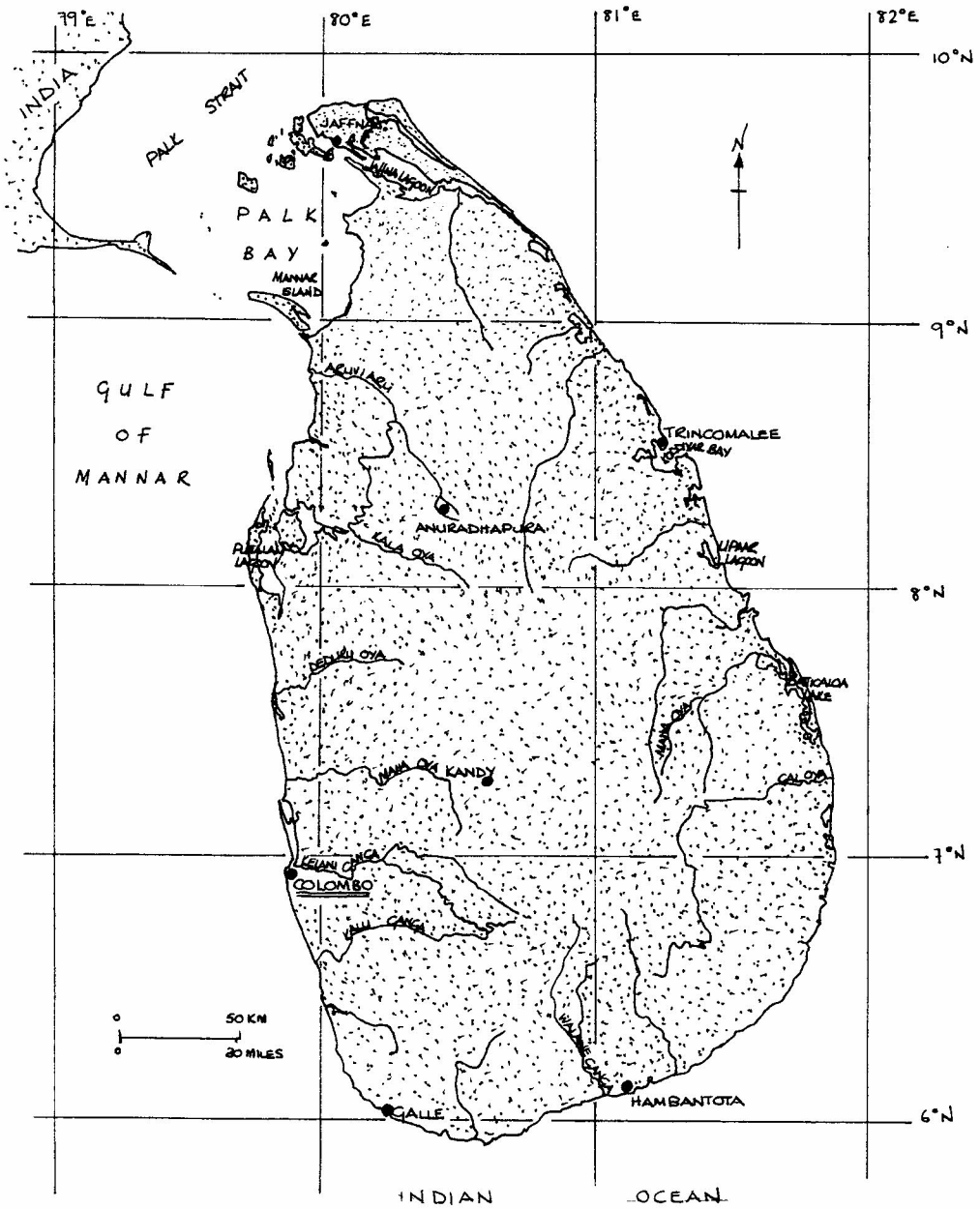
This publication was funded through the UK Overseas Development Organisation's Link Project between the University of Sri Jayewardenapura (USJ) and the University of Wales, Bangor.

The Participatory Training Course was organised and co-ordinated by Dr. D.M.S.H.K. Ranasinghe of USJ, with support from Dr. Sydney Banyard (Lecturer in Forestry, USJ), Dr. Visumperuma (Director, Sri Lanka Foundation Institute (SLFI)), Mr. J. Perera (SLFI), Mr. G. Wickramasinghe (Hector Kobbekaduwa Agriculture Research and Training Institute (HKARTI)), and Miss Raveeswary and other staff of the Forestry Unit, USJ.

Resource persons included: P.A. Huxley, D.M.S.H.K. Ranasinghe, W.L. Weerakoon, H.A.J. Gunathilake, M. de S. Liyanage, L. Nugawela, G. Wickremasinghe, P.B. Dharmasena, T.N. Jayatileka, and A. Palinawadana. Dr. Huxley's participation was funded through the Link Project which is administered by Fountain Renewable Resources Limited (FRR).

Thanks go to Jenny Huxley, who typed early drafts, and Jaquelien Chapman, who dealt with the layout editing and typed the camera ready copy; also to Joanne Wainwright and Dr. Jim Redhead for proof reading and suggesting changes to the text; and to all individuals who provided photographs for inclusion. All illustrations (including the cover) are by Jaquelien Chapman.

SRI LANKA


79°E
80°E
81°E
82°E
10°N
9°N
8°N
7°N
6°N
INDIA
PALK STRAIT
PALK BAY
JAFFNA
MANNAR ISLAND
GULF OF MANNAR
ACHUVELI
TRINCOMALEE
ANURADHAPURA
MAHA OWA
KANDY
COLOMBO
GALLE
HAMBANTOTA
50 KM
30 MILES
INDIAN OCEAN

SOME BASIC STATISTICS ON SRI LANKA

Land area:	65,610 km^2
Population:	17 million
Literacy:	85%
Major climatic zones:	Low and mid country wet zone ($27^{\circ}C$*; 2,500-5,000mm m.a.r.)
	Dry zone ($30^{\circ}C$*; 1,250-1,900mm m.a.r.)
	Low and mid country intermediate zone
	Montane wet zone ($13\text{-}16^{\circ}C$*; 2,500-5,000mm m.a.r.)
	Montane intermediate zone
	Arid zone ($32^{\circ}C$*; < 1,250mm m.a.r.)
Main economy:	Agriculture (25% GDP)
Major plantation crops:	Tea
	Rubber
	Coconut
	Minor export crops
	Forestry
Natural high canopy forest cover:	24% of the land area of the country
Forests/capita:	< 0.1 ha.
Main energy source:	Hydropower

* Mean annual temperatures
m.a.r. Mean annual rainfall

Welcoming Address

D. M. S. H. K. Ranasinghe

Aims and Objectives of the Course

In the broadest sense, the term 'agroforestry' encompasses any form of landuse that includes both trees and agricultural production on the same piece of land. Agroforestry is a traditional, indigenous form of landuse practised by many farmers in the Asia-Pacific region and there are several reasons why in recent years it has emerged as an appropriate way of using land.

One reason is the deteriorating land:man ratio in the Asia-Pacific region and the potential that various agroforestry practices have to increase productivity. The region contains 69% of the world's agricultural population, but only 28% of the world's agricultural land. Consequently, the *per capita* availability of agricultural land in the region is only 0.27 ha. as compared to 1.64 ha. in the rest of the world. In many countries of the region, the arable land 'frontier' has already been reached and means of meeting the needs of increasing populations must be found.

Another reason for the emergence of agroforestry is the improved levels of sustainability that it can confer. As population pressure intensifies, people in lowland areas often migrate to nearby uplands and practice rainfed cropping. Consequently, around two million hectares of land are deforested annually in the region and about 50,000 ha. per annum in Sri Lanka. About 75% of this deforested area is used for agriculture, resulting in many cases of spontaneous, unplanned settlements. With the destruction of forests and the depletion of the thin mantle of fertile top soil, these lands are quickly rendered unproductive. The high ecological and social costs of land degradation have therefore become a major concern of governments in the region and this has led to a renewed focus on landuse systems such as agroforestry.

In general we are here to consider the agroforestry practices currently being practised or tested in Sri Lanka and we need to evaluate agroforestry as a suitable approach to using our land. We also need to discuss and explore the assumptions about productivity and sustainability often made for agroforestry, using the range of experience and knowledge that participants bring with them.

Specifically, the aims and objectives of this three-day Participatory Course are to encourage the senior level agroforestry practitioners and researchers who have been brought together here, to raise issues and exchange views on how best to select and adopt agroforestry approaches that will satisfy Sri Lanka's future needs. During the course, while bearing in mind the underlying biological and functional aspects, due attention needs to be given to the social and economic considerations.

Finally, we need to explore what supportive actions are needed and suggest how best they may be implemented. For example, are there appropriate information exchange mechanisms for agroforestry in Sri Lanka? Do we need to increase our educational and training facilities for the next generation of agroforesters? And so on. To help with such deliberations there will be five Working Groups, to be guided by experienced participants, that are to focus on particular sets of issues.

Resource Persons

There are many participants here with considerable knowledge and experience of agroforestry. The following are some of the resource persons whose expertise is available:

- Dr. Lionel Weerakoon is at present a consultant to the SCOR Project of the International Irrigation Management Institute (IIMI) and he has worked in the Agricultural Research Station of the Ministry of Agriculture at Mahailluppallama as a Senior Research Officer. He has been responsible for the introduction of the concept of 'Conservation Farming' to Sri Lanka.

- Dr. Jayantha Gunathilake, a Research Officer at the Coconut Research Institute, has many years of experience to his credit in performing many intercropping trials with multipurpose trees under coconut.

- Mr. P. B. Dharmasena who is the Head of the Water Management Division of the Agricultural Research station of the Ministry of Agriculture at Mahailluppallama will discuss agroforestry in relation to watershed management.

- Dr. Tissa Jayatilleke, who will be dealing with animals in agroforestry, is presently working as a consultant in the Hector Kobbekaduwa Agriculture Research and Training Institute (HKARTI) and is a veterinary surgeon by profession.

- Mr. Gamini Wickremasinghe, who has been working as a Research and Training Officer in the HKARTI for more than 20 years, is a anthropologist by profession. He has a wealth of experience in dealing with people and communities in various agriculture based activities in the country.

- I am, myself, a Senior Lecturer in Forestry with special training in the fields of silviculture and agroforestry. I am responsible, as Course Co-ordinator, for the 2-year Forestry M.Sc. programme conducted by the Forestry Department of the University of Sri Jayewardenapura.

- Finally, Dr. Peter Huxley is known for his various responsibilities during his 13 years at ICRAF, Nairobi, Kenya, having held the posts there of Senior Research Scientist, Programme Co-ordinator of the Technology Programme, Director of the Research Development Division and Principal Research Advisor. Currently, Peter Huxley is a private consultant specialising in organising and running courses in agroforestry.

With these and other senior resource persons, together with many of you who bring to our forum a wealth of different levels of expertise and experience, we hope that the formal presentations, the activities of the Working Groups and, above all, the opportunities at such a meeting as this for informal exchange of views, will serve to enlighten and inform all of us, as individuals, of the progress and potentials of agroforestry for Sri Lanka.

Inaugural Address

P. A. Huxley

One of the characteristics of an 'Agroforester', to be found anywhere in the world, is a sense of enthusiasm for the subject. Even in countries such as Sri Lanka, where indigenous agroforestry practices have been part of the history of landuse from early times, a continuing eagerness to explore agroforestry opportunities is clearly apparent. All this has resulted, I believe, because we are experiencing a 'paradigm shift' in our approach to landuse. A switch from an emphasis on production, epitomised by high input sole cropping, to the ecologically wiser and less destructive forms of 'sustainable' farming that we now see to be essential if the natural resource base is to remain intact.

I say "less destructive" because many modern day proposals for so-called sustainable forms of agriculture still involve a decline in the resource base *in the long term*. Intensive agriculture and plantation forestry practices are all too often highly extractive and the achievement of sustainability will depend very much on the time scale that we set. However, forms of landuse such as the Kandy homegardens and spice gardens are renowned as examples of truly sustainable practices, although we must go cautiously because other forms of agroforestry, such as alley cropping, have yet to be fully explored in this respect.

So the popular image of agroforestry is that it is new (which we know it is not), complex and therefore interesting but, above all, that it holds promise in helping to solve some of our current landuse problems. For these reasons many wish to become involved in it, as our meeting here bears witness. Enthusiasm is not enough, however, unless the practices we recommend are soundly based on both practicality and good science.

When I first joined ICRAF, I was returning to a part of Africa in which I had lived and worked previously as an agricultural scientist; but I saw the landscape with new eyes. Much of it seemed to be filled with trees and shrubs the names of which were unknown to me. Farmers obviously used trees in their systems in all kinds of ways that I was unaware of. As a newly-fledged 'agroforester' I was asked "Am I using the right species of tree?", "How many

trees do I need?", "How do I best arrange and manage them to obtain the outputs I want?". There were no scientific answers to such questions at that time, only guesses! This situation has rapidly changed, but not fast enough to satisfy the urgent need that now exists to answer, as completely as we would wish, the host of queries that have come flooding in from the field. Above all, we must not forget that agroforestry is just part of a whole spectrum of sensible ways to use land. Whether or not it is the practice of choice should be objectively evaluated in technical terms and remain, finally, the farmer's preference. To carry this out effectively involves having a sufficient level of understanding of the bio-physical and socio-economic factors involved. Some of these issues we shall raise in this Participatory Course.

Some forms of agroforestry involve the simultaneous intercropping of woody and non-woody plant components; that is they occupy the same piece of land at the same time. However, there can still be many factors that regulate how they compete with one another and, clearly, we have to understand what these are. Such landuse systems may be less apparently protective of the natural resource base than those in which trees and agricultural crops are grown separately on the same land in some sequential or rotational practice because, in the latter, the beneficial effects of growing trees or shrubs during the 'fallow' stage is so often very apparent. Indeed, at first sight it may seem curious that we expect a partial cover of woody plants (such as hedgerows spaced 5 m apart in alley cropping) to achieve a level of continuous, sustained production when the presence of trees and bushes in the form of a fallow may be needed for 10 to 12 times or more the length of the subsequent cropping period. Obviously, again we need to be quite clear about the factors that are operating, and have some basis for judging what the outcome will be under any particular set of circumstances.

We know from many examples that trees may enrich the site on which they grow, and we feel, intuitively, that 'trees are good!'. However this does not mean that they are beneficial under all circumstances, nor that all species will contribute equally to land improvement. What about the time-scales? Many examples of site enrichment by trees can be considered to have occurred in what I call 'ecological time', which has to be measured in appropriate units (say, 25-years?). However, in providing food and other resources for people we need to

think in terms of 'agricultural time', or in units of five years or less. Certainly, the processes by which trees can improve soil are well known, but they need to be more fully explored, and their practicality measured, in agroforestry situations. We need to remember that many agroforestry systems function in a sustainable way because of the levels of biomass they produce, but the emphasis on 'fast-growing' trees to produce this biomass in the form of usable products plus litter, to protect and enrich the soil for example, may be misplaced, as we shall discuss later.

What we are finding is that the scientific understanding of agroforestry practices has fallen far behind the levels of indigenous knowledge about how to manage such systems; this indigenous knowledge being especially rich in countries such as Sri Lanka. In her paper Dr. Ranasinghe has pointed out the pressures we now face from growing human populations, together with their domesticated animals, and how this means that basically sound landuse practices such as shifting cultivation (chena) cannot be carried out as they were. Thus changes are required in old practices, and we should grasp the opportunities to introduce new ones.

There are two pathways through which these changes can come about. First, there can be progress through intuitively-formed steps in which farmers and experienced advisors draw up a 'picture' of new, improved systems. In doing this we must take into account the need to balance productivity and sustainability, and to work within the constraints that limit the farmer's ability to install and manage such systems. We shall hear examples of these initiatives in the talks to be given later on the Sloping Agricultural Lands Technology (SALT) and on 'Analog' Forests. Second, by understanding more about the ways in which agroforestry systems function, we can design and manage them better. That is we must investigate how the woody and non-woody components interact, and how these plant components interact with the soil. Another key issue is to be able to define the biological characteristics of the plant components that we need to use, particularly the 'multipurpose trees', because only then can we select them appropriately and undertake their genetic improvement along sound lines. In the first instance, this means understanding the ways they grow, flower and fruit, and how they can be encouraged to do what we want from them *as part of a multiple cropping system.*

Clearly, we need to progress along both pathways which, in practice, are mutually supportive, but neither will serve us if we do not take into account the economic realities within which farmers operate, or the intricate social pressures which regulate the decisions which they and their families take. Nor can we ignore the impact of large-scale policy initiatives and directives, the legal structures within which tree growers operate and those aspects of tenure and family security that form a basis for successful landuse of any kind. Like any other tree growing enterprise, agroforestry systems involve long term investment and often higher levels of skill with regard to management. It is, indeed, the essential multi-disciplinary nature of agroforestry research that makes it such a stimulating field to be involved in.

In conclusion: the history of landuse in Sri Lanka provides fine examples of the development of productive, sustainable and well-adapted forms of agroforestry. The concerns now being expressed in this country about maintaining successful indigenous agroforestry practices in their present form, and the growing initiatives to introduce new forms of agroforestry and/or to introduce agroforestry to new areas, are particularly relevant in the wider context of tropical agroforestry in general. However, we must not treat agroforestry as a 'panacea for all ills', and we should not recommend its practice without an adequate knowledge of the behaviour of the systems we are promoting. Let us avoid the danger here that enthusiasm out-runs knowledge! In today's world we must find the right balance between productivity and sustainability. Can agroforestry help us achieve this goal? What can be learned from the agroforestry practices of the past to help design new ones for the future? Certainly, Sri Lanka has much to contribute towards the advance of knowledge and the implementation of agroforestry practices. Thus, this meeting is both timely and necessary and it is a pleasure to be invited to join you in your deliberations.

1. Agroforestry in Sri Lanka: An Overview

D. M. S. H. K. Ranasinghe

INTRODUCTION

Sri Lanka is a tropical island with a total land area of 65,610 km^2. Rainfall is well distributed in the Wet Zone in the south and west of the country, ranging from 1,900 to 5,000 mm $year^{-1}$. In the lowland Dry Zone rainfall is below 1,900 mm $year^{-1}$. Population is 17.5 million, projected to be 21.9 million in the year 2001 AD. In 1981 45.2% of the population was employed in agriculture, fisheries or forestry.

Large areas of the country are covered by natural forests, man-made forests, scattered non-forest trees, tea, rubber and coconut plantations and well-stocked traditional homegardens; especially in the west, central and south low to mid-elevations. These homegardens comprise fruit, fuelwood, timber, fodder, shade and ornamental trees. In most of these homegardens, rubber and coconut plantations the canopy cover is dense, with a canopy closure of over 75% . The country depends predominantly on agriculture, including paddy and perennial crops such as tea, rubber and coconut. These three major agricultural tree crops cover 228,000 ha., 206,000 ha. and 419,000 ha. respectively, or 13% of the land area; paddy covers 990,000 ha. Taking forests and all other forms of tree associations into account, more than 66% of the country is estimated to be under tree cover (Sri Lanka Forestry Sector Master Plan, 1995).

There is an age-old agroforestry tradition in Sri Lanka and numerous examples of agroforestry practices are to be found in all climatic zones of the country. The most important of these are outlined below (and see 'Issues in Agroforestry', this volume). There is a bewildering array of species of both trees and crops cultivated in these systems; homegardens alone cover an area of 616,000 ha. in the south-west part of the country. Although high canopied natural forest covers about 24% of the country, around 50% of the country's demand for timber and 80% of the requirements for biomass fuel are met from

non-forest resources. Today, our traditional agroforestry knowledge is being developed and practised with the objectives of further enhancing the living standards of rural people in Sri Lanka and improving environmental conditions so as to increase the country's vegetative cover and relieve pressure on the natural forests (Sri Lanka Forestry Sector Master Plan, 1995).

AGROFORESTRY PRACTICES IN SRI LANKA

Chena or Shifting Cultivation

Chena cultivation is an age-old form of tree-crop practice where crops and forest of one kind or another alternate sequentially in time, with the main objective of growing agricultural crops. All kinds of subsistence and cash crops are cultivated in these chenas. Economically, this was a simple form of self-sustained subsistence farming with virtually no external inputs. It was sustainable as long as there was a reasonable fallow period of at least 15 years (Nanayakkara, 1987). However, with the increase of the rural population, and the lessening extent of forest lands, the fallow period has been shortened, resulting in a loss of soil fertility and soil structure and, finally, land degradation. As a result of uncontrolled chena cultivation, extensive areas of natural forest in the Dry Zone are now totally degraded.

From the end of the last century to about 20 years ago, chena cultivation was widespread and regularised by the issue of cultivation permits by District Government Agents. However, with settled agriculture taking its place, and also due to the initiation of huge hydropower/irrigation and settlement projects (*e.g.*, Mahaweli), the area of chena cultivation has diminished and, in 1981, the issue of permits was officially terminated. Today, there are only some sporadic, illegal chenas in the more remote Dry Zone natural forest areas (Mellink *et al.*, 1991)

Co-operative Reforestation by Taungya

This form of agroforestry is based on the 100-year old taungya practice developed in Burma to raise teak *(Tectona grandis)* plantations. Modified in

Sri Lanka it was called the 'Co-operative Reforestation Scheme', essentially a state intervention institutionalised in the country's Forest Department. It was a practice to convert degraded Dry Zone natural forest into mainly teak plantations with the additional objective of providing the chena cultivator with the opportunity of raising agricultural crops over a three-year period while he was also paid three monetary rewards by the Department. Individual lessees, especially in the Eastern Province, formed Co-operative Societies and participated in this reforestation scheme with good results. The teak was planted at a spacing of 3 x 3m after clearing and burning the debris. Almost all the best teak forests in the Dry and Intermediate Zone were raised under this scheme. The practice fell into disuse because agricultural crop production on the mostly marginal leased lands was not good enough to compete with increasingly intensive agriculture elsewhere and the incentives offered became insufficiently attractive (Ranasinghe and Newman, 1993).

Intercropping of Coconut

Coconut is the most widely planted agro-based industrial tree crop covering 25% (419,000 ha.) of the total cultivated area of Sri Lanka. About 55% of coconut lands are small-holdings, each of less than 4 ha. in size. Cultivation is mostly concentrated in the 'coconut triangle' in western Sri Lanka, comprising the districts Kurunegala, Puttalam, Gampaha and Colombo. A large number of crops are grown in association with coconuts in most coconut estates. Cattle grazing is also practised in some areas (Reynolds, 1989).

Under coconuts we find food crops such as tubers, cereals, legumes, fruits, spices and condiments such as arecanut, betel leaves, chillies, ginger and turmeric. Many are grown as cash crops, for example black pepper, cinnamon, clove, nutmeg and cocoa; pastures are common, also. The most preferred crop species are bananas, black pepper, coffee, ginger, turmeric, betel, vegetables (Fig. 1.1) and pineapple, and, in matured coconut plantations, coffee and banana or pineapple, pineapple and papaya, or banana mixed with coffee and cacao. The overall return from a unit of land can be increased by intercropping. Coconuts benefit from the manure and fertilisers given to the

crops, weeds are eliminated and soil-working helps both the palms and the crops (Liyanage *et al.*, 1984).



(Photo: D.M.S.H.K. Ranasinghe)

Fig. 1.1. *Amaranthus* spp. being grown as an understorey with other vegetable crops in among *Gliricidia sepium* and scattered coconuts.

There is a complex relationship between land ownership, supervision and intercropping in coconut cultivation in Sri Lanka. Of the intercropped holdings, 63% are cultivated and supervised by non-owners with non-resident labour because owners are also involved in cultivating other crops, for example paddy rice. This coconut-intercrop agroforestry practice has potential for widespread adoption, including coconut-growing areas outside the coconut triangle, and, through the help of government subsidies, the expansion of intercropped coconut lands is now around 1,000 ha. year^{-1}.

Tea, Coffee and Cocoa Under Shade Trees

Tea

Tea covers around 228,000 ha. and is mainly cultivated in the central hills, but it is also grown in the wet south-west lowlands. Land ownership is both private and state-owned. State-owned estates are either managed by the State Plantations Corporation or the Janatha Estate Development Board. A large number of leguminous and other shade trees are grown. Partial shade

increases tea yields in the long term and fuelwood and timber-producing shade trees can also provide other benefits. These can include nitrogen fixation, which enriches the soil in the case of legumes, microclimatic amelioration through the reduction of temperature and evapotranspiration, and shelter from wind. They may also help to control soil erosion whilst providing organic matter for mulch and the improvement of soil fertility.

Coffee

As coffee demands more shade than tea, shade trees are usually more densely-planted in coffee. Coffee is confined to some small estates in a few central districts, namely part of Matale and Kandy. The socio-economic benefits are similar to tea and, again, the land tenure system is both state and private. The shade tree most commonly used with coffee is *Gliricidia sepium* which casts a partial shade and is known to enhance soil fertility. Some species of *Albizia* and *Acacia* are also planted at relatively wide spacings.

Cocoa

Similar to tea and coffee, cocoa plantations are found in small estates or holdings, mainly privately-owned in the Matale, Kurunegala and Kandy Districts. The total area cultivated is around 8,000 ha. (Mellink *et al.*, 1991).

Fruit Trees and Crops in Rubber

This practice is found mainly in the Wet Zone and parts of the Intermediate Zone in the east. Rubber *(Hevea brasiliensis)* covers about 206,000 ha. The shade cast by rubber in the later stages of its rotation is intense and restricts intercropping. Therefore, only a few rubber plantation estates have adopted intercropping by planting fruit trees. In the Intermediate, and parts of the Wet Zones, cacao is underplanted where the rubber canopy is not too dense (Fig. 1.2) and, sometimes, tea (Fig. 1.3). Pineapple is grown under rubber in many Wet Zone areas.



(Photo: P.A. Huxley)

Fig. 1.2.
Intercropped rubber, cocoa and pepper. Pepper is a particularly high-value crop that does well intercropped in this way.

Palmyra Palm and Cashew Nut

The intercropping of palmyra palm and cashew nut is a practice found in the coastal areas of the Dry Zone and semi-arid areas in the northern and eastern coastal districts. The palmyra palm (*Borassus flabellifer*) is a multipurpose tree, with cashew as the main intercultivated crop. *Casuarina* species and margosa *(Azadirachta indica)* are cultivated as windbreaks and for fuel, medicinal use and timber in these plantations. Almost all land under this practice is privately owned. Cashew is a very valuable export crop, also fetching high prices in the local market. In some areas *Prosopis juliflora* is also interplanted for fuel or as a live fence. All these species; palmyra, cashew, *P. juliflora, Casuarina* spp. and *A. indica* perform well on coastal, marginal semi-arid lands.



(Photo: D.M.S.H.K. Ranasinghe)

Fig. 1.3.
Tea is sometimes intercropped with rubber when the rubber canopy is not too dense.

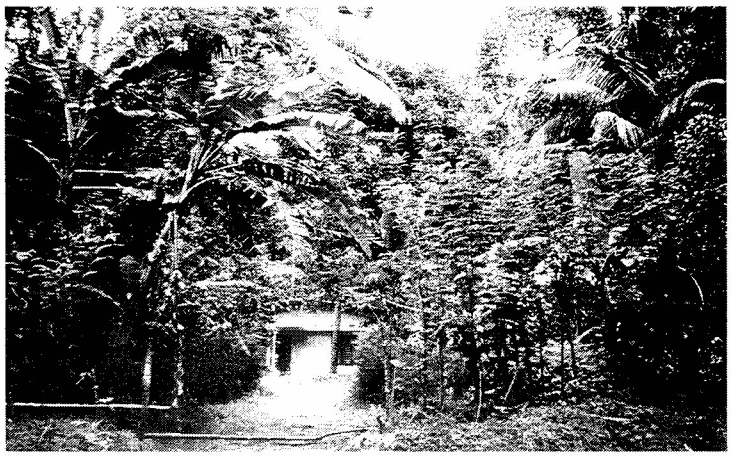
Homegardens

Kandyan Homegardens

This world-famous tree-crop practice is an ideal form of land use combining agriculture, forestry and livestock. Trees are grown in a multi-tiered arrangement (Fig. 1.4.), terraced where necessary and planted according to local topography and soil conditions. It is a traditional practice of mixed cropping of trees yielding timber, small wood, fuelwood, fodder, food, fruits, spices, nuts, medicines and other cash crops. The entire system provides an ideal healthy microclimate for both man and animals. As well as in Kandy District, it is frequently found in adjoining Matale and Kurunegala Districts.

The holdings are small, on average about 1 ha., and they are mostly privately owned. The gardens are generally owner-cultivated and the bigger the farm the less the density of plants. Operating costs are approximately

Rs.1,200 ha^{-1}. Economically the practice is quite profitable and, with better management it has the potential for continuous high levels of production and high returns. Among the many crops grown in these homegardens are jackfruit, durian, rambuttan, papaya, citrus, avocado, plantain, pineapple, passion fruit, mango, breadfruit, coffee, cacao, tea, black pepper, kitul, spices, yams and fodder grasses (Jacob, 1987).



(Photo: D.M.S.H.K. Ranasinghe)

Fig. 1.4. Part of a Kandy homegarden. Note the live fence of *Gliricidia sepium* and the multi-layered canopy.

Other Homestead Gardens

Less intensively-managed homegardens are found in most other districts of Sri Lanka, especially in the low country Wet Zone in the western and southern coastal belts, and in the low country Dry Zone. Except for cocoa and coffee, most of the Kandy homegarden species are grown in the low country Wet Zone, less intensively. In addition, fruit-bearing species like rambuttan and mangosteen can be found there.

Homestead gardens usually have fences of *Gliricidia sepium* (Fig. 1.5) and, in the Intermediate and Dry Zones, fences of kapok *(Bombax malabaricum)* are found. The canopy cover in these less intensively managed homegardens is not dense and ranges from about 25 to 75%. Cattle, goats and poultry are reared in these systems, especially goats in the Dry Zone.

Leucaena leucocephala is now grown profusely in homegardens in this zone, increasing soil fertility and providing food and fodder.



(Photo: D.M.S.H.K. Ranasinghe)

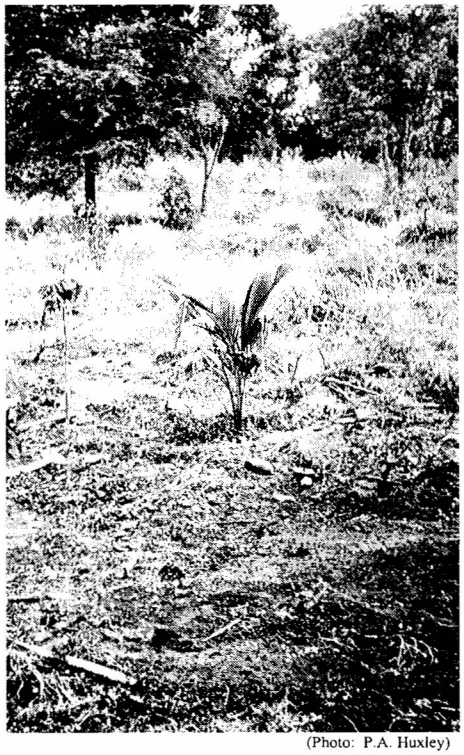
Fig. 1.5. Live fence of *Gliricidia sepium*. This is a common sight in the Intermediate and Wet Zones in Sri Lanka.

In some homestead gardens in the Dry Zone the planting of useful tree species is widespread (Figs. 1.6 and 1.7). The 'drumstick' tree *(Moringa oleifera)* is grown in fences or hedges as its crown is very light and the pods are a popular and very nutritive dish. Production starts within one year of planting and the bark of the tree is of medicinal value.

In some other systems, *Sesbania grandiflora* is planted. It is a short-lived tree of medium height, mostly planted in the Intermediate, Dry and Semi-Arid Zones. Local people use the tender leaves and flowers as vegetables. Production in this case is also within one year of planting. It is an important producer of green manure and fodder, especially in the dry season (Ranasinghe, 1991).

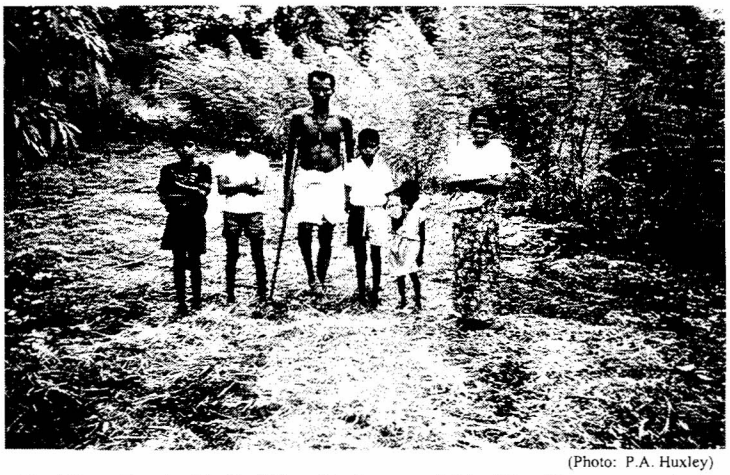
Silvopastoral Practices and Apiculture

These practices are found in the mid to high elevations in central Sri Lanka, and also in the 'coconut triangle' in the south-west. The practice is widespread in the hilly patanas or wet grasslands. Trees grown are mainly species of *Eucalyptus, Pinus*, and *Cupressus*.



(Photo: P.A. Huxley)

Fig. 1.6.
Recent spontaneous tree establishment around the homestead by the farmer in Fig. 1.7. Some 15 or so useful woody species had been planted.



(Photo: P.A. Huxley)

Fig. 1.7. Despite his disability, this farmer at Maha Illuppillama was actively trying agroforestry with the help of his family. Hedgerow intercropping ('alley cropping') with *Gliricidia sepium* was not favoured, however. One reason given was that the hedgerows obscured his view of marauding elephants before he could drive them off. He was keen on planting many tree species for different purposes in a more dispersed way near to his house.

Cattle are raised on coconut lands which are not intercropped to any large extent in the main coconut areas. However, some plantations that are intercropped, also raise cattle in paddocks (Reynolds, 1989). Especially in the mid mountain areas, there is a danger from fires created by herders who burn the dry grass just before the rains in order to get a new flush of grass for their cattle. Excellent examples of apiculture are found near the towns of Diyatalawa, Bandarawela and Welimada. Cattle grazing is practised and bee keeping is encouraged. The best honey has been found to come from *Eucalyptus robusta* flowers.

Silvo-Aquaculture

This practice is restricted to the mangrove forest areas along the coast. The country has around 12,000 ha. of mangrove forests which produce timber, fuelwood, bark, fish and shell-fish. Prawns are cultivated in some areas near Negombo, Colombo and Kalutara along the west coast. The mangroves provide the spawning grounds for prawns and other shell-fish and many types of fish. A mangrove park has also been established near Negombo to demonstrate the benefits of mangrove forest. The mangrove forests along the north-western and eastern coasts are also familiar breeding grounds for indigenous and migratory water birds. Mangrove fuelwood is used by villagers and small industries that make bricks and tiles. Mangrove bark is also produced and removed under controlled tenders on permits issued by the district authorities (Mellink *et al.*, 1991).

Medicinal Trees With Pasture

These are ancient systems located in the districts east of central Sri Lanka, and the best examples are found near the town of Bibile. The trees are scattered in typical savannah grasslands and are said to have been planted first in the days of the Sinhalese Kings; the lands are state-owned. Aralu *(Terminalia chebula)*, bulu *(Terminalia belerica)* and nelli *(Emblica officinalis)* are the principal tree species found. Cattle-grazing and goat-rearing are practised on the intervening grasslands. Fire hazard is a problem in the dry months of May

to August, but the trees can withstand ground fires. Wildlife move into these areas, including elephants from nearby National Parks, but no damage is done to the valuable medicinal trees (Mellink *et al.*, 1991).

Alley Cropping *(Avenue Cropping, Hedgerow Intercropping)*

In this practice, trees are grown in strips creating 'alleys' for raising agricultural crops; it has gained recognition in Sri Lanka as a sustainable form of land management.

Leguminous trees are widely used in the hedgerow strips so as to increase the organic nitrogen content of the soil in the alley. *Gliricidia sepium, Leucaena leucocephala*, *Calliandra calothyrsus* are widely used. The practice is low-capital but highly labour-intensive; maximum holdings are around 5 ha. An important aspect of alley cropping can be a considerable reduction of weed growth, especially when fast-growing trees are planted in rows about 2 m apart (Ranasinghe and Newman, 1993).

Conservation Farming

So-called 'Conservation Farming' is being practised mostly in the dry parts of Sri Lanka. It is reported to be a viable low-input, sustainable way of using land suitable for use in subsistence tropical farming (Weerakoon, 1987). It is designed to conserve soil resources and to promote the natural recycling of forest vegetation. This practice has several features:

- mixed cropping with a multi-storeyed canopy, which includes crops with different ages at maturity - this feature reduces soil erosion and weed problems as compared with pure crops;
- the use of crop-residue mulches to prevent raindrop impact and soil crusting, - these also improve soil temperature and moisture regimes as well as reducing weeds (Fig. 1.8);
- the use of live mulches of legumes, such as species of *Centrosema, Pueraria*, *Macroptilium, Psophocarpus* and *Mucuna*, which have an important role in maintaining fertility and minimising erosion;

- zero tillage (which implies that weeds probably need to be controlled by herbicides) with all dead organic matter left as a mulch on the soil surface, so helping to eliminate soil erosion; and
- alley cropping, i.e. hedgerows of *Leucaena* or *Gliricidia* interplanted with field crops.



(Photo: D.M.S.H.K. Ranasinghe)

Fig. 1.8.
Young limes mulched with leaves and dead stems of *Gliricidia sepium*. The production of plant residues for use as mulch and for increasing soil organic matter is a key feature of many agroforestry practices.

Community Forestry

Community Forestry programmes often have agroforestry components. The Sri Lankan Forest Department has undertaken a community forestry project, with the financial aid of the Asian Development Bank, in Badulla, Nuwara-Eliya, Kandy, Matale and Batticaloa Districts. It was designed to combat deforestation by involving the communities in the establishment, management and protection of tree crops. An immediate aim was to create an awareness of

the importance of homestead planting and tree planting on roadsides and around governmental buildings including schools. The benefits expected included beautification, soil conservation, dust control, noise control and shelter from wind. Tree planting on farms was also undertaken for windbreaks, green manure, fodder, fuelwood, timber, fruit, minor export crops, watershed protection and soil conservation. Under this project, the Forest Department has established part of the projected 1,200 ha. of farmers' woodlots (0.5 - 1 ha.). The woodlots have been leased out on a 25 year agreement to selected farmers who are supplied, free of charge, with seedlings, fertiliser, tools and technical know-how by the Forest Department.

A recent major initiative in Sri Lanka funded as a participatory forestry project by the Asian Development Bank (for US$ 25 million), incorporates a very strong forestry extension programme. It is planned to develop about 15,000 ha. of land under its participatory component while strengthening the extension capabilities of the Forest Department. The participatory component of this project is divided into four sub-components: homestead gardens, farmers' woodlots, protective woodlots and miscellaneous plantings.

- Under the *Homestead Garden* component, it is planned to plant 9,000 ha. of homegardens with the participation of about 45,000 low income households which have land titles or leaseholds. Participants are given free planting materials of their choice as the starter package, together with the right to harvest. They are also encouraged to adopt soil conservation measures and participants are supplied with *Gliricidia sepium* cuttings and vetiver grass *(Vetiveria zizanioides).*

- Under the *Farmers' Woodlots* component, it is planned to plant trees on the blocks of government land which will be given to the farmers on long lease agreements. It is targeted to have 6,000 participants on 4,000 ha. of land. Land will be identified and quantified and the access will be given to selected participants during the project implementation period. As an incentive, the participants are provided with food aid to

compensate for the time spent in establishing the woodlots, in addition to the provision of free planting materials and the right to harvest and sell trees and their produce.

- The *Protective Woodlot* component is being operated on steep, state-owned lands that are not suitable for agriculture due to their vulnerability to erosion. These areas will be planted to establish a permanent tree cover with the participation of various rural societies, non-governmental organisations and interested individual households. It is expected to plant 1,500 ha. with the participation of 1,500 families who are willing to work 200 days per year for the establishment as well as maintenance of plants. The participating societies/ organisations are being provided with free planting materials and food aid for the people involved in order to compensate them for the time spent on planting and after-care practices. However, the lands will not be alienated under this activity.

- *Miscellaneous planting* involves tree planting in various places, i.e. roadsides, railways, canal reservations, coastal planting and tree planting in schools, temples and other public places. It is expected to plant along 250 km. of category A and B roads, and 450 km. of C, D and E roads, 100 ha. of railway settlements and 150 ha. of railway protective lands annually. A further 50 km. area of irrigation canal reservations will also be planted under this project. Lands along the coastline will be planted up with species like *Casuarina* which can provide shade and shelter from wind. In addition, the Australian International Development and Assistance Bureau has granted food aid to those participate in Farmers' Woodlots, Protective Woodlots and Miscellaneous Planting programmes.

Apart from the activities listed above, forestry awareness programmes have been developed for schools and technical assistance provided to start up

school nurseries by the Extension Division of the Forest Department. Linked to the School Agroforestry Programme is another innovative programme to establish Village Forest Societies (VFS) in the districts and these have started up their own agroforestry plots on state lands simulating, again, the homegarden practice. They are provided with technical assistance and incentives by the Extension Branch of the Forest Department.

Janasaviya Agroforestry

This state intervention in agroforestry commenced in 1990. Up to 0.4 ha. of land presently not utilised is given to the poor under the Government's 'Janasaviya' ('People's Strength') Programme on a long term basis. Any kind of crops plus trees can be cultivated and plants are supplied free by the Forest Department and Agricultural Departments. It is an island-wide project administered by the district authorities. At least 100 persons in each Assistant Government Agent's Division will benefit from this programme. These beneficiaries are 'food stamp' holders, or persons who are provided with a certain quantity of food by the government free of charge because of their low income level (Punyalal, 1994).

Sloping Agricultural Land Technology (SALT)

This practice has been introduced to Sri Lanka from the Philippines. It is now increasingly being undertaken on degraded land and in abandoned tea, coffee or cacao in mid elevations of the hilly north-eastern part of the Central Province. Hedgerows along contour lines alternate with crops, and trees are planted on the crests of hills. Continuous mulching with pruned biomass from the hedgerows improves soil conditions and reduces evaporation from the soil surface. Added fertiliser benefits the hedges, crops and the trees. This practice is widely used in degraded low hills in Walapane, Central Province (see also 'Sloping Agricultural Land Technology (SALT), this volume).

CONCLUSIONS

Agroforestry systems amount to the 'remarriage' of trees and agricultural crops, and where they are newly introduced they are a brave step in the right direction. They are potentially sustainable land management practices that aim at increasing productivity and reducing dependence on monocropping. However, emphasis needs to be placed on the socio-cultural dimensions of agroforestry development in order to make our understanding more complete. Some of the constraints experienced by farmers in expanding intercropping practices include lack of funds, price instability, lack of knowledge of intercropping management techniques and difficulties over the timely availability of inputs. Research, under controlled conditions, is best directed at investigating and improving practices that are already in use, rather than in trying to transfer new technologies.

Research in agroforestry is a complex task, and there are relatively few scientists available who have the necessary multidisciplinary approach. Agroforestry is not a panacea, but a *tool.* If it is used carefully it can help solve many of the landuse problems that are being faced in many countries. There are numerous traditional practices in Sri Lanka that have been in use for a very long time and newer improvements based on scientific knowledge are still in an experimental stage. If we increase our efforts Sri Lanka can make a significant contribution to the development of both the science and the practice of agroforestry.

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2. Agroforestry: Needs and Expectations

P. A. Huxley

WHY BOTHER WITH AGROFORESTRY?

Botanists believe that there are more than 350,000 plant species in the world, of which around 3,000 supply the human population with food. Perhaps some 300 or so are cultivated, i.e. used widely or more locally in some form of agriculture. But much of the world lives mainly on about 30 species and of these, only *eight* assume a major strategic role in global food security!

Such statements need to be treated cautiously, however, especially when the key word is 'global'! The factors that can control the provision of food and other agricultural products (fibres, fuel, materials for shelter and construction, etc.) involve some very different levels of scale, ranging from international down to the family unit, or even the individual. As well, we have to consider a whole range of commodities that may, or may not, play a part in international trade, but are vital regionally or at the village or household levels. Although estimates of the production of the major cereals (rice, wheat, maize) are certainly indications of incipient famines or sufficiency's at the grand scale, many people in rural populations commonly supplement their major intake of cereals with the many other food sources that they may have access to, especially in hard times. We often need to be concerned with production and self-sufficiency at the *local* level, therefore.

World Population and Food Consumption Trends†

The present world population is some 5.7 billion, and recently revised estimates suggest that there will be about 8.5 billion by the year 2025. That is, there are going to be 2.8 billion more mouths to feed in 30 years time; 83% of these will be in Low Income Countries (LICs), and perhaps more than two

† Data have been obtained from the following sources: Oram, 1993; Mackenzie, 1994; McCalla, 1994; Pinstrup-Andersen, 1994.

thirds of the human population will be living in cities even by the year 2000! After 2025 the rate of increase of the world population is thought to slow so that by 2050 the estimate for the world's population is around 10 billion or so.

What are the predictions about providing food for this inevitable increase in world population? The picture in the past has been one of some considerable success. The yields of the main cereal grains have been increased by roughly 2% per annum overall, and food energy per capita in the LICs has increased by 0.7% per annum since the 1980s. In North Europe and North America, so much food has been accumulated that there is a policy to 'set aside' agricultural lands in order to decrease surpluses but there are still, nevertheless, an estimated 25 LICs (half in Africa) that are, for one reason or another, unable to assure their own food sufficiency. Moreover, although opinions differ, it seems unlikely that increases in yields due to plant breeding, crop protection, and the use of irrigation and fertilisers will be maintained in the future as they have in the past. For technical reasons there is much less chance of raising production levels with grain legumes and root and tuber crops than with cereals.

An individual needs something of the order of 200 kilograms of cereal grain (or its equivalent[†]) a year for a minimum calorie intake and, just at present, there would seem to be more than enough food on a global basis to go round. In fact, if we divided all the food available in the world amongst the current population there would be 300 kg. of food grain per person per annum. Of course, figures like this by no means show the total picture. As we know well, overall, there can be a world sufficiency of food, but in many places people may be too poor, disadvantaged or ill-provided for to produce or purchase even the minimum they require. Estimates suggest that there are currently some 1.1 billion people affected by poverty and some 700 million people who, because of this, have insufficient access to the food they need. Thus the causes of famines are both population increases and inequities, so that Malthus and Marx were both right!

Food consumption can be greatly affected by urbanisation of populations and also, where people do become affluent, meat consumption

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† Ignoring the need for proper protein:calorie ration and all the necessary vitamins and minerals that constitute an adequate diet.

rises very fast, so that land may have to be used to grow animal feed grains. If we add to this scenario the fact that something of the order of 7 million ha. are lost permanently to erosion each year (0.5% of the world's farmlands), then we have added yet another concern.

How Can Agricultural Food Production Be Increased?

For the future, *as long as world food production can increase at around 2% year^{-1}*, even by the year 2025, with an estimated population of 8.5 billion people, there would still be 247 kg. *capita^{-1}* per year available on a global basis; and in 2050 some 244 kg. *capita^{-1}*. But, as now, local availability will remain a major problem unless self-sufficiency is encouraged.

Currently, therefore, the arguments rage less around what the world's population will be but more about the supply side, and what actual increase in annual food production is likely. That is, whether or not the past rate can be maintained, and what will be the situation in particular regions. Some are more optimistic than others, but the consensus suggests that there are doubts as to our ability to keep up the past rate of increase in food production; for the internationally-traded commodities, that is. So what are the ways in which the production of food of any kind can be increased? And what part can agroforestry have to play in this?

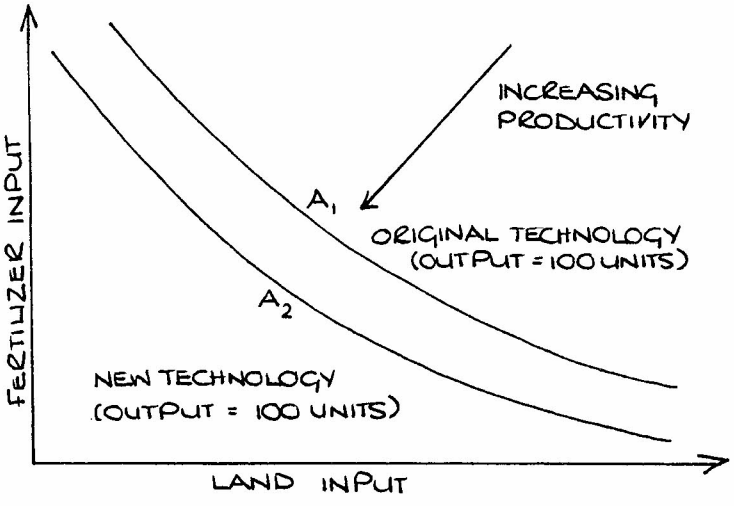
Increases in agricultural production can be brought about in a number of ways. For example, by:

- expanding the net area under production;
- increasing the cropping intensity on existing areas (Fig. 2.1);
- reducing yield variability;
- increasing productivity (output per unit input) (Fig. 2.2);
- utilising environmental resources (light, water, nutrients) more fully and/or more efficiently;
- combating environmental degradation, and so preventing a declining cropping capacity; and by
- reducing losses to crops (e.g., by pest and disease control, a reduction of storage losses, etc.).



(Photo: P.A. Huxley)

Fig. 2.1. Hedgerow intercropping with *Gliricidia sepium* and maize (in Zambia). Such practices are expected to be more productive and more sustainable than low-input, sole cropping in the tropics. But whether they are or not will depend on how well they are designed and managed. It will also depend on the characteristics of the woody component(s) and how compatible these are with crop species, and on what level of biomass is extracted from the system.



(Source: after Wylie *et al.*, 1993)

Fig. 2.2. A two factor productivity diagram (representing the much more complicated total factor situation) showing how equal output can be obtained by substituting one factor for another (just fertiliser inputs for land area in this case) as one moves *along* an isobar line; or how the system can be raised to a new level of efficiency (e.g., by introducing new technology such as agroforestry). The latter moves the isobar line *nearer to the axes* (i.e. A_1 to A_2), illustrating the use of less inputs to produce the same output.

Moving into under-utilised land areas, as well as increasing productivity through the use of improved genotypes combined with inputs such as irrigation and fertilisers that help them to achieve their potential, has been the foundation for past increases in world food production. However, there is now very little scope for expanding agricultural cropping into new areas, and even the major national and international agricultural research centres are cautious about maintaining the past levels of gain in cereal production. Any increase in the use of pesticides brings with it a new awareness of the environmental issues involved. The installation of major capital-intensive irrigation schemes is unlikely to continue at the same pace, and many existing schemes have problems arising from sedimentation, salinity and/or weed infestations. The rate of increase in world fertiliser use is actually declining (Oram, 1993). If our rapidly disappearing forests are to be protected[†], and fragile marginal lands kept from further decline, the consensus is that agriculture has also to find other ways to increase production.

WHAT CAN WE EXPECT FROM AGROFORESTRY?

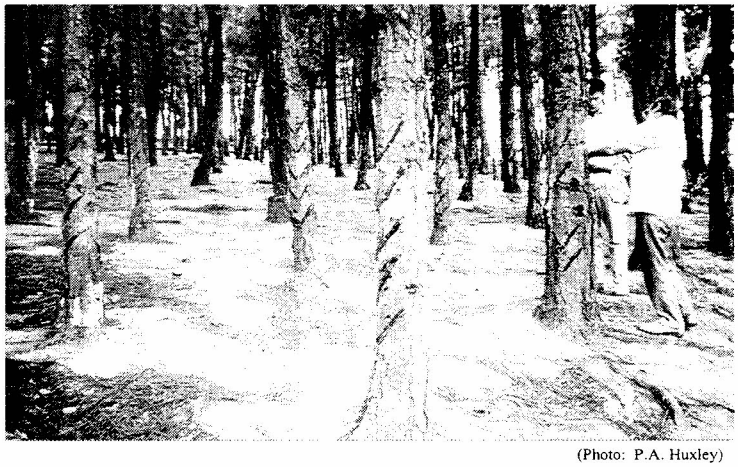
Interestingly, if we look at the list above we find that agroforestry *can*, potentially, help to increase production through all except the last[‡]. Furthermore, there are many marginal or degraded areas that are not suitable for agriculture at all, but in which there may be a possibility for an appropriate form of agroforestry. Agroforestry by its very nature increases the cropping intensity, and can reduce the variability of overall yields. It may do so, as we shall discuss later, by increasing productivity through the better use of environmental resources (light, water, nutrients). Depending on what species are grown agroforestry practices are able to provide a *range* of foods and other products; homegardens, boundary plantings and enriched fallows are good examples. Such landuse practices (Appendix 2.1) can, therefore, contribute to

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† Over all countries, and for the period 1981-1990, FAO estimated that deforestation has occurred at some 0.9% per annum (0.4% for the Caribbean to 1.8% for Central America and Mexico). Compare this with an overall estimated figure for the period 1976-1980 of 0.6% (FAO, 1992).

‡ Even here, there are possibilities that mixtures of woody and non-woody plants may, in some circumstances, afford better levels of pest management than those commonly found in monocrops (Altieri and Liebman, 1986; Altieri *et al.*, 1987).

some extent to a better level of food security, especially on a local scale. Certainly the combined use of trees and crops, if undertaken wisely, can prevent run-off and help utilise more of the incoming rain, and it may also combat environmental degradation by preventing soil loss (see 'The Salt Technology, this volume). Trees alone may not always achieve this, however (Fig. 2.3).



(Photo: P.A. Huxley)

Fig. 2.3. These *Pinus carribaea* are being tapped for resin. This extracts relatively little from the system but, at this site in Sri Lanka however, lack of ground cover on a steep slope is eroding the soil severely and the trees, alone, are not sufficient to prevent this.

It is these ' expectancies' that need to be thoroughly investigated and given substance. There are many hopes and hypotheses about what agroforestry *might* do, some of which are, as yet, unproved. Certainly, we are now in a position to evaluate the possibilities and constraints, and we know what has to be done in order to prove or disprove earlier, perhaps somewhat over-enthusiastic, claims!

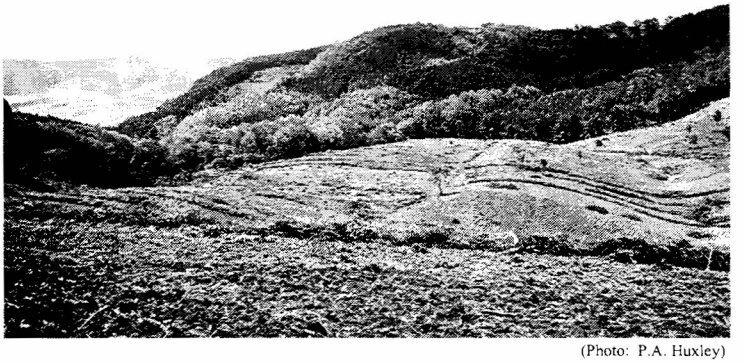
CONCLUSIONS

In whatever ways we use land it looks as if the main opportunities for maintaining or increasing the rate of food production throughout particular regions will have to be mainly through the use of *improved technologies*. This can be achieved in two ways:

- a continuation of the improvement of genotypes, pest and disease control, irrigation and the use of fertilisers; and
- the better utilisation of environmental resources through the design and management of improved landuse practices.

Both of these are addressed in conventional agricultural research but, clearly, it is in this latter mode that agroforestry may be able to provide a significant contribution. However, there are two issues that we need to bear in mind:

- increasing production per unit area and *exporting it* in the form of non-returnable harvests can lead to non-sustainability if the output from the land exceeds that which the natural resource base can reasonably support (Fig. 2.4.), unless additional inputs are supplied; and



(Photo: P.A. Huxley)

Fig. 2.4. Land under afforestation in Machakos, Kenya (background), and after felling, has been sown to a maize crop (foreground). Note that all the woody debris has been removed for firewood. Expectations about the soil-improving potential of trees and other woody plants will be moderated by the amount of biomass removed from the system, and this is true for agroforestry also.

- for technological change to improve productivity (output per unit input) in a significant way the *basis* of production has to be lifted to a higher level of productivity. This cannot be achieved just by substitution (see Fig. 2.2.).

In short, because exporting *any* kind of plant material from the land is an extractive process, even in agroforestry, we must be careful about the levels of production and export from any system, i.e., see how best to strike a balance between yield output and total biomass production, and try to judge how this might affect sustainability (see 'Agroforestry and Sustainability' in this volume). At the same time we need to see whether we can use available environmental resources better and therefore increase productivity because, in this way, more biomass can be formed with the same environmental resources (see 'Agroforestry: Some Functional Aspects' in this volume).

Thus, as well as all the social and economic aspects that have to be satisfied, there is a need to understand how agroforestry systems are utilising environmental resources, and precisely what the environmental impacts of different agroforestry practices will be. These are issues that will be addressed in later contributions.

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Appendix 2.1. Agroforestry Practices

TREES WITH CROPS (AGRISILVICULTURE)

Rotated in time (*sequential practices*):

- Shifting cultivation (sometimes with enrichment of the woody components)
- Improved tree fallow
- Taungya (i.e. cropping during the establishment phase of commercial forest tree plantations)

Spatially mixed (*simultaneous practices*):

- Trees on cropped land
- Multiple use of trees in crop plantations
- Mixed multi-storey tree and crop arrangements (e.g., tropical homegardens)

Spatially zoned (*simultaneous practices*):

- Hedgerow intercropping ('alley cropping')
- Contour hedging or barrier planting and other types of linear tree plantings
- Boundary planting for various products, or live fencing
- Strip planting in forests or timber plantations ('corridor farming')
- Windbreaks, tree-enrichment widestrips, shelterbelts and wild animal habitat plantings

Appendix 2.1. (contd)

TREES WITH GRASS AND ANIMALS (SILVOPASTORAL)

SIMULTANEOUS SYSTEMS

Spatially mixed

Trees planted on rangelands, in permanent pastures and grass-legume leys for leaf and/or pod fodder (sometimes for edible flowers, additionally)

Tree-crop plantations with pastures

Spatially zoned

Alley farming (sometimes with 'energy' gardens of shrubs and grass mixtures)

Live fences

Boundary planting, mainly for fodder

MANAGED TREE PLOTS

Fodder banks using woody species

Fuelwood lots

Mixed orchards (especially if several products, e.g., fruit and honey)

OTHER COMBINATIONS

Agrisilvopastoral (crops, pastures, trees and animals)

Trees can also be grown, or nurtured, to provide products from insects such as bees (honey), lac insects (shellac varnish), silkworms (silk), and so on

Fish farming also sometimes utilises leafy tree fodder

3. Issues in Agroforestry Development in Sri Lanka

W. L. Weerakoon

INTRODUCING THE ISSUES

There is considerable interest in agroforestry in Sri Lanka, but also numerous concerns about how best to develop it. The various issues are dealt with individually below but, overall, the initiatives required concern a wide variety of reforestation/tree-planting activities that must be facilitated through the removal of barriers and the provision of appropriate incentives and technical support. Only then will the right conditions for the rapid expansion of agroforestry emerge.

In particular, we need to consider carefully the various roles that trees may have when grown outside Forest Department lands, for example, when established, privately, on state-owned lands not under the control of the Forest Department (Fig. 3.1). Evidence indicates that most of Sri Lanka's firewood and timber comes from such areas. In addition, they provide non-timber products from trees such as food, fruit, fodder, medicinal and ornamental products, and so on. So what kind of trees/shrubs are best suited for these purposes? Is production in this way sustainable in the long run? In particular, can agroforestry practices provide more sustainable forms of landuse than existing chena ('slash-and-burn') agriculture†? Should such activities receive more attention from the Forest Department and other supportive institutions than they are getting at present? What are the constraints on the development of this sector?

Although such broad questions easily spring to mind there are others, more specific, that demand attention. I would like to suggest that we need, first, to find answers to the following:

† For chena see Figs. 3.2. to 3.7. throughout this contribution

- *Landuse considerations.* What lands are available for agroforestry? Can agroforestry complement 'normal' agricultural cropping, livestock production and forestry? Will agroforestry utilise land and labour which, at present is divided among these activities, more efficiently? Can appropriate agroforestry practices restore degraded lands in mid-country and the Dry Zone, and also benefit watershed management, without causing any deleterious affects?



(Photo: P.A. Huxley)

Fig. 3.1. Typical montane forest in the Wet Zone between Kandola and Nuwara Eliya (partly disturbed, main species *Calophyllum walkeri*). Evidence indicates that much of Sri Lanka's firewood and timber comes from the areas *outside* Forest Department lands!

- *The role of rural populations.* The precise role of rural populations in controlling the lands presently owned by the Forest Department needs to be established. What rights do they have to the land, or to the produce from it? Should the present forms of forest management be replaced by agroforestry in which control is devolved to people and other institutions rather than be monopolised by the State? Can rural communities obtain land tenure that is 'bankable' and/or secure private ownership of the land together with the privileges and obligations of ownership?

- *Profitability.* The economic profitability of agroforestry under various situations and in comparison with other landuses has yet to

be established. When this has been done precisely what development techniques should be used to promote economically successful agroforestry practices?

- *Policy and legislation.* If tree growing is to be encouraged legislative reforms will be needed, and additional policy changes will be required to support agroforestry initiatives if these are to flourish. How can we best remove, for example, legal disincentives, and what positive policy incentives and/or other policy decisions will be needed to provide the conditions that will promote and nurture efficient agroforestry practices?

- *The institutional framework of forestry.* As a central 'player' we should ask, "What role does the Forest Department have, or should have, for tree-growing enterprises on lands outside those it presently controls?". Is there a role for the Forest Department extension service, or would an integration of these extension services with those of the Departments of Agriculture and Livestock best suit Sri Lanka's needs? Is there a requirement to institutionalise agroforestry research separately, or is it adequately covered by existing Departments? What role should NGOs and other state institutions have in agroforestry development?

These are not questions that can be easily answered at present, but they need to be the subject of detailed consideration and debate. With such questions in mind it is useful to consider, briefly, some examples of the current state of tree-growing and agroforestry in Sri Lanka.

The Present Situation

The Sri Lankan Forest Department, as well as other institutions, has been involved in a number of initiatives aimed at raising the well-being of rural people. The following are examples, with comments:

Taungya or Co-operative Reforestation[†]

This was essentially a State intervention which was institutionalised in the Department of Forestry. It aimed to convert degraded Dry Zone natural forest into tree plantations (mainly teak), with the additional objective of providing the chena farmer with the opportunity of raising agricultural crops over a three year period. For this he was paid by the Department. Plots of 2.3 ha. were given out on three year permits.

The main species planted under this reforestation scheme were teak *(Tectona grandis)*, but plantations of some other species were also raised in this way. For example, *Eucalyptus camaldulensis*, *E. tereticornis*, *Artocarpus heterophyllus* (Jak), *Swietenia macrophylla*, *Dendrocalamus strictus*, *Azadirachta indica*, *Filicium decipiens*, *Vitex pinnata*, *Alstonia macrophylla*, and *Berrya cordifolia*. At the end of 1978 there were 65,154 ha. of teak plantations raised under taungya and, up to 1978, 12,551 ha. of *E. camaldulensis* and 1,116 ha. of *D. strictus* have been planted in the Dry Zone. Jak and mahogany are restricted to the Intermediate Zone. The cultivators grew practically every kind of crop. In 1978/79, of the total area of 4,157 ha. planted with teak and eucalyptus in the Dry Zone, 3,876 ha. were interplanted with food crops (Nanayakkara, 1993).

Most of the cultivators lived in the villages and not on the taungya land, where only temporary shelters were constructed. The farmers were not interested in maintaining the quality of the land or tree crops because of insecurity of land tenure, and the community development aspect received little consideration. Taungya has been criticised as a labour exploitative system as it capitalises on the poor farmer's need for food and his/her willingness to offer labour for plantation establishment and profit.

A basic problem is that this system divests local peoples of their rights to continue to make a living from the trees they have helped to raise. Also, these tree species did not satisfy the requirements of the villager for food, fodder, fruit, etc. As in other parts of the world, this system of raising forest plantations has not been found to stimulate full community participation.

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† See 'Agroforestry in Sri Lanka: An Overview', this volume.

Intercropping Under Coconut

This agroforestry practice has evolved over time and it is being promoted by the Coconut Research Institute of Sri Lanka. Coconut is cultivated in about 25% (419,200 ha.) of the total cultivated area of Sri Lanka. Fifty-five percent of the coconut lands are smallholdings, each of less than 4 ha. in size (Liyanage *et al.*, 1989).

The three planting practices recommended for sole stands of coconuts in Sri Lanka are 'square' (7.9 x 7.9 m), 'rectangular' (8.5 x 7.3 m) and 'triangular' (at 8.5 m, equilateral). Each of these represents a planting density of about 160 palms $ha.^{-1}$

The pattern of utilisation of soil resources and solar energy in monocrop coconut stands suggests that these can conveniently be intercropped when they are either young (up to about 8 years after planting), or fully-grown and bearing (25 years from planting). Thus, some 70 - 80% of coconut plantations in Sri Lanka could be intercropped. Why are they not? Interestingly, the reason lies in the rather complex relationship between land ownership, owner cultivation/supervision and intercropping in these smallholdings.

The majority of coconuts in the country are, indeed, not cultivated, or even supervised, by their owners. Furthermore, the majority of coconut farmers are also engaged in cultivating paddy rice and other crops. Smallholders who cultivate their own land seldom practise intercropping because most of their time is utilised in growing rice. There are also other problems that are faced by farmers intent on expanding their intercropping activities: drought, lack of funds, price instability, lack of technical 'know-how', problems of timely availability of labour, and availability of planting materials.

Notwithstanding, the practice of intercropping under coconuts has great potential for expansion in Sri Lanka. In principle, this is a sustainable system provided that the necessary inputs (e.g., fertilisers) are available in the right quantity and at the proper times, and the system is managed appropriately. At present, intercropping practices are being extended, due to several Government subsidy schemes.

Examples of intercrops under coconut are:

- coffee/banana;
- banana mixed with either ginger/turmeric or pineapple;
- pineapple/papaya;
- banana mixed with coffee/cocoa; and
- cocoa/coffee.

Coconut trees also contribute significantly to the small-timber requirements of the country.

Shade/Shelter/Windbreaks

The planting of shade trees has long been associated with tea and coffee in Sri Lanka. A large number of leguminous and other shade trees have been grown in this way. Although no quantitative data exist, shade trees play a substantial role in supplying wood; especially fuelwood from the tea plantations. The Forest Department has advocated the planting of 10% of the tea lands with fuelwood to meet all the energy needs of the estates, including the energy for tea production and for the domestic needs of tea estate workers. Old stands of shade trees are uprooted prior to replanting and, in addition to shade trees, mixed stands of *Grevillea robusta* and *Hakea saligna* are planted to shelter tea from winds.

Usually the shade trees are planted as a mixed stand of high and medium shade. The recommended shade tree species for different tea areas are as follows:

A.	Up-country - over 1200 m	
	High shade	*Grevillea robusta*
	Medium shade	*Calliandra calothyrsus*
		Erythrina lithosperma
		Acacia pruinosa
		A. decurrens
B.	Mid-country Wet Zone - 600-1200 m	
	High shade	*Grevillea robusta*
		Albizia moluccana
	Medium shade	*Calliandra calothyrsus*
		Gliricidia sepium

C.	Mid-country Semi-Dry Zone 600-1800 m		
	High shade	*Grevillea robusta*	
		Albizia moluccana	
	Medium shade	*Acacia pruinosa*	
		Acacia decurrens	
		Calliandra calothyrsus	
		Erythrina lithosperma	
		Gliricidia sepium	
D.	Low-country below 600 m		
	High Shade	*Grevillea robusta*	
		Albizia moluccana	
	Medium shade	*Calliandra calothyrsus*	
		Gliricidia sepium	

Hedgerow Intercropping

Alley cropping

Alley cropping has been indicated as an appropriate agroforestry technology for smallholder farmers throughout the ecologically marginal areas of Sri Lanka. Research was first done in the Dry Zone under the Department of Agriculture. Although positive results were obtained under controlled conditions, the transfer of the technology to farmers has not been very successful as yet. There could be some merit in integrating this technology, with necessary adjustments depending on the requirement of the crop and the farmer, to Dry Zone rainfed upland farming. The Shared Control of Natural Resources (SCOR) Project, facilitated by the International Irrigation Management Institute (IIMI), has undertaken this task, and there are plans to introduce alley cropping, with farmer participation, to the Huruluwewa Watershed with the view of stabilising upland farming as an alternative to wasteful chena cultivation. Nitrogen fixing plants will be grown in alleys with a distance of 5 m between hedges. Macro earth bunds 20 m apart will further reduce soil erosion.

Sloping Agricultural Land Technology (SALT)

Since 1988 the Mahaweli Authority of Sri Lanka has been working jointly with GTZ, the German Agency for Technical Co-operation, to establish this innovative practice† on the steep slopes of the upper catchment of the Mahaweli river. Soil erosion is a serious problem in this area, not only in

† Introduced from the Philippines.

terms of sustainability of upland agriculture, but also because of the threat from sediment to the longevity of Sri Lanka's principal hydroelectric and irrigation reservoirs which are on this river.

The particular form of hedgerow intercropping followed in this area is a package ('SALT') based on a framework of barrier hedges formed by planting a nitrogen-fixing woody species such as *Gliricidia sepium*, *Calliandra calothyrsus*, *Flemingia congesta*, and *Desmodium rensoni* along the contours at close-spaced intervals. *Senna (Cassia) spectabilis* is also used. The systems are characterised by a sequence of two alleys of seasonal crops and one alley of perennial crops, repeated up the slope. There are other variations where, for example, for a system including livestock, a block of alleys is used for fodder production. At present approximately 5,000 ha. of lands are under SALT in Upper Mahaweli. The Ceylon Tobacco Company (CTC) has promoted this technology extensively in the Mutare Intermediate Zone†.

The success of both these projects depends on their relative profitability compared with alternatives. Alley cropping practices and SALT may have no direct benefit for crop production, and improvements in soil conservation are not easily measurable in the short term. Any benefits have to be quickly apparent to the farmer. So far the practice to promote SALT has been by way of payments. This is done in two instalments as stated below, and once the hedges are properly established:

- at the rate of Rs. 4.50 m^{-1} of well established hedge (a minimum length of 350 m has to be in place to receive this payment); and
- a second payment of Rs. 2.50 m^{-1} once a year after establishment, if the hedges are well maintained.

It is estimated by the Tea Research Institute that the expenditure on the establishment of SALT, in planting tea, and in new clearings are Rs. 13,840, Rs. 16,800 and Rs. 10,240, respectively. In addition, the expenditure on maintenance of hedgerows is another Rs. 4,000 $ha.^{-1}$ $year^{-1}$.

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† See 'The Sloping Agricultural Land Technology', this volume.



(Photo: D. Perera)

Fig. 3.2. Burned land prior to cultivation at the onset of the rains. Land is cleared in July when residues can dry, and burning takes place in August.

The NADSA Model

It has been estimated that some 76,082 ha. of land in mid-country, formerly marginal tea and degraded shrub lands, are available for development. Since there is much social and political pressure for access to lands for settlement, the National Agricultural Diversification and Settlement Authority (NADSA, Hadabima) has undertaken a programme with the objective of land rehabilitation through soil conservation and drainage, and the planting of forests or grass.

This 'model' package is, at present, more widely used in other parts of the country, for example in Central, Sabaragamuwa and Uva Provinces, where the total area amounts to some 1,100,000 ha. It is estimated that the total cost of settlement is Rs. 1,971 $ha.^{-1}$. Payment is in the form of dry rations, per unit (ha.) of land for completion of the appropriate development process, as in Table 3.1.

Resolving The Issues

The Need For Agroforestry and the Availability of Land

All countries are concerned with protecting and improving their supply of

wood products. Sri Lanka's Forestry Sector Master Plan (FSMP), prepared during 1983-1986 recommended the adoption of comprehensive management and development of the forest and non-forest wood resources by establishing farmers' woodlots on 36,000 ha. and increasing tree planting on 205,500 ha. of new area, including homestead gardens, lands with mixed trees and other crop lands. The FSMP also noted the important contribution of non-forest resources to the supply of fuelwood for energy and timber for industry. Although it was recognised that the total supply of wood from existing resources was generally in balance with demand at that time, a serious shortage of industrial wood was expected to occur in 1990, followed by a shortage of fuelwood in 1995. It was proposed to plant 151,000 ha. over the 15-year period 1986-2000, or an annual plantation target of about 10,000 ha. $year^{-1}$.

Table 3.1. Payments made under NASDA

	Cost $acre^{-1}$ (Rs.)	Cost $ha.^{-1}$ (Rs.)
Stone bunds		
flour	2,586	6,387
dhal	862	2,129
sugar	276	682
Total	**3,724**	**9,198**
Earth bunds		
flour	899	2,221
dhal	300	741
sugar	96	237
Total	**1,295**	**3,199**
Live bunds		
flour	494	1,220
dhal	165	409
sugar	52	128
Total	**712**	**1,756**

Homegardens: Supplying Food and Wood

Fortunately, in Sri Lanka, a major contribution to wood supply is made by the homegardens which are found throughout the island. Estimates claim 26% of all fuelwood, and 39% of timber needs are produced in homegardens. Homegardens in the Kandyan area form some 4.1% of the national tree cover compared with 24.9% cover by forests. The homegardens found in Kandy, Kurunegala, and Matale Districts have been well-studied. They are dominated by five species: jackfruit, coconut, mango, areca nut and breadfruit. Very

similar forms of homegardens are found in other parts of the Wet Zone, both in hill country and lowland areas. In the low country, homegardens contain various fruit trees including rambuttan and mangosteen. Depending on the availability of moisture, the crops grown in homegardens in the Dry Zone are different for example coconut, mango, banana, jack, papaya, orange and guava are amongst the most common species found. Indigenous tree species including halmilla *(Berrya cordifolia)*, satinwood *(Chloroxylon swietenia)*, teak *(Tectona grandis)*, tamarind *(Tamarindus indicus)* and margosa *(Azadirachta indica)*, form substantial private planting on farmlands. *Gliricidia sepium*, *Leucaena leucocephala*, *Thespesia populnea* and *Euphorbia* spp. are commonly planted along homestead boundaries as live fences.

One of the results of widespread interest in homegardens, and the population increase in Sri Lanka, is that the total area under trees in Sri Lanka is actually expanding because the area under homegardens, of one form or another, is increasing. The results of the landuse studies for the FSMP showed that the area under homegardens has been increasing by about 3% annually since the 1980s and, in 1992, there were some 918,300 ha. planted.

Deforestation is, however, still a serious problem in Sri Lanka, having an adverse impact on forest cover and biodiversity. Here, again, homegardens have become a veritable store-house of the Nation's plant genetic resources. Dharmasena (1993) has reported on the tree and crop species in the Dry Zone, and Jacob and Alles (1989) on the Wet Zone homegardens.

The development of a homegarden over time is usually *ad hoc*, and fashioned to the needs of the farmer and the family. The trees grown are often 'multipurpose', providing the rural community with various subsistence needs, i.e., food, fruit, medicinal products and fodder, in addition to wood. Farm activity in terms of harvesting, consumption and the receipt of family income, is relatively well distributed throughout the year.

Sri Lanka's increasing wood demand could be met, or at least strongly supplemented, by enhancing the utilisation of existing homegarden agroforestry systems, and intensifying landuse in order to expand the various forms of homegarden. However, the availability of suitable lands for homegardens and other agroforestry practices is a major issue. The

Community Forestry Project (CFP), a most ambitious attempt at social forestry which ran for 8 years from 1982, demonstrated that most land selected for farmers' woodlots was degraded, offering only limited possibilities for agroforestry and other forms of intercropping. Today most of the State lands available for agroforestry are found in the Dry Zone and are marginal.



(Photo: D. Perera)

Fig. 3.3.
Generally, maize, mustard, sesame and vegetables are grown in cleared and burned over land. Isolated trees such as *Vitex altissima*, *Grewia damine*, *Syzygium cumini* and *Bridelia retusa* are left standing but seldom kept weeded

Recently published landuse information about Sri Lanka has largely been based on aerial photography and remote sensing data carried out in 1982. These have shown that the area that is under-utilised and/or partially or completely degraded through soil erosion or burning etc., is about one million hectares. Most of these lands are located in the Dry Zone. Under the Presidential Task Force on Land Utilisation and Distribution, 400,000 ha. have been identified for distribution to 500,000 families for the purposes of agriculture, housing and industry, and some 110,000 ha. have been alienated to landless farmers (January, 1994). Since these lands are designated mainly for

the purpose of settled farming they will eventually be converted to homestead farms. Clearly, there is a need to improve the productivity of these degraded rainfed lands as quickly as possible. To do this it is necessary to adopt appropriate soil and water conservation measures and diversify crops to include tree species and perennials, as we see in homegarden agroforestry. This will also increase cropping intensities. NADSA and SALT programmes follow such landuse practices and can help stabilise rainfed farming.

It is estimated that some 121,000 farm families are settled in Mahaweli systems (including Upper Mahaweli). Although the size of the holdings are quite small (about 0.3 ha.) the potential for developing these lands as 'homegarden' homesteads to satisfy the needs for subsistence foods and wood is very high. This potential needs to be explored in future programmes. Homegardens could also be established on deforested State lands, as well as on agricultural lands where shifting cultivation is practised at present, provided they can compete economically with crop production or other agricultural enterprises.



(Photo: D. Perera)

Fig. 3.4. Women harvesting sesame in her shifting cultivation (*chena*) land.

The Participatory Forestry Project in Sri Lanka, currently in progress, provides Government lands to farmers on long term leases for the purpose of tree growing in the form of farmers' woodlots. This is another project which has additional scope to expand even further agroforestry practices such as

homegardens and taungya. The selection of trees would then be broadened to cover the whole range of farmers' needs in addition to wood production, and those that could be used with appropriate soil and water conservation measures (for example species such as *Gliricidia sepium* grown together with pavatta or sunflower to help stabilise the hedge). Annual cropping is permitted in these State lands until the tree canopy cover is formed so that the farmer can secure a short-term cash income.

The Shared Control of Natural Resources (SCOR) Project encourages the rural community to grow trees along the Yan Oya river bank reservation following the multistrata agroforestry model. Twenty metre strips on each side can be set aside for this purpose, as set out by the State, and this mechanism for establishing permanent reservations will protect the river bank and also supply agroforestry products to the community.

The existing homegardens in the Dry Zone are not fully occupied by trees. The main limitation is inadequate rainfall and lack of irrigation facilities to raise perennial tree crops. Surveys carried out have shown that the presence of a water source makes a significant impact on the floristic composition of the homegarden. Also the ratio between endemic and introduced species depends upon the availability of water. Endemic species, often suitable for fuelwood, flourish even under harsh soil conditions, while introduced species do better where more moisture and a more favourable microclimate are available. The situation could be improved by adopting soil and water conservation measures and water harvesting (e.g., techniques such as 'eyebrow' terracing and 'pitcher pot' irrigation). Mulching, green manuring and/or composting could also be practised.

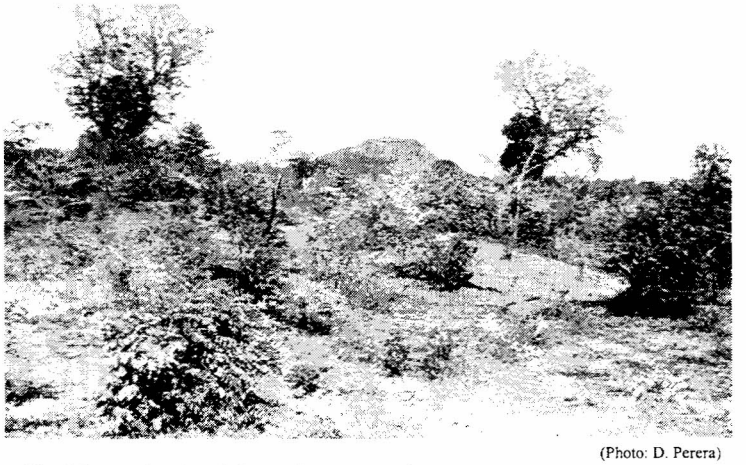
These examples show that there is, undoubtedly, both the opportunity, as well as considerable promise, in expanding the homegarden concept, an agroforestry practice in which Sri Lanka already has substantial experience.

Land and Tree Tenure

Land and tree tenure issues constantly constrain tree planting in Sri Lanka. Thus long-term conventional soil and water conservation, or improvement of degraded lands through tree growing, is made difficult. Farmers with insecure

tenure to land or to the trees they plant or farm, may be unwilling to participate in the adoption of agroforestry. The land tenure problem has become evident as 82% of the land is owned by the State and only 18% by the private sector. Complex systems of land tenure result in considerable delay in the allocation of lands.

A prerequisite for any agroforestry development scheme is not only the provision of security to farmers in respect of land tenure, but also the rights to agroforestry products. These aspects require special attention in agroforestry development initiatives that are specifically directed at erosion control and land rehabilitation, such as the SALT and NADSA Project, or alley cropping, because most degraded sites are characterised by a lack of secure access to land and/or its products.



(Photo: D. Perera)

Fig. 3.5. Abandoned chena after one month.

There are various programmes that exist for land distribution based on the Land Development Ordinance Schemes. Various lease arrangements ranging from one-year-renewable to long-term (i.e., 30 years) time periods may be given out on crown lands. Specific agroforestry lease arrangements need to be worked out by the Forest Department. Such arrangements would then have to be approved by the Land Commissioner's Department and the Attorney General. Certainly, proper and timely land lease arrangements are essential ingredients for the success of any agroforestry programme. In

addition, the conditions related to renewal of the leases and tenure rights of trees should be clearly stated. The failure of taungya has been attributed to the fact that there were no rights or benefits from those trees planted by the farmer. Taungya may still have a future as an agroforestry practice in the Dry and Intermediate Zones, but only if the tree tenure policies can be changed and there is a guaranteed market for the tree produce.

As yet, no general considerations seem to have been developed as to how these tenurial systems for providing security to land and tree products can be formulated so as to promote agroforestry development. It should also be noted that under the Forest Ordinance all newly established forest plantations automatically belong to the category of 'Forest Reserves', i.e., they are to be managed by the Forest Department. This is also the case if such forest tree plantations are intercropped with agricultural or minor export crops. The Forest Ordinance distinguishes four types of forests: 'Forest Reserves', 'Proposed Forest Reserves', 'Other Crown Forest', and 'Village Forests'. Forest Reserves are strictly protected by law and, under no circumstances, are individuals allowed to harvest products in them. In the others, the Forest Department can issue permits to individuals for collection of minor forest products. Some liberalisation is needed here so as to encourage individuals to expand agroforestry programmes.

The Legal, Supportive Policy and Institutional Frameworks

Much has still to be done in Sri Lanka with respect to forestry policy, legislation and institutional support, so that farmers will be encouraged to adopt agroforestry practices. The constraints on the development of agroforestry and private tree planting centres around three factors; legal restrictions on the transport of timber products, uncertainty about the legal status of land, and the promulgation of supportive policies.

The Forest Ordinance enacted in 1908, and amended many times thereafter, lays down the power governing the use of forests and transportation of forest produce. However, the regulations concerning the cutting and transporting of timber from private lands discourages private planting. This impedes the establishment of agroforestry because of the restrictive provisions

on wood harvesting and trade, and on the choice of tree species to plant. Thus, the appropriate legislation needs to be changed if the rural population can benefit fully from agroforestry development and play a full role in contributing to wood production from private lands.



(Photo: D Perera)

Fig. 3.6. One year-old secondary forest after shifting cultivation

A range of Government agencies are already engaged in various aspects of agroforestry development. Most of these now fall under the Ministry of Agriculture, Lands and Forestry. Of the institutes and relevant supportive projects, the Integrated Rural Development Project (IRDP), NADSA, the Land Use Policy Planning Division (LUPPD), the USAID-funded IIMI-SCOR Project, the ADB-funded Perennial Crop Diversification Project and quite a number of non-Governmental organisations (NGOs) are involved in promoting and supporting tree crops and wood production. However, there is insufficient co-ordination of such developments, and there is a need for an overall strategy for agroforestry activities among the agencies and the Forest Department. Indeed, lack of such co-ordination has, in the past, led to conflicts between different agencies, and also the duplication of effort. The present situation is most likely to be complicated by the establishment of Provincial Councils which will probably be shared with direct responsibilities for land development programmes, for example. Against this background it is necessary to provide a sound basis for discussion with the Government of Sri

Lanka on ways and means to enhance co-ordination and provide an appropriate institutional framework for implementation at the national, regional and community levels.

In addition, agroforestry initiatives need to be incorporated into National Land Use Planning on a district and agro-ecological zone basis and established with a firm scientific foundation. The Land Use Policy Planning Division is in charge of formulating an overall policy on rational landuse and the conservation of land resources. In addition to the preparation of several regional landuse plans, this division is at present setting up District Land Use Planning Committees, which will oversee the preparation of indicative landuse plans at district level. Land suitability maps are being prepared that include, among others, areas suitable for general tree-crops and agroforestry cultivation (8-16% slope), for more intensively managed tree crops and agroforestry cultivation (16-30% slopes), and for forest plantations (30 to 60% slopes). Once this work is completed a firm starting point will be available for planning and localisation of agroforestry programmes, as well as the intensification of soil conservation activities at a national level.

Other interventions can have a stimulatory role in agroforestry development, as mentioned earlier with the taungya, NADSA, SALT, intercropping under coconut, and the integrated Rural Institutional Homegarden Schemes. For example, co-ordination of line agencies implementing agroforestry could help establish a proper policy in deciding subsidies. In addition, long-term credit and banking facilities should be made available to agroforestry programmes. The co-ordination of relevant support systems such as the supply of seeds and planting materials, technical assistance and marketing facilities for agroforestry products such as fruits, medicines, etc., have to be explored.

Extension Services: What Kind and How Organised?

The Extension Services of the Forest Department were established in 1982 with the formulation of a National Forestry Extension Programme. In the beginning, the main activity of this service was to produce departmental nurseries, and the plants needed for forestry activities. Tree seedlings

produced were distributed free-of-charge to the public, state institutions, schools and other Government and non-Governmental organisations. During this early period there were no forestry staff involved exclusively in these activities, which were carried out by the territorial staff in addition to their normal forest protection duties. Compared to the Department of Agriculture, the Forest Department Extension Service is still in its infancy relying, as it does, on an existing structure of Range and Beat Forest Officers. The research support for forest extension is weak and there is no formal feed-back mechanism from farmers to carry their problems to the service. The opinion now is that the Forest Extension Service has not yet documented suitable and complete packages (farm models) to extend to farmers. This has become a serious problem in promoting agroforestry programmes.

However, unlike forestry extension, in agroforestry we require information and advice from a wide range of disciplines, but it will best reach the farmer or contact group through a single unified agency. Forestry, horticulture, and the cultivation of coconut, rubber, food crops, export crops and the provision of fodder for small ruminants and other animals must all be catered for, and in my view, within a truly unified extension service. As yet, such a service is hard to find anywhere in the world. Agroforestry is clearly not the narrow discipline it is currently interpreted as in Sri Lanka. What is now required is a 'whole farm' approach for rural development of crops, animals and trees and shrubs that provide a whole range of products and services.

Looking to agriculture, the Department of Agriculture makes available a wealth of information to indicate the potential for growing each one of commonly grown annuals and perennial tree crops in each agro-ecological region. For this purpose five lists of crops have been made: lowland crops, upland rotation crops, semi-rotation crops, plantation and orchard crops, pasture and paddy crops. The Second Agricultural Extension Project (SAEP) of the Department of Agriculture has been established recently to evolve a system to replace the Training and Visit (T & V) extension system, introduced in 1979. In essence SAEP could be described as a group technique supported by mass media, where the extension efforts of the four agencies, namely the Departments of Agriculture, Animal Health and Production and the Coconut

Cultivation Board are focused to formulate and implement an integrated agricultural extension work plan through active farmer participation. This would support a variety of in-service training efforts for extension staff making full use of the Department of Agriculture's national institutes, regional training institutes, as well as the training institutes of the participating agencies, using a modular training approach developed by the agencies.

Thus, the question now arises as to whether or not there really should be a Forest Department Extension Service to promote agroforestry practices? Considering the general shortage of resources in the Forest Department, and the lack of knowledge in agroforestry practices and of agricultural and horticultural crops, a strong argument can be made that the continuation of an extension service is an unnecessary cost to the Forest Department. The present thrust to promote agroforestry, and the progress being made by rural communities and private tree growers to shift to agroforestry models rather than practise monoculture forestry, suggests that it would be advisable for the extension functions presently carried out by the Forest Department Extension Service to be integrated into the SAEP. The investment on extension could then be shared by all the participating implementing agencies. An additional requirement is that all participating organisations and agencies should, perhaps, be provided with some basic training and, certainly, with regular updates about the technical progress of agroforestry in Sri Lanka.

The system of extension to be followed by the unified extension service is such that the field extension programme content must be based on farmers' needs rather than on a top-down approach, but any field extension programme has to be supplemented by a mass-media component. Extension is the on-going process of getting useful information to people (communication-dissemination), and then assisting those people to acquire the necessary knowledge, together with the skills (and attitudes?) to utilise this knowledge effectively (the educational dimension). Mass media methods such as radio, newspapers, magazines, television, motion pictures, slide shows, exhibits and printed educational promotional materials on agroforestry with other agricultural extension messages are useful to reach large numbers of people quickly. The justification for the use of mass media in agricultural extension in Sri Lanka is that (a) the majority of farmers speak either sinhala or tamil;

(b) media availability is wide (there are many radios and TVs in rural areas); and (c) the literacy rate is over 85%. This all results in an ability to reach a large number of farmers quickly. A by-product of the use of mass media in unified extension initiatives would be that the non-farming community, for example, policy makers and bureaucrats, would also learn what was being done in the field of agroforestry.

Seed production and the supply of planting materials to the rural community is a critical aspect. This activity is best shared by both the Department of Agriculture and the Forest Department. To achieve this we need to establish seed centres, seed processing and storage facilities, and a vegetative propagation unit. This would ensure timely availability and adequate quantities of seed and planting material of superior quality according to agro-ecological region based on sound scientific information and farmers' preferences. In addition, there should be a centre to preserve wild and indigenous varieties grown in traditional homegardens in Sri Lanka for any future crop improvement programmes. Farmers should also be given the necessary 'know-how' and support to establish their own nurseries in villages. Village nursery operators must be given proper training by the unified extension service to raise species such as teak, mahogany, bamboo, rattan and non-forest species. Where specialised skills, such as budding and grafting, need to be mobilised, contracts could be arranged with private nurseries.

The Role of Local People in Agroforestry Development

The Forestry Department has been involved in a number of people-based rural forestry programmes, as we have seen. Co-operative forestry, or taungya, has been used as a means to allow the farmer to grow agricultural crops between rows of newly-planted trees. The ADB-funded Community Forestry Project ran from 1982 to 1990 focusing on two initiatives: Community Forestry and Private Woodlots. Both achieved only poor acceptance for two main reasons:

- the rural community was not convinced about the benefits accruing to the participants; and

- no surplus labour was available in rural areas for planting and tree maintenance because of the heavy labour demand of agricultural activities.

These constraints are not uncommon in such projects, of which a number have already been mentioned.

The community participation in tree planting cannot be separated from other activities in the village; it has to be a part of the village development and not an isolated activity. There should be some prospects for individual activities. Farmers need to be given the choice to grow trees on their land provided these are useful (i.e., for fruits, timber and fuelwood), and that planting materials are available. They may prefer to have their own woodlots on an individual basis, rather than as community woodlots. External support can be extended to the community, but the benefits need to accrue to individuals. Indeed, tree planting on private land, particularly homegardens, is currently taking place on a large scale without any line agency involvement.

Then, how best do we overcome the lack of security of land and tree tenure mentioned earlier? Currently, land remains the property of the State and restrictions are imposed on landholding and landuse, but any change of policy in this respect must ensure that local people play a major role in agroforestry development. Experience all over the world has shown that forestry is often a failure in countries where the State entirely owns the forest resources, but it is quite successful in countries where some form of private ownership of forests is allowed. This does not mean that landusers involved in tree planting should be given land on a private ownership basis, but there should be some *sense* of ownership such as long-term leases i.e. for a period of at least 25 years.

Access to loans or other similar financial support for tree planting and maintenance activities is another important issue. It may determine how readily any practice will be adopted by a farmer. And this will also be influenced, not only by potential profits, and how soon they come, but by the market infrastructure for the produce and the institutional support by way of extension services and subsidies. In agroforestry systems the time period for tree harvests is long and, in the early stages, some way of giving food aid may

need to be considered. Some agroforestry practices, such as homegardens, are socially very acceptable, and they are considered to be economically viable; hence they may be adopted readily.

Although the Forest Department is attempting a major effort at what, in broad terms, can be called 'Social Forestry' (see Appendix 3.1), it can be difficult for a Department which is primarily concerned with the management and protection of natural and plantation forests to engage in more participatory forms of forestry. It is here that NGOs will be valuable instruments in mass communication, community-organising and the monitoring of programme implementation, but this will need financial support including, perhaps, some State financing. A study conducted in relation to the revision of the Forestry Sector Master Plan shows more than 250 NGOs were involved in forestry in Sri Lanka. This report states that these NGOs participate in many aspects of forestry such as extension (tree planting campaigns, plant distribution, nursery programmes awareness programmes and training), reforestation, medicinal plant promotion, participation in forestry planning activities, campaigns in conservation issues, energy conservation programmes and monitoring environmentally sensitive activities, to name some.



(Photo: D. Perera)

Fig. 3.7. Twelve to fifteen year old secondary forest following ten years of continuous cultivation with intervening 6-month fallow periods. Such continuous cultivation and burning is followed by a form of secondary forest containing species of noxious grasses such as *Imperata cylindrica* and *Cymbopogon nardus*.

Participatory agroforestry will be different from ordinary forest planting activities. Agroforestry involves different plant components that provide farmers and their families with a range of benefits and it is essential that the farmers' constraints, and the benefits being sought, are thoroughly understood. It is here that some form of Rapid Rural Appraisal is needed. Thus agroforestry demands wide-ranging technical support because it involves so many different disciplines, so that refocussing extension activities by providing the appropriate education and training to extension workers is clearly a key issue.

The Profitability of Agroforestry Models

The profitability of different agroforestry 'models' will vary with outputs and markets. Of course, yields will be dependent on the climate and on soil potential, and on good management, freedom from pests and diseases, and so on. An annual source of income has to be obtained while waiting for the trees/shrubs to mature, which is why the planting of timber trees for fuelwood alone is often unacceptable to rural people. Intercropping prior to tree canopy closure, for example, will help provide income/subsistence. At the same time, as in taungya, the performance of the trees may be enhanced by the cultural operations (although some competition from the crops is to be expected, also). By properly planning the tree plantings, the farmer can maintain a fixed area under agricultural crops every year. Other forms of agroforestry (e.g., alley cropping) will provide agricultural produce from the start.

What sort of returns can be expected in Sri Lanka? Unfortunately, only fragmentary data on profitability are available. For example, those relating to the separate structural components for a Wet Zone forest garden (of 0.4 ha), have shown the mean labour resources on this unit to consist of 723 male adult equivalent labour days. Surprisingly, of this only 112 days were directly absorbed by crop production work and 611 days were, apparently, idle; but some amount of this time would have been used for general farm work and home development. In terms of cash income the most important agricultural crops were cloves, coffee, pepper, banana, nutmeg, coconut, and the most important consumption crops, coconut, jak and banana. The total

value of farm produce (at 1978 prices) was Rs. 6,350 month^{-1} and, of this, Rs. 5,300 month^{-1} would have been sold and Rs. 1,050 used in the home. This particular model indicated no livestock or wood production values.

Another study, carried out by a UNDP/FAO Project at the Research Station of the Department of Export Agriculture in Kandy, estimated that the return from mixed cropping (a homegarden model), after all the crops attained full production, was US$2,880 ha^{-1} annually (at 1983 rates, i.e., 1 US$ = Rs. 49.00). There were 14 different plant species, varying in canopy structure and growth habits used in this combination.

In a mixed cropping model at Delpitiya an annual return of Rs. 182,000 ha.$^{-1}$ was obtained, confirming the potentially high returns from homegardens. The species cultivated included pepper, coffee, clove, nutmeg, coconut, mango, jak, breadfruit, avocado, areca nut, banana, and lime. Again, the model showed no estimate of returns from livestock or wood components.

The most comprehensive estimates have been presented by Nuberg and Evans (1993), who used 'desktop' farm computer (spreadsheet) models for the Upper Mahaweli Project. Some, including a forest garden component, could be implemented within the context of SALT. The method employed was first to calculate the net financial returns over ten and twenty year periods together with the seasonally-distributed labour requirements of the 7 candidate models used. The exercise consisted of five production systems presented in combinations, some using the SALT layout, to form seven farm models. The general model size being 0.5 ha. divided into 15 alleys of 4 m width with 0.5 m wide double hedgerows of *Gliricidia sepium* planted at close spacings (15-20 cm in-row) along the contour. The forest garden model consisted of three modifications establishing one third (i.e. five alleys) each year for the first three years of the model run. Those alleys not under forest garden during this time were just cultivated for seasonal crops. Seasonal crops only provided the base-line comparison.

The component production systems of the models were:

- seasonal crops (i.e. reflecting what farms in the Badulla District would most likely choose);
- a coffee/pepper intercrop;
- a dairy/fodder scheme;

- a woodlot; and
- forest garden ('analog forest', with 23 tree/crop species representing emergents, canopy, sub-canopy, shrub and groundcover layers).

All input costs and output prices used were 1990 annual averages, agricultural labour was taken as Rs. 70 day^{-1}.

The financial productivity of the SALT models never exceeded that of seasonal cropping, while the forest garden models took until the seventh and eighth years for this to occur. The relative productivity of the models at system maturity (shown at the 12th year) indicated a 20% increase from the forest garden models, and greatly lower labour inputs at that time (see Figs. 2 & 3 in Nuberg & Evans, 1993).

The labour input required for establishing all the agroforestry models was greater than the labour requirement in later years. This establishment labour included that required for preparing the land, planting the contour hedgerows, planting the perennial crops and cultivating the seasonal crops (which included those crops interplanted with perennial seedling for the first two years). The models with a forest garden component required the most labour for establishment, mainly because of the greater number of perennials to be planted. For the same reason these models required the least labour in the third year when seasonal crops cannot be intercropped with perennials.

Even though they are only estimates these simulations help us expose some lessons. First, from a farmer's point of view, the quick and potentially high returns from seasonal crops indicates that some *have* to be included from the beginning, i.e. a woodlot will not provide this, and it is probably only appropriate on land of very poor quality. Second, in Sri Lanka the livestock/fodder option does not make economic sense. Third, dedicating every third alley to perennial crops, as in a SALT layout, offers a partial solution; the economic future of the coffee/pepper intercrop is uncertain as it still receives substantial institutional support.

This exercise in economic forecasting still lacks information concerning the relative sustainability of the different models, of course. Intuitively, we might feel that this is where perennial woody species will

benefit the land. However, until further information becomes available it is only possible to speculate.

SUMMARY

In conclusion I have set down the following outline to help summarise the comments and suggestions made above.

- Agroforestry should be promoted and the occurrence of large expanses of monoculture plantations avoided.

- Agroforestry should be seen as a significant tool in the overall rural development process. Thus, different institutions involved in agroforestry need to provide support to grassroots operations.

- Local people, NGOs and the private sector should all be encouraged to participate in agroforestry development in a coherent way. This means introducing schemes to provide long-term financial assistance and credit. Existing incentive/subsidy/credit schemes under different agencies will need to be pooled.

- Species and cropping systems have to be evaluated on the basis of agro-climatic region and farmer preference. Any agroforestry practice has to be established bearing in mind the need for adequate soil and water conservation.

- A co-ordinated approach to field extension for agroforestry is needed among the agencies involved. NGOs can also have a valuable part to play in agroforestry extension, in the provision of technical assistance, and in monitoring progress.

- Local people need to be consulted and informed. The latter will involve using appropriate mass information methods in order to explain the technical aspects of agroforestry, as well as spread news

about new developments in forestry sector policy, laws and regulations, and in progress generally. Organising the local communities and villagers to take advantage of available opportunities, and training of local people to prepare them from their new roles is essential.

There will be particular needs for an appropriate policy and a legal framework. The provision of new forestry sector policies that are relevant to agroforestry development are as follows:

- National landuse policies need to be redefined in order to accommodate agroforestry, and security of tenure is needed.

- With regard to the rehabilitation of deteriorated lands, and where agroforestry is practised, the Soil Conservation Act of 1951 could be fully implemented as a matter of policy.

- There is a need for a provision that specifies that all deforested State lands outside protected areas are to be allocated for land reform, including leasehold agroforestry. Thus, deforested State and other lands need to be delineated from protected forests for agroforestry development and more emphasis placed on homegarden/forest garden development, as well as exploring agroforestry opportunities for Dry Zone lands.

- The country should aim for self-sufficiency in most wood-based products by the year 2010. If enough medium rotation tree crops are established starting now sufficient wood products will be available for Sri Lanka's needs in some 15 years or so.

- Appropriate support systems will be needed which will provide technical assistance and finance and develop markets for tree products.

- De-regulation of laws relating to the cutting and transport of timber from private leaseholds has to be addressed.

If agroforestry develops as it should in Sri Lanka, and through the right policy initiatives, there will be many benefits. Among these we might expect significantly improved land and water conservation and the rehabilitation of degraded lands, as well as an improvement in deforestation and forest encroachment with better control of illegal logging. Biodiversity will be favoured and, possibly, there will be decreased risks from pests and diseases affecting trees and crops grown as monocultures. Increased employment should result through the initiation of new agroforestry enterprises and by alternative means of livelihood based on agroforestry. Thus, wealth will be more equitably distributed with an increase in the income of rural households.

Whether or not these potential benefits will be realised will depend very much on effectively exploring the technical agroforestry opportunities best suited to Sri Lanka, which I have outlined, and then on the promotion of these where they are socially and economically possible, within a beneficial policy and institutional framework.

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Appendix 3.1.

The following terms are useful in distinguishing 'agroforestry' from other reforestation programmes conducted in Sri Lanka[†] :

- *Social Forestry* - This is used in broad sense to cover all forestry activities which do not conform to traditional direct management models of plantations and natural forests. It excludes commercial plantation forestry. In some sense or another 'Social Forestry' is oriented towards the needs of the local population.

- *Community Forestry* - This is used in a narrow sense to denote forms of forestry in which communities work together as productive units and share common rights.

- *Participatory Forestry* - This term is used to denote forms of forest management in which rural people, to a greater or lesser extent, participate in forest and tree management.

- *Farm Forestry and Tree Farming* - 'Farm Forestry' and 'Tree Farming' should be terms reserved for application to privately (family) -owned trees on privately (family) owned land. The difference between the two is that in 'Farm Forestry' the dominant activity is food cropping, whereas in 'Tree Farming' the dominant activity is growing trees, usually for cash sale.

- *Agroforestry* - This is a system of landuse where woody perennials are deliberately used on the same land management unit along with annual agricultural crops and/or animals, sequentially or simultaneously, with the aim of obtaining diverse outputs, on a sustained basis. 'Agroforestry' refers to the land management practices used. It can be applied to more than one landuse type and certainly to almost all forms of 'Social Forestry'. Agroforestry

† See 'Community Participation in Agroforestry', this volume.

practices usually provide more effective soil and water conservation in catchments than tree monocultures.

4. Understanding Agroforestry

P. A. Huxley

THE BACKGROUND

In this contribution I would like to introduce, briefly, some issues that I suggest are all-important if we are to comprehend how agroforestry systems function. Some of these are dealt with in rather more detail later on.

What is now recognised as 'Agroforestry' has been with us in one form or another from historical times (King, 1987). In Sri Lanka, for example, early land users established chena cultivation and in the wetter regions they developed various multistrata homegarden systems. Surprisingly, it is only relatively recently that we have realised how little we know about the *science* of combining woody and non-woody plants. If we are to select, arrange and manage woody/non-woody plant mixtures to our best advantage we certainly need to understand how such mixtures *behave*. Evaluating the true output of an agroforestry system may be difficult because agroforestry systems provide both products and services; that is the tree components can give shelter, help prevent the loss of soil and water and improve soil fertility, etc. Nevertheless, this is another area where critical quantitative assessments are needed, particularly as we have to consider both productivity **and** sustainability.

Multiple cropping with trees, as we have in agroforestry, should really be considered the original 'norm' for, in many old-established ways of working land, the utilisation of woody with non-woody plants would have been a deliberate choice, and monocropping can be seen as a recent, specialised innovation. One which, in certain circumstances, has advantages in terms of potential increases of productivity over a season, if not always in long-term sustainability. However, we need to remember that *all* landuse practices that remove harvest from the land are extractive, including agroforestry. So that, at least for low-input systems, depending on the amounts we are taking out, there will usually be a decline in productivity of the system which may occur rapidly or over a prolonged period, depending on

the circumstances. To maintain stable production from many tropical agroforestry systems that have low inputs, i.e., of fertilisers, irrigation, pesticides, etc., involves, therefore, making the most use of what environmental resources are there, and not loosing or wasting any. Nutrients must be recycled, soil and water conserved and the best use made of climatic periods that are favourable for growth. Trees *can* be good at all of these things, but not always in all circumstances.

Agroforestry research is exciting. Not just because it is a new field of study, which requires us to draw on knowledge from a large number of well-established disciplines such as agriculture, horticulture, forestry, ecology, range management, soil science, etc., but because it forces us to re-interpret, modify and adapt the principles derived from these for our needs. The differences in stature and in the length of the life cycles of woody and non-woody plant components in agroforestry systems means that they are biologically very complex. Also, of course, we have many alternative ways in which they can be arranged and managed; and managing mixtures of such plants demands high levels of skill (Fig. 4.1). Thus, even the 'simplest' of agroforestry practices, for example alley-cropping, presents challenges in both implementation and evaluation.



(Photo: P.A. Huxley)

Fig. 4.1. A hedgerow intercropping ('alley cropping') experiment with *Inga* spp. and rice at Yurimaguas, Peru. In practice a farmer needs a good deal of skill to manage even such a 'simple' agroforestry system as this in order to optimise production and strike a balance between this and sustainability.

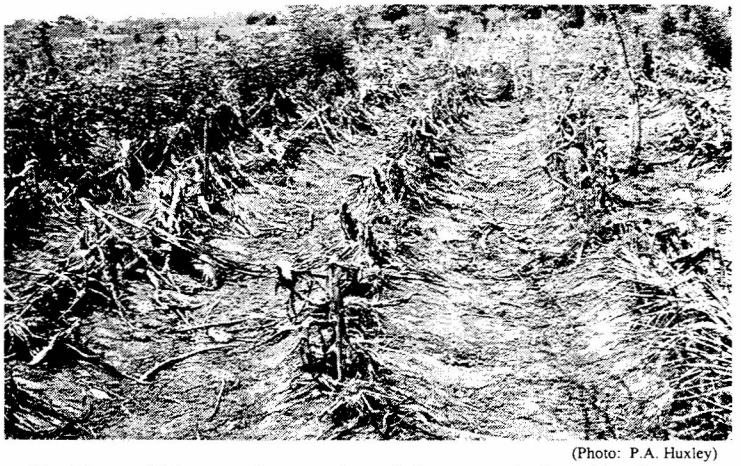
Of course, farmers do not engage in agroforestry only to concern themselves with the biological aspects of their systems. There will always be social and economic constraints and opportunities that we have to be aware of. For example, any form of tree planting involves long term investment, if only of labour inputs, and the whole pattern of income and expenditure on the farm will be altered once woody plants become part of the system. Gender issues and the distribution of tasks and rewards are also factors to be considered; tenure and other legal matters, and the over-riding effects of government policy may be all-important. Agroforestry research, as we know, is all the more satisfying because it involves working in inter-disciplinary teams in order to tackle this wide range of issues.

It pays to reflect on what is involved in the woody habit, because 'woodiness' reflects certain useful attributes (see below). But woody and non-woody plants interact, and this can result in *either* a favourable *or* an unfavourable outcome for the system as a whole. We certainly know of many situations where trees and shrubs benefit the land and those living on it. Forests provide a huge range of products, they can ameliorate climate, regulate stream flows and provide habitats for a vast diversity of organisms (Myers, 1982). Even small clumps of trees can provide shelter and shade around homesteads and protection for cattle against heat stress. Beneath individual trees the soil under the canopy will often be more fertile than that in adjacent open spaces (e.g., Belsky *et al.*, 1989). On the other hand, trees can encourage pests (insect pests, fungal pathogens, birds, rodents and other small mammals, snakes, etc.; Huxley and Greenland, 1989) (Fig. 4.2). They can exert allelopathic effects (Brunig and Sander, 1983), and actually enhance soil erosion if they are planted in the wrong arrangement. Above all, we know that trees can *compete* strongly with adjacent crops and pastures (e.g., Ong *et al.*, 1996).

Some Characteristics of Trees

Because plant characteristics are so important in determining competitiveness as well as output potentials, and because there is such a huge range of

potentially woody species to choose from (Burley, 1984), we need to consider briefly some of their main characteristics.

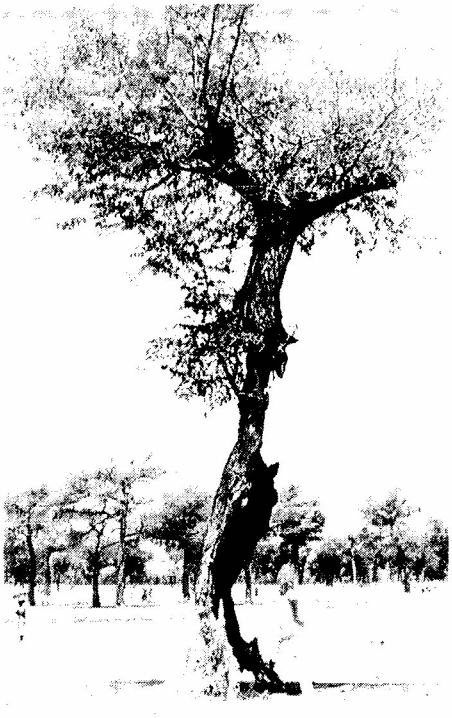


(Photo: P.A. Huxley)

Fig. 4.2. Hedgerow intercropping ('alley cropping') with *Leucaena leucocephala*, maize and yams (*Dioscorea* spp.) near IITA, Ibadan, Nigeria. Large amounts of persisting woody plant residues can form favourable habitats for rodents and snakes.

Trees and other woody plants often have an *elevated structure*, as we have mentioned already. They possess *longevity* and therefore, together with their lignified structure and the possession of dormant meristems, they have *'survivability'* (Fig. 4.3). We have also to recognise that over their life cycle they go through various phase-changes in development from juvenility, through maturity, to senescence. A woody structure also confers *'shapability';* a most important attribute in agroforestry where we may wish to modify canopy shape so as to mitigate competition.

Trees, and especially tropical species, often have *complex behavioural patterns* (i.e. their phenology is often not the same as that of the crop plants they are associated with). Of importance to those using trees and shrubs as fodder sources they may well have *different proportions of constituents*, for example proteins, carbohydrates and minerals, from those of grasses. Together with a differing phenology this may help them complement and extend animal 'feed profiles' (Fig. 4.4).



(Photo: P.A. Huxley)

Fig. 4.3.
This *Faidherbia albida* growing in the southern part of Sudan has been frequently damaged when nomads light fires at its base. Nevertheless it shows what 'survivability' woody perennials can have!

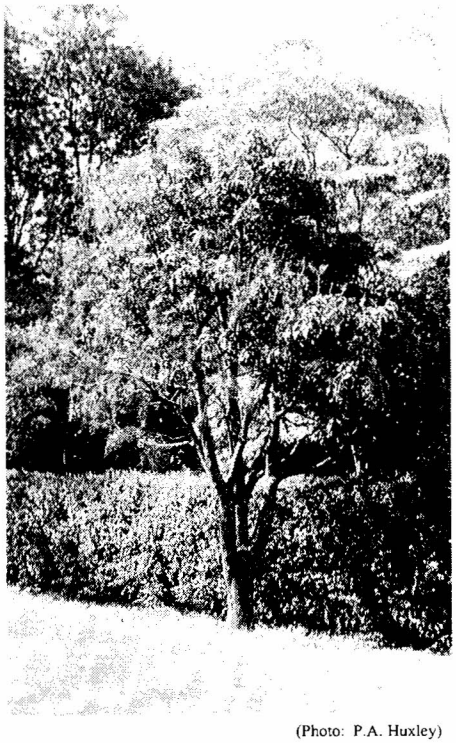


(Photo: P.A. Huxley)

Fig. 4.4. Grass (*Panicum maximum*) interplanted between alternate hedgerows of *Leucaena leucocephala* and *Gliricidia sepium* at IITA, Ibadan, to form a 'feed' garden or 'fodder plot'. Mixing grasses and shrubs in this way can extend the animal's feed profile.

Flowering and fruiting in woody plants depends on the position in which flower buds are initiated, i.e., on new wood, old wood, or on fruiting spurs, and on how these sites have been affected, not only by the current season's climate, but by that of past seasons also. Furthermore, although woody plants often flower prolifically, numerous factors can affect how many fruits actually 'set'. A consequence of this is that woody plants often have *erratic fruiting* (Fig. 4.5). Under good management this can be controlled, to some extent, by appropriate pruning as long as the way flowering comes about is sufficiently well understood.

Fig. 4.5.
Woody plants typically have erratic flowering and fruiting patterns between seasons so that, in the tropics especially, even individual plants can show a great deal of variability. In this example (*Brachychiton acerifolius* in Nairobi, Kenya) flowering has occurred only on the left side of the tree.



(Photo: P.A. Huxley)

The *rooting systems* of woody perennials differ in a number of ways from that of herbaceous crop plants and cereals. Like the branching system above-ground the perennial woody roots are 'already there' and this gives an opportunity for fine 'feeder' roots to occupy volumes of soil early in the season before crop or grass roots can reach them. Another aspect of woody

plant roots is the likelihood of *'fine root turnover'* (Bowen, 1985). This has been shown to add considerable amounts of organic matter to the soil under some circumstances.

Finally, many woody species are *outbreeding* and so do not come 'true' from seed. However, they lend themselves to some form or another of vegetative propagation (e.g., by cuttings or layers), and so the problems that may arise in establishing them can sometimes be overcome in practice, although this may add to a farmer's costs (Fig. 4.6 a and b).

Fig. 4.6.(a)



(Photo: D. Perera)

Fig. 4.6. Many woody species can be propagated vegetatively for example by stem cuttings, bud grafts or by layering, so maintaining the genotype. It might also be possible to use root cuttings as many species, especially those from dry areas, sprout from roots: (a) shows root-sprouted forest trees emerging during the cultivated phase of chena among the sesame and vegetables; and (b) shows leafy shoots that have sprouted from roots of a local shrub that were exposed about 1 m down the side of a soil pit at ICRAF's Field Station, Machakos, Kenya.

Agroforestry and Plant Cover

The productive capacity of any landuse system will depend on producing and maintaining a canopy of active, healthy leaves. Canopies such as we find in forests, or even in crop lands, have very complex structures. Both laterally and vertically there are changes in the numbers, size, and orientation of the constituent leaves, which also can vary in age and physiological efficiency. Leaves are sometimes clustered and there are often gaps of different sizes.

Fig. 4.6. (b)



(Photo: P.A. Huxley)

A characteristic of forests and plantations is that the canopies are usually very dense and, in tropical rain forests for example, very little of the incoming solar radiation reaches the forest floor until a gap is formed by the death of an old tree. Agricultural crop canopies are also complex, but more regular, and they occupy the land for just the crop season. Manipulating the plant density so as to create a closed canopy soon after sowing, or planting out, is a feature of the way both agriculturalists and foresters concerned with commercial plantations regulate canopy characteristics (and, incidentally, alter the form of the plant because close planting of trees in plantations, for example, ensures that more of the fixed carbon is partitioned to the woody trunks than would otherwise be the case).

Both foresters and agriculturalists know a great deal about plant canopies, and how to manage them. So much so that, in many cases, they can use computer models to predict what dry matter increases will occur under particular circumstances and, from this, what potential yields might be. With the even more complex canopy arrangements found in agroforestry (Fig. 4.7) we are not yet in a position to do this, although a start has been made (Lawson, 1995).

Plant canopies also protect the soil surface from erosive rainfall and the plant litter produced helps to prevent soil being washed away. One important difference between forest and agricultural crop canopies is that the former are invariably aerodynamically 'rough'. This facilitates the ready transfer of

water vapour, carbon dioxide and heat energy between the atmosphere and the canopy layers. Such canopies are considered to be 'closely-coupled' to the environment around them. Agricultural crops (i.e. fields of wheat or cotton, etc.) are often compact and are not so 'closely-coupled', so there is considerably more resistance to the exchange of gases and energy into and out of such canopies (Jarvis, 1985). We can assume that because they are also very rough, agroforestry canopies, although less dense, will also be 'closely-coupled'. Why is this important? The reason is that, in such canopies, the control of water loss and the regulation of carbon assimilation are much more a consequence of plant characteristics (e.g., stomatal sensitivity) than would be the case in the more uncoupled canopies that we find in monocrops.



(Photo: ICRAF)

Fig. 4.7. This agroforestry 'scene' (above Nairobi, Kenya) illustrates the complex association of different plant canopies that occur in agroforestry situations.

Canopy arrangement is particularly important if we want to understand how our agroforestry systems photosynthesise, and canopy density and 'roughness' will both affect how water is distributed and used by the plant-soil-environment system. In the future we should be able to select and design appropriate tree and crop arrangements bearing these functional aspects in mind, as well as just the more easily-perceived issues that concern us at present.

Phenology

Another consideration that can have considerable impact on the functional aspects of agroforestry systems is that the woody components may not be 'behaving' throughout the year in the same way that the crop plants do (Huxley *et al.*, 1989; Akunda and Huxley, 1990). A characteristic of woody plants, especially in the tropics is that, frequently, there are patterns of growth and development that occur outside what we would normally consider to be the 'cropping season'. These have evolved in order to enhance 'survivability', and so as to confer benefits of competitive advantage. There are many examples where there are major periods of growth, for example, in the dry season in seasonally-arid regions. This implies that woody vegetation has access to water that crop plants either do not use or cannot reach; and this we know to be often the case.

In agroforestry, therefore, we have not only a complex arrangement of the canopy but we can have diverse canopy behaviour. Furthermore, we can manipulate this through management practices such as pruning and thinning. This capacity of woody plants for growth and development throughout the year is one very important way in which agroforestry practices can, potentially, achieve greater overall productivity than ordinary agricultural cropping. It is also important when we come to consider issues of 'competition' and 'complimentarity' and, by changing the status of the canopy in the 'off-season', and hence of the timing of litter-fall, it may also influence nutrient cycling and soil sustainability issues.

Below-Ground Activities

The complexities we see above-ground are more than mirrored in those we find below it. We are only quite recently beginning to investigate the way tree and crop or grass roots occupy the soil profiles in agroforestry systems. Clearly, it depends very much on the species and soil type but also on the climate, topography and management. Here again we are interested in both *how* the root systems occupy space and in *when* they are active. It is a mistake to think that trees are always deeper rooted than crop plants or grasses (Fig.

4.8). If subsoil conditions are unfavourable, for example due to compaction, low pH or waterlogging, then they may well not be. Some species of trees and shrubs are, in any case, shallow-rooting and perennial grasses can often root more deeply than trees.



(Photo: P.A. Huxley)

Fig. 4.8.
Tree root systems are by no means always 'deep'. This example of a large *Eucalyptus macrorhynca* growing on a duplex soil in New South Wales, Australia, shows how shallow they can sometimes be.

Competition and Complementarity

Time spent on understanding how plant canopies function, and on the activity and disposition of root systems is not wasted. They underpin the efficient utilisation of environmental resources, the maximisation of biomass and the optimisation of yield and, for low input agroforestry practices, biomass accumulation is the key both to productivity and sustainability. More than this, the form and behaviour of the constituent parts of the canopy, and of the root system, will determine to what extent the presence of one plant component will affect that of others, i.e. to what degree adjacent plants hinder or help one another.

The 'Tree/Crop Interface'

If an agroforestry system is to function efficiently, the various plant components have to do this *without interfering with one another too severely.* Adding trees to a cropping system may help capture more environmental resources, but it will not necessarily make the system more productive from the farmer's point of view, because the crops or the animals on his pastures may then yield less than he wants them to. So a key issue is to understand what is happening at the 'tree/crop interface' (Huxley, 1985) (Fig. 4.9).

In order to compete, plants have to be close enough to interact and then they do so, usually, by modifying the environment around them. If they are successful competitors adjacent plants will be deprived of light, water and/or nutrients. As they grow older trees have the advantage, because of their stature, of being good competitors for light compared with shorter-statured crop plants. Below-ground competition for water and nutrients is, 'two-way', that is, in agroforestry, *tree* growth may often be reduced because of competition from the crop or grasses; especially when trees are young.



(Photo: P.A. Huxley)

Fig. 4.9. A 'typical' tree-crop interface where the effect of the tree *(Senna siamea)* on the crop (*Zea mays*) apparently extends over about 4 rows. In fact, this represents only the one-sided competitive effect of the taller component *(S. siamea)* for light and nutrients. Underground the tree root systems extended right across the maize plot and further. The maize also competes for water and nutrients with the tree ('two-sided' competition).

In agriculture and in plantation forestry we manipulate the intensity of competition between plants of the same species by changing the space between them, i.e., the plant population density. In agroforestry we can also do this for the individual plant components, but we then have the option to manipulate the way these components are arranged each compared with the others, i.e. we can manipulate the *'intimacy'* of the arrangement. For example, scattered trees in crop land have a higher proportion of tree crop interface than a zonal arrangement where the trees and the crops are each planted in blocks or strips. Alley-cropping is a zonal arrangement, although it still has a high level of tree/crop interface because the hedges are narrow.

The amount of tree/crop interface will depend on design, but what happens *at* the tree/crop interface will depend on the species chosen and on the availability, and time of availability, of environmental resources in relation to their growth patterns. Growth patterns will also directly affect how plant components interfere with one another. If the woody components are actively growing when the crops are not, as may often be the case to some extent or another in the tropics, then although they conjointly occupy the same land in either a mixed or a zonal arrangement they will not be competing at these times (although they may be at others). The phenology of woody plants may overall, therefore, *lessen* their competitiveness, although there are other factors of the woody habit that make them excellent competitors!

As we can see, so far, there is more to agroforestry than just throwing a few woody and non-woody plants together!

Sequential Systems

The agroforestry practices we have been considering up to now have had plant components occupying the same unit of land at the same time ('simultaneous' practices), although the various plant components might grow at different times, for example as with *Faidherbia albida* grown with sorghum or millet in West Africa.

In some agroforestry practices, however, the plant components *occupy the land* at different times(e.g., in shifting cultivation). This is considered to be a 'sequential' practice and, being permanently separated in time, no

competition occurs between plants growing in the two phases; although there are other factors that need consideration. Major features are the changes that occur in soil fertility during the tree fallow period, and the speed and relative efficiency with which these occur; indeed, this can be enhanced by the use of 'enriched fallows'. The labour requirements for such practices, however, can be very onerous at clearing time and so the social and economic aspects are often pre-eminent. With increasing population pressures, substitutions for these systems, which have served well in the past, are now being sought (e.g., Warner, 1991; ICRAF, 1995).

Because sequential systems are effectively 'land rotations', experimentation is necessary long-term and constrained by all the problems that rotation investigations carry with them (Huxley *et al.*, 1987).

Complementarity

In agroforestry when different plant components are close enough together to interact, some level of competition is certain to exist, either within-day, within-week or within-season. The extent and intensity of such competition will be characterised very much by the form and growth characteristics of the plant components involved, i.e., by the different sets of plant traits that each possesses. However in agroforestry, as in agricultural intercropping, we are hoping that the plant mixture will make *better* use of the environmental resources available than any of the components would grown separately. When this occurs it is called 'complementarity' and, again, it will depend on various sets of plant traits to do, for example, with the canopy, or with below-ground features and the ways in which the plants are distributing and using the dry matter that they accumulate. It may also depend on the ways in which plants change the environment around them so as to 'facilitate' the sharing of nutrients.

Complementarity is a *net* beneficial effect, it does not mean that some level or another of competition does not also exist. Environmental conditions within any plant mixture change throughout the day: those obtaining at dawn are not those found at midday. Thus both the existence and 'strength' of competition for light, water and nutrients will be constantly fluctuating. What

we see, perhaps after some weeks, is the overall outcome of many changing circumstances for each component plant brought about by the others around it; some detrimental and some (perhaps) beneficial. If we can understand how competition and complementarity come about, and especially whether they are to do with the way the plants are interacting and affecting one another *at the same time,* and/or because of events occurring at *different* times, then we will be in a very strong position to design and manage highly efficient systems. We are still a long way from doing this, but a great deal of work has now started in this field to help provide a sound scientific background to what, otherwise, would be a purely pragmatic approach (Ong and Huxley, 1996).

CONCLUSIONS

Trees, shrubs and other woody plants have many attributes that can be useful, but they must be made to 'match' the other components in the system if it is to be productive. If farmers are to adopt agroforestry practices then the woody plants should:

- enhance the efficiency of the system as a whole with respect to environmental resource capture;
- share these resources in ways that are not detrimental, or perhaps will even enhance their utilisation by associated crops or grasses;
- benefit the natural resource base and not be detrimental in any way to the landuse system (e.g., by encouraging pests); and
- give the farmer what he wants within a management structure and with required levels of inputs that are feasible for his situation.

To achieve all this it is clearly essential not only to appreciate fully the economic and social constraints that the farmer and his family face but, also, to understand how the plant components function and interact. In later contributions in this meeting we can explore some of these in a little more detail.

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5. Multiple Cropping under Coconuts

H. A. J. Gunathilake and M. de S. Liyanage

Monocotyledonous plants provide us with a wide range of useful crop plants (Purseglove, 1972), including the coconut (*Cocos nucifera L.*), belonging to the family Aracaceae (previously Palmae). Unlike many other monocots, which have short life cycles, the coconut has a useful life span of 60 years or more and, in Sri Lanka, it is popularly referred to as the 'Tree of Life', indicating its innumerable uses to mankind.

THE COCONUT SECTOR IN SRI LANKA

Coconuts occupy a total area of around 400,000 ha. in Sri Lanka, which accounts for 25% of the total cultivated land area in the country. Annual production is in the range of 2,300 to 2,500 million nuts. It also provides a livelihood for about 400,000 rural families, both through direct and indirect employment. Certainly, the coconut sector plays a significant role in providing food, and in the socio-economic life of the people in our country.

As in the other countries growing coconuts in a similar situation, they are essentially a smallholder's crop with 86% of holdings having an area of only 2.0 ha. or less (Anon, 1991). Of the total area under coconut, 70% is found in the Districts of Kurunegala, Puttalam, Gampaha and Colombo, which are popularly known as the 'Coconut Triangle' (Fig. 5.1). Thus, about 30% of coconuts are grown in Sri Lanka's Wet Zone, 50% in the Intermediate and 20% in the Dry Zone.

The average *per capita* consumption of coconut products in terms of nut equivalents is 130 nuts year^{-1}. This provides 22% of the calorie intake in the daily diet of the Sri Lankan people. The annual export earnings from coconut and coconut products amount to Rs. 3.5 billion in foreign exchange.

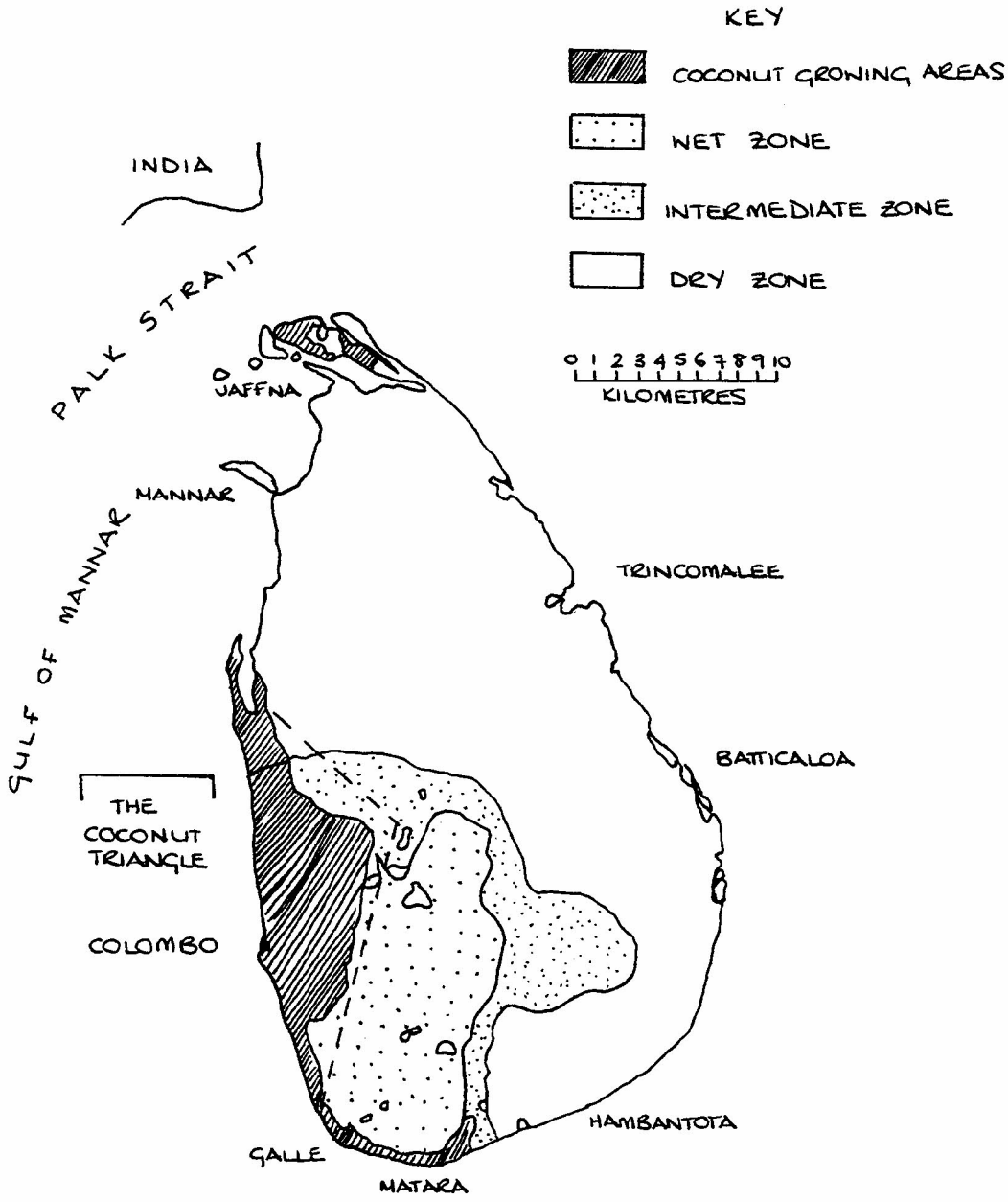


Fig. 5.1. Map of Sri Lanka showing the three major rainfall zones and the coconut growing areas.

THE SCOPE FOR MULTIPLE CROPPING

In Sri Lanka most of the coconut holdings are maintained as monocultures. This inefficient form of landuse provides only relatively low returns to the grower. The problem has become very acute with the increasing prices of inputs, particularly fertilisers, and with stagnant, low farm-gate prices for coconut. Thus the continuation of monocultural holdings at low production levels is becoming increasingly difficult and uneconomic. Multiple cropping is one of the strategies for improving the utilisation of coconut lands so that productivity is increased. The production alternatives may be to use a single intercrop and/or animals, or through a mixture of intercrops or crop-livestock associations.

Coconut palms are generally spaced 8 m x 8 m apart, thereby 75% of the area remains below its production potential from the age of 20 years or so. This land area can be made available for multiple cropping in mature coconut stands. The area available for multiple cropping in young plantations (age 0-5 years) could be as high as 80 to 90% (Liyanage, 1994). The in-between years are less suitable (Fig. 5.2).



(Photo: P.A. Huxley)

Fig. 5.2. A maturing coconut plantation (7-8 years old). At this stage the low canopy is dense and spreading so that there is less opportunity at lower levels to share light (see text).

Consideration has to be given to the bio-physical environment when considering multiple cropping. In Sri Lanka, the coconut is grown primarily as a rainfed crop. Therefore, the total rainfall as well as its distribution pattern are vital considerations for successful coconut cultivation and multiple cropping practices. The active root system of coconut palms is normally found within 150-180 cm from the base of the stem (Rosairo, 1983). Fertilisers and mulch are usually applied in this zone (Fig. 5.3) and it is advisable to establish other crops leaving two metres from the base of the palm in order to reduce competition for soil moisture and nutrients.

Among the socio-economic considerations, it has been estimated that about 4,000 ha. of coconut plantations are being lost each year for various development programmes in the country (Liyanage, 1986). Since major coconut growing areas have a high population density (800 km^{-2}), a shift from the monoculture system to a multiple cropping approach has become a necessity to meet the demand for food and other essential supplies.

All these factors highlight the considerable needs and the potential for multiple cropping in coconut lands.



(Photo: D.M.S.H.K. Ranasinghe)

Fig. 5.3. Cut *Gliricidia sepium* branches placed around the base of a coconut palm (old palm fronds would normally be added as well).

Suitable Intercrops for Coconut Lands

The most common intercrops grown in coconut lands are as follows:

- *Perennials* (over 10 years)

  Cocoa, coffee, pepper, clove, cinnamon, rambutan, avocado, lime, lemon, cashew, mango, arecanut, pasture and fodder for livestock;
- *Semi-perennials* (2-5 years)

  Banana, pineapple, passion fruit, papaya and betel; and
- *Seasonal crops* (less than one year)

  Pulses and cereals, tubers and yams, ginger, turmeric, chillies and vegetables.

A diagnostic survey carried out in 1993 by the Coconut Research Institute of Sri Lanka showed that seasonal crops are popular in the Dry Zone (DZ) and Intermediate Dry Zone (IMDZ), whereas semi-perennials are popular in the Wet Zone (WZ) and Intermediate Wet Zone (IMWZ) (Somasiri *et al.*, 1993). Banana is intercropped in all agro-climatic zones (Table 5.1a & b). Among perennials, cashew is an attractive intercrop for farmers in the DZ.

Table 5.1. Distribution of popular intercrops under coconut in Sri Lanka (% occurrence)

a) Agro-climatic Zones

	WZ	IMWZ	IMDZ	DZ
Seasonal Crops				
Cassava	0.9	1.2	1.9	0.0
Chillie	2.7	1.2	5.7	13.3
Ginger	8.0	3.5	0.0	0.0
Pulses	0.0	1.2	7.6	0.0
Vegetables	0.0	0.0	20.8	6.7
Yams	0.9	0.0	1.9	0.0
Semi-perennials				
Banana	55.4	62.8	39.6	40.0
Betel	2.7	7.0	1.9	0.0
Pineapple	5.4	8.1	3.8	0.0
Perennials				
Arecanut	3.6	0.0	0.0	0.0
Cashew	0.9	8.1	11.3	6.7
Cinnamon	6.3	0.0	0.0	0.0
Coffee	2.7	0.0	3.4	0.0
Cocoa	0.9	0.0	0.0	0.0
Pepper	6.3	4.7	0.0	0.0
Mango	0.9	1.2	0.0	0.0
Lime	0.0	1.2	0.0	6.7

(Source: Somasiri *et al.*, 1993)

b) **Land size**

Intercrops	Land Size Classes (ha.) 0.8-2	2-4	4-8	> 8
Seasonal Crops				
Cassava	8.6	4.7	0.0	0.0
Chillie	1.7	2.1	10.0	0.0
Ginger	5.2	11.9	0.0	0.0
Pulses	0.0	5.0	16.7	0.0
Vegetables	1.7	2.4	25.0	0.0
Yams	1.7	2.4	5.0	0.0
Semi-perennials				
Banana	10.3	16.7	0.0	16.7
Betel	3.4	4.8	5.0	0.0
Pineapple	8.6	21.4	10.0	0.0
Perennials				
Arecanut	0.0	0.0	0.0	0.0
Cashew	0.0	2.4	5.0	0.0
Cinnamon	8.6	0.0	0.0	0.0
Coffee	20.7	4.8	0.0	0.0
Cocoa	0.0	2.4	0.0	0.0
Pepper	10.3	9.5	10.0	0.0
Mango	1.7	2.4	20.0	16.7
Lime	0.0	7.1	0.0	0.0

(Source: Somasiri *et al.*, 1993)

Land Suitability Classification for Coconut and Possibilities for Multiple Cropping

Although coconut grows on a wide range of diverse soil types, other crops do not possess the same adaptability and, in most cases, require specific soil conditions for optimum growth. In coconut-based multiple cropping systems, therefore, adapted intercrops should be chosen to suit particular soil types bearing in mind, also, that they should not compete severely with coconut for soil nutrients and moisture. Moreover, the growth and management of intercrops must not cause soil deterioration.

Coconut performs well in Land Suitability Classes 1 and 2 (Table 5.2) where priority should be given to maximise the production of coconut alone (Somasiri *et al.*, 1994). However, for Classes 3, 4 and 5 the lands policy should be to maximise productivity of land growing coconuts through multiple cropping. Possibilities for multiple cropping in Classes 4 and 5 are enhanced due to the moderate performance of coconuts because, on such lands, they tend to have small crowns which result in increased light infiltration to ground-level. Also the soils in these classes (e.g., well drained, sandy-clay loams) have favourable physical properties for some intercrops. Therefore, a wide

range of light-loving crops (e.g., ginger, cocoa) as well as shade-tolerant crops (e.g., banana, cinnamon) are often suitable for such lands.

Table 5.2. Potential coconut yields of different land suitability classes

Suitability Class	Potential Yield (nuts $ha.^{-1}$ $year^{-1}$)
S_1	> 15,000
S_2	12,000 - 15,000
S_3	10,000 - 12,000
S_4	5,000 - 10,000
S5	2,500 - 5,000

(Source: Somasiri *et al.*, 1994)

Multiple Cropping Practices

Liyanage (1994) has identified five prominent agroforestry practices in coconut lands; intercropping, multiple cropping, mixed cropping, alley cropping and mixed farming. Here, multiple cropping means growing combinations of perennial/semi-perennial crops on the same land as the coconut. In the IMWZ, multiple cropping with a combination of banana, pineapple and ginger in young coconut stands is a very popular practice while cashew, lime, banana and groundnut have been found to be a compatible mixture in the IMDZ. In mature plantations, banana/ginger/ black pepper or coffee/banana multiple cropping systems are common in the WZ (Liyanage, 1994) (Tables 5.3 & 5.4).

During the period 1988-1994 the Coconut Research Institute of Sri Lanka (CRISL) conducted several on-station and on-farm experiments to develop suitable multiple cropping systems to increase productivity of coconut lands in different agro-ecological regions (Anon, 1994). This programme revealed that cocoa and pepper are ideal intercrops for the WZ and they come into production in three years. (Gunathilake *et al.*, 1994). In the IMDZ and DZ the perennial crops, cashew, mango and lime have shown promise exhibiting drought tolerance even up to a 100-day dry spell. Cashew and mango reach production within 2½ years of planting, but lime takes approximately five years.

Table 5.3. Yield of seasonal and annual intercrops under coconut.

Type of Crop	Crop		Yield t. ha.$^{-1}$ yr^{-1}
1. Food crops			
Root and tubers	Cassava	*Manihot esculenta*	11.0
	Sweet potato	*Ipomea batatas*	4.8
	Taro	*Colocasia sp.*	6.5
	Cocoyam	*Xanthosoma sp.*	19.6
Grain legumes	Cowpea	*Vigna unguiculata*	0.8
	Groundnut	*Arachis hypogea*	1.3
	Pigeonpea	*Cajanus cajan*	1.0
Fruit crops	Banana	*Musa sp.*	49.0
	Pineapple	*Ananas comosus*	14.0
	Passion fruit	*Passiflora edulis*	6.0
	Papaya	*Carica papaya*	10.0
2. Spices			
	Ginger	*Zingiber officinale*	20.0
	Turmeric	*Curcuma longa*	7.3

(Source: Liyanage and Dassanayake, 1993)

Table 5.4. Yield of perennial mixed crops under coconut

Crop		Mean Yield (kg ha.$^{-1}$ yr^{-1})
Cocoa	*Theobroma cacao*	720
Coffee	*Coffea canephora*	445
Black pepper	*Piper nigrum*	930
Clove	*Eugenia caryophyllus*	136
Cinnamon	*Cinnamomum verum*	435
Lemonime	*Citrus sp.*	24,000
Lime	*Citrus sp.*	5,000
Betel	*Piper betel*	35,500
Mulberry	*Morus alba*	12,000

(Source: Liyanage and Dassanayake, 1993)

Crop Models

The inclusion of chosen intercrops with coconut in an individual system for a particular farmer results in a specific 'crop model'. In designing an appropriate crop model for a particular farmer, or agro-climatic zone, there are many factors to consider: agronomic feasibility, economic viability, social acceptability, general adaptability, long-term sustainability, the distribution pattern of harvests and income reception and easy management.

Fig. 5.4 gives details of one of the crop combinations with a mature stand of coconut designed to maximise productivity and to reduce the cost of production by green manuring with *Gliricidia sepium* planted *in situ*. In this

model, a row of *Gliricidia* established in the centre of the coconut avenue produced a fresh biomass yield of 5 kg tree^{-1} year^{-1} from the third year on. The coconut was fertilised with 35 kg of *Gliricidia* leaves supplemented with P, K and Mg according to the recommended fertiliser mixture. Yield improvement of the coconut indicated that *Gliricidia* could be used to successfully fertilise it while the land still provided some perennial crop products such as pepper and coffee (Gunathilake *et al.*, unpublished).

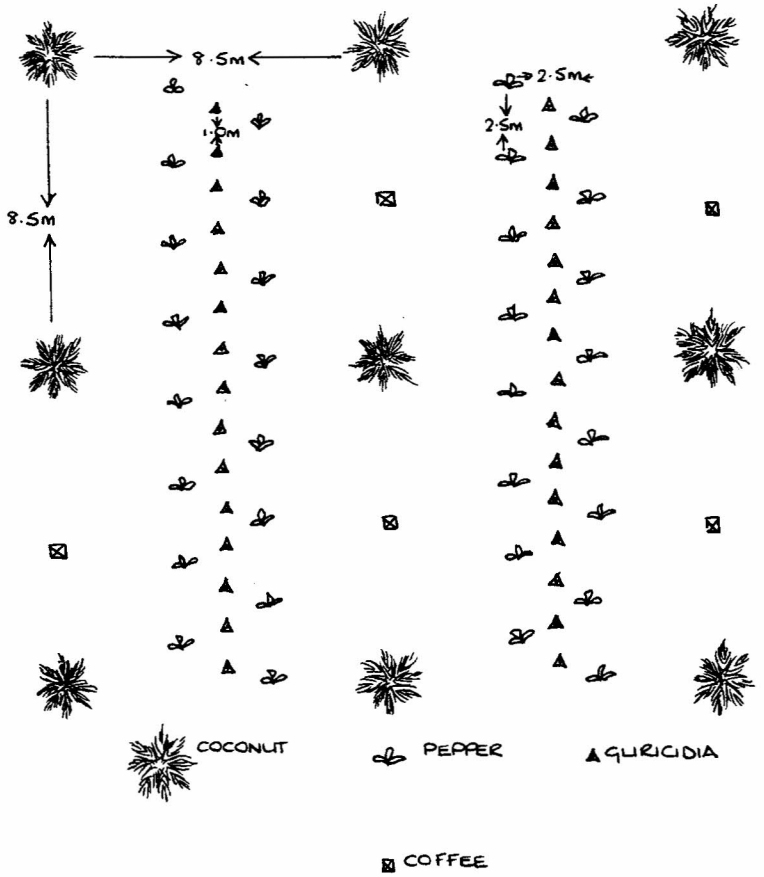


Fig. 5.4. Planting pattern of pepper and coffee with *Gliricidia sepium* in a 40 year-old coconut plantation (see text).

Fig. 5.5 shows details of another arrangement with a crop combination of pineapple and banana that was established in a mature stand of coconut in the IMWZ of Sri Lanka at Kuliyapitiya which produced a satisfactory income for the farmer. Multiple cropping is helpful to rehabilitate poor-yielding coconut lands (Table 5.5) where the production can even be as low as 2,000-4,000 nuts ha^{-1}. The data clearly indicated that coconut yields of low yielding plantations improved as a result of the benefits that accrued from multiple cropping. In terms of economic benefits, multiple cropping systems increased the cost:benefit ratio to 3:2 compared with 2:1 in low-yielding monoculture coconut.

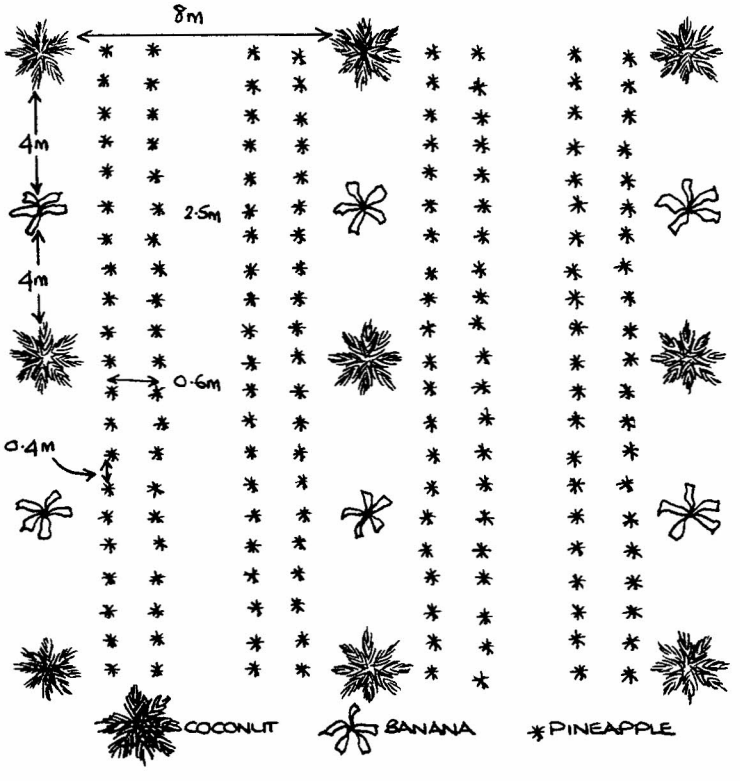


Fig. 5.5. Planting pattern of pineapple and banana in a 45 year-old coconut plantation (see text).

SEVERAL BENEFITS OF MULTIPLE CROPPING SYSTEMS

These can be listed as follows:

- *Maintaining/increasing coconut production:* Because coconut is the main crop, the cumulative effects of any intercrops on coconut yield is of primary concern to the grower and the main objective of multiple cropping is to increase overall productivity from unit holdings without adversely affecting coconut production. Recent investigations at the CRISL have shown that this is possible in areas where there is no competition for soil moisture and where both crops are properly managed (Tables 5.5 and 5.6). Yields of coconut grown with cocoa, coffee, cinnamon, banana and seasonal crops were actually improved when compared with the control.



(Photo: P.A. Huxley)

Fig. 5.6. Various nitrogen fixing tree species are being tested under coconuts spaced at 8 m x 8 m at Lunuwila to establish which provides most biomass/plant nutrients.

- *Improving soil fertility:* In Sri Lanka more than 50% of the coconut area is inherently low in soil fertility. Poor soil physical conditions, and depletion of topsoil are the two major contributing factors to low coconut yields in such marginal lands. Beneficial effects of multiple cropping on soil fertility have been reported in

Sri Lanka (Liyanage, 1994) in terms of soil physical, chemical, and biological properties (Table 5.7). Figs. 5.6. to 5.11. illustrate some experimental work with nutrient-supplying shrubs grown under coconut.



(Photo: P.A. Huxley)

Fig. 5.7.
Leuceana leucocephala growing under coconuts to supply plant nutrients, particularly nitrogen.

- *Creating a favourable microclimate:* Coconut-based multiple cropping systems produce a favourable microclimate for the understorey crops. In one study (Nair and Balakrishnan, 1987) it was reported that coconut/cocoa multiple cropping produced a 30% reduction in evaporative demand because of a lower temperature and a higher humidity within the system. The coconut palm also serves as an economic shade tree by providing conditions to complement the growth of several shade- loving/ shade -tolerant crops such as cocoa, coffee, pepper, yams, ginger and turmeric.

Table 5.5. Effect of multiple cropping systems (crop models) on coconut yield from several on-farm trials

Crop Model	Agro-Ecological Zone	Mean Nut Yield (nuts ha.$^{-1}$ year^{-1})			Mean Copra Weight (g nut^{-1})		
		No Inter-Crop	With Inter-Crop	% Increase	No Inter-Crop	With Inter-Crop	% Increase
Coconut+Pepper+Coffee+Ginger	WL_3	6,406	7,427	16.0	197.3	217.8	10.4
Coconut+Cacao+Pepper+Ginger	WL_2	5,738	6,657	16.0	197.7	219.5	11.0
Coconut+Pepper+Coffee+NFTs	IL_1	4,541	6,970	53.5	20.41	237.6	16.4
Coconut+Mango+Lime+Banana	IL_3	6,688	6,934	3.7	202.3	229.3	13.3
Coconut+Cashew+Banana	IL_3	5,139	6,794	32.0	163.6	185.4	13.3

(Source: Gunathilake *et al.*, - unpublished)

Table 5.6. Effect of multiple cropping systems on coconut yield (1977-1987)

Cropping System	Mean Yield (nuts ha^{-1} yr^{-1})	% Increase	Mean Copra Yield (t ha^{-1} yr^{-1})	% Increase
Coconut only (Control)	6,123	-	1.79	-
Coconut+Cocoa	7,504	22	2.18	22
Coconut+Coffee	8,216	34	2.26	26
Coconut+Pepper	6,424	05	2.03	13
Coconut+Clove	7,191	17	2.13	19
Coconut+Cinnamon	7,633	26	2.35	31

(Source: Liyanage and Dassanayake, 1993)

Table 5.7. Effect of mixed cropping on soil fertility (0-15 cm depth)

Cropping System	Physical		Chemical				Biological
	Bulk Density (g cm^{-1})	Soil Moisture	Organic Carbon (%)	Total N (ppm)	Avail. P (ppm)	Exch. K (meq 100g^{-1})	Earthworms (no. m^{-2})
Coconut only (Control)	1.56	9.06	0.86	957	9.6	0.14	28
Coconut+Cocoa	1.26	18.55	1.42	1,184	29.4	0.18	214
Coconut+Coffee	1.23	12.91	1.36	1,022	27.8	0.15	218
Coconut+Pepper	1.27	11.20	1.27	1,461	55.9	0.12	191
Coconut+Clove	1.19	11.30	1.20	1,154	32.3	0.18	204
Coconut+Cinnamon	1.25	10.69	1.46	1249	28.9	0.16	233

(Source: Liyanage and Dassanayake, 1993)



(Photo: P.A. Huxley)

Fig. 5.8.
Acacia auriculiformis growing under coconuts to supply mulch/plant nutrients.

Table 5.8. Net income of coconut monoculture and coconut+rambutan multiple cropping system (Class-S_4 coconut land 6,000 nuts $ha.^{-1}$ $year^{-1}$)

	Coconut only		Coconut+Rambutan	
	Years 1-7	Year 7	Years 1-7	Year 7
A) Expenditure (Rs.)				
Materials	36,654	5,900	61,108	18,278
Labour	43,225	6,100	162,773	35,197
Total cost	79,879	12,100	223,881	53,475
B) Return				
Yield (no. of nuts)	43,225	6,175	43,225 (385,320)	6,175 (197,600)
Net Income (Rs. $year^{-1}$)	71,408	9,509	698,047	363,337
Net Income (Rs. day^{-1})	27.00	27.00	272.00	988.00

(Source: Gunathilake *et al.*, unpublished)

- *Economic benefits:* Among the major plantations crops in Sri Lanka (tea, rubber and coconut), coconut is the least income-generating crop. Tables 5.8 and 5.9 show that coconut monoculture does not generate a reasonable income for a grower. Multiple cropping with crops such as rambutan and

pineapple can provide a much higher income than monocropping (Table 5.8, Gunathilake *et al.*, unpublished).

Table 5.9. Profitability from different mixed cropping systems

Systems	Total Cost (Rs. ha.$^{-1}$ yr^{-1})	Total Income (Rs. ha.$^{-1}$ yr^{-1})	Net Income (Rs. ha.$^{-1}$ yr^{-1})
Coconut monoculture	3,125	9,292	6,167
Coconut/cocoa	9,866	44,856	34,989
Coconut/coffee	10,905	29,970	19,065
Coconut/pepper	12,607	76,743	64,136
Coconut/clover/banana	6,784	17,358	10,574
Coconut/cinnamon	6,565	23,545	16,980

(Source: CRI Annual Reports, 1982-1986)



(Photo: P.A. Huxley)

Fig. 5.9. Well-established, lightly pruned *Gliricidia sepium* in an old coconut plantation. This may be competing with the coconuts. Pepper was also being grown in this mixture.

PROBLEMS AND PROSPECTS

There are some constraints (Table 5.10). Coconut is not a labour-intensive crop and any form of multiple cropping demands a relatively high labour input. In the past, the generation of additional employment was a factor to be encouraged. However, at the present time the availability of labour is scarce and the high costs of wages is not compatible with profitable crop returns. A recent diagnostic survey conducted by CRISL (Somasiri *et al.*, 1993), has

revealed that risk and uncertainty (due to fluctuations of market price and droughts) also play a significant role as a constraint for the adoption of multiple cropping. Lack of knowledge and lack of marketing facilities can be significant additional constraints.

Table 5.10. Constraints for multiple cropping as expressed by growers in the Wet Zone (WZ), Intermediate Wet Zone (IMWZ), Intermediate Dry Zone (IMDZ) and the Dry Zone (DZ).

Constraint	WZ	IMWZ	IMDZ	DZ
		(%)		
No constraints	34.8	40.8	34.6	52.9
Risk and uncertainty	25.5	25.0	32.7	20.6
Lack of knowledge	11.2	5.8	9.6	11.8
Shortage of family labour	11.8	10.8	6.7	5.9
Lack of marketing facilities	6.8	8.3	1.0	2.9
Non-availability of planting materials	0.0	0.8	0.0	0.0
Other reasons	9.9	8.3	15.4	5.9

(Source: Somasiri *et al.*, 1993)



(Photo: P.A. Huxley)

Fig. 5.10.
Coppiced mulberry (*Morus nigra*) under test at the CRI, Lunuwila.



(Photo: P.A. Huxley)

Fig. 5.11. Experiment at the Coconut Research Institute, Lunuwila, to test the response of coconut to mulching with *Gliricidia sepium* being grown as an understorey and subjected to three pruning regimes.

Despite the problems, and considering the low productivity and poor returns from existing monoculture coconut plantations in Sri Lanka, there is a critical need to maximise the use of our land. Thus, a shift from the old monoculture system to new multiple cropping systems has become a national priority in order to satisfy the growing demand for food and other supplies caused by the rapidly increasing population in the major coconut growing areas. Since new land for further expansion of coconut culture is very limited, increasing the productivity of existing coconut plantations by multiple cropping can be seen as the most appropriate development strategy.

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6. Biology and Ecology of 'Multipurpose Trees': Some of the Things We Need to Know

P. A. Huxley

INTRODUCTION

The Nature of Multipurpose Trees

The trees and shrubs utilised in agroforestry are often called 'multipurpose trees' (MPTs); that is woody perennials that are purposefully grown to provide more than one significant contribution to the production and or service functions of the landuse systems that they occupy (Huxley, 1985). This term includes not only trees and shrubs but also palms, bamboo's and woody vines (Fig. 6.1). Before we look more explicitly into how we need to use such plant components in various agroforestry practices, the whole proposition of 'multipurposeness' needs to be examined rather more critically; especially if farmers are not to be misled and if tree selection procedures are to proceed along sound lines.

First of all, *every* tree, or other woody species, is potentially 'multi-purpose'. For example, if we plant a commercial forest tree by the house to provide shade, or we grow fruit trees that we intend, finally, to use for timber and/or fuelwood, these too are 'multi-purpose trees' (Fig. 6.2). To some extent multipurposeness depends on the time scale we use. Over a whole life span, a commercial forestry species grown for timber will supply poles and possibly firewood from prunings during the first part of its life span. So, in agroforestry, we mean something more - perhaps that *individual* MPTs will, or can, supply several products from the same tree within the same season? For example, fuelwood *and* leafy fodder, timber *and* extractants (gum/resins), fruit *and* leafy shoots to provide residue for mulching, and so on? Certainly there are some MPT species that can do this readily. We can call these 'obligate' MPTs, and good examples are palm species; perhaps also species like *Leucaena leucocephala* and *Gliricidia sepium*. However, most species will be

'facultative' MPTs. That is although structurally and functionally they can, over their life span, be made and or encouraged by suitable management techniques, to produce several different products, they are, at any one time, best suited to produce only one. Obviously, some species will be better able to provide particular service functions than others because of, say, their height or form. In some cases we may choose nitrogen-fixing species (Giller and Wilson, 1991).



(Photo: P.A. Huxley)

Fig. 6.1.
Trees, shrubs, palms, bamboos and woody vines are all included in the term 'multipurpose tree'. Rattan palms, such as these growing by the roadside, are commonly found in Sri Lanka and they are a valuable plant resource.

There are well over two thousand proposed MPT species (Burley, 1984). Many of these are thought to be out-crossing and therefore very heterozygous (Fig. 6.3). Mostly they are selected at the species level and only a few, again *Leucaena leucocephala* is a good example, have undergone selection and breeding. However, naturally occurring genetic segregation within-species ('provenances') is an important issue because of genotype x environment interactions. Some species are easily propagated vegetatively,

usually from stem cuttings or stumps but sometimes from root suckers (e.g., *Gliricidia sepium*, *Erythrina* spp.), others only from seed *(Azadirachta indica*, *Grevillea robusta*, *Casuarina* spp.).



(Photo: Oxford Forestry Institute/University of Peradeniya Link)

Fig. 6.2.
Jak or jackfruit (*Artocarpus integrifolia*) - a most important multipurpose tree used for food in many ways and providing a good timber. It is a variable species that offers considerable scope for both genetic improvement and intensified management.

Requirements for Agroforestry

So what do we need from MPTs in agroforestry? Certainly, a much wider spectrum of attributes for different purposes in different kinds of agroforestry practices than is usually needed in commercial forestry. We need MPTs in a whole variety of different sizes and shapes, for example, tall or short trees in amongst crops, trees for windbreak components, woody species for hedges, and so on. They have to be cheaply and easily propagated and to have good 'survivability'. Species grown to provide leafy fodder pose a particular dilemma because, to do this they have to be palatable but, if they are palatable they will be at risk when they are first planted out. An appropriate level of

vigour is very important[†] , and they have to be easily managed for particular purposes. Obviously, freedom from pests and diseases, especially those that could be transmitted to adjacent crops, is also an important issue.



(Photo: P.A. Huxley)

Fig. 6.3. Woody plants often show prolific flowering as with this specimen of *Croton macrostachyus* growing at ICRAF's headquarters. This species is bee-pollinated. A large majority of MPTs are outcrossing and, therefore, a high degree of genetic variability is to be expected.

A question that farmers often ask is "What type of species should I use?", or "Is there a better tree than the one I am using now?". Before we can answer questions like this from a biological point of view, it is obviously necessary to establish exactly what the farmer's objectives are, what resources are available, and what are the constraints and potentials in working the land in that way? Answers to such questions can be found through 'Rapid Rural Appraisal' methodologies; for example 'ICRAF's 'Diagnostic and Design' procedures (Raintree, 1987). However, the outcome of such an exercise is usually a substantial 'wish-list' of characteristics that the suggested MPTs should have and, at this stage, it is important to realise that these are sometimes biologically infeasible! For example, it is not possible to maximise production of both woody parts *and* fruits at the same time. Wood arises from stem cambia and fruits from fruiting meristems, which actually *compete* within the plant for resources (i.e. assimilated carbon, nutrients, etc.) (Cannell and

† See 'Agroforestry: Some Functional Aspects', this volume.

Dewar, 1994). Again, removing leafy shoots, for example, for use as fodder, will limit photosynthesis and reduce the activity of stem cambia and so reduce the amount of wood that any such tree will produce, and so on. Of course, by being very skilful and experienced, it is possible to manipulate a tree so as to provide several products in roughly the proportions we may require, for example, *some* fruit, *some* wood, *some* leafy shoots for mulch, etc. However, such a tree will not be using environmental resources optimally. What is much better from a biological point of view, and simpler, is to grow trees singly or just in small groups, and manage each of them so as to concentrate on providing a single main product. This certainly requires relatively less management skill, and each tree or group of trees will be operating more efficiently.

The Real Meaning of 'Multipurpose Tree'?

There is, of course, another option. An individual tree species may have the biological capacity to produce several products depending on how we arrange and manage it, but it does not have to do so all at the same time. From a farmer's point of view this is a valuable attribute because it means that he can convert his system so as to supply other products if, as and when they are required. For example, he may plant up an agroforestry plot mainly to supply fuelwood, but convert it later (perhaps by also planting grass between the trees) into a fodder production unit, and do this *without having to dig out the old species and start all over again*. The perennial woody structure offers this eminently useful facility. Clearly, the original planting design needs to have this in mind. Thus the term 'multipurpose' implies an intent or opportunity rather than describing necessarily, a current state.

Categorising Multipurpose Trees

Functional Types

Trees can be classified in many ways, for example according to above-ground shape, or architectural form (Barthélémy *et al.*, 1989). Generally, in

agroforestry, this is not nearly sufficient for our purposes, however; although such schemes can give a general indication as to shape and branching behaviour. Because we are growing MPTs next to crops or in grassland we have to categorise them, ultimately in terms of both above-ground and below-ground attributes (Fig. 6.4). Terms such as 'fast' or 'slow-growing', or 'shallow' or 'deep rooting', 'evergreen' or 'deciduous' are commonly used, but they are too broad and unreliable to be of much use. We need to be able to define sets of attributes in considerably more detail than this, and particularly to be able to specify those aspects that combine characteristics of both form and function. That is we need to describe 'functional types'.



(Photo: P.A.Huxley)

Fig. 6.4.
This *Trema orientalis* is a 'pioneer' species (it establishes itself quickly in disturbed forest sites). Seen here at the Neo-synthesis Research Centre's Analog Forest at Mirahawatte it has been planted as part of the early stages of the 'forest'. Comprehensively describing the physiological as well as morphological features that are required from MPT species in the form of 'functional types' is essential if we are to classify them in a useful manner. We are still clarifying the necessary characteristics both above and below ground.

Foresters and agriculturalists already use this concept. For example 'pioneer' and 'climax' tree species can be readily identified in forests. Agriculturalists use the term 'catch crops' to describe short cycle crops that will fit between two maincrop species. Such descriptions carry along with them not one but a

number of attributes. However, even descriptions which identify 'tree temperament' (Oldeman and Van Dijk, 1992) in ways that can be helpful to those studying forest dynamics, are not in themselves so useful for agroforestry situations.

This is not a straightforward task and we still have to assemble sets of attributes that are meaningful, in both biological and practical terms, that will serve to categorise the large number of multipurpose trees that are available for agroforestry purposes. In Sri Lanka, *Gliricidia sepium*, introduced many years ago, is well-accepted as a species suitable for hedgerow, boundary and barrier plantings[†] . So that if we now wish to look for other species to use for these purposes then we need to analyse, critically, what *whole package* of attributes it is that *Gliricidia sepium* provides that makes it suitable for these purposes. So far such lists are far from complete; and they tend to deal, rather superficially, with aspects of form rather than function.

Relating form to function in agroforestry is not easy (Huxley, 1996) because there are so many attributes to consider and the *interactions* between the plant components is always a potential source of limitation that has to be borne in mind. Nevertheless, if we try to relate form to environmental resource capture and environmental resource utilisation abilities then we can begin to add a new dimension to other important and more easily-seen attributes that are currently our limits(e.g., such as thorny or not-thorny, vigorous or non-vigorous, deep or shallow-rooting). This means that we have to delve very much more deeply into the behaviour (phenology), rooting characteristics, flowering and fruiting behaviour, types of meristems, and the likely activity of these under different management regimes, than we have done before. This is a complex but necessary task. However, we do know enough to make a start.

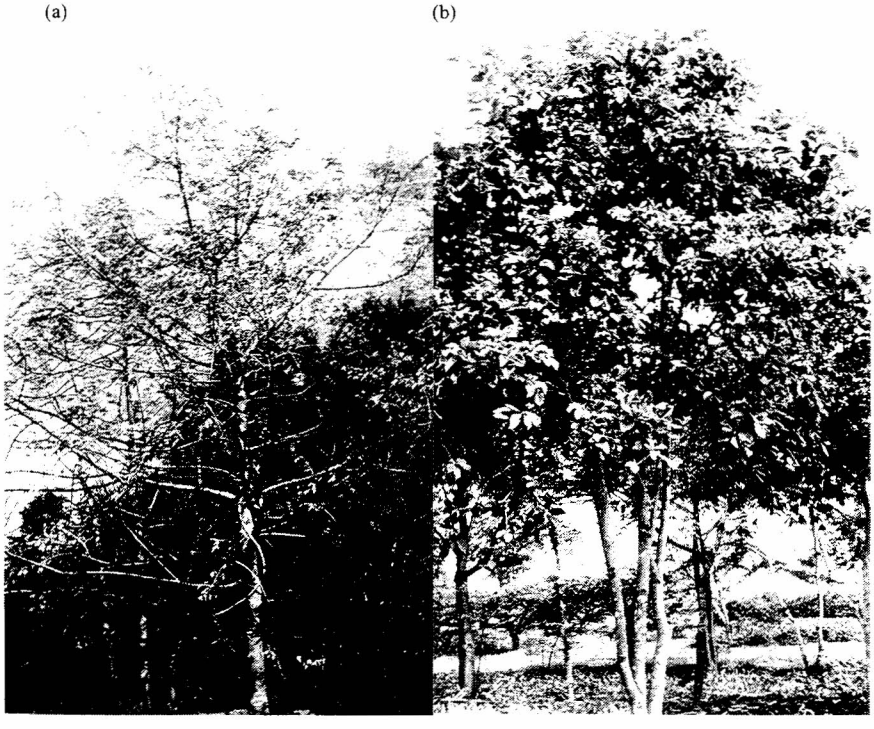
Two of these issues are worth considering here in a little more detail because they are central to the interactive nature of woody perennials in agroforestry systems. These are plant behaviour ('phenology') and roots.

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† See 'Sloping Agricultural Land Technology', this volume.

PHENOLOGY

I have mentioned the importance of plant behaviour earlier and now, perhaps, we should look at the reasons more closely. First, in its natural habitat, a woody species will have evolved a 'strategy' so as both to make the best use of the climatic conditions in which it finds itself and, also, so as to compete and/or survive among its naturally-occurring associate species. Thus one finds an incredible range of flexibility with regard to periods of vegetative growth, times of flowering, a leaf fall, etc. expressed by woody vegetation, especially in the tropics (Huxley and Van Eck, 1974) (Fig. 6.5).



(Photos: P.A. Huxley)

Fig. 6.5. The growth, flowering and fruiting behaviour of tropical trees can show a remarkable degree of within and between season variability, both within and between species . Marked phenological differences are shown here for 4 species photographed on the same day in January (dry season) at ICRAF's Field Station, Machakos, Kenya: (a) *Melia volkensii*, mainly deciduous and dormant and (b) *Terminalia brownii*, leaf-retaining and beginning to 'flush'. (Also see following page).

(c)



(d)

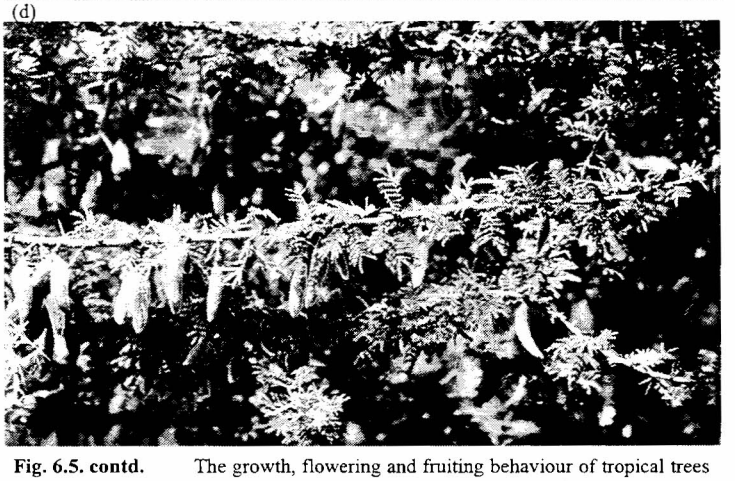


Fig. 6.5. contd. The growth, flowering and fruiting behaviour of tropical trees can show a remarkable degree of within and between season variability, both within and between species. Marked phenological differences are shown here for 4 species photographed on the same day in January (dry season) at ICRAF's Field Station, Machakos, Kenya: (c) *Samanea saman*, actively growing vegetatively, and (d) *Acacia stulmanii*, leaf-retaining, vegetatively dormant but covered with maturing fruits. (Also see preceeding page).

If we know about the likely behavioural pattern of a particular species in its centre of natural distribution it provides us with clues as to what to expect when it is moved to another climatic environment (Huxley, 1983) (Fig. 6.6). For example, if in the new environment it does not 'behave' so as best to take advantage of suitable periods in which to capture light and water resources, then we can take it that it is poorly adapted. There is no need to

wait for a long-term result measuring biomass growth. This does not mean that an adapted woody species will conform *exactly* to the behavioural pattern that it expressed in its original environment, rather that it is seen to conform to its new one. Secondly, it is possible to modify the phenology of any woody species through management. This can be done particularly by pruning, but also by irrigation and the application of fertilisers. Fruiting also affects subsequent vegetative growth so that de-fruiting is another management tool. This capacity to 'entrain' the behaviour of woody species so as to get them to grow, flower and fruit at times that are different to when they would do naturally is important in, for example, manipulating harvest times (e.g., so as to obtain fruit when prices are higher). However, in agroforestry it takes on a new dimension because it is another way in which we can manipulate the interactions between the woody and non-woody species and so diminish competitive effects.



(Photo: P.A. Huxley)

Fig. 6.6. Although matching climates and soils can assist with the initial selection of suitable MPT species many possess a degree of phenotypic plasticity that enables them to do well outside the 'expected' range. These young *Acacia mangium* trees have survived well on this dry slope (in Costa Rica) when other species, apparently better suited, failed.

So far phenology has been given scant attention in agroforestry research and we need to establish not just descriptive but quantitative ways in which we can measure the way genotype and management result in different behavioural patterns (Akunda and Huxley, 1990). All this ties in very well

with the structural attributes of our MPTs because, for example, removing a shoot apex as we do when pruning a hedge for fodder, results in quite a different response depending on the species. This is because both the number and the nature of the buds in the axils of the leaves down the shoot are likely to be different. Depending on the season at which we carry out the operation different numbers of buds will sprout, and they may do so after a delay that can vary considerably in duration. It is in studying such 'simple' relationships between form and function that we can begin to understand how best to manipulate our multipurpose tree species so as to provide what it is that we require.

Roots

Roots and the Woody Habit

Another key area in which MPTs need to be categorised is in the nature of the root system and, especially, the ways in which rooting occurs[†] . Again, not just in relation to form but with regard to the implications for functional ability. Although the ways in which the roots of annual and perennial species grow are very similar, the root systems differ considerably. Once again, the possession of a woody structure confers certain advantages. It can function as a storage organ, and it enables new roots growing at the beginning of a climatically favourable season, to be spatially well -orientated in the soil so as to take advantage of available nutrient and water resources; perhaps, by 'pre-empting' their uptake by adjacent crops or grasses.

All root systems can be greatly modified by climate, soil conditions, plant management and the influence of adjacent plants; although their overall growth pattern will, essentially, be controlled by the characteristics of any particular species (Atkinson, 1991). We have to remember that, although the roots of a certain tree species may be *potentially* deep rooting, this does not necessarily mean that they will be so in practice. An interesting but invariably unanswered question, with significant implications for agroforestry

† There are several publications on how to examine roots and root systems in soil; see Bohm, 1979 and Mackie-Dawson and Atkinson, 1991, for example.

intercropping situations, among others, is "Do plants really need all the roots they produce?". Plants tend to adjust their root : shoot ratio so as to diminish the overall size of the root system in fertile, well-watered soils. Certainly, plants kept under experimental conditions which have had large portions of their root systems removed have remained healthy and continued to grow vigorously. The same applies to trees grown outside that are root-pruned from time to time. However, this does not tell us very much because removal or either root or shoot is followed, in due course, by differential growth to re-establish the relationship between the parts that existed before. Furthermore, short term experiments to examine changes in rates of nutrient uptake, for example, disregard all the other important functions that roots have. That is, in conferring structural stability, producing hormones, such as kinins, that are essential for shoot growth regulation, carrying out the chemical transformation of organic compounds from and back to the shoots, as well as the storage of organic compounds, and so on.

Because they are exploring a relatively small volume of soil, young trees that are becoming established are more likely to suffer from water and nutrient shortage than older ones, where the volume of soil occupied is not only larger but contains many parts not yet filled with roots, or where previous 'root modules' have died out. As young trees grow and their total nutrient requirement increases, the entire volume of soil occupied by roots, or root clumps will increase but, as Fig. 6.7 illustrates, it is only necessary for the root system to increase in radial extent by the cube root of 2 in order to double the soil volume occupied.

When trees are raised from seedlings the initial main structural roots are usually derived from earlier-rising primary seedling roots but, perhaps depending on how deeply the young tree has been planted, some roots can arise from the transition zone; i.e., the part between the stem and the root proper. There may well be a case for encouraging this to happen, for example, by sunken planting (von Carlowitz and Wolf, 1991). In practice, the architectural plan of tree and shrub roots can often be divided into three parts which are related to function to some extent: a pattern of main surface roots providing some stability and, as this is usually the site of maximum soil

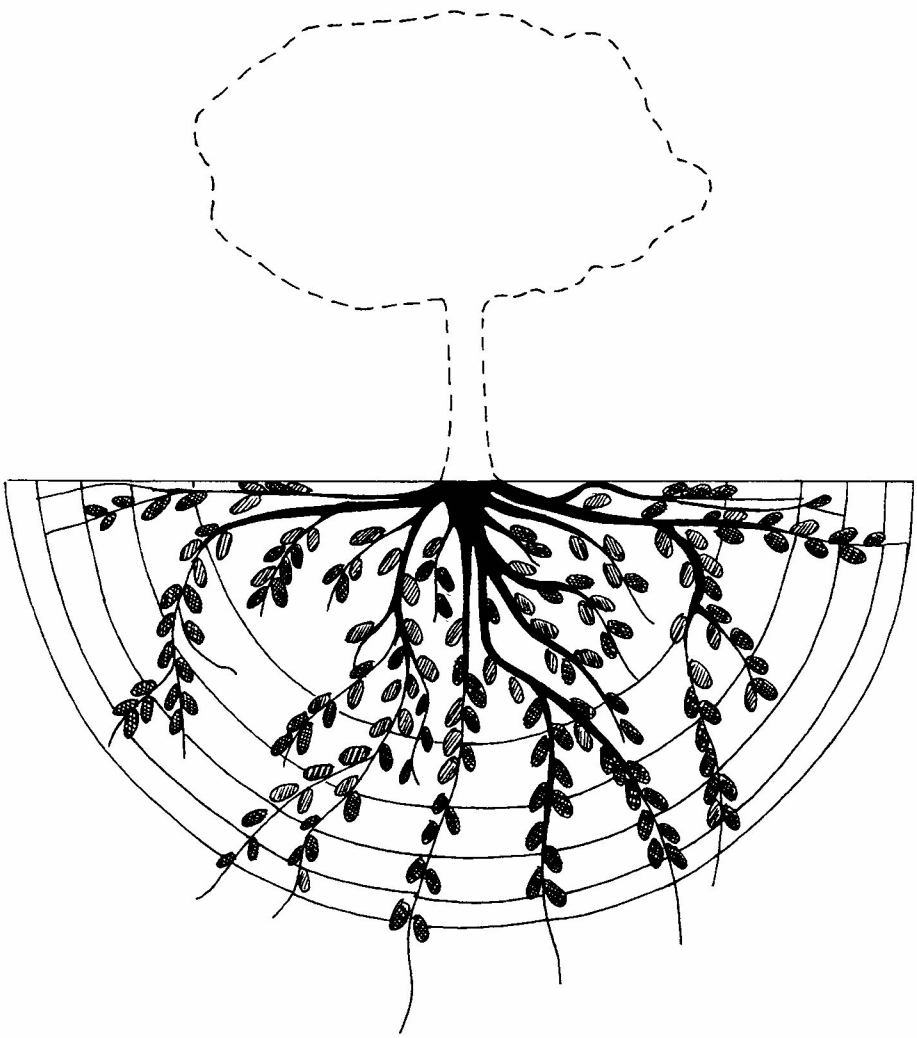


Fig. 6.7. The root system of grasses and annual crops tend to fill the soil profile with small roots ('fine' or 'feeder' roots), but many woody perennials have 'clumpy' root systems that can leave parts of the soil profile unoccupied at any one time (Huxley, 1994). Characterising the root system of MPT species and understanding more about how below-ground environmental resources can be shared is a key element in current agroforestry research (Source: P.A. Huxley).

fertility these roots access most nutrients; some diagonal structural roots growing into deeper soil horizons; and one or more verticals which may, or may not include the original tap root. Because the lower soil strata are very unlikely to contain large amounts of plant nutrients compared with the top soil

the main season-to-season function of these deep roots is almost certainly to do with maintaining a water supply. Only in the long term will the supply of nutrients from deeper soil zones contribute much to the nutrition of the tree (and thereby, through its plant residues, contribute to improving the fertility of the top soil). Of course, the acquisition of nutrients 'gleaned' from several metres depth of soil and deposited in a few centimetres of top soil can be well worth having, but we do need to be cautious about the time scale needed to move significant quantities of nutrients from lower to upper parts of the soil.

When tree roots first grow they produce 'long' roots which occupy the soil volume without, necessarily, branching very much. These may form part of the main structural system or they may branch and form clumps or 'modules' of fine roots. When these form there is still, often, and depending on species, considerable volume of soil left unoccupied. The extent of the empty spaces will depend, also, on how closely planted the trees are to one another, for example, in a hedgerow system these clumps or modules may be less apparent after a few years and the soil may become completely filled with roots. However, one can see that woody species that form 'clumpy' root systems may be more compatible with associated plants than those which tend to fill the soil volume completely.

Another issue that has emerged in recent years is that of 'fine root turnover'. Mainly working with north temperate conifer species it has been shown that a considerable part (sometimes up to 60%) of the carbon assimilated in any one year in a tree may go below ground, and a large proportion of this will be found in the fine roots which eventually die and release organic matter into the soil. This source of plant residue material below ground can be as much as that deposited by leaf litter above, or even more.

Clearly, we still have much to learn about the way different species form patterns of fine roots in soil, and about their persistence. Again, such characteristics will determine growth ability and competitiveness and thus help us define 'functional types' more precisely.

Relating Above- and Below-Ground Activity

Another area in which we lack information concerns the relationship between events happening above and below ground. Annual plants have a close synchrony between root and shoot growth, but, if we are to understand fully how below-ground resources are shared between trees and crops then it is essential to know about the times at which tree root activity takes place and relate it to the phenology of the above-ground parts, as well as to what the crops or grasses are doing. The apparently 'erratic' behaviour above ground of many tropical trees makes this even more essential.

It is beyond the scope of this contribution to compare different ways of investigating roots and root systems, but two methods (i.e. root trenching and mini-rhizotrons) are increasingly being used to study multipurpose tree species. The first is simply exposing a trench face dug in a transect across an appropriate part of tree or hedge root system and counting the number of roots exposed using a grid on the trench face. The second involves sinking a glass or plastic tube in the soil and using an optical device so as to observe the roots that come into contact with the transparent wall; both have their problems. Neither method is quantitatively accurate and if root weights, or better still 'root length densities', are required this is normally done by augur-sampling and washing out the roots. Competition between different root systems is sometimes explored by putting vertical barriers between them (Ong *et al.*, 1991).

Mycorrhizas

Finally, we need to remember that roots and mycorrhizal fungi are often associated. Such mycorrhizas can be expected to increase both water and nutrient uptake (e.g., Janos, 1987) and, as fungal hyphae are extremely fine, and can ramify extensively through soil, they can effectively form an additional resource capture system. We are still only just beginning, however, to explore the seasonal changes in the extent and efficiency of this form of symbiotic association.

CONCLUSIONS

It is because we use woody plants in so many different ways, and for so many different purposes in agroforestry that we are forced to review our knowledge of how such plants 'behave'. When we come to categorise them we find that classifications used in other forms of landuse, or from botanical studies, are inadequate. So we need to derive a set of 'functional types' that fit our purposes, and which, because of the other plant associations, and the need to always bear potential competition or complementarity in mind, will relate form with function and take into account the relationships between above- and below-ground activities. This task still remains to be done.

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7. Sloping Agricultural Land Technology (SALT)†

A HARMONY WITH NATURE

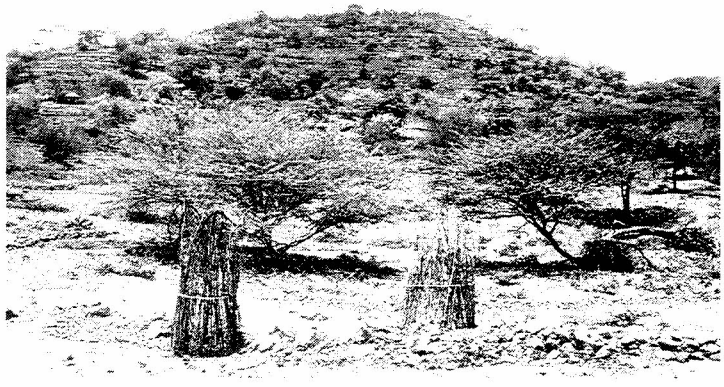
"For thousands of years the people of Sri Lanka have lived in harmony with nature. They farmed the land and enriched the soils with the natural fertility of trees to give a cycle of continuing regeneration. This was a cultural system that blended beautifully with the tropical climate through alternating dry and wet seasons. This agriculture was *sustainable* through a blend of 'lowland' farming with 'highland' farming. Rice, from China, has adapted well and weeds were kept out using large quantities of water. Yields from this system are today, supplemented by the use of chemical fertilisers. The agriculture of the highlands was originally tree farming. Species such as breadfruit, jak, coconut and bananas formed effective canopies with their large leaves.

In these systems, too, hardly any weeds emerged and those that did were smothered by the fertility-providing leaves that fell and protected and mulched the soil.

In order to cultivate seasonal crops such as beans, maize or kurakkan a farmer would lop the side branches of the trees to let the sun shine through. The main trees were left to sprout new foliage and regenerate with time. There was no machinery to disturb the soil - it was already friable and free of weeds - all that had to be done was to dibble seeds into the mulched soil and wait for the crops to grow with the onset of the rains. After two to three seasons the farmer moved away to another suitable plot, leaving the forest to renew itself. A form of shifting cultivation that has proved itself an effective form of sustainable landuse in low-populated forested areas world-wide. Any burning of the forest in this system of 'chena' cultivation was very slight, just enough for the crop to grow. It was an efficient system of natural regeneration as long as population pressures on limited land and resources did not draw the farmer back to the first plot before it had time to regenerate fully.

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† Extracted verbatim from a video presentation provided by the Ceylon Tobacco Company.



(Photo: P.A. Huxley)

Fig. 7.1.† This eroded hillside in Baringo District, Kenya, has been 'rescued' using simple conventional soil conservation methods (stone bunds and cut-off drains). Elsewhere in Kenya terrace-forming is usually done by digging a trench and throwing the soil uphill ('fanya juu'), but it is costly in labour. Tufted grasses (*Panicum maximum*) are often planted on the terrace risers and trees, and shrubs can also be put there. The 'Sloping Agricultural Land Technology' has not yet been adopted so widely in Africa as it has in Asian countries.

New Crops and New Ways

Then the commercial crops such as tea, tobacco, cotton and potatoes arrived with the adoption of land-clearing practices and tillage for weed control, practices common in western countries - machinery for managing weeds, fertilisers for restoring the soil. The cultivation of rubber was the closest form of agricultural landuse to the natural forest and it has, therefore, proved the most sustainable. Rubber lands are invariably covered by a soil-protecting mulch, giving protection against the rain. By contrast coconut has proved to be only partially sustainable; its substantial requirements for potassium (K) and Magnesium (Mg) deplete the reserves of these minerals in the soil, which then need to be supplemented. The needs of the coconut palm for the essential element nitrogen are largely supplied through cover crops such as *Pueraria* spp. which keep the soils moist and protect it from erosion. Intercropping in this way helps recycle fertility and manage weeds.

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† Figs. 7.1 - 7.3 show some conventional methods of soil and water conservation for comparison.



(Photo: P.A. Huxley)

Fig. 7.2.
Another hillside, but in Sri Lanka, with the same erosion measures as in Fig. 7.1. Here terrace risers are likely to be faced with stones eventually.

The management of weeds and the maintenance of fertility represent the two most critical elements of productivity for the tropical farmer and, indeed, of farming anywhere. The clean-weeding system of farming which accompanied the introduction of tea plantations was, indeed, a tragedy. What superficially appears as a fine cover of tea bushes is revealed as bare land weeded clean beneath. These bare and scraped soils quickly erode down the steeply-sloping hills with every shower of rain, together with their reserves of fertility. Losses in the order of 100 t $ha.^{-1}$ of fertile soil each year, are common place, flowing as a thick, reservoir-congesting mud down the rivers into the sea. A colossal waste of resources!

Open-field clearing with modern machinery was also encouraged as 'modern' with the rich and fertile vegetation bulldozed into lines and then destroyed with a vicious burn. Land thus cleared had lost its cover of trees and the fertility inputs from leaf mulch. Sri Lanka became totally dependent on imported fertilisers and upon tilling soil which blew in the July/August winds

and was eroded in the September/October rains. With the declining fertility yields had dropped to less than 2,000 kg ha.$^{-1}$ of made tea. Tobacco, which was grown on former tea lands, has also declined drastically in yield, and added fertiliser has had little effect.

Revisiting the Past

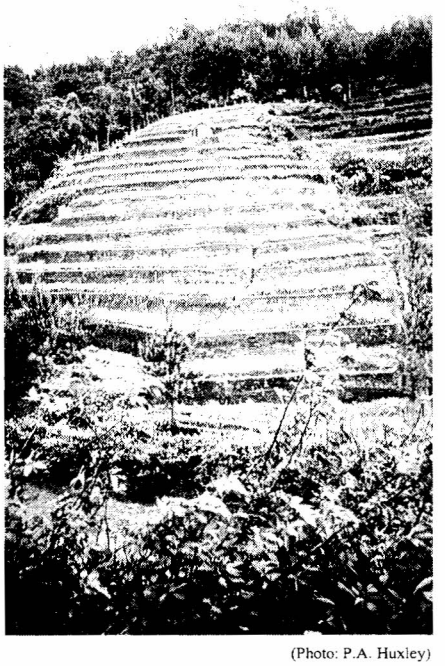
A farming technology was desperately needed that brought the trees and shrubs back to their time-proven role that kept the soil well covered against the extremes of sun and rain. Tea and tobacco growers, as the two largest users of the chena uplands, needed to re-evaluate their farming practices and re-evaluate they did, with heartening results. While it was not feasible to return to the practices of the past, the same sound principles could be revived. Fast-growing nitrogen-fixing trees are grown in twin hedgerows along contoured hillsides (each four to five metres apart) to serve as filters and barriers against further erosion, and against which new terraces can develop. The hedgerows are lopped periodically, perhaps once each month or two, and the mulch laid over the soil in the avenues between them; thus recycling fertility and protecting the soils against erosion. Further, it also provides protection against weeds. This is a well-proven practice† called SALT (Sloping Agricultural Land Technology). It applies nature's own way of recycling fertility, or managing weeds, by the smother of the mulch and the shade of the trees, rather than by tilling and exposing the soil to further erosion.

Sri Lanka's Department of Agriculture recommended this approach in the 1930s, but lost momentum to powerful commercial interests whose profits lay in the sale of fertilisers and machinery for tillage. Now, with renewed interest in and commitment to the natural low-cost method, SALT is gaining ground, and is being successfully applied both in the growing of tea and tobacco. For example, tea lands on which new clones were to be planted were usually left seriously exposed, as even the prunings and roots from the old plants were removed. But such fields need to be protected quickly, both by the planting of bana grasses *(Pennisetum* spp.) to help bind the soil, as well as by the creation of hedgerows as permanent barriers that can still permit heavy

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† *Originating in the Philippines.*

rainfall to infiltrate cleanly through. A range of hedgerow plants is under evaluation under different agroclimatic tea-growing conditions. The method in Sri Lanka, is to plant the tea bushes in rows about one metre apart and to have four to five rows of tea between a pair of hedgerows. All the bana grass is lopped and laid as a soil cover and around the newly planted tea bushes to keep them cool and moist. Shade trees are also planted to help shelter the young tea as it grows to maturity. Using this system new clones of tea have come into plucking a year earlier than is usually expected. The moisture and fertility provided by the mulch and hedgerow loppings have changed the economics of tea growing.



(Photo: P.A. Huxley)

Fig. 7.3.
Well constructed stone terraces for vegetable growing near Nuwara Eliya. An excellent but costly form of soil conservation.

For tobacco farmers the results have, likewise, been dramatic. One can see on steep hillsides that were formerly tea lands a clear contrast between bare land in one part and the well-established plots of those who have progressed to SALT on the other. Lush hedgerows already reflect the

improved crops of tobacco growing in such areas, and there will certainly be improvements as more biomass becomes available from increased lopping of the now-maturing hedgerows. Farmers are becoming keen to protect their lands and provide improved yields of crops that grow with tobacco, such as kurakka, soya and maize. They are not just tobacco farmers but farmers who grow a *variety* of crops in which tobacco is just one in the rotation. Barren hillsides, with about 100% gradient, have been restored to the productive farming of both seasonal and permanent crops. These farmers are proud of their achievements and have hopes for the future.

THE DADYAMPOLA EXAMPLE

In one trial area (Dadayampola), chena ('slash-and-burn') cultivators usually cut the shrubs in August and maize and karukkan are sown in September with no soil conservation. At the end of 1989, however, the Ceylon Tobacco Company (CTC) approached 90 such cultivators and, by arrangement, promised them all the use of 0.5 to 1.5 acres, of mostly crown land. A meeting was held to explain the potential benefits of soil conservation through SALT and farmers were co-operative. The land was very steep and not suitable for living on or farming, so conventional soil conservation ideas were not promoted (Figs. 7.1 to 7.3), but it was thought that they could try SALT. The Janasaviya† were the ones approached and these are now successful farmers.

First of all the entire area was surveyed and 0.5 and 1.0 acre plots were allotted according to the size of their previous plots. Twin rows of *Gliricidia* were planted on the contours from cuttings (Fig. 7.4 & 7.5); each contour was 5 metres apart and the two rows were 0.5 metres apart (Fig. 7.6). Any trash was stacked behind the hedge (Figs. 7.7) and branches were lopped when the bushes had grown and the soil enriched thereby. In this area coconut was also planted, and every third contour had coffee and pepper; the other two grew banana, maize, kurakkan, chillies and vegetables such as brinjals beans and cabbage. Tall *Gliricidia* was left every ten feet to be used for climbing pepper,

† See 'Agroforestry in Sri Lanka: An Overview', this volume.



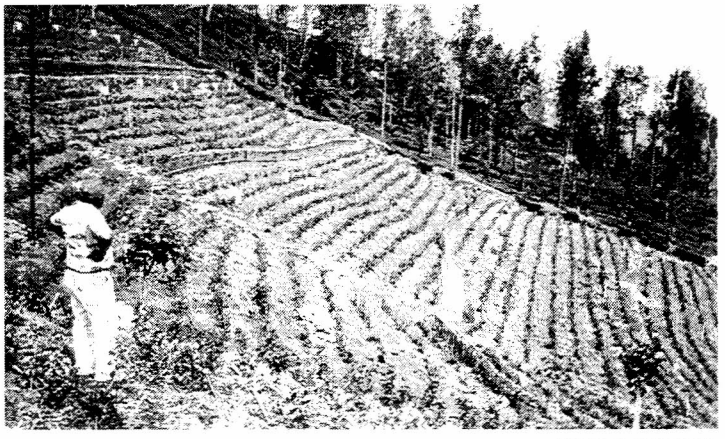
(Photo: Ceylon Tobacco Company)

Fig. 7.4. Two rows of *Gliricidia sepium* cuttings with vetiver grass (*Vetiveria zizanioides*) in-front of the terrace (right), and trash uphill behind the *Gliricidia* (left).



(Photo: P.A. Huxley)

Fig. 7.5.
Bundle of stakes of *Gliricidia sepium* being rooted to supply material for new hedgerows. This plant roots freely from hardwood cuttings such as these. Double-row hedges are planted, the rows being 0.5 m apart and, depending on the slope, the double hedgerows may be 5 m apart.



(Photo: K. Rajapalese)

Fig. 7.6. Barrier hedges, 5.0 m apart, in a SALT initiative in Dyraba, Sri Lanka.



(Photo: P.A. Huxley)

Fig. 7.7. Plant residues are stacked behind the hedge (upslope) to help trap water.

and also strips of *Acacia* were planted above and below a road in this area in order to prevent erosion.

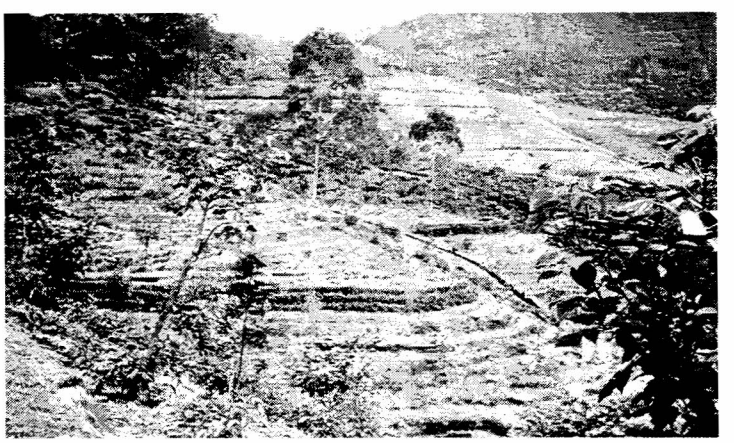
Farmers also used vetiver grass *(Veteveria zizanioides)* (Fig. 7.8). Bamboo has been planted in the ravines and cover crops were planted on eroded banks. Farmers were paid for planting work; for example, when they planted coffee and pepper and bananas and dug pits. They were also paid for planting the hedges. CTC is now planning to provide water so that people can

construct houses. In this particular scheme, some 125 acres of hilly terrain is now being farmed sustainably by around 100 farmers (Figs. 7.9 & 7.10).



(Photo: P.A. Huxley)

Fig. 7.8.
Vetiver grass *(Vetiveria zizanioides)* is also used to hold terrace fronts secure. It is tufted, and so does not interfere too much with cropping on the terrace. It also roots deeply (see hand)



(Photo: K. Rajapalese)

Fig. 7.9. Established barrier hedges of *Gliricidia sepium* in foreground, and newly-planted hedges (on slope in mid-distance).



(Photo: H.M.C.A.B. Helarawa)

Fig. 7.10. Barrier hedges integrating several species including *Acacia auriculiforma* and *Gliricidia sepium*. The hedgerows are lopped for use as mulch.

SALT WILL PROVIDE LAND FOR THE LANDLESS

This modern practice is a return to traditional methods to preserve the soil and its fertility which will yield a rich dividend if the system is more widely applied. It will save the irrigation systems from being clogged with sediment and help reduce the money spent on expensive, imported fertilisers. In effect, SALT is a return to an old, well-established method of soil preservation and fertility maintenance that has sustained the nation for thousands of years. It's adaptation and application to Sri Lankan agriculture, in the form of the initiatives taken so far, have proved that the practice *can* yield results.

SALT has transformed whole areas that have been ravished through open-farming systems. It is the meaningful way of giving land to the landless, it teaches them to restore and renew the land while making it yield. However, there are many thousands of acres of our land which yet need to be restored and the technology now has to be applied on a bigger scale. The tobacco industry has adopted SALT and will farm responsibly. Likewise the tea industry is adapting the system widely to bear truly substantial and highly profitable results. A wider application of SALT is now called for."

Editors' Note: Readers who are interested in the technical aspects of Barrier Planting may wish to refer to:

Kiepe, P. and Young, A. (1992) Soil conservation through agroforestry: experience from four years of demonstrations at Machakos, Kenya. In: Hurmi, H. & Tato, K. (eds.), *Erosion, Conservation and Small-Scale Farming*. Geographica Bemensia; Berne, pp. 303-312.

Kiepe, P. and Rao, M.R. (1994) Management of agroforestry for the conservation and utilisation of land and water resources. *Outlook on Agriculture*, **23**, 17-25.

8. Community Participation in Agroforestry

G. Wickremasinghe

THE BACKGROUND

Community participation is an approach that is receiving attention across the globe, and one that marks a departure from the 'catching up', 'top-down' orientation which characterised the cultural dimension of the modernist perspective of development which was in vogue in the 1960s. Consequent upon the disappointments, and the attendant critiques that emerged in the late 1970s, when each different landuse discipline developed its own science, the 'ecological perspective' became seen in the 1980s as a way forward in terms of which "it is impossible to see food production as distinct from forests, water and animal systems" (Shiva, 1989).

The need to address and re-evaluate our approach to landuse has been forced on us by the environmental 'alarm bells' set ringing by the force of rapidly expanding populations, but there are different ways of viewing the problems and resolving the needs. One is to suggest curbing excessive demands which the increasing populations in the third world countries are shown to be making on the environment; another to propose that it is the dominant development model which is to be blamed, since it has had the effect of alienating many people from nature, whilst simultaneously marginalizing others who were not incorporated into the process of development. Yet others point at the need for some sort of amalgamation of these two perspectives, suggesting that it is both possible and desirable for modern scientific approaches to be implemented in close collaboration with indigenous knowledge systems (e.g., Walker *et al.*, 1994). An alternative is to break away totally from the Cartesian view of the world, which is reductionist and foreign, and 're-invent' the all-inclusive and holistic philosophy of life which is indigenous to civilisations such as ours. This approach is based on respect for diversity and, as such, it can provide de-centred or 'stand-alone' models of

agroforestry. Forestry, on the other hand, is integral at the large scale with other major land uses such as crop and animal husbandry.

Against this background, the purpose of this paper is to examine the concepts associated with community participation in agroforestry for sustainable development, and comment on both the potentials and the limitations of these concepts.

AGROFORESTRY, COMMUNITY FORESTRY AND SOCIAL FORESTRY

Agroforestry: The Missing Part of the Definition

As a term 'Agroforestry' is relatively easier to understand than 'Community Forestry' or 'Social Forestry', although these are frequently found in literature on forestry-related development, particularly in the past few decades[†] . A layman's understanding of modern-day agroforestry is that of growing various types of trees on farmlands in a way that is based on age-old practices but adapted to enhance and retain farm productivity though mixing compatible woody and non-woody species. It is not too distant from current technical definitions; as Dr. Huxley points out elsewhere in this volume, the interactions are the most fundamental aspects of the concept. The following definition illustrates the point:

"Agroforestry is not simply the sum of agriculture and forestry it is a collective name for landuse systems and technologies in which woody perennials (trees, shrubs, bamboos) are deliberately grown on the same land management unit as agricultural crops and/or animals, either in some form of spatial arrangement or in a time sequence, and in which there are both ecological and economic interactions between the woody perennials and the other components of the system" (Baumer, 1991).

Such a definition is technically comprehensive, and one which seems to have found acceptance (Lundgren 1987: Gregersen *et al.*, 1989). However, it entirely misses out the *human* dimension, and fails to suggest how

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† See 'Agroforestry: An Overview' and 'Issues in Agroforestry Development in Sri Lanka', this volume.

agroforestry is to be implemented. Agroforestry development need not be limited to 'Social Forestry' programmes (see below) because agroforestry can be conducted at various levels of scale and sometimes, even, in order to generate work and cash rewards. One confusion is that the terms 'Community Forestry' and 'Social Forestry' are used interchangeably, evidently without much regard for conceptual distinctions. The recent EDI/World Bank publication entitled *People and Trees* (1989), for example explicitly does *not* make a conceptual distinction between these two terms.

The definition of agroforestry quoted above allows us to view it only as a *production* technique. In practice, it is clear that it can be applied in many economic situations and social contexts. Thus 'Agroforestry' can be part of 'Social Forestry' and 'Community Forestry', but not a subdivision of either.

The Distinction Between 'Social Forestry' and 'Community Forestry'

Agroforestry' as Part of 'Social Forestry'

Though frequently used in popular discourse, 'Society' is a large-scale concept used in sociology with a certain meaning. It refers to that social reality arising from the dynamics associated with group behaviour within which individuals have no power. Similarly, 'social' is a large-scale descriptive concept which is related to 'Society', but which involves the relationships produced through interaction among the groups that make up a society.

Throughout the world a large number of projects and programmes are being implemented under such terms as 'Social Forestry', 'Community Forestry', 'Farm Forestry', 'Farmers' Woodlots', 'Village-Woodlot-Forestry', 'Forestry-for-Community-Development', and so on. All these can be considered as Social Forestry programmes in that they generally indicate one common denominator (i.e. the involvement of the people of the project area). These are, again, variously designated as the 'Beneficiaries', the 'Target Group', 'Local People', 'Group Members', etc. Diverse as these terms may seem they all imply something which is basic (i.e. local needs, or in the context of most development programmes in low income countries, the needs of the rural poor). Thus, as far as 'Agroforestry' may be considered part of

'Social Forestry', it will involve *local participation in order to meet local needs*.

Within Indian and Chinese civilisations, for example, this kind of activity is not new; it is part of an age-old paradigm that is the resultant of, and compatible with, a particular kind of world view which recognises harmony with nature, not dominion over it.

The FAO, which issued a document entitled *Forestry for Local Community Development* in 1978, recognised local need-related activities thus:

> "...a spectrum of situations ranging from woodlots in areas which are short of wood and other forest products for local needs, through the growing of trees at the farm level to provide cash crops, and the processing of forest products at the household, artisan or small-industry level to generate income, to the activities of forest-dwelling communities".

Those types of forestry programmes which contribute to rural development through employment of wage labour are clearly and rightly excluded from the definition.

Social Structures and Community Forestry

Societies are hierarchical and comprised of communities and groups, which themselves are comprised of individuals. For a collection of individuals to be identified as a group, community or a society, they need to be organised in terms of certain principles of social organisation which pattern their behaviour in certain ways so as to result in a *social structure*. 'Social Forestry' programmes will, of course, require collective action in varying degrees at different levels within the social structure. At the level of the nation, they include national campaigns. Group forestry activities would form the next level, and 'Community Forestry' programmes would be conducted at the *village level*. The individual obviously forms an essential part of the society, or the social system, or the group to which he/she belongs, but has to be distinguished from these. Accordingly, a programme to establish nurseries to provide trees for individual farmers is not 'Social Forestry' or 'Community

Forestry', although it would definitely fall within an 'Agroforestry' programme. Contractual programmes and tree planting programmes under supervision are to be similarly distinguished.

If we define 'Community Forestry' programmes as those which are village-based and require *collective* action we can see that this will allow us to include different types of collective forestry programmes, regardless of the ownership of the land on which such programmes are implemented. For example, a community may opt to lease Government-owned land and collectively carry out an agroforestry programme with the assistance from Government agencies in terms of technical advice and supervision, and also share the earnings as agreed. On the other hand, the Government may provide such inputs free of charge, so as to let the community have the profit entirely. In both these instances, the programmes can be considered as 'Community Forestry' programmes.

It is not uncommon to find instances in the literature where community has been redefined as an 'Undifferentiated Whole'. This is just as erroneous as identifying the 'State' with industrial and commercial interests within the larger scale part of the economy. The concept of 'Community' is mainly used by the anthropologists as a unit of study, but they do stress the different identities within the community as well as other processes and interactions that link it with the economy and society.

Community programmes are distinguished from other programmes in their emphasis on the incorporation of the truly needy segments of the people in that community (i.e., the 'Poorest of the Poor' (Fig. 8.1.)). However, the needy, as well as the not-so-needy segments of the community, who have different powers and interests, are expected to be partners in community-based projects. All these people must be satisfied that the particular programme in which they are supposed to participate brings them the minimal requirements to ensure that participation itself is sustained. All other programmes are affected by the land ownership pattern of the community, and as such may only strengthen the already well-off. In fact, one might even point at the apparent contradiction: "What agroforestry can be expected from the landless?". This is the real challenge. Community programmes are the hardest and the most complicated to plan and implement. Yet, at the same time, they

represent the greatest opportunity for positive change in rural populations. Individual-oriented projects, or for that matter, group-oriented projects are easier to initiate, less costly to implement, and have a greater chance of success.



(Photo: P.A. Huxley)

Fig. 8.1.
Communities have a duty to consider the well-being of all their members. Discussions with elders and different classes of farmer during an ICRAF 'D&D' in southern India about the potential benefits of introducing various agroforestry practices still left a gap on how best to help the 'landless poor'.

Of the great number of 'Social Forestry' and 'Agroforestry' projects, many may not necessarily be sustainable, for they are not socially acceptable. Thus, the best hope for sustainable agroforestry lies in community-based programmes, however complex these may be.

COMMUNITY PARTICIPATION

Understanding the Participatory Process

It is in the transition from the technical to the human aspects of agroforestry

and rural development as a whole that 'Participation' receives its meaning and substance. For example, the choice of which species of tree to plant can be as much a cultural as a technical ecological decision and, again, the womens' role in cooking, is critical in any 'Agroforestry-for-Fuelwood' programme. Communities almost invariably know which woody species produce good fuelwood for heating, and which best fit their production systems and livelihood strategies. Acquiring such ethno-botanical knowledge is vital for project developers. Perceptions are clearly important, and if participation is to be achieved it is necessary, for example, to view 'Agroforestry-for-Fuelwood' as part of a cultural-ecological system that has to be comprehended within its historical framework. Anchoring agroforestry to indigenous knowledge systems contributes positively to community participation.

Again, in implementation, no programme that is expected to ensure community participation can be imposed from above; local people must be involved *throughout* the planning process (Fig. 8.2). Different economic interests produce different ideas about land and water use so that existing inequalities are bound to affect views on participation. However, it is not inequality *per se* that is at issue, but rather the mechanisms that violate the cultural norms of behaviour that have to be rendered ineffective. Nevertheless, despite inequalities people are bound together through a range of different kinds of bondings, such as friendship, kinship, patron-client relationships, etc., and these must be taken into account.

Technically, participation can be of various types. It is possible to enjoy benefits without contributing in any way to obtaining them (i.e., merely 'participation' in sharing benefits!). Again, participation can be just as a wage labourer in the implementation stage without being involved in the decision-making or decision-taking processes. This can cause active involvement in the whole planning process, and it is this kind of participation - especially by the poor and by women - that is most often implied when the term 'Participation' is used. That is, it is a process that is to be depicted as furthering the process of democracy through community participation in forestry-related programmes. An illustrative example is given in Shiva (1989) who shows how critical forests are for women, given the central role that women play in relation to nature - the forests, the food chain and water and fuel supplies.



(Photo: P.A. Huxley)

Fig. 8.2.
Field discussions such as those being held by a mixture of agroforestry experts at ICRAF's Field Station, Machakos, most certainly help to establish one view of research needs and priorities. However, the interests of local societies and communities will only be exposed through participatory activities.

Communities and Forests in Sri Lanka

One pertinent question we should ask in Sri Lanka relates to the relationship between communities and forests. We are neither a pastoral nor a tribal society. Our society is basically one of cultivators so that we are not so intimate with, or culturally attuned to forests as are others. Moreover, a 'Cultivator Society' will normally choose to clear forests to make way for crop husbandry. In addition, if communities have been actively alienated from the forests, for example though the State appropriating the ownership of communal land, as has happened under colonial rule, then this too will make it extremely difficult to persuade such communities to become 'forest-oriented'.

There is a further distinction to be made, that is between ownership, management, and dependence on forests. Culturally and spiritually many societies, whether forest-oriented or not, have a tradition of religious

veneration of trees. Also, communal or common land does not necessarily mean that it is 'free', or that there is no-one responsible for it. In such situations the social customs play the role of governing or regulating usage; or at least they have done so in the past. It needs no special effort to prove that people in Sri Lanka are still *dependent* on forests; it is just they have not been given opportunities to share the management responsibilities.

In agroforestry programmes in which community participation is an explicit goal, the whole process, including benefit distribution, should be clearly spelt out at the outset. For this, a thorough understanding not only of the cultural and socio-economic structures are required, but also of local politics. Above all, it is important that the Government demonstrates its commitment to such programmes. As stated before, for community participation in agroforestry to be obtained and sustained, it has to ensure satisfaction of the minimal requirements of the different segments of the community, particularly in the short run. How can Government commitment best be obtained and expressed? To achieve this, community participation must be presented as complementary to the existing rural development programmes, not as an alternative, nor as a panacea for all ills. Those with a technical training in forestry are now coming to appreciate the importance of social, cultural, economic and political factors. There is a genuine and growing interest in seeing that forestry-related activities are community-oriented. However, conventional forestry, in whatever form, cannot *alone* solve the problem of shortage of fodder and fuelwood, for example, let alone rural poverty, and the help of social scientists is needed.

Finally, despite the moral appeal of the idea of community participation in Sri Lanka, and the countless attempts at it by numerous agencies, both Governmental and non-Governmental, there is a general feeling that most of these projects are failures, in so far as the goal of community participation is concerned. We need to analyse such community-oriented projects, and not be discouraged, but go on to reach an understanding of what is needed to achieve success because, in those instances where community participation has occurred, the result has been a valuable contribution towards sustainability.

CONCLUSION

My purpose in presenting this contribution has been to address the issues of how to think about how individuals, communities and societies operate and to emphasise the role of community participation in agroforestry for sustainable development. It is a complex subject but, nevertheless, there is clearly a need to conceptualise the relevant issues and translate these into appropriate actions if agroforestry is to play the role in development that it can achieve in Sri Lanka. The human dimension is complex and does not lend itself to easy comprehension!

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9. Agroforestry: Some Functional Aspects

P. A. Huxley

CROPPING CONSIDERATIONS

The design and management of woody/non-woody plant mixtures poses some very interesting choices. These are less of a concern with regard to the seasonal crop components, which we are usually quite familiar with, but they are more focused on the woody components and on how to arrange the interactive areas between 'trees' and 'crops'. In trying to understand how agroforestry systems function, a good starting place is indeed, to reflect on what we already know about how monocrops and seasonal intercrops are managed. Some of these issues are mentioned here[†] .

Seasonal Crops and the Agricultural 'Crop Season'

There are many reasons why farmers choose to grow particular seasonal crops, and many more relating to their decisions on how to manage them. When agronomists and other plant scientists consider ways of improving farmers' practices, and helping them to increase productivity, they pay particular attention to certain issues:

- the choice of genotype (variety);
- the most appropriate time to sow the crop, bearing in mind the duration of the growing season;
- the optimum sowing rate; and
- how best to keep the crop growing healthily for as much of the season as possible.

After choosing a crop or variety that is adapted to a particular locality these issues are all interlinked because, basically, they all address one main

† The reader is referred, in particular, to Alvim and Koslowski, 1977; Goldsworthy and Fisher, 1984; Francis, 1986; Squire, 1990; Loomis and Connor, 1992 and Ong and Huxley, 1996 - only some key issues are highlighted here.

consideration: to sow the crop so that it forms a leafy canopy *as soon as possible,* and to see that this canopy is *maintained through the season.* To measure this we often use the concept of leaf area index (LAI) or, better, leaf area duration (LAD), to express the 'density' of the crop canopy and its continuation over time[†] . These are primarily useful when considering sole crops ('monocrops') and/or mixtures of crops growing more or less at the same time. It tells us nothing about the functional status of the leaves in the canopy. It becomes less useful, therefore, when comparing different crops or crop mixtures.

In agriculture this concept of a 'cropping season' is paramount. Part of a cropping season may be wasted if crops are not sown on time. In the tropics, farmers know that late sowing carries penalties in loss of yield with most crops (Law and Cooper, 1976) although they may have reasons to delay sowing, for example in Africa, food crops will always be sown before cash crops if labour is in short supply. With monocultures, a good deal of attention is given to selecting cultivars (crop varieties) that 'fit' a particular cropping season; although sometimes for management reasons we may pick a crop variety that matures before the cropping season is over.

UTILISING ENVIRONMENTAL RESOURCES

Resource Capture

The concern over creating a leafy canopy as quickly as possible, and then maintaining it through most of the cropping season is because, in order to maximise crop growth, we need to *capture* as much of the available environmental resources (light, water, nutrients) as are needed to maintain steady growth, and to have the growth sequences such that resource use is maximised. Hence the need to sow early and to keep the growing plants healthy.

One way to ensure that a leafy crop canopy forms early and develops satisfactorily is to choose an optimum sowing density. We know a good deal

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† LAI = area of leaf per unit area of land. LAD is the LAI integrated over the time although we really need to consider *green* (i.e. potentially active) leaf area.

about the way LAI and yield are affected by plant population for most of our major crops. In intercropping (including agroforestry), crop mixtures may achieve greater LADs than monocultures.

Other factors, that affect canopy formation are the availability of water and nutrients. Nutrient needs and nutrient uptake will be linked to crop growth rate. With regard to availability, the supply of soluble plant nutrients in the soil will be dependent on soil water status, but access to less soluble nutrients, for example, phosphorus, will depend more on the active growth of roots. Soil water availability will, together with the saturation deficit of the air, control growth through affecting stomatal activity and hence photosynthesis. Water stress particularly affects leaf expansion adversely, and in severe cases can cause leaves to drop off, but even short periods of water stress can detrimentally affect canopy formation.

Temperature plays an important part because it will affect the rate of development of plant organs, including the leaves, and their subsequent growth and activity. For example, an increase in the temperature up to an optimum will effect the *rate* of growth and hence the *duration* of growth because, at optimum temperatures, plant organs, for example leaves and fruits, reach maturity much sooner than at sub-optimal ones. This means that for determinate crops (or, individual growth units on trees) the overall duration is *shortened* at optimum temperatures. Indeterminate crops or growth units continue to grow and utilise resources as long as the environment remains favourable, however.

It is clear that we cannot just think about one factor without considering the affect of all the others, but a good deal of information is available from experimental work, particularly with monocrops, that helps us understand how best to manage seasonal crops so as to maximise environmental resource capture and environmental resource utilisation. Indeed, plant species do differ considerably in their ability to utilise environmental resources efficiently, and to allocate them to different structures in ways that fit with their overall growth strategy (Fig. 9.1). Potential growth maxima are hardly ever achieved in the field (i.e. individual plants in a crop end up by competing amongst themselves for limited resources), but the concepts of resource capture and use, together with our understanding of

competitive interactions, can help to describe and predict what will happen when crop plants grow together, or in mixtures. The challenge in agroforestry is to take these concepts and use them appropriately in our situations!



(Photo: P.A. Huxley)

Fig. 9.1. This roadside picture of a Kandy homegarden illustrates how the canopy is, overall, composed of many different clumps of leaves. Within each clump, leaves will be of different ages and physiological states. Such a canopy will capture light effectively and distribute and utilise it efficiently. Below ground the root systems of all these plants will be intermingled, again to form an effective biological layer helping to prevent nutrient loss through leaching. Species include: jak, pepper, *Gliricidia sepium*, banana, papaya, coconut, *Areca* and *Caryota* palms, vegetables, and so on. Stall fed cattle are kept.

Some Key Issues of Resource Capture Applied to Agroforestry

These ideas are, indeed, all directly relevant to agroforestry, the difficulty is to see exactly how they apply to the very complex arrangement of plant components that we usually find in various agroforestry practices (Ong and Huxley, 1996). Here we are dealing with plants of very disparate statures and with different growth cycles, so that the structure of the canopy may change both in shape and in physiological activity throughout the year. This challenge has to be accepted, however, because unless we understand how such agroforestry canopies function there is very little chance that we shall get the best out of any particular agroforestry practice. What are some of the major points we need to consider?

- A first complication is when the woody species grow (or are made to grow) *outside* the recognised 'cropping' season† (Fig. 9.2.a and b). We find that this can vary not only between species but, often, even the same species will not behave in the same way each year! Thus, the extent of the combined canopy of woody and non-woody species at any particular time will not always be predictable as it will change depending on which of the plant components are growing. This also implies that at any one time the leaves of different plant components will be of very different ages and, therefore, have different levels of physiological activity.

Fig. 9.2. (a) (see following page for Fig. 9.2.(b))



(Photo: P.A. Huxley)

Fig.9.2.
Leucaena leucocephala cv K8 growing at ICRAF's Field Station, Machakos, Kenya either (a) unpruned or (b) pruned as a barrier hedge. These pictures were taken in the January dry season and the unpruned plant has fruited heavily and is vegetatively dormant. The plants in the hedgerow were pruned on the previous 20 December and they are now growing new leafy shoots.

Vegetative dormancy of tropical woody plants can often be overcome by pruning at the correct time and, thus, the plants 'entrained' to grow at periods other than would normally be the case. Also, cutting off the shoots of plants diverts future carbon assimilates so as to re-establish the aerial parts at the expense of further root growth; i.e., there is a general allometry between plant parts.

† See 'The Biology and Ecology of Multipurpose Trees', this volume.

- Second, if we want to maximise environmental resource capture by maintaining a healthy plant canopy for as long as possible, then agroforestry *can* afford an opportunity to do this more effectively. Partly as a consequence of differences in the phenology of the plant components and, also, because we can adjust the plant populations and the arrangements of the various components in the mixture so as to maximise the capture of light (cf. crop plants). What is interesting here is that we know from experimental evidence that crop growth rate under non-limiting conditions is a linear function of accumulated light interception (Fig. 9.3a), and this tells us that, other factors not being unduly limiting, *the more light our system can capture the greater the biomass produced.*

Fig. 9.2. (b) (see preceeding page for legend)



(Photo: P.A. Huxley)

- Third, the relationships between water stress and leaf production/expansion and leaf photosynthesis are also well explored (see Squire, 1990 for details). Here we find that, for a crop growing in a particular environment, there is, an overall linear relationship that is characteristic of the crop species and the climatic conditions, between water use and dry matter accumulation (the 'water use ratio') (Fig. 9.3b). Once again, what this means is that if the plants in agroforestry systems can utilise

more of the available rainfall, for example through exploring parts of the soil profile not used by or available to the crop, and/or by using soil water for longer, then more biomass will be produced than would be the case for a short-term agricultural crop[†] . As an arrangement of trees and crops/grasses can often help prevent run off, and increase water infiltration to the soil, there may be an added bonus in that there is more water to use, anyway.

The possibility for an extension of active canopy growth and the potential to capture more light and use more water are very important because they not only increased yields of the crop components, but, overall, can result in an increase in biomass production. These issues represent part of the 'promise' that agroforestry holds which we need, by appropriate species selection and design and management, to translate into successful operational systems.

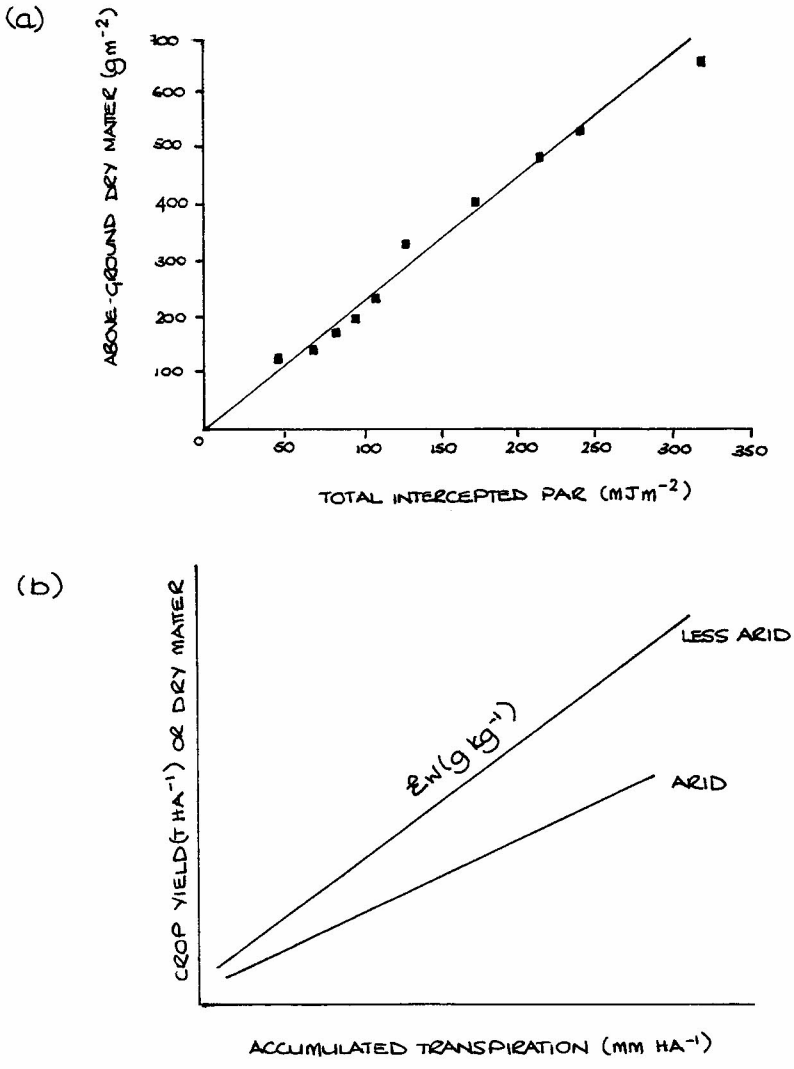
BIOMASS DISTRIBUTION

How much of the biomass created will go into crop or grass yields, or the parts of trees that we want? The answer will depend on a whole range of factors, such as exactly how the environmental resources are shared between crop components (i.e. the relative area of the site occupied by the different species and the relative proportions of time over which they actively grow), or how we regulate the upper canopy to let more light through, how any species distributes dry matter and, not the least, by the ways in which the plant components compete with or complement one another as they grow in proximity. Obviously, the *arrangement* of the plant components and the way we manage them (e.g., how we prune the trees), will affect these factors.

The manner in which individual plants distribute their dry matter will also be a factor in regulating outputs of different kinds for agroforestry systems. These outputs are usually measured as *yields*. For example, grain, leaf, fruits, and also the woody parts we use (such as round timber from

† For example at Hyderabad, India, a sole millet crop utilises less than 40% of the annual rainfall (Ong, *pers. comm.*).

Fig. 9.3. Generalised relationships between crop biomass production (or yield) and (a) accumulated light interception, and (b) water actually transpired by a crop (the 'water use ratio'). These apparently simple relationships hold good in each case as long as another environmental factor does not become limiting, or the plants fruit or become aged. The slopes of these lines indicate the light use efficiency and water use efficiency, respectively. The significance of this for agroforestry is to suggest that any plant association that can capture more light and/or use more water (through the plants) will be more productive, at least in terms of biomass. Many agroforestry practices could, possibly, achieve this.



trunks, and fuelwood from branches and twigs). But what about the proportion of the total plant dry matter that is allocated to other parts (e.g., the roots)? Fortunately, we know a good deal about the factors that affect the distribution of dry matter throughout a plant and, again, there are established *principles* to guide us when considering plant behaviour in agroforestry systems. For example, there is considerable stability in the way that any plant genotype allocates dry matter, so that plants that have leafy shoots pruned away, as for example hedges in alley cropping, will subsequently allocate carbon assimilates and other resources so as to re-establish their original root/shoot ratio. However, this balance can be modified by changing the environment so that we find that, for example, both shade above ground and an increase in soil fertility below will decrease the proportion of dry matter that goes to roots (see Cannell, 1985). In many agroforestry practices (e.g., homegardens, scattered trees in croplands, etc.) the ways in which light transmission is regulated from one plant component to another will affect both growth *and* changes in dry matter distribution.

GENOTYPE X ENVIRONMENT INTERACTIONS

We know that season-to-season weather fluctuations are responsible for large differences in yield with crop plants. Indeed, yield stability is a key issue in choosing varieties. Such changes of plant behaviour in response to changing environment (i.e. the 'genotype x environment interaction' (G x E)) is a major consideration in plant breeding. It is tested by growing new crop varieties in a number of different sites representing different ecozones. In agroforestry, we know very little of significance about the G x E for multipurpose tree species. There have been some efforts to test the same selection of multipurpose trees under carefully controlled management at a range of different sites[†] . Table 9.1 shows some of the results from one such trial conducted by the Oxford Forestry Institute (Stewart *et al.*, 1992). The cost of such trials, and the time over which they can be maintained, limits the number of such investigations. Furthermore, their outcome may also fall short of expectations Nowadays,

† FAO; Winrock International; The Nitrogen Fixing Tree Association and the Oxford Forestry Institute.

most multipurpose tree selection trials contain, if possible, one or two species which are known to be locally-adapted and against which the performance of the others is compared. At present this is the best that can be done without recourse to much larger resources.

Table 9.1. Ranking order of wood biomass production for 25 Central American woody species grown at 2 locations (Hoskote, India (Hos) and Tiptur, India (Tip)). Note that the ranking order changes between the sites indicating a high level of genotype x environment (G x E) interaction.

Species	Hos	Tip
Leuceana leucocephala	15	**1**
Leuceana collinsii	**3**	**2**
Acacia pennatula	1	**3**
Gliricidia sepium	7	8
Senna atomaria	**2**	5
Albizia guachapele	**5**	9
Alvaradoa amorphoides		
Acacia farnesiana		**4**
Leuceana shannonii	8	10
Apoplanesia paniculata		
Ateleia herbert-smithii	**4**	
Haematoxylum brasiletto		11
Guazuma ulmifolia	14	
Parkinsonia aculeata	19	7
Caesalpinia coriaria	6	6
Caesalpinia velutina	9	14
Acacia picachensis	12	17
Prosopis juliflora	16	13
Enterolobium cyclocarpum	10	15
Pithecellobium dulce	11	12
Albizia saman		
Crescentia alata	17	18
Caesalpinia eriostachys	13	16
Albizia niopoides	20	
Myrospermum frutescens	**18**	

(Source: Stewart *et al.*, 1992)

Experimentation can only help us up to a point. The responses to environmental change that result in G x E interactions will be a consequence of numerous plant traits, some morphological others physiological. If we can identify some major plant characteristics that relate to responses to changes in environmental factors (e.g., phenological characteristics, processes concerned with rapid canopy development, the underlying characteristics that promote tolerance to particular environmental stresses, and so on), then by testing the ways in which these are influenced by different environmental factors it might

be possible to predict, to some extent, how a MPT species will behave in a new environment.

CONCLUSIONS

Obviously, if we can establish a set of guidelines by which to access the functional behaviour, and functional interactions, of the plant components in agroforestry systems we shall be in a much better position to predict what might happen when we change the plant arrangement, the management and/or the site. We are still quite a long way from being able to do this but, as I hope this contribution has shown, there is a good deal of basic information available from crop studies, and from the work of tree physiologists, that will enable us to begin to put together some ideas on how to make a start.

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10. Agroforestry in Watershed Management

P. B. Dharmasena

INTRODUCTION

Land Degradation Processes in Sri Lanka

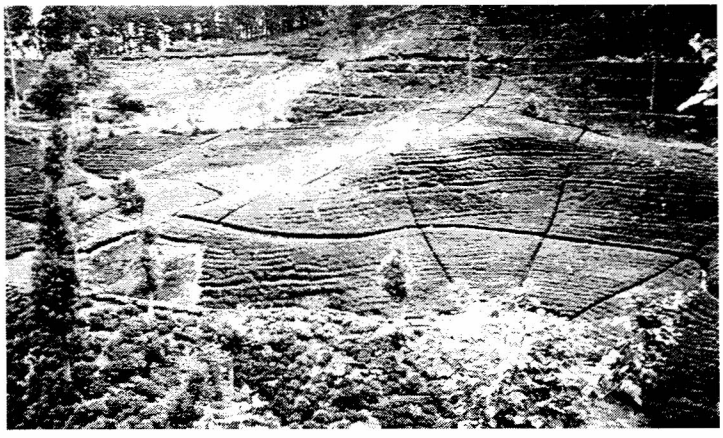
During the last four decades or so, rapid changes have occurred in the natural environment of Sri Lanka which have brought us to a situation whereby sustainable production of resources is no longer possible in many areas. Due to the increase in population growth, the demand for food, shelter and other needs has increased tremendously. It has been reported that the closed-canopy forest in Sri Lanka has declined from 44% in 1956 to 24% at the present time. Mangrove vegetation has been removed, agricultural land extended, land use intensified, often with resulting soil erosion, coral reefs mined, wetlands filled, urbanisation intensified, new settlements established, industrialisation increased and most of the main rivers have been dammed.

It is evident that a process of environmental degradation is in progress through soil erosion, coastal erosion, water and air pollution and the creation of unbalanced ecosystems. It is true that all these changes in the natural environment have contributed much to improve living conditions of people in the short run. Nevertheless, it is questionable what may happen to our valuable resources in the longer term if such exploitation continues to take place. Such environmental degradation cannot be allowed to progress unchecked (Fig. 10.1). There is, clearly, a need for a master plan to combat land degradation of all forms, including that occurring in the Dry and Intermediate Zones in Sri Lanka. These concerns are addressed in this contribution.

The Need to Counter Desertification at the Watershed Level

The design and management of landuse practices so as to take account of

watershed requirements applies to all of Sri Lanka's agroecological zones, but the second part of this presentation focuses on aspects of landuse in the Dry Zone. The increasing extent of degradation of lands in low-rainfall areas, 'desertification', has been of concern worldwide for some few decades, and the need to combat desertification, particularly in Africa and in those countries experiencing serious drought, was addressed at a Convention held in October 1994 in France by both developing and developed countries. It's purpose was to assist affected countries to achieve sustainable development through effective action at all levels, supported by international cooperation and partnership arrangements, in the framework of an integrated approach; Sri Lanka was a signatory.



(Photo: P.A. Huxley)

Fig. 10.1. There are many cases where tea has been planted on unsuitably steep slopes in Sri Lanka leading to severe erosion. When abandoned, the land is then used for chena operations and the chena farmers, in turn, abandon the plots when erosion and weeds overcome them. Hence the erosion problem continues to deteriorate. Tea here, near Nuwara Eliya, has not been planted on the very steep slope (top centre-left), but this has been left virtually bare. The tea mid-field is not showing signs of erosion except in the very centre. However, the steep bank (mid-foreground) probably should not have been planted with tea.

To combat desertification the convention suggested activities which aim at the following:

- the prevention and/or reduction of land degradation;
- rehabilitation of partly degraded land; and reclamation of desertified land; and

- an involvement in long-term integrated strategies that focus simultaneously, in affected areas, on improved productivity of land, and the rehabilitation, conservation and sustainable management of land and water resources leading to improved living conditions, in particular at the community level.
  - Recognising that fulfilment of the needs of individuals within a community, and the requirements and the patterns of landuse by which they achieve this, are often largely determined by climate and the topographical attributes and soil characteristics found within individual watersheds.

The efficient management of land and water resources on a watershed basis thus plays a key role, and agroforestry can be one of the strategies which could be adapted to satisfy the aims set out above. This contribution briefly discusses the potential role of tree-based landuse in watershed management in the context of sustainable development.

THE 'WATERSHED' AND WATERSHED MANAGEMENT

The Need for a Management Plan

Many definitions have been developed over the years for the terms watershed, catchment, drainage basin, and river basin. While these definitions employ a wide variety of words and local terminology, they all mean practically the same thing. A very simple definition that can be applied to any of the above is that they embrace all of the land and water areas which contribute run-off to a common point.

Watershed management is defined as the 'administration and regulation of the aggregate resources of a drainage basin for the production of water and the control of erosion, streamflow and floods'. Although the definition is much more related to production of water, the primary objective of watershed management in the present context is to maintain a desired water balance to achieve the required watershed hydrology.

One or more of the following purposes may be expected from a particular watershed management plan:

- improvement of agricultural production in the watershed;
- the generation of hydro-power by damming rivers;
- provision of irrigation water for agriculture by damming or diverting river water;
- the control of flooding of valley regions by regulating river flows;
- production of clean, pure water for drinking;
- development of pasture lands in the watershed for livestock husbandry;
- production of timber;
- the development or preservation of forest for environmental enhancement; and
- the reservation of areas for recreational purposes.

The management of water in a watershed must be planned so as to integrate the use of all the water available to the best possible advantages rather than just focusing on the production of water. In this context, good watershed management requires one of the following criteria:

- if the watershed is utilised for rainfed farming, the maximum possible amount of rain water has to be absorbed into soil, especially in low rainfall areas; and
- if the purpose is downstream irrigation and hydropower generation then water production from the watershed has to be maximised without increasing soil erosion.

In situations where both above requirements need to be accommodated, then management must achieve the required balance between absorption and runoff.

Clearly, watersheds receiving a given amount of rainfall can produce different amounts of water depending on their characteristics, such as topography, size, shape, land use, soil type, etc. Land use and topographical condition are the two factors which can be manipulated by man to achieve the desired watershed hydrology.

Landuse practices that enhance the proportion of rainfall which proceeds into and is retained by the soil are well documented. They include the following:

- the use of barriers (e.g., terrains, bunds of various kinds, and cut-off drains etc.) in order to reduce or eliminate the effects of surface water movement;
- soil surface management; for example hoeing, ploughing, tie-ridging etc.;
- the provision of soil cover which acts both directly, through limiting the erosive effect of rain-drop impact, and indirectly through the incorporation of plant litter into the topsoil, so increasing the infiltration rate at the soil surface and stabilising it; and
- the incorporation of soil organic matter within the soil profile and the other changes in soil physical status, (e.g., the increase in macropores) that growing vegetation produces[†].

The effects of changes in landuse on catchment water yield need to be given more careful consideration; for example, changes of vegetation cover due to afforestation or deforestation. In this respect Bosch and Hewlett (1982) concluded, after reviewing the results of nearly one hundred paired-basin experiments, that "no evidence could be traced from past experiments to state either that a reduction of vegetation cover causes any reduction in water yields, or that an increase in cover causes an increase in water yield". Similarly, Hamilton *et al.* (1985), summarising the state of knowledge on the protective role of tropical forests, concluded that reducing tree cover on a forested catchment increased the water yield from the catchment with the majority of the increase occurring in the base flow component. Such observations have led us to believe that afforestation of upland catchments is not necessarily beneficial with regard to the provision of water resources. More recently, Madduma Bandara (1992) has reported that the Kirindi Oya Basin shows an increase in the total volume of discharge as a consequence of deforestation. Also, the Upper Mahaweli Basin shows an increasing discharge during wetter months and a decreasing trend in the drier months. The actual outcome on

† These are discussed in relation to agroforestry practices by Young (1989).

streamflow, for example, will, clearly, depend on many circumstances, but there is a strong possibility of managing a watershed through manipulating its landuse characteristics.

Watershed Planning

Planning a watershed is not just the preparation of a technical plan for correcting the land and water problems of the land area, but it should incorporate a watershed development programme. Watershed management from a technical point of view is not a panacea for all soil and water problems. It is a tool that can be used for solving many of them, but there are other aspects which have to be included. To do this effectively it is always essential to understand the desires, ability and willingness of the landowners to undertake change. Thus, the report should include views and experiences of local communities. In this sense it has to be a team effort, and the development of a complete and comprehensive plan for a watershed requires the support of various types of experts. The engineer, forester, agroforester, agronomist, hydrologist, geologist and economist must all work together to develop the best coordinated programme. Judgement must be exercised by the individual experts in order to fit their speciality into an overall plan, rather than push for an unbalanced programme emphasising any particular interest. Watershed planning should not be confined only to the watershed itself. It has to emphasise the present situations and future needs of surrounding areas, in order to avoid future conflicts.

When it has been finally determined that a watershed project is feasible, and needed, then the surveys and investigations necessary to obtain the information for the development of the watershed plan should be initiated. The steps involved in making the surveys and investigations, and to develop the plan, are as follows.

- Collection of basic data
  - maps and aerial photographs of the watershed rainfall and runoff records, soil survey, availability of resources, cost of labour, etc.

- Preparation of the physical inventory
  - present landuse, land ownership, flood plains, possible flood retarding structure sites, gulleys, potential areas for agriculture, irrigable areas, areas requiring drainage, areas requiring water, etc.

- Recommendations for watershed development
  - the proposed landuse map, and reclamation and conservation guidelines
  - designs of proposed structures
  - recommendations for community or village scale protective measures and sites to be protected
  - an implication report on the hydrology of the watershed due to introduction of the watershed development programme
  - a cost-benefit analysis

- Development of a participatory implementation plan with local organisations.

- Where agroforestry is a feasible option then there has to be a parallel appraisal to determine the constraints and/or possibilities for implementing suitable practices (perhaps using ICRAF's 'Diagnostic and Design' procedures; Raintree, 1987).

WATERSHED MANAGEMENT AND THE DEMANDS FOR LAND AND ENERGY

Population Growth, Watersheds and the Environment

The average net rate of population growth in low income countries (LICs) is 2.2% while it is as low as 0.4% in developed countries. Therefore, there is a demand for increased production in our countries. Most LICs, including Sri Lanka, attack this problem through industrialisation and moves to advanced practices. The electricity required for industries and domestic purposes is

generated from hydro-power in Sri Lanka. To increase agricultural production further, land and water resources have to be managed efficiently, and this we have to do in order to cater for our increasing population† (Fig. 10.2).

To satisfy a growing demand for industrialisation and more productive use of land, there is clearly a need for watershed management. However, this can create a dilemma. For example, environmentalists have criticised the damming of rivers to increase national food production and power generation. Certainly, some of the implications of water resource development programmes cannot be disregarded. Among these are the loss of lands to people who have been living there for generations, the drying of downstream areas and the flooding of upstream areas, sedimentation of dams and the development of salinity, even earthquakes! Some of these problems can be, at least in part, offset by planting trees, including, the adoption of agroforestry practices.

The Role of Forests in Watersheds

Sri Lanka has experienced severe landuse degradation as a result of forest clearance, especially at high elevations and on steep slopes. During the period from 1930 to 1985 the number of reported landslides was 31, out of which 17 were accounted major events with the loss of human life and damage to houses. Landslides in Sri Lanka are brought about by high intensity rainstorms coupled with geological instabilities, and they are exacerbated through human interventions. For example, the land clearing in the hills that was done in colonial times, the cultivation of tobacco on oversteep slopes, effects of the Mahaweli Project, and so on. In some situations only natural forest cover can stabilise land adequately.

Forests usually create a well-balanced hydrological situation. Although some 25-30% of the annual precipitation can be intercepted by the canopy, water infiltration into the soil is greatly improved and a high soil moisture status is often found, as is shown in Fig.10.3 from a study in the Dry

† See 'Agroforestry: Needs and Expectations', this volume.

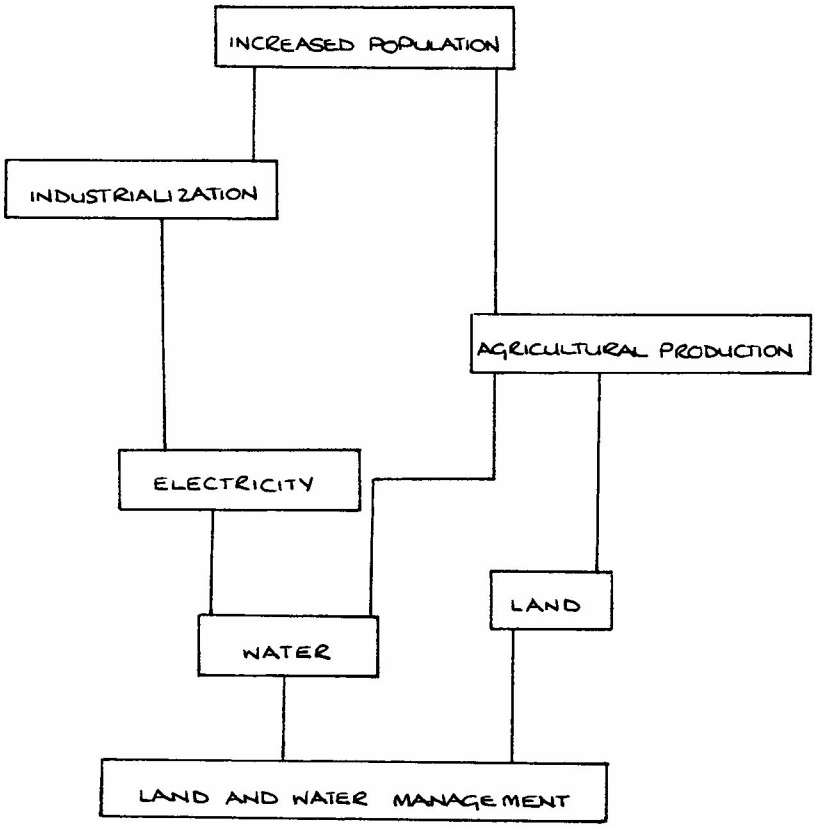


Fig. 10.2. Demand for Land and Energy

Zone. Indeed, one of the most important roles of forest in large watersheds is to regulate the base flow of rivers. If the land is covered by a forest canopy the stream discharge following rainfall is minimised. This reduces flood damage, as well as promoting a more even streamflow. In the absence of forest cover a watershed may experience wide fluctuations in streamflow and, as a result, flood-controlling dams may have to be constructed so as to regulate this. Where there are only small watersheds with storage tanks, forest cover does not play such a significant role because the sub-surface flow into such

tanks is negligible. Small tanks receive water mostly from surface run-off and direct rainfall (Dharmasena, 1989) (Fig. 10.4).

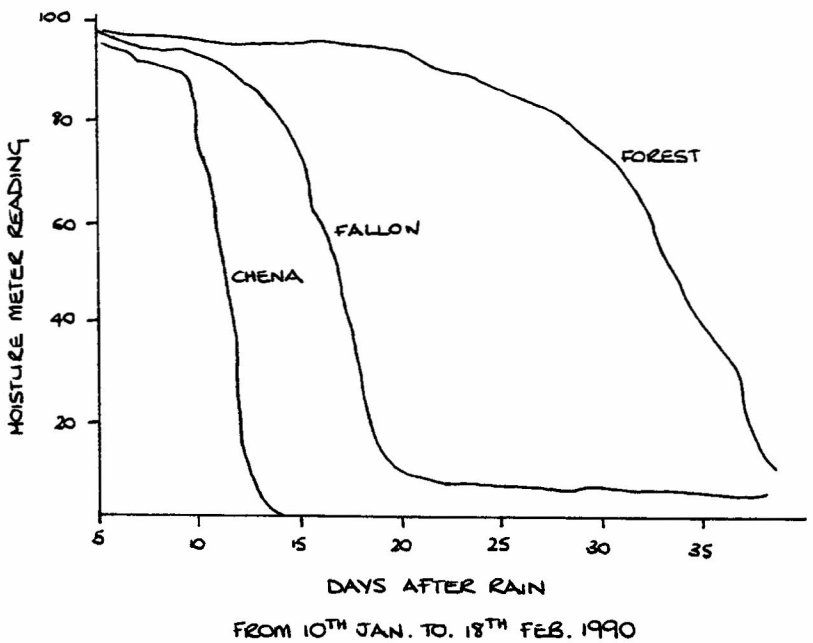


Fig. 10.3. Moisture depletion pattern in forest, fallow and chena lands.

In as much as agroforestry practices promote some degree or another of woody plant cover, their effects on water balance situations need to be considered and compared with those found in cultivated cropped lands or in forests.

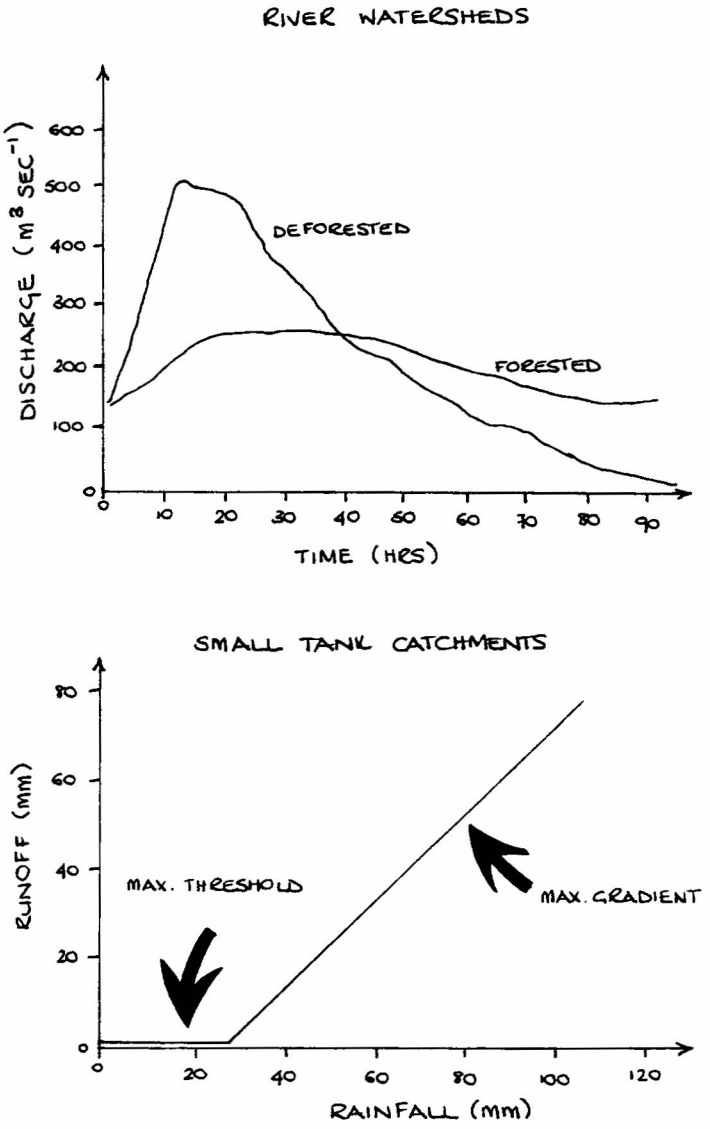


Fig. 10.4. Water yielding patterns of river watersheds and small tank catchments.

Agroforestry and Sustainable Development

Indiscriminate and badly-planned development schemes can cause deterioration of physical resources, particularly in arid and semi arid regions.

Although the concept of 'Sustainable Development' was introduced in 1972 at the first Environment Summit, it has become clear over the last two decades that sustainable development in agriculture is more difficult to put into practice than to define! One of the concepts for combining increased productivity with sustainability is agroforestry. Although long-term sustainability will still depend on placing some limits on production (and hence removal of biomass from the system). It thus remains to be seen whether agroforestry practices can fulfill all the demands that Sri Lanka's increasing population will lay at its door!

The term agroforestry and its place in tropical landuse has been elaborated by several contributors. Simply, it can be considered the art of practicing a form of landuse that includes woody and non-woody plants, and by understanding the processes and interactions brought about by woody vegetation, and applying these within the limitations imposed by farming practices.

This suggest that agroforestry may have a very beneficial part to play in watershed management, and that it will be most appropriate for achieving sustainable agricultural production. Research experience pertaining to this aspect gained from the Dry Zone in Sri Lanka is discussed below to indicate the possibility of applying agroforestry practices for successful watershed management.

DRY ZONE TANK-BASED SYSTEMS

Dry Zone Watersheds and 'Village Tanks'

The Dry Zone of Sri Lanka is largely composed of small watersheds where earth dams have been built up across ephemeral rivulets to form small reservoirs called 'village tanks'. The catchment areas of these tanks are used for rainfed farming on a shifting basis (Fig. 10.5). This traditional system of cultivation, which is locally known as 'chena', is similar to shifting cultivation practised elsewhere in the world (Figs. 10.6 to 10.8).

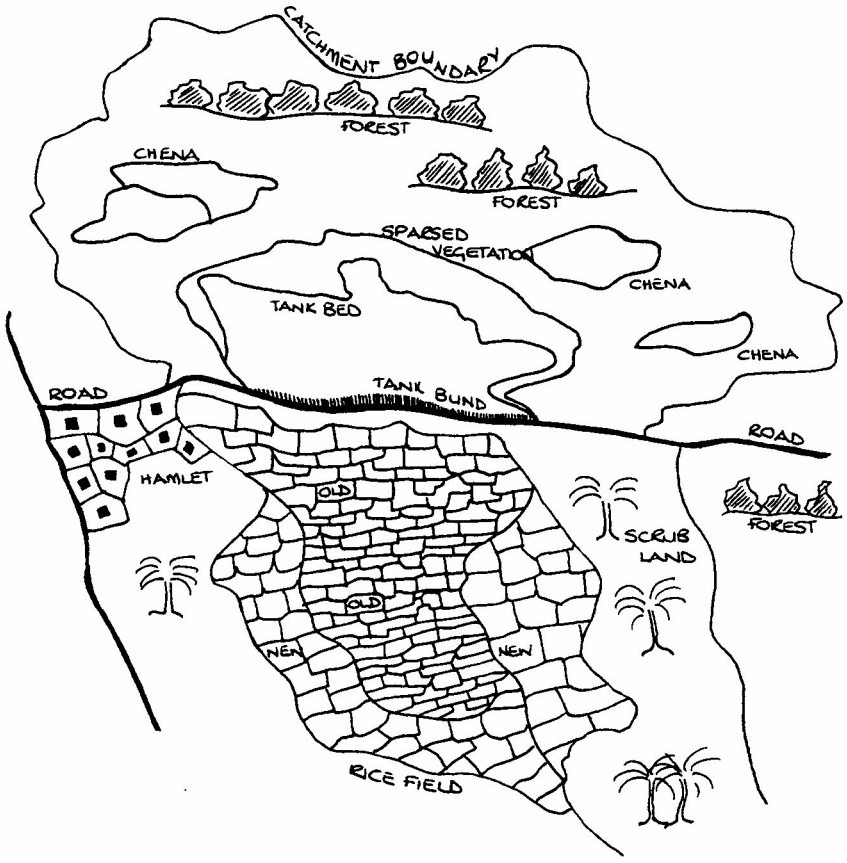


Fig. 10.5. Tank village ecosystem.

The art of chena cultivation has now been changed to continuous rainfed upland cultivation due to increasing pressure on the use of land. Soil erosion is the most critical issue in this type of farming and most of the uplands have already been degraded. Consequently, tanks are becoming filled with sediment and such sedimented tanks are no longer capable of providing adequate water for downstream rice-growing lands.

There are two forms of farming in this ecozone: rainfed chena (shifting cultivation) within tank catchment areas, and irrigated rice cultivation in the



(Photo: P.A.Huxley)

Fig. 10.6. View of typical 'uncleaned' chena at the Popham Foundation Trust site, Dambulla, where regeneration and the productive management of Dry Zone scrub forest, previously subjected to chena, is under study. Mainly fire-resistant woody species remain and a vigorous growth of grasses and twining plants severely restricts the regeneration of the tree and shrub species. Natural regeneration can take 45 years or more.



(Photo: P.A. Huxley)

Fig. 10.7. Land as in Fig. 10.6 that has been 'cleaned' (ground cover is scraped off, creepers are dug out and all the trash is burned *in situ* twice a year). Subsequent fires are much less damaging to re-generating tree seedlings and root suckers. The cost is said to be around Rs. 6,600 ha^{-1} for the first year (Rs. 45 to US. $1), and much less thereafter.

lower parts of the tank system. Animals are also kept[†]. In well-managed systems the risks of crop losses due to rainfall variability are therefore spread. However, if sedimentation in the tanks occurs it reduces the irrigation potential, and farmers resort more and more to chena cultivation, resulting in yet further sedimentation. Eroded lands, themselves, suffer reduced crop yields so that farmers need to cultivate larger and larger rainfed areas in order to eke out an existence. Fig. 10.9 illustrates this vicious circle and suggests that a 'systems' approach could be used to improve the ecology and production potential of the Dry Zone village-tank landuse practice.



(Photo: P.A. Huxley)

Fig. 10.8. Young trees growing vigorously in cleaned land, as in Fig. 10.7.

In arresting the soil erosion process in farmed areas of the tank catchment both agronomic and mechanical measures can be adopted as a combination. Furthermore, in order to increase production over the total system there is a necessity to generate more run-off from the catchment so as to increase tank storage. However, removing more water from the catchment as run-off can detrimentally affect soil moisture storage in the catchment where rainfed farming is being practised. As far as the hydrology of the total system is concerned there is, therefore, a direct interaction between the water use of rainfed upland farming in the tank catchment and the irrigable lowland farming in the tank command area (Fig. 10.5). Considering the bi-modality of

† See 'Animals in Sylvopastoral Practices in Sri Lanka: Past and Present', this volume.

the rainfall distribution, and the wide variation of monthly rainfall, it is essential to promote maximum absorption of rainwater during relatively dry months and high run-off to the tanks during relatively wet months. Further, this logical approach must be compatible with the operations and objectives in the whole farming system.

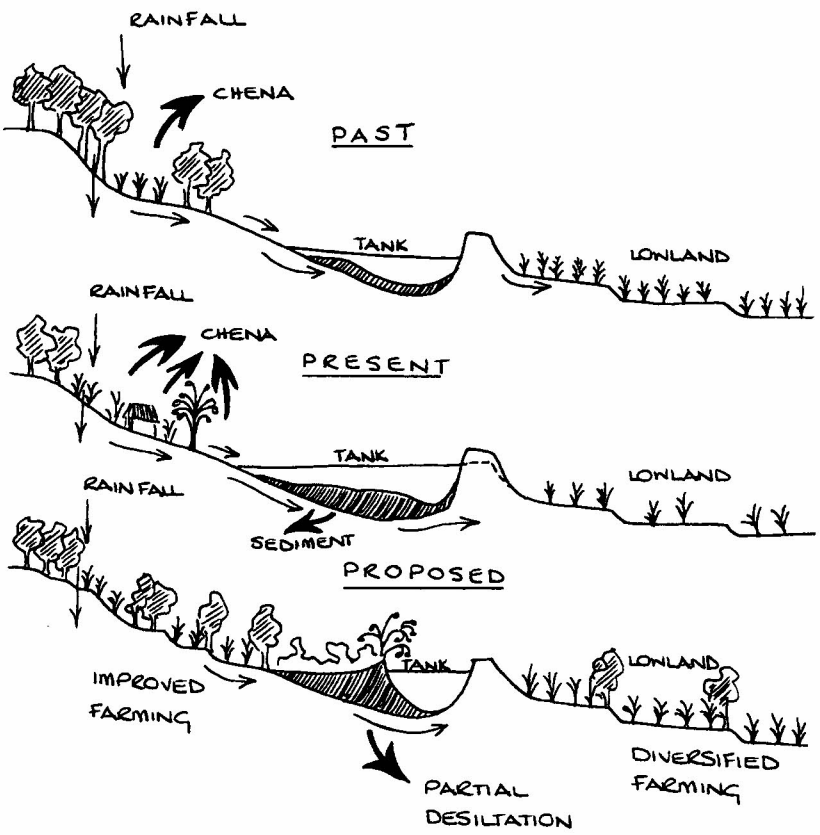


Fig. 10.9. Tank-based agriculture: problems and prospects.

The Results of a Watershed Management Study in the Dry Zone

The objective of this study was to identify a farming package for tank catchments which would be helpful in solving the water scarcity problem in both an upland and lowland farming context. The following conditions were considered essential in identifying the farming package:

- soil fertility must be sustained;
- soil erosion to be controlled and tank sedimentation to be minimised;
- rainfall infiltration and absorption in relatively dry months to be promoted; and
- run-off generation in excessively wet months to be improved.

The study was conducted during the major rainy season from October, 1989 to January, 1990 in the rainfed experimental site at Field Crops Research and Development Institute, Maha Illuppallama. It consisted of two investigations. The first was to determine the runoff characteristics of most prevalent land uses on the tank catchments: forest (natural vegetation more than 20 years old); fallow (cultivated land abandoned for more than 8 years) and cultivated chena (land utilised for rainfed upland farming). The study was carried out using 22 x 4 m runoff plots. The second investigation was to study the rainfall-runoff relationships of four landuse practices, as outlined below:

- *Plough farming*: Land ploughed with a disc harrow at the beginning (i.e. with the first rains) of every Maha season (October - January).

- *Terrace farming*: Construction of a series of earth bunds, 60 cm high and 120 cm wide at the base across the slope with a slight gradient of about 0.4 - 0.5%. A shallow surface drain was constructed at the upper side of each bund, usually 10 - 15 cm deep and 30 - 40 cm wide.

- *Graded hedgerow farming*: An alley cropping system where leguminous trees were planted on graded ridges at 4 to 5 m apart, constructed across the slope with a gradient of 0.4 - 0.5%. A small drain was constructed on the upper side to facilitate the diversion of excess runoff into a protected waterway. *Gliricidia sepium* was used in the study as the tree crop (Fig. 10.10).

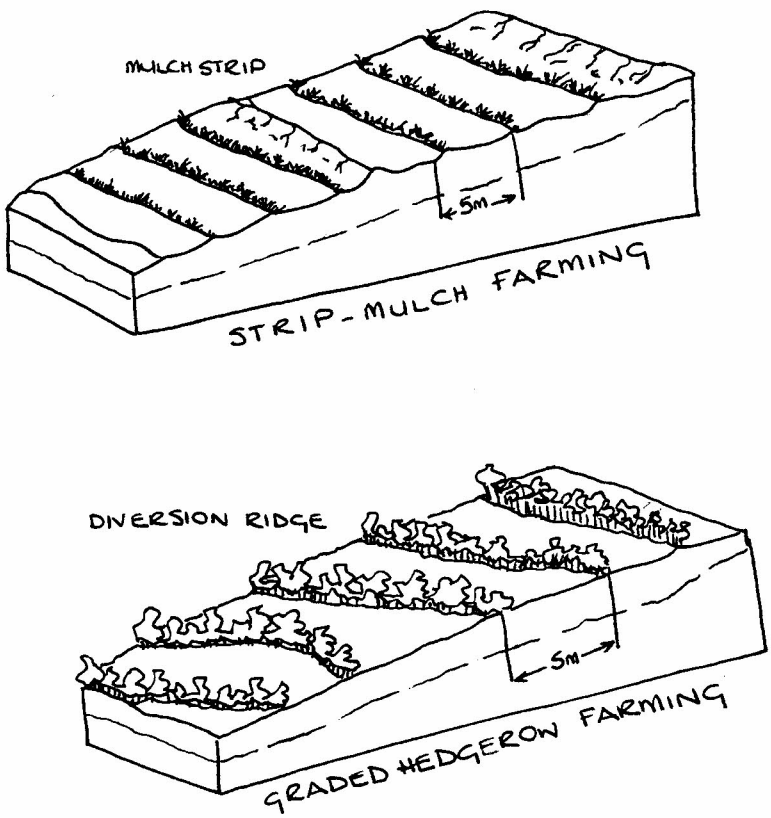


Fig. 10.10. Suggested farming systems for dry zone watersheds.

- *Strip-mulch farming*: A permanent strip of live mulch established at 5 m intervals and 0.75 m wide rows across the slope. *Centrosema pubescens* and *Mucuna utilis* were used as live mulch species. Weed and crop residues were also heaped on the same strip in order to form a runoff filter to reinforce the live mulch. The excess part of this trash barrier was spread over the crop land periodically (Fig. 10.10).

These four practices were evaluated for their efficiency in controlling erosion and soil water balance by measuring runoff and soil loss. The experiment was carried out in 100 m x 40 m field plots. Soil loss and runoff data were collected from 16 storms that occurred during the period of study.

Although the study was carried out as two experiments, the results have been interpreted together. Soil loss data were interpreted by using The Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1965 and 1978), which was found to be applicable to the study region. The USLE was modified for the study as:

$$\mathbf{A = R.K.(LS)\ max.\ Ec} \qquad \text{(Eq.1)}$$

Where A is soil loss, R is a rainfall factor (energy x intensity), K is a soil erodability factor (the resistance of the soil to erosion), L is a slope length factor and S a steepness factor and, here, where (LS)max is the maximum LS factor which could be obtained from the land, with Ec as the soil and crop management factor, termed an Erosion Coefficient (Ec).

By using the above equation the effects of different soil and crop management practices on soil loss were compared when other factors were known, but different. Runoff data were compared by establishing rainfall-runoff relationships through regressing runoff against rainfall data. The effect of slope and slope length on the rainfall-runoff relationship was assumed insignificant as the slope and length of flow used in plots were both relatively small.

The Rainfall - Runoff Relationships

Runoff data on a monthly basis in all practices showed a strong linear relationship with rainfall (Table 10.1). The general relationship can be expressed in the form:

$$\mathbf{Ro = b.Rf - a} \qquad \text{(Eq. 2)}$$

Where, Ro is monthly runoff (mm), Rf is monthly rainfall (mm) and a and b are site specific constants.

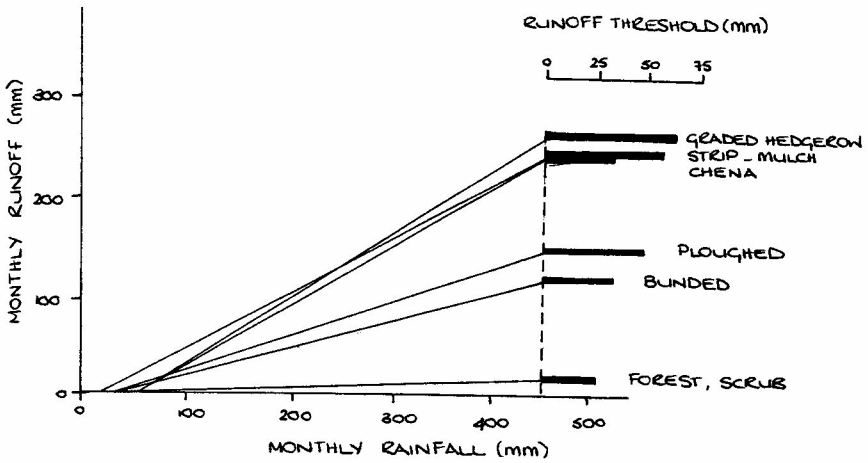


Fig. 10.11. Rainfall-runoff relationships and runoff thresholds for different farming methods.

From this relationship, it can be stated that runoff would be generated only if the monthly rainfall amount exceeds a value equal to a/b which is

termed a 'runoff threshold' in this context. If the runoff threshold value is high, it indicates that more rain water could be absorbed by the soil before it generates runoff. Once the soil is saturated a fraction of subsequent rainfall would flow downward as runoff. This fraction is given by the gradient b in the equation. In order to obtain high moisture absorption in relatively dry months, and a high runoff in relatively wet months, a farming environment must create a particular rainfall-runoff relationship which has a relatively high b value and high runoff threshold (a/b) value. Results given in Table 10.1 show that the above conditions are provided by graded hedgerow farming and strip-mulch farming (and see Fig. 10.11).

On the basis of the relationships given in Table 10.1, monthly runoff values were estimated by using monthly mean rainfall data of Maha Illuppallama in order to obtain the annual runoff amounts and their seasonal distribution (Table 10.2).

Table 10.1. Rainfall-runoff relationships and runoff threshold values.

Landuse/farming practice	Equation	r^2	Runoff threshold (mm)
Plough farming	R_O=0.34 Rf-16	0.79**	47
Chena	R_O=0.54 Rf-17	0.87**	31
Terrace farming	R_O=0.26 Rf-8	0.66**	31
Strip-mulch farming	R_O=0.58 Rf-34	0.86**	59
Graded-Hedgerow farming	R_O=0.64 Rf-40	0.89**	63
Scrubland	R_O=0.02 Rf-0.5	0.81**	25
Forest	R_O=0.01 Rf-0.2	0.72**	20

(Source: Dharmasena, 1994)

Relatively dry months which would affect field crop cultivation are September and January for the Maha season and March and May for the Yala season. Although high annual runoff could be expected from chena lands, this farming method does not allow higher moisture absorption during dry months compared to strip-mulch and graded hedgerow farming methods. About one third of annual rainfall would flow into small tanks if these new farming methods were adopted in rainfed upland cultivation in tank catchments. At present, only about one fifth of the catchment rainfall flows as runoff into small tanks under existing land uses (Dharmasena, 1989).

Table 10.2. Estimated runoff from different landuses/farming practices.

	Yala season (Mar.-Aug.)		Maha season (Sept.-Feb.)		Annual	
Mean rainfall (mm)	439		942		1381	
Runoff	mm	%	mm	%	mm	%
Ploughed farming	75	17	224	24	299	22
Chena	146	33	406	43	552	40
Terraced farming	71	16	198	21	269	19
Strip mulch farming	107	24	343	36	450	33
Graded hedgerow farming	111	25	365	39	476	34
Scrub land	6	1	17	2	23	2
Forest	4	1	8	1	12	1

(Source: Dharmasena, 1994)

Soil Loss

The erosion coefficient (Ec) value reflects the soil and crop management effect on soil erosion process. High Ec values indicate poor protection against soil erosion. Table 10.3 gives Ec values calculated from the two experiments.

Table 10.3. Erosion coefficient (Ec) values - Maha Illuppallama, Sri Lanka.

Landuse/farming	E_C value	Soil loss protection (%)
Chena cultivation	0.435	-
Plough farming	0.432	1
Terrace farming	0.260	40
Strip mulch farming	0.087	80
Graded-hedgerow farming	0.061	86
Scrub vegetation	0.005	99
Forest	0.000	100

These results show that the soil erosion from ploughed land was the highest compared to other practices. Protection provided by different farming methods and land uses is given as a percentage calculated from Ec values, taking the Ec of ploughed land as the reference level (Table 10.3). It shows that strip-mulch and graded hedgerow farming methods provide about 80% protection while terracing can provide about 50% protection against soil erosion.

These findings suggest that hedgerow farming, together with strip-mulching practices can be successfully introduced to tank catchments where rainfed upland cultivation is practised. However, further research is required to determine the adaptability of these farming methods under farmers' conditions and to identify constraints that the farmers could face in practising these new technologies.

SUMMARY

The proper management of a watershed involves applying landuse strategies that will efficiently integrate the total water available so as to satisfy the needs of those occupying and/or relying on that land. Plans must emphasise not only the needs of the nation but also the desires of the people themselves. At present, major watersheds in Sri Lanka are mainly utilised for forestry, agriculture and hydo-power generation. The Dry Zone minor watersheds are composites of forested and agricultural lands with small reservoirs and settlements. Although the scope, objectives and hydrological management of these two kinds of watershed are different the increasing demands in Sri Lanka for more cultivatable land and for energy generation have both to be accommodated. In this contribution I have concentrated on the use of agroforestry practices to improve landuse in small tank watersheds, which is one part of the whole picture.

The investigations so far carried out in the Dry Zone have certainly highlighted the potentials for agroforestry. For example, the potential of barrier hedgerow planting (a form of 'alley cropping'), for arresting soil erosion and maintaining the hydrological well-being in small tank watersheds. One third of the annual rainfall could be collected in the 'downstream' tank with hedgerow farming, with a high level of control of soil erosion (over 80%) as compared with chena farming.

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11. Agroforestry and Sustainability

P. A. Huxley

INTRODUCTION: THE BACKGROUND TO SUSTAINABLE LANDUSE

A good deal of attention is given nowadays to Sustainable Land Management or, in the broader context, 'Sustainable Development'†. As the world's population has grown, and economic expectancies have moved to new levels, there has been an increasing and inexorably adverse effect of human activities on land. Despite large differences of opinion about the supply side (McCalla, 1994, and see 'Agroforestry: Needs and Expectations', this volume), the current predictions for world population growth and food supply, make it clear that any form of landuse that offers sustainable production *must* be given serious consideration.

In agroforestry there are many different practices and combinations of plant components, with or without animals, but this whole approach to landuse has been promoted very much on the basis of its supposed ability to raise environmental well-being (Steppler & Nair, 1987). Originally, it even focused on the rehabilitation of 'Wasted Lands' (King & Chandler, 1978) (Figs. 11.1 to 11.3). Certainly, there are some agroforestry practices that seem inherently sustainable, and the exploration of *how* such systems function may well provide us with better clues on how best to manage others that are less so (ICRAF, 1989). For example, homegardens in Indonesia, Sri Lanka and many other parts of the tropics have, with no external inputs, maintained rural populations for hundreds of years, and continue to do so. More recent examples of the same kinds of practice, such as Chagga homegardens in Tanzania are similarly productive and seem sustainable (Fernandes *et al.*, 1984). However, there are other forms of agroforestry such as alley cropping that were initially promoted as environmentally improving (e.g., Ranasinghe,

† This contribution briefly considers only sustainable land management in relation to agroforestry.

1993; Nuberg and Evans, 1993), but current evaluations have not shown them to be as promising as they were first thought (e.g., Ong, 1994, 1996).

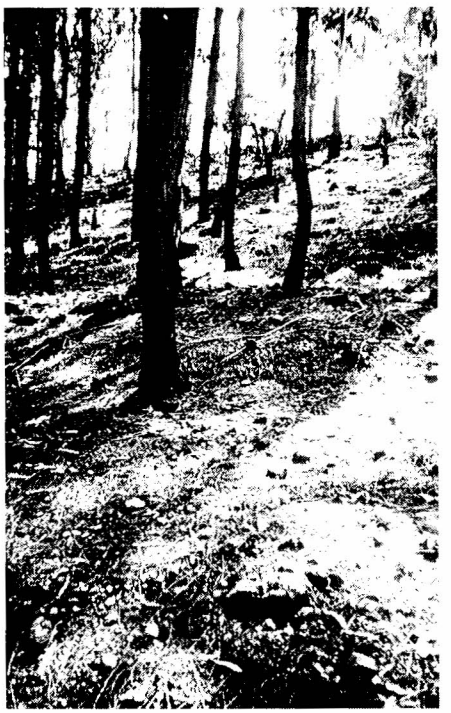


(Photo: P.A. Huxley)

Fig. 11.1. Perennially-cultivated land now exhausted, near the NeoSynthesis Research Centre, Bandarawala in the Intermediate Zone.

In agroforestry the biophysical processes and the complex interactions between components and their environment that may promote or discourage sustainable production, yet remain to be adequately explored; as do the socio-economic complexities. Furthermore, many agroforestry practices are concerned not only with production but with maintaining the provision and quality of service functions. The World Commission on Environment and Development, the 'Brundtland Report' (FAO, 1992), started a wide debate on sustainability and sustainable development, about which a great deal has since been written. Many of the initial discussions about sustainability were not just concerned with how to achieve it, but on what it actually *was*! The current definition is that 'sustainable landuse is that which achieves production sufficient to meet the needs of present and future populations, while conserving or enhancing the land resources on which that production depends' (FAO).

Clearly, we could maintain production from any form of landuse just by increasing inputs, so some limit to those has to be set. Furthermore, all forms of agriculture, and many forms of forestry, are basically extractive and therefore we have to define sustainability in terms of a particular output goal.



(Photo: P.A. Huxley)

Fig. 11.2.
Pinus caribaea planted on a slope at Bandarawala. Seedling pines were regenerating between this plantation and the contiguous *Eucalyptus grandis* but lack of ground cover means that this land will degrade even though timber will be produced.

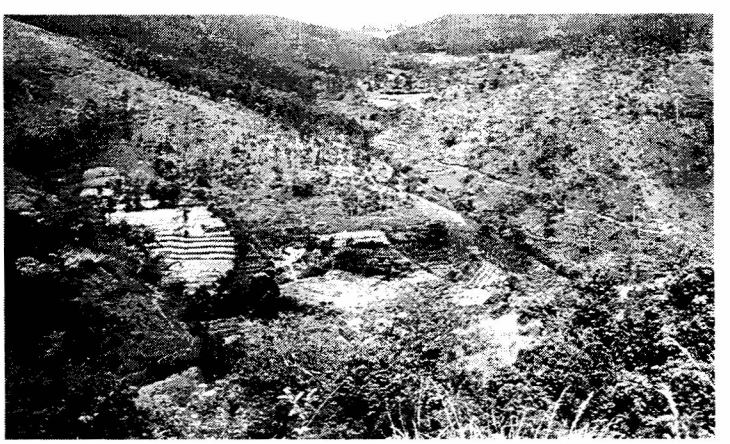


Fig. 11.3. Denuded slopes and a burnt out *Eucalyptus* plantation (right) on old chena land, Bandarawala. Such tree monocultures are prone to fire damage. Some terracing has been started (to left).

In this respect, trying to define sustainability for the needs of 'future populations' may, clearly, not be a very precise objective! Finally, we have to think of sustainability, as with all forms of conservation, as dynamic and not static, so sustainability obviously refers to a *continuing* set of processes. Individual systems must respond to changing ecological, social and political factors, and it may not be easy to predict exactly what these will be.

In order to establish whether or not any particular landuse system is sustainable, or not, we need to establish what biophysical, social or economic trends will occur if we take certain actions regarding land management or, conversely, if we *fail* to take certain actions where there is an indication of non-sustainability.

It is helpful, therefore, to consider sustainability from four aspects:

- *Production:* the total outputs of the system per unit area over time;
- *Efficiency:* the ratio of conservation of various inputs into outputs (including energy losses);
- *Stability:* the degree of fluctuation around the production trend; and
- *Resilience:* the speed of restoration of output trends after a major disturbance (or repeated disturbances).

HOW DOES AGROFORESTRY STAND WITH REGARD TO SUSTAINABILITY ISSUES?

Production

Any agroforestry practice will provide several products, and these may have to be measured in different ways. For example, we may have crop yields (t ha^{-1}), timber (m^3 ha^{-1}), or poles (as a number). We can compare these only in terms of a common unit. For example, as price, or sometimes a fundamental energy unit (calories or joules). In addition, the service outputs must be accounted for, but we have not yet worked out how best to do this in all cases. Obviously we can measure improvements in soil physical and chemical characteristics brought about by trees, or the hedges in an alley cropping scheme. For example, as tonnes of top soil saved, or millimetres of rainfall conserved in

run-off control, and so on. However, it may be difficult to quantify the value of a secure boundary for cattle owners, or improvements in the quality of life where shelter and shade are provided for the farmer and his family. However, benefits from such factors will be reflected in some way in improvements in the overall efficiency of the production unit, so they cannot be neglected.

The levels of outputs from the various plant components may also be expected to vary year-by-year, and not necessarily synchronously[†]. Seasonal fluctuations in weather will affect crops differently. We know, also, that a characteristic feature of all woody plants, especially in the tropics, is irregularity of flowering and fruiting. What is more, woody perennials develop from a juvenile phase through to maturity and then senescence, so that we are often measuring a process extending over several to many decades. Harvests from woody plants may be seasonal, intermittent, or final, i.e., at the end of their life span, or they can be all three. Clearly the outputs from an agroforestry system, whatever the practice, are not going to be so simple to measure as the more or less consistent production from an agricultural plot. Some of the 'outputs' from an agroforestry system will be in the form of plant residues that will affect soil organic matter content, nutrient recycling, and so on. These are not part of the 'normal' harvests, but they must not go unrecorded if we are to measure sustainability trends, especially those affecting the natural resource base.

One feature of agroforestry is that many of the various practices lend themselves to change. For example, an alley cropping system that is designed and managed for soil fertility improvement can easily be converted to supply leafy fodder or fuelwood if these are needed instead. Boundary plantings for demarcation and fuelwood can be managed differently, if required, in order to allow the trees, or some of them, to grow taller and produce timber, poles or fruits. These substitutions and/or alterations need not, at least biophysically if not economically, be considered as changing the system completely, but just modifying it. Once again, this highlights the need to understand the fundamentals of what is creating the *elements* of a sustainable condition, so that we can see how such changes might affect them.

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† See 'Understanding Agroforestry', this volume.

Because most of our landuse systems *are* extractive, we are usually working on what we might consider to be a 'degradation curve' (Fig. 11.4).

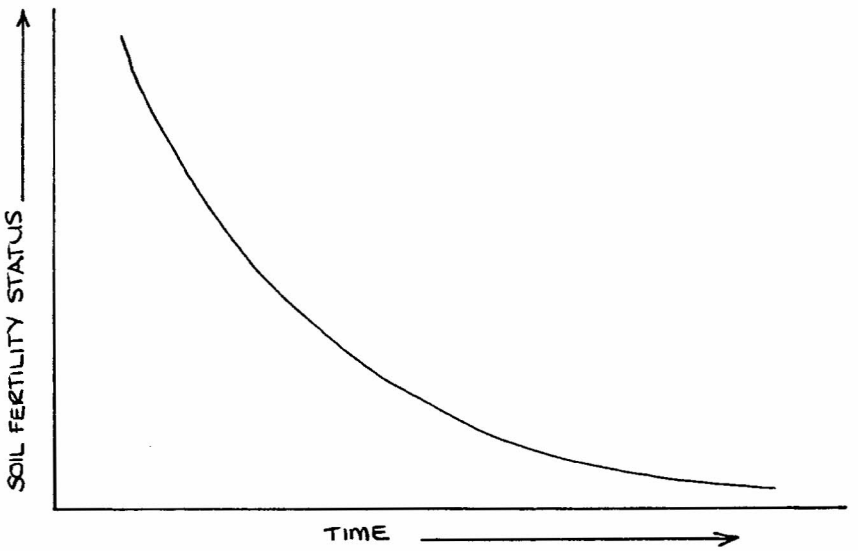


Fig. 11.4. A hypothetical curve showing decline in soil fertility with time (years or decades). When evaluating the sustainability of any landuse system, and assessing the consequences of any decline, we need to know where abouts on such a curve we are at present.

This decline in the natural resource base (Eberstadt, 1980) is often principally through the loss of soil fertility. This can occur either through a direct loss of soil (e.g., on slopes), or because of a loss of plants and a reduction in the plant canopy, with consequences for soil organic matter (SOM.) and soil surface protection (Young, 1989). There are accompanying consequences for the productivity of labour, and income and other benefits, of course. There is enough practical evidence, backed by theory, to confirm that such a decline in soil fertility occurs rapidly at first, i.e., from a high fertility base, and then in an ever diminishing way. It is important to know where we are on this 'degradation curve' because systems low down on the curve will only degrade further rather slowly (unless a catastrophe occurs), so that their decline may be that much harder to detect and monitor. Furthermore, moving

to agroforestry in such systems could have a rapid and significant short-term impact.

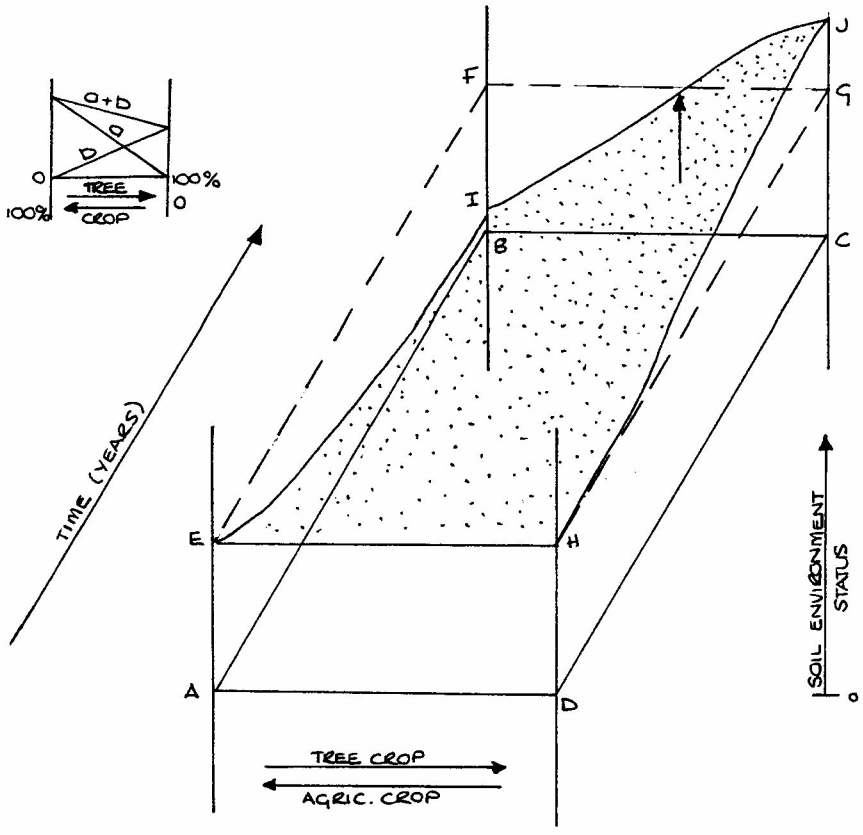
There are two important issues to remember in this respect when we are considering agroforestry practices:

- The first of these is that, except over periods of ' ecological time'[†] , agroforestry systems will not really be adding anything to the natural resource base with the exception, perhaps, of N if nitrogen-fixing plants are used. When we get an '*increase*' of soil fertility under agroforestry, what we often mean is that we have *transferred* nutrients from one part of the system (e.g., the lower parts of the soil profile) to where we want to use them (the upper soil profile where the crops grow). If we are thinking in terms of relatively short-time scales then this is fine (Fig. 11.5), but if our time dimension is measured in hundreds, or even thousands of years, then we can see that we have not achieved very much!

- The second is that where we have tree-crop mixtures, both short-term and long-term benefits can occur (Huxley, 1986). The short term changes are those that bring about an immediate, but possibly transitory affect. For example, where plant residues such as mulch and litter affect the surface root growth, and the sudden release of nutrients facilitates rapid uptake by both the crops and the trees. The long-term benefits will be those accruing through the development of 'labile' and 'stable' humus fractions which affect soil physical conditions; sometimes over long periods. Obviously time-scale comes into this again, and if we want to measure a lasting, residual effect of the system on the natural resource base we have to separate the two sets of activities.

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† 'Ecological time' can be considered to be expressed in units of decades or, perhaps, 'quarter-centuries'; whereas 'agricultural time' is within the expectancy of a farmer, say in 'five-year' units, at most.



(Source: Huxley, 1983)

Fig 11.5. A hypothetical response surface for soil fertility trends (vertical axis) in a tree-crop mixture. The left-hand boundary (E-I) is 100% crop and that on the right (H-J), 100% tree cover. The mixture is treated as a 'replacement series' across the body of the diagram and the trends are shown over time. We know that many tropical cropping practices result in land degradation over a shorter or a longer time period. There is also evidence that trees and shrubs can improve the fertility of the soil (topsoil at least) of the site in which they grow, although this may be a slow process. So what can we expect from any particular tree-crop mixture? So far there is not one set of experimental data that would enable us to plot this response surface (EIJH) for any single combination. Almost certainly, to do this, the *trends* will have to be established and the outcome predicted from a computer model.

Efficiency

For reasons previously given (see 'Agroforestry: Some Functional Aspects', this volume) agroforestry practices have the potential to be relatively efficient

at capturing, and sometimes also at utilising environmental resources. The result of this will be to produce more biomass per unit land area. Landuse practices can be either low- or high- input and efficiency is measured in each as the ratio of outputs to inputs. In practice, we find some fundamental differences between landuse systems at the two input levels, the consequences of which strongly influence management practices and, because of their different operational modes, the approach to research also.

At the extremes we can designate practices as those which depend almost entirely on the Existing Resource Base (an ERB), i.e., low input practices, or those that rely on Additions to the Resource Base (ARB), i.e., high-input practices (Huxley, 1989) (Table 11.1).

Table 11.1. Characteristics of different contrasting forms of landuse. Those that utilise the **E**xisting **R**esource **B**ase ('**ERBs**') and those that require **A**dditions to the **R**esource **B**ase ('**ARBs**')

General objectives for the improvement of ERBs (these will often involve multiple cropping)
To *optimise* regular outputs of products (in agroforestry usually several to many)
To maximise environmental resource capture and to make the system less 'leaky'
To maximise total biomass production
To use 'better' germplasm (not only to increase productivity but also to produce more plant residues)
Often to use more people and to share labour resources
Common objectives
To improve organisation and management ('timeliness' of operations such as sowing, weeding, pruning)
To improve pest management
To utilise and/or develop more skills
General objectives for the improvement of ARBs (these will often be monocrops)
To optimise the use of fertilisers and/or additions of farm-yard manure, irrigation and pesticides etc. (from other systems)
To utilise better equipment for example, for tillage machinery, irrigation pumps, pest sprayers etc.
To manage the system so as to *maximise* the selected product (usually just one, e.g., grain)
To use improved germplasm (largely to maximise the (single) product required)

A typical high-input agricultural ARB system would be a monocultural wheat or a cotton enterprise where high levels of fertiliser are applied, soil is mechanically tilled and there are inputs such as pest, disease and weed control with, possibly, irrigation. In such practices the crop is grown over the 'best' period (or periods) of the year, and it has been 'tailored' genetically to do this, as well as to respond to fertilisers and irrigation. Such crops have also been bred to have a high ' harvest index'. Low input agroforestry represents an ERB type of practice, i.e., with minimum tillage, recycling of plant residues and virtually no material inputs except, perhaps, dung from cattle that have been allowed to graze elsewhere. ARB practices are usually 'leaky' for light, water and nutrients, despite the fact that they are efficient during the time the crop is actually in the ground. ERB practices are likely to be far less leaky, and a key feature is that they will probably produce more total biomass. In fact, the best type of plants to use in ERB systems might well be those that contribute to biomass production. Biomass production is the key to producing plant residues, and plant residues are the key to improving both short and long term benefits accruing in the soil. Of course, both ERB and ARB practices may not be sustainable if too much material is exported from them.

Stability

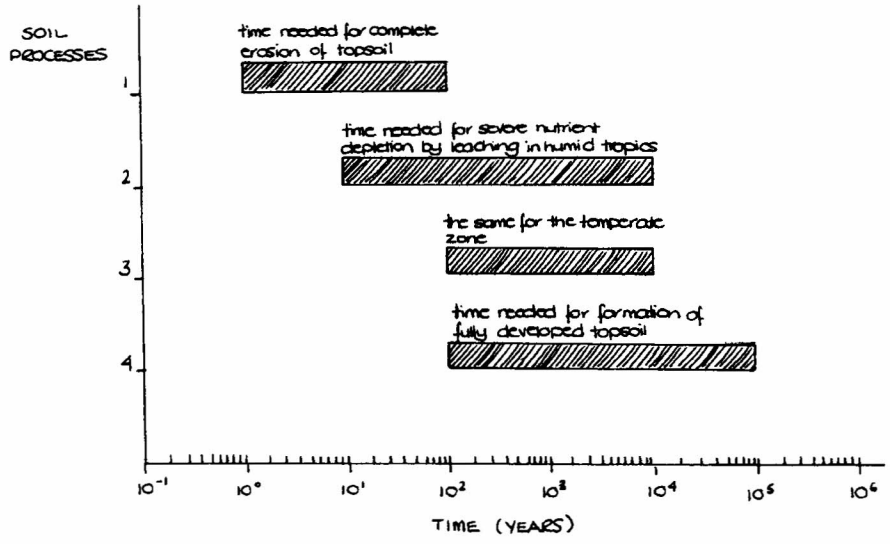
The individual yields within any agroforestry practice will, as in agricultural monocultures, fluctuate season-by-season, or year-by-year. But there is a greater stability in agroforestry systems because they produce a *set* of products, so that a farmer may be able to substitute to some extent, one for another. When we come to monitoring landuse systems for sustainability, a major problem, which is not related to agroforestry alone, is that before one can detect departures from a yield production line you have to establish the trend. The greater the yearly fluctuations from the trend line the harder this becomes and, in any agroforestry system, separate trends for different outputs may coincide or not.

Resilience

This is the ability of a system to absorb change and return to its original condition (Hollins, 1973). The addition of trees or other woody components to a system may well raise its 'buffering' capacity and afford better protection from total failure when it is under pressure from severe adverse events or environmental catastrophes. This may be, in part, because of multiple outputs and, in part, because of the beneficial environmental effects of woody plants, as well as their 'survivability'.

TIME AND SPATIAL SCALES

It is clear from what has been said already that time scales are important when considering sustainability issues and so, also, are spatial scales (Fresco and Kroonenberg, 1992) (Fig. 11.6). We can consider sustainability at the plot



(Source: Fresco and Kroonenberg, 1992)

Fig. 11.6. Many processes affect land sustainability but they operate at different spatial scales (international, national, regional, district, village or watershed, farm, plot). There are also many time scales to consider, as this diagram of soil processes shows.

level on the farm, on aggregates of farms (e.g., in a watershed), and at regional, national and international scales. Trees can exert an influence far beyond their immediate environment. For example, the roots of trees may extend well outside the plot in which they are growing. Clumps of trees and windbreaks exert a sheltering effect over some distance. Trees existing upslope on farm land will affect land downslope, and the whole aggregation of trees in a valley will affect its hydrology. From a socio-economic point of view sustainability might be affected by what happens at the family level, village or community level, and in the society as a whole. The infrastructure and policies existing at national and at international levels will also be crucial for sustainability. Off-site and on-site interactions will often need to be evaluated, as will the benefits accruing to individuals versus the community. In some cases the welfare of individuals may best be set aside so as to ensure the sustainable landuse of the community.

In these sorts of instances we are not merely considering the benefits from agroforestry as the products, but also the services and the way these affect the natural resource base (Fig. 11.7). To do this we have to consider some form of 'natural resource accounting'; this means finding a way to cost off-setting a loss. It may not be too difficult to do this in terms of accounting for plant nutrients in the system, but the social benefits of agroforestry services may be harder to quantify. For example, shelter and amenity aspects related to tree planting will affect the 'quality of life' and hold a level of importance to those living close by far beyond their apparent worth to outsiders. The impact of changes in such factors may be hard to evaluate in terms of sustainability effects, but they may often be part of the outcome of practising agroforestry in one form or another. Similarly, if an agroforestry practice assists with the avoidance of risk, because it offers a diversity of products, then this may be a contribution to the sustainability of the system. Risk is a combination of a farmer's perception of the likelihood of success ('uncertainty') combined with the consequences of making a wrong decision. Again, scale will affect this aspect because a farmer with a small amount of land is less likely to operate at risk than one with more land. Thus, agroforestry options such as alley cropping or boundary planting are generally more readily adopted as farm size increases.



(Photo: P.A. Huxley)

Fig. 11.7.
Trees and shrubs on their own will not stop gulleying. Part of the reforestation scheme on old chena at the Popham Trust, Dambulla.

Trees represent a long term resource which, in some ways, resembles the investment a farmer might make in animals. Trees are grown for timber, or are kept as fuelwood 'reserves'. Such stored wealth can increase year-by-year to be 'cashed in' and used when needs, economic pressures and/or social opportunities dictate. This is another area, therefore, in which agroforestry may contribute to sustainable landuse. Finally, tree management invariably involves a higher level of skill than does the cropping of annual plants. Acquiring and passing on such skills is necessary if the system is to persist efficiently.

MONITORING SUSTAINABILITY IN AGROFORESTRY PRACTICES

If 'sustainability' is to have any meaning it has to be measurable. To do this we have to decide what criteria to use; that is which factors we will investigate in order to decide whether the sustainability of a particular system is being maintained or not. In sustainability work we call such attributes 'descriptors'† and the precise form of assessment that is made is called an 'indicator'. Sometimes it is also useful to set a 'threshold' value, below which (or above which, if it refers to a toxic state) it is unwise to allow the system to move. We can define these as follows:

- ***Descriptor:*** A term that describes which attribute of sustainability is being discussed; for example, 'soil organic matter', 'plant cover', 'labour productivity'.

- ***Indicator:*** A precise form of assessment relating to a descriptor. It can be quantitative (a measurement), or qualitative (an evaluation of a condition). Quantitative indicators might be: 'levels of soil organic matter' (or its fractions) assessed chemically from soil samples; an estimate of 'above-ground biomass', using an appropriate sampling technique; records of 'labour inputs for various tasks compared with yields per unit area'; an assessment of 'food consumption', 'food storage', 'production' and 'cash income' for the household. A qualitative indicator might be an attempt to ascertain how a farmer and his/her family perceive changes in their 'quality of life' over time, using field interviews.

- ***Threshold:*** A value of an indicator above or below which it is considered that sustainability is not achieved.

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† Sometimes just called 'Criteria' but this is, perhaps, a broader term used in common speech, to mean any kind of factor used to make a judgement.

Descriptors can be of very different kinds, for example, simple, compound, 'surrogate', indices, and so on. Soil organic matter is, in fact, a 'surrogate' i.e. a 'stand in', for soil fertility, which itself is a compound descriptor involving many factors. 'Above-ground biomass' is also a descriptor that could represent the biological 'health' of the system, but it is related in complex ways to yield, and the below-ground condition of the plants. Furthermore we can only accurately measure total biomass destructively, and often it involves a considerable amount of work if we are to assess the below-ground biomass as well. Because the different plant components in an agroforestry system are interacting with one another, and they may be affecting within-plant dry matter distribution, total biomass in the system may not change with time although individual yields can do so. 'Labour productivity' is possibly another important descriptor which is easier to measure the simpler the system. Unfortunately in agroforestry, there will be greater complexity in the allocation of tasks and labour responsibilities.

Clearly there are many different kinds of descriptors and indicators which can be measured in agroforestry, but without doubt the process is going to be more difficult than it would be in ordinary agriculture (Huxley, 1995). A single 'suite' of indicators may not be sufficient and it is likely that several will be necessary, covering biophysical and socio-economic aspects. Furthermore, indicators must be simply-defined, relatively low-cost and be repeatable over time so as to discriminate trends. To discriminate a trend means that one must have a base-line against which to note whether there is a departure or not, and therefore, departures from trends will only be established after a number of years of recording. Again agroforestry, because of the variable ways in which the woody components may be harvested, may require a lengthy period in which to establish a reliable trend.

Even when we have chosen descriptors and indicators for a particular agroforestry practice, there is the problem of sampling to be overcome. If we take some descriptor relating to the soil or the plant canopy then we can see that it will be much easier to measure in, say, an agricultural monocrop than it would be in a mixed cropping agroforestry enterprise. Agroforestry systems will be 'patchy' for, indeed, the very nature of agroforestry is both to exploit and create 'patchiness'!

A FINAL COMMENT

Agroforestry has been 'sold' as being, in its various forms, 'sustainable'. We have considered, briefly, what is meant by 'sustainable landuse' and reflected on what is involved. There is no doubt that many agroforestry practices could, if well-designed and well-managed be both productive *and* sustainable. However, it is only by investigating and eventually understanding the ways in which agroforestry systems *function* that we will be able to predict just *how sustainable* (or unsustainable) any particular agroforestry system may be. Even then the problems of sampling and quantifying the sustainability of agroforestry systems, in both space and time, will make monitoring such systems even more difficult than those we commonly find in agriculture.

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12. Animals in Sylvopastoral Practices in Sri Lanka: Past and Present

T. N. Jayatileka

INTRODUCTION: THE PAST

This presentation gives a short, historical commentary followed by some data from a present-day study.

Some Background and Comments

In Sri Lanka the integration of animals in tree-based systems has a long history. The productivity of crops and livestock in various practices was sustained principally through the use of indigenous knowledge systems (IKSs) developed over the generations to manage natural resources. IKSs involved the judicious utilisation of integrated natural resources by communities (DeWatt, 1994). The cohesiveness of traditional societies and social groups led to holistic approaches that resulted in appropriate, environmentally-friendly and sustainable technologies. Not only did such a structure empower traditional farmers with greater control over their own destinies, but it also created technologies that had just and equitable socio-economic implications. Additionally, a comprehensive understanding of natural phenomena and astronomical and spiritual influences resulted in the management of natural resources by more appropriate technologies through the application of astrology and psychic or supernatural powers.

It was within this benevolent infrastructure that animal-agriculture (sylvopastoral practices) developed and contributed to the needs of the traditional societies. The practices based on such indigenous knowledge can be viewed as some of the most complex, yet holistic, systems for tackling human development that we know. Social welfare, food requirements, human and animal health issues, leisure activities and physiological fulfillment, as well as energy requirements in terms of general animal power and stable

programme development, were all wisely co-ordinated so as to fulfill the needs of an increasing population.

A unique feature of the traditional agroforestry practices that flourished in Sri Lanka in the past was the intimate integration of trees, crops and agricultural farm-power animals (cattle and buffaloes) in the farming system. Human needs were satisfied by the efficient use of forests, small dams (tanks), and all other resources in the village ecosystem. Trees provided not only timber, fuel and fodder, but food. 'Modernisation' has ignored the virtues of IKSs; the very basis which promoted the inter-dependence and cohesion of societies and groups. Scientists are often rightfully blamed for social turmoil, ecological imbalances and the development ills and emergent diseases that have been precipitated! Today, there is a growing recognition that modern technologies used for intensive agriculture, including animal production, are not sustainable, and that they can be a major cause of zoonosis and environmental degradation.

The death knell of the indigenous agroforestry systems of the South East Dry Zone (SEDZ) of Sri Lanka is recorded after a massive uprising of the Uva-Wellessa settler-farmers against the rule of Governor Robert Brownrigg in the year 1818. The annihilation of the agroforestry infrastructure was a major setback (Beligalla, 1995: quoting Wolf, 1914). The remnants of one of these sustainable agroforestry practices is clearly visible in low country home gardens. It is also to be seen in the extensive grazing of cattle and buffaloes in tank-based systems and common properties. The historical evidence on animal production systems that existed in Sri Lanka re-emphasises the point that agroforestry, as we know it now, is but a new fashion based on old traditions (French, 1985).

Efforts to reconstruct a more stable and socially-just domestic animal production system by investigating the potential utilisation of current IKSs is urgently needed, because the relevance of these to modern-day sustainable development lies in the low capital demand and the ingenious integration of diverse adaptive strategies that have evolved over centuries. A dependence on local resources is generally important in developing countries, where populations with only sparse economic means are struggling to provide their basic food needs.

The 'Development' Stage

The application of IKSs appears to have been at a very low level during the period prior to current developments when intensive food production models were introduced on Government farms. IKSs became a subject of ridicule and dispute by a generation that received education and alien religions under colonial rulers. Privileged classes from the north, central and southern regions developed as aggressive power groups by suppressing the peasants and the middle class (Beligalla, 1995: quoting Wolf, 1914). This strategy to divide and rule, is a phenomenon common to all colonial administrations and it marks the beginning of the destruction of the traditional societies in Sri Lanka. The onset of major episodes of contagious diseases, such as cholera (1871-1873), of droughts, famines, global depression and world wars (1918 and 1944) all increased the vulnerability of the population to adverse forces. Food security was threatened and an increased dependency on imported foodstuffs came about.

By the mid-20th Century, in an attempt to circumvent the precarious food situation, and amid a series of serious malaria epidemics, the abandoned tanks were again colonised, principally by migrant herdsmen and in order to utilise the grazing lands and forests in the vicinity of tanks for cattle and buffalo production. In addition, under rainfed conditions, crop production was recommenced by 'chena' or shifting cultivation, using destructive slash-and - burn techniques.

The restoration of the 'Ellegala Anicut system' by Engineer Dawson, (1868-1875) was a landmark that provided for the re-operation of the cascade tank systems of Tissa Wewa, Yoda Wewa, Pannegamuwa Wewa, Weerawila Wawa and Debera Wewa. Human re-settlements and the revival of the tank-based animal agroforestry systems were again operational, but with modifications to suit the circumstances rather than the actual needs, and poor integration of the system was an unfortunate feature. Even then, thousands of village tanks continued to remain ruined within jungles. The ruins of the small tanks distributed within the agroforestry systems at Ruhuna (Appendix 12.1), are confirmed by aerial photographs (taken in 1956).

Paddy rice and chena cultivation as well as cattle and buffalo

husbandry became major occupations of the new settlers. Paddy production was possibly under rainfed conditions only during a good rainy season. However, it did become successful in the Ellagala Irrigation Scheme. Rice production was entirely dependent on draught power and became a major source of income for cattle owners, along with Ruhuna curd produced in the settlements; fresh milk had no market demand. The ownership of large herds provided social security and recognition and a new generation of power groups, comprising large herd owners, the 'Gambarayas', were evolved. In many cases the animal owners were also crop cultivators and the opening of new villages, based on rehabilitated small tanks, was influenced by these Gambarayas.

Tractorisation during the mid-20th Century (c. 1950), precipitated critical changes to the agroforestry systems, already under stress due to the demands of modernisation. The gradual de-emphasis of a dependency on buffalo draught power for rice production resulted in the sale of animals to supply the demand in the urban beef markets organised through middle operators. In addition, the expansion of the irrigation and agricultural infra-structure brought about by the Kirindi Oya Irrigation and Settlement Project (KOISP, 1979-1990), under the development support of the Asian Development Bank (ADB), brought further geographical, functional and socio-cultural changes. The ensuing development ills are, therefore, attributable to the absence of holistic approaches, and a lack of understanding of the environmental issues by those entrusted with rehabilitation and infrastructural establishment in Sri Lanka.

THE DRY ZONE TRADITIONAL AGROFORESTRY SYSTEM

Background

The Origins

The eastern regions of Hambantota provide an excellent example of the use of indigenous knowledge to harness the critical resources needed for cattle and buffalo production in agroforestry systems. The use of buffaloes and cattle for

draught power, milk and manure in agroforestry systems in this region dates back to the 4th Century BC (Siriweera, 1993) and the ancient chronicle called the 'Papancasudani' (Rev. Buddhagosha, 5th Century BC) refers to the existence of specific herd management practices within agroforestry systems.

Herd Management

According to later literature, the application of IKSs for domestic animal management has always been a significant feature of this traditional farming system. Some of its features are outlined in Appendix 12.2.

According to chronicles, a vast network of small tanks (Wewa cascade systems) for irrigation and agroforestry production were established by the ancient Kings who governed Ruhuna (Mahanaga-Parakramabahu 1, from 1153-5 BC). The system flourished under various rulers until the decline of the Ruhunu Kingdom from political pressures and foreign invasions at the end of the 12th Century. As was recorded in the early 19th Century, however, this crop-livestock practice, developed over the centuries, was abandoned after the Uva-Wellassa rebellion.

Operation of the Traditional Tank-Based Agroforestry Infrastructure (Wew System) in the SEDZ (Ruhuna)

Introduction

This tank village culture or 'Wew gama' system, established by traditional societies, is unique to Sri Lanka. The heavy rains in the hill country (Wet Zone) provided excellent opportunities for water harvesting and conservation in the Dry Zone. An in-depth knowledge and understanding of the topographical significance of diverse steep slopes enabled the establishment of successful watershed areas. This provided the basis for the development of the major irrigation schemes, and water harvesting and water purification systems. The massive tank cascade systems dispersed over the North Central Province (NCP) and extending to the eastern regions display a system of resource use that has been used for central management by the ancient Kings. However, in

the SEDZ, the existence of numerous small tanks and some 100,000 paddy fields, as recorded by historians as 'Uva Wellassa', indicate more complex sustainable resource management systems by settler farmer communities.

The Sri Lankan 'tank', or Wawa, is a man-made indigenous water-harvesting system devised long ago. Wew Gama was established in order to utilise run-off water from the catchment areas by 'living with' the environment and developing the knowledge to construct earth bunds appropriately. The Wew system included unique concepts for the operation of the whole agroforestry infrastructure, integrating inland fish farming in addition to the management of cattle and buffaloes. Spiritual needs played a part and integration was perfected by the use of astrology to predict auspicious times and spiritual practices, such as 'kems', rituals and religious rites. Offerings ('poojas') to deities, were made in accordance to socio-cultural beliefs and so as to sustain the prosperity of the system. The various components needed for the physical operation of the traditional tank infrastructure are referred to in literature by specific names given in Appendix 12.3.

The Infrastructural Integration

A schematic illustration of the infrastructure of a 'tank' system to indicate how the component parts are related to one another is depicted in Fig. 12.1.

As the investigation below showed, these traditional tank systems are maintained to this day. They not only offer food, shelter, resting grounds, medicinal herbs and grazing opportunities for ruminants, but also promote organic nutrient flows for the growth of fish and agriculture crops. As shown in Fig. 12.1., the integrated tank system can provide *all* the needs of the community. The village homesteads are situated on one or both sides of the tank. The homegarden systems are cultivated with permanent crops such as jak, breadfruit, mangoes and other varieties of fruits, coconuts, spices, tamarind, margosa, etc. Soil fertility in the homegardens is maintained through the application of a comprehensive IKS applied so as to regulate the complex animal-plant biocycle (see Appendix 12.3).

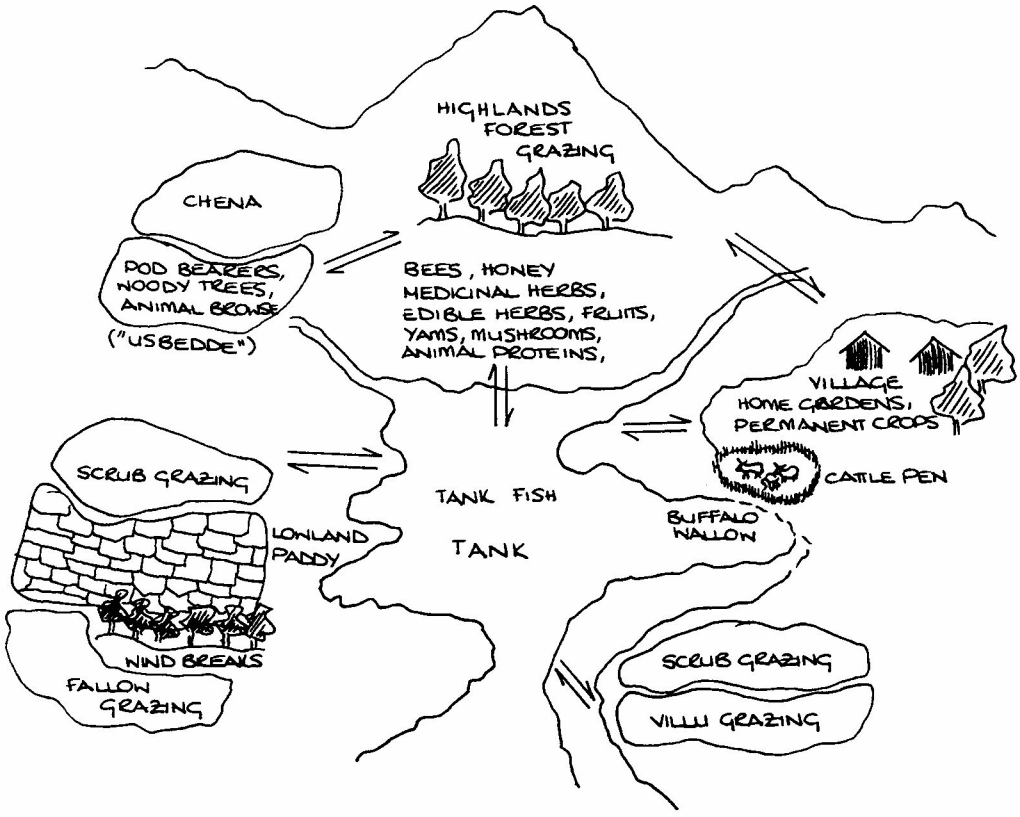


Fig. 12.1. The Dry Zone Tank - Village Integrated System.
(Feeds and water are critical needs for animals).

Animal Management

Under 'traditional husbandry' only lactating cows and calves were allowed to remain in the 'gangoda', or the surrounding areas of the village settlements. At sunset the calves were separated from the lactating cows which were released for scrub grazing over-night. The calves were sheltered in open cattle

pens, usually behind the village tank so as to optimise the distance to tank water, the grazing areas and the settlements. The cows returned to feed their calves in the morning, when milking took place. Names were given to all the calves and cows by the herdsmen to which they responded. Establishment of this human-animal bond was a feature of the IKSs applied in large herd management, continuing today in the SEDZ. The adult males and dry animals were free-grazed in the jungles away from the settlements (Fig. 12.2). The herds that survive jungle grazing returned to settlement scrub grazing only at the end of the cropping season so as to graze fallow paddy lands. They remained to provide farm power for the next cropping season and were driven to the jungles at the completion of land preparation. Ownership of cattle and buffaloes represented wealth and power in the social structure while providing milk, manure, haulage and agriculture farm power. Large herd numbers, ranging from 400 to 1,500 head are recorded in the literature (Siriweera, 1993) providing insurance against crop or total herd failure.



(Photo: T.N. Jayatileka)

Fig. 12.2. Dry season free grazing (Ruhuna).

The free-grazing management in these systems provided a 24-hour grazing opportunity for cattle and buffaloes with free-wallowing and water intake to satisfy the animals requirements. The maximum feed intake occurred during night-grazing because the harsh agroclimatic conditions of the Dry Zone retards daytime feeding. Night grazing of cattle was an important

traditional husbandry practice to ensure the correct feed intake by a ruminant according to its requirements. Our study (below) revealed that, today, a majority of farmers (76.3%) prefer free-grazing of animals over tethered grazing, even in the NWP. Observations on the free-grazing behaviour of cattle and buffaloes indicated that feeding to appetite is fulfilled only under the free-grazing systems, provided the feed resources from the available biomass are adequate (Jayatileka, 1993).

Products

Milk produced under these practices is renowned for its high quality and purity, attributable both to the genetic traits and the intake of a variety of different kinds of roughage and medicinal herbs. The farmers believe that milk quality increases when cattle graze the 'usbadde' (Fig. 12.1) or the upper reaches of forest vegetation. Milk is used in the preparation of five important preferred traditional dairy products of pre-determined keeping quality. These high value dairy products are known as 'pasgorasa' to describe, overall , the five different tastes of excellence, i.e., fresh milk ('kiri'), curd ('di-kiri'), whey or butter milk obtained by churning curd or cream ('yodaaya'), ghee ('gitel'), and butter ('vendaru'). Buffalo milk is used in the preparation of curd and also buffalo ghee ('dumtel'). The fine quality of the curd known as 'Ruhunu curd' encouraged the establishment of the curd industry in Sri Lanka.

Recent findings indicate that the taste qualities are due to a particular di-acetyl flavour possibly formed by *Lactobacillus* spp. involved in the fermentation (curdling) process and not found in other regions. The traditional methods of processing value-added dairy products are fast disappearing and could be witnessed in our investigations only among a small percentage (1.3%) of traditional communities in the Dry Zone. These dairy products are usually unrefrigerated.

Crop management

Seasonal crop cultivation during the twin monsoon periods is a community activity where the decision-making is done by the village chief or 'gamarala'.

The collective decisions of the farming community provides the guidance required to execute the animal agroforestry production programme planned according to indigenous practices.

Cultivation practices such as minimum or zero tillage, mixed cropping, extended sowing, mulching, cultivation of small land portions for water conservation, pest management, harvesting and heaping in the fields, are seemingly supported and accompanied by indigenous customs of making vows to deities, by 'kems' or rituals and religious rites, through the prediction of auspicious times for protection from evils, predators, pests and the inevitable adverse changes of the climatic conditions. Records are cited in folklore of the use of supernatural powers, aromas from tree leaves and tree barks, the need for identifying auspicious times to initiate particular practices and to avoid attack from wild beasts, including wild elephants. Separating portions of the harvest for deities, performing 'poojas', and celebratory festivities are common practices recorded in chronicles. Examples are the ancient 'mutti sellama', or the 'festival of the pots' held before the start of crop production, the 'bahirawa pooja' offering to spirits that look at crops and cause losses, and the 'mangara pooja' a special offering to the diety 'mangarta' to protect buffaloes. Chanting of 'suththaras' or 'pirith' to protect human, animal and plant life from epidemics, or to increase health, longevity and yields according to Buddhist philosophy, are important spiritual features of the traditional system.

Factors Maintaining the Traditional Practices

The issues that have supported the continuation of traditional animal agroforestry practices can be summarised as follows:

- The essential application of IKSs relating to environmental resource management, arising as an outcome of in-depth comprehension of the ecosystem. This has been built up, over centuries, through the perception, observation and understanding of natural phenomena.

- A holistic approach to integrate crops, trees, animals, fish, wild life, and forests based on a potentially sound bio-physical/socio-economic infrastructure; i.e., the tank-village system.

- An essentially participatory, but efficacious, approach to decision-making by one individual, the 'Gamarala', in strict adherence to the collective rights of the local community, and without external pressures.

- The operation of the system to satisfy and balance the critical needs of the community whilst maintaining the natural resource base (see Appendix 12.3).

THE CURRENT INVESTIGATION: RESULTS AND DISCUSSION

Investigations of the place of animals in agroforestry practices obviously, itself, requires a holistic approach. It is a formidable task, given the areas to be covered, and the extent of variation generally associated with the application of traditional knowledge in farming systems. Since the village-based tank, crop-livestock system is a major income source for farmers in the South East Dry Zone (SEDZ), a preliminary study was undertaken to examine traditional methods of cattle and buffalo management within such systems. The results of modernisation have been analysed by focusing on the present farming systems in three agro-ecological zones - the Dry Zone, the Intermediate Zone and the up-country Wet Zone. The study was undertaken by the Agriculture Resource Management Division (ARMD) of the Agrarian Research and Training Institute (AR and TI).

Objectives

Overall, the study was undertaken in order to:

- expose issues that can support sustainable development through the application of IKSs relating to the integration of animals in traditional agroforestry practices in Sri Lanka;

- identify the existing situation concerning the status of agricultural animals (cattle and buffaloes) within specific agroforestry practices; and
- examine and evaluate the problems and prospects for the reconstruction of IKSs concerning animal agroforestry and the possibilities of combining these with modern scientific knowledge.

Only a limited number of studies have been conducted by previous researchers to enumerate the socio-economic details and the constraints for cattle and buffalo management in the different Districts and agro-climatological regions in Sri Lanka (Wimalasuriya, 1992; Abeygunawardena, 1993). The present study was conducted specifically to examine the use of IKSs in cattle and buffalo farming systems for the utilisation of critical resources, feeds and water, from agroforestry systems in three major agro-climatic zones in Sri Lanka. The remnants of the traditional animal agroforestry system, developed over the centuries by the farmers of the SEDZ has been particularly investigated by this research study in an attempt to understand why the intensive dairy farming models and specialised dairy breeds introduced from the industrialised world have failed to increase in-country milk production.

Methodology

The Study Area

The first study was made in the Southern Province (Ruhuna) in the Hambantota District (see also Smith, 1986), and a brief analysis was also made of a present farming system in the North Western Province (NWP) and in the Central Province (CP), in order to determine their dependence on traditional practices. The modernisation of farming systems, based on models copied from the industrialised world and using pure *Bos taurus* breeds and crosses, are significant features in the NWP and the CP.

The study areas (Table 12.1) are located by maps in Appendices 12.4 to 12.7. These areas, selected from the three Provinces, make a major

contribution (>55%) to the in-country milk production. The areas differ considerably in terms of their ecological, cultural, historical and institutional features.

Table 12.1. Location of Study Areas (see Appendices 12.4-12.7)

Province	Study Area	Agro-ecozone
Southern	Hambantota	Dry (DL 1-5)
North Western	Kurunegala	Intermediate (IL 1-3)
Central	Nuwara Eliya	Wet (WU 1-2)

The Survey Technique

The techniques employed included a literature survey, interview schedules with farmers and role players, and field sampling.

The population of traditional farmers in the study areas were identified through the traditional cattle and buffalo farmers themselves, and through indigenous animal health practitioners in villages. In addition, government and non-government organisations active in the traditional sector community were utilised and livestock owner farmer associations, milk cooperatives and milk collecting points were usefully referred to.

Data collection was done through reactive measures, eliciting responses from individual farmers, farming families, village elders, astrologers and role players such as traditional medical practitioners, spiritual/divine healers (Kapurala/Yakaduras), indigenous medical practitioners, priests and members of farmer groups. Information was also obtained by direct field observations.

A participatory rural appraisal (PRA) technique was adopted in carrying out the informal discussions. In addition, the field survey was further supported by a questionnaire designed to lead the discussions of about 40 traditional farmers from each study area. The total sample covered 234 individuals. The outcome of interviews and the observations that were recorded in the questionnaires were analysed to obtain summaries and statistical averages, where essential.

The SEDZ - Hambantota District (Ruhuna)

Background

Hambantota District (Ruhuna) is in the SEDZ of Sri Lanka (see Appendices 12.4. and 12.5, and see Smith, 1986). A major negative impact on the sustainability of animal agroforestry systems has been caused by the distribution of land settlements based from the Kirindi Oya Irrigation and Settlement Project (KOISP) and the use of ruined tanks for crop cultivation only (see also Appendix 12.1). Changes occurred without any considerations for the land/use and husbandry patterns of free roaming, large livestock herds (Fig. 12.2). This traditional cattle husbandry practice was viewed as a 'Stray Cattle Menace' by those responsible, through a lack of knowledge about the economics of traditional animal husbandry and the model that had been developed over centuries by the farmers.

Construction of a dam (a massive 'tank') in the Kirindi Oya basin at Lunugamwehera, demolished innumerable small tanks, but failed to fulfil the expected water output. This was attributed principally to an inappropriate site and a high evaporation loss from the tank surface. The positioning of the dam within a poor catchment area is still a major techno-political controversy. Thus, despite the recent influx of development support from the international community, problems still remain.

The Farming Systems

The present status of cattle and buffalo farming within the agroforestry systems in this region, as enumerated by our study, reveals a continuation of the 'traditional system', but with many modifications. A lack of integration with crop production and of alternative feeding systems, as well as organised cattle theft, are major constraints to cattle productivity. This has given rise to a complex situation resulting from major conflicts between the crop and cattle owners. The issues are as follows:

- a modernisation policy directed at irrigation and crop production with land alienation and human settlements for increased crop production;
- lack of a land policy for cattle and buffalo production, with reference to the economics of farming systems adopted by cattle owners; and
- a lack of direction of development support to strengthen the indigenous animal agroforestry production systems based on local resources.

Deviations of the free-grazing management due to the expansion of agricultural lands can be summarised as follows:

- *Forest-based grazing:* Animals are grazed within forest reserves with herdsmen in charge of the herd welfare.

- *Village-based grazing*: Animals are grazed in common areas within villages, tank bunds and fallow rice fields. The grazing areas are restricted tethering in the highlands during the cultivation season.

- *Pastoral grazing*: This management system involves extensive grazing but with the lactating cows and calves kept in the vicinity of the villages, or 'ganagoda', to graze fallow lands, scrub jungles and parklands outside cultivated areas. The rotation of non-lactating herds and male animals in forest reserves, woodlots and parklands out of the village areas, particularly during the period of cultivation, is an important feature. After the completion of land preparation for rice production, these herds are driven deep into the jungles until the end of the harvest. The seasonal migration of cattle and buffalo herds to uncultivated common properties, forest reserves and abandoned small tanks during the cultivation season is therefore a common feature. The animals return during the off-season to graze fallow fields not being used for crop cultivation.

The migratory patterns established are illustrated in Fig. 12.3. The release of irrigation water for crops during the two rainy seasons (known as 'yala' and 'maha') heralds the outward movement of animals in the SEDZ.

The present efforts of farmers to harness all possible resources in common properties in this low input-output system, are significant in providing supplementary cash incomes.

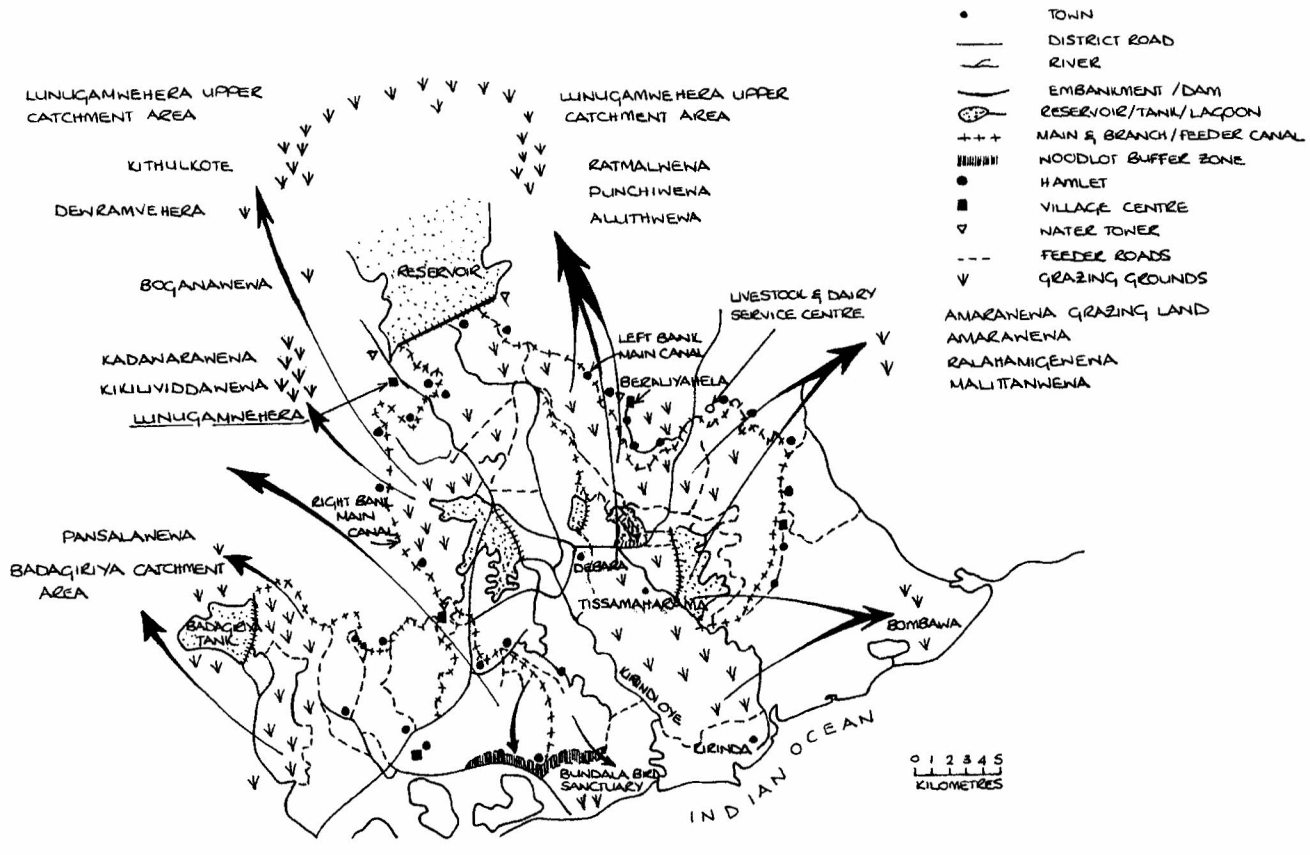
Cattle Resources

The multipurpose nature of the indigenous zebu cattle and of the buffaloes, together with their presence in large numbers, are significant features.

Only a low level of productivity of indigenous zebu cattle was recorded in the study, i.e., a milk yield of 0.72 to 1.1 litres day^{-1}. The low mature live weight attained (150 to 200 kg) is attributed to inbreeding within herds. This is further confirmed by low birth weights of 12 to 15 kg and poor growth rates. However the high fertility rates (83%) result in productive female herds with a capacity to produce a calf every year. Inherent resistance to diseases, and the ability to withstand harsh environmental conditions are considered as positive features. Indigenous buffaloes have higher body weights (150-300 kg) and can thrive better than cattle on poor quality roughage. The ownership of animals is, however, limited to relatively few individuals or 'Gambarayas', with large herds ranging from 150 to 500 animals. Individuals often herd both species together, cattle and buffaloes.

Seasonal loss of body condition is commonly seen in cattle and buffaloes and is attributed to a deviation from the traditional feeding system as well as agro-ecological stress factors. The latter are a major constraint to cattle productivity in the SEDZ. Random visual assessments of body condition (as scores) during the wet and dry season, indicated that a majority of cattle had 'poor' (23.2%) or 'thin' (27.4%) body conditions during both seasons. However, in buffaloes the seasonal loss is less, 10.2% and 7.3%, respectively, confirming their ability to thrive better under harsh conditions. Loss of body weight during the wet season, despite the more prolific

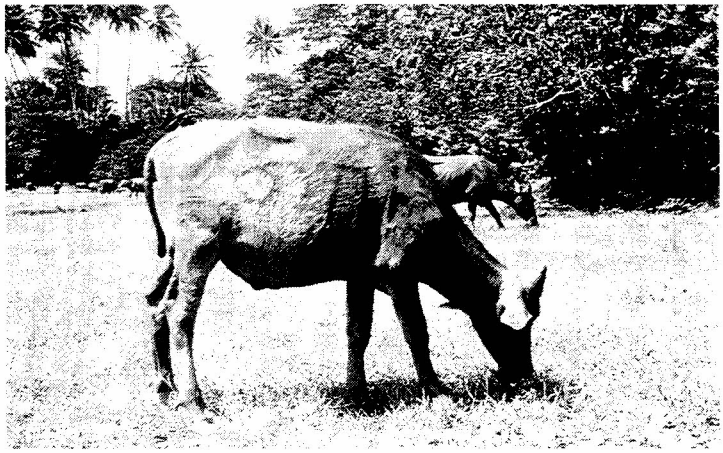
Fig. 12.3. The dislocation of cattle and buffalo grazing patterns during crop cultivations in the Kirindi Oya Basin, Ruhuna.



growth of vegetation, results from poor accessibility to forage from the non-integrated cropping systems.

Indigenous Production Practices

A majority of farmers (96%) provide animal health welfare through IKSs. Clinical services are also available from a few indigenous veterinary physicians. These practitioners are a neglected lot, currently disillusioned due to the non-recognition of their services by the Government (Jayatilleka, 1994). A majority belong to the older generation and the practice is dying out as second and third generation youths are not willing to learn the profession. Such practitioners are capable of providing both spiritual assistance and material medications to cure sick animals (Fig. 12.4). Modern veterinary services in urban centres are also available to farmers.



(Photo: T.N. Jayatileka)

Fig. 12.4 Moxibustion of vital points is an indigenous treatment for buffaloes which is considered to strengthen the immune system.

The socio-economic parameters under the present animal agroforestry system are given in Table 12.2.

Forest-based systems appear to provide low incomes (Rs. 30.9animal^{-1}) while higher returns are possible under pastoral grazing (Rs. 101.6 animal^{-1}). However, the farmer's objective (Table 12.3) is seemingly important in determining the family income.

It is evident that the present cattle and buffalo production systems closely follow the traditional ways, using unimproved indigenous zebu cattle and with a few modifications according to the farmer's own situation. The herd size averages 62.9 for cattle and 71.8 for buffaloes. Herd size is a major determinant of the family income. An inherent tendency for profit maximisation through cost minimisation is evident from the husbandry methods adopted within the agroforestry systems. Therefore, technological changes which warrant high cost inputs are slow to develop and hitherto have not been attempted, unlike the situation in rice production, for example.

Table 12.2. Socio-economic data for cattle farmers using different animal production practices in the SEDZ

Grazing System	Chena (acres)	Paddy (acres)	Herd size	Income (Rs herd^{-1} month^{-1})
Traditional	1.5	2.5	69	4,580
Forest-based	0.8	3.5	473	14,630
Pastoral	0.4	2.5	94	9,565
Village-based	1.8	3.4	12	86

(Source: Survey data, 1994)

Table 12.3. Reasons for keeping animals in the SEDZ (Ruhuna); the percentage kept for different purposes.

Species	Marketing Objective (% of total animals kept)		
	Animals for meat	Animals for dairy	Animals for other purposes
Buffalo	28	39	33
Zebu	42	36	22
Zebu + Buffalo	56	34	10

(Source: Survey data, 1994)

With the exception of forest-based grazing, the farming system fails to ensure the year-round nutritional requirements of cattle. However, only 9% of farmers provide additional feeding other than free-grazing. The use of leguminous tree fodder from introduced species in the SEDZ is minimal, just 1-2%, due to a greater dependency on the availability of tree leaves from indigenous species such as *Prosopis* spp. and *Bauhinia* spp., which are used during the dry periods. Where milk production is concerned, the system does not promote the milking of cows. Milk production per cow is inversely related to herd size; a significant finding. Milk is left in the udders for calf-raising

and the sale of live animals forms a major part of family income (Table 12.4). The number of animals in a herd is an important feature to determine the economic returns to the farmer. However, a majority 83.7% refused to indicate exact herd numbers as this is not in accordance with the traditional beliefs of the herders.

Table 12.4 Farm family income from zebu cattle on cattle production farms in the SEDZ

Herd Size	Total	Milk	Meat	Income from milk (%)	Income from meat (%)
	(Family Income, Rs^{-1} $year^{-1}$)				
<50	24,225	16,252	9,744	0.69	0.31
50-100	61,356	29,284	32,072	0.48	0.52
>100	118,490	40,365	78,125	0.34	0.66

(Source: Survey data, 1995)

The percentage income from milk production in small herds below 50 provides is modest, but a duel objective of milk and meat with a herd size above 50 can provide sizeable cash returns. The feed cost under the traditional agroforestry grazing system was assessed to be very low (ranging from 0-7% of production costs), and this has a very high potential for further development provided structural adjustments are forthcoming to ensure a sustainable production system with linkages to modern marketing strategies.

The investigations also indicated that animal agroforestry systems in the SEDZ became severely stressed as a result of the tractorisation policy that took place during the mid-20th Century. At present, the SEDZ is a major supplier of live cattle and buffaloes to the urban beef markets, but the informal marketing system produces sizeable incomes for butchers and middle operators at the expense of farmers. Such a marketing system favours the raising of large rather than low herd numbers under these low input-output systems, so that only herds that range between 50 and 100 animals or more, raised for both milk and the sale of live animals, can provide significant returns to farmers.

Some Conclusions

There are inefficiencies within the present animal production systems:

- There is an absence of a land alienation policy for ruminant production.

- Inbreeding results in poor animal performance.

- The various grazing systems adopted result in low farming efficiency. This is associated with many factors, for example, the absence of night-grazing, the loss of grazing and wallowing opportunities, trekking for long distances, increased calf mortality, poor adoption of alternate feeding strategies, non-recycling of animal wastes and the non-integration of animal production with crop production.

- Conflicts exist due to itinerant herds and organised cattle theft.

- Damage is caused to irrigation canals and there are threats to the use of common properties (Fig. 12.5).

- Feed resources and the agricultural by-products available in the region are poorly utilised, for example, fodder from leguminous trees and other indigenous tree species, rice straw, bran, sugar cane lopping, bagasse, molasses, etc.

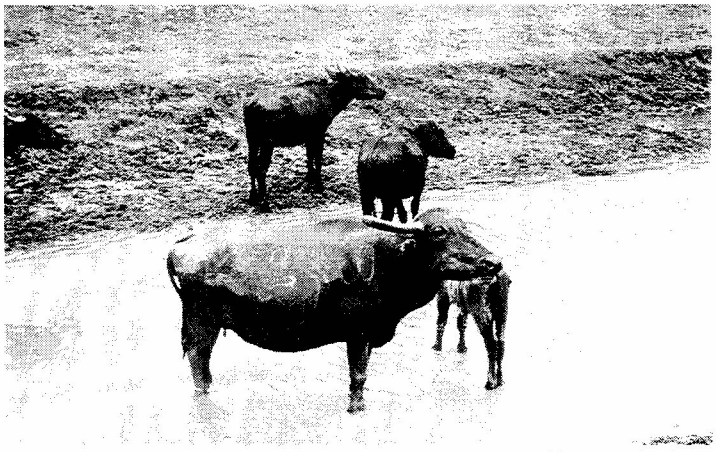
- The marketing strategy favours middle operators.

However, there are two important issues which outweigh the low farming efficiency which are of significance, as follows:

- Sizeable cash incomes can still be achieved by the farmers and the many intermediaries involved in this production system.

- The tank-based animal agroforestry system is an indigenous production model developed by the farmers according to their own

situation, and it is still potentially able to harness environmental resources in a way that is environmentally viable and socially acceptable.



(Photo: T.N. Jayatileka)

Fig. 12.5. Free wallowing and grazing by buffaloes can cause damage to bunds.

Results and Discussion: The North Western Province (NWP)-Kurunegala District

Kurunegala District is an ancient fortress in the NWP and it lies in the Low Country Intermediate Zone (Appendices 12.4 & 12.6). Agro-ecological stress on cattle and buffalo production is less prominent; there are many resources available for multi-species animal production within the agroforestry and coconut plantation systems. Water resources are harnessed from the ground, minor irrigation tanks and streams (such as the Deduru Oya and Maguru Oya). Rice-based agriculture, animal husbandry and coconut plantations (covering 155,113 ha. in all), are the principal means of livelihood; mostly under rainfed conditions. However, the emergence of multiple-income generation strategies within the coconut plantations in the Intermediate and Wet Zone areas are positive features that support opportunities for rural employment.

Coconut is the most important commercial crop and the area under coconut is popularly termed the 'Coconut Triangle'[†] . It is of major

† *See 'Multiple Cropping Under Coconuts', this volume.*

agricultural importance and it also supports livestock enterprises (Fig. 12.6), often poultry, dairy, goats and pigs, all of which are integrated with plantations or rice. These have developed as major economic activities during the past two decades. Egg, broiler and provender feed operations, under contract-grower models, are well integrated in the coconut plantations. The cropping and landuse patterns indicate a very high demand for economic returns from limited land holdings. However, crop failure during droughts is a common feature and this requires the adoption of other income-generating strategies. This is where animal husbandry occupies a central place.



(Photo: D.M.S.H.K. Ranasinghe)

Fig. 12.6. Sheep grazing in a fenced coconut plantation.

Animal Husbandry in the Agro-plantations

About 44% of the families involved in plantation agriculture are engaged in animal husbandry using multi-species livestock. Despite the limited holdings, and poor profitability, cattle and buffalo raising is undertaken in order to achieve a supplementary income to goat production for milk, meat and manure. Access to large property resources under coconut plantations are made through traditional usage agreements. These agreements are a unique feature of the NWP which provides landless peasants the means whereby they can integrate their livestock enterprises with rice fields and coconut plantations. Farmers rotate cattle and buffaloes so as to graze vegetation in the

general agricultural and plantation sector through a traditional labour exchange system. In return for family labour to provide general security and bush clearing, and for the cattle manure provided, the non-resident land owners allow access to grazing opportunities and crop residues in the plantations for cattle and buffalo production. Demand for buffalo and cattle draught power for agricultural plantation crops is high, ranging between 51-61%; a distinct contrast from the rest of the rice-producing areas in Sri Lanka. Crop - livestock conflicts were recorded at a lower level in this area as the crop plantations are generally protected by fences, and a majority of farmers practice tethered-grazing of animals.

In a similar way to the landuse agreement, cattle and buffaloes are entrusted to individuals under a indigenous arrangement called the 'Ande Cattle System'. A person without animals can, therefore, become a livestock 'owner' by enrolling in this scheme. A modified 'Ande' scheme is operated by the Provincial Council through the Government Veterinary Officers for poverty alleviation and also for the commercialisation of elite farmers.

Milk Production Potential

Based on the 1993 population estimates of 81,120 milk cows, the potential milk production from the agro-plantation sector is estimated at 19.2 million litres annum^{-1}. The highest concentration of buffaloes is found in this district (177,177), but only a few (3.8%) are milked (Jayatileka, 1993).

Farmer Objectives and the Economics of Cattle and Buffalo Production

Findings indicate that, again, farmers keep cattle and buffaloes for multiple objectives, depending on the grazing resource available within accessible agro-plantations and on the cropping pattern (Table 12.5). As indicated, a majority raise cattle and buffaloes for milk production.

Our investigation also revealed that the economics of the farming systems are, as expected, dependent on the agroecology (IL1, IL3 and DL1 - see Appendix 12.3), the cattle breeds and management inputs. For semi-intensive farming systems, breed improvement, better nutrition, housing and

husbandry are all feasible. A satisfactory level of farming efficiency can be obtained with relatively small herds on limited land areas, in comparison to the larger herd sizes found under extensive management. Yet, although smaller, these systems depend on traditional land agreements, and/or accessibility to common areas.

Table 12.5. Reasons for keeping animals in Kurunegala; the precentage kept for different purposes.

	Multiple Use (% of total)	Dairy Use (% of total)
Cattle + Buffaloes	27	30
Cattle only	11	32
	38	**62**

(Source: Survey data, 1995)

The traditional production system relies on the feed available from standing biomass. Free-grazing herds are common in IL3 and the DL1 zones. Semi-intensive, tethered grazing (Fig. 12.7) is common in IL1 and IL2. Supplementary night-feeding with straw, high quality pasture, leguminous tree fodder (cattle utilise 35% and goats 90%) and concentrate rations with mineral supplements (ranging from 1-8 kg milking cow^{-1} day^{-1}), are to be found. However, the feeding systems are only marginally adequate to meet the production potential of the improved *Bos taurus* breeds in the 'Coconut Triangle', a major detrimental factor for milk production.

Average milk yields examined under three farmer classes - Class I, II and III, respectively (see Table 12.6), differ according to the management intensity and the breed types kept in the different climatic zones. The breeds vary from the pure *Bos taurus* types, their crosses, and the indigenous zebu types. Further data are also given in Table 12.7.

The milk production costs incurred by Class I farmers are high, 52% more than the Class II and III farmers as shown by Table 12.8. The production costs in the DL1 and IL3 under free grazing management is similar to that in the SEDZ. Therefore the rotation of animals in these systems is, seemingly, important to landless farmers in Sri Lanka, and this aspect requires to be effectively reorganized with development support.



(Photo: P.A. Huxley)

Fig. 12.7. Tethered grazing under coconuts at Lunuwila.

Table 12.6. Average milk yields according to management intensity (classes I - III) and breed types (Zone IL1)

Farmer Group	Average Milk Yield (litres cow^{-1} day^{-1})	Standard Deviation
Class I	6.24	± 1.3
Class II	4.6	± 1.3
Class III	3.84	± 0.79

Class I - Intensive to semi-intensive with improved breed
Class II - Semi-intensive with improved breeds
Class III - Semi -intensive with local breeds

(Source: Survey data, 1994)

Table 12.7 Milk, meat and total income by farm and animal

Income per year (Rs. farm^{-1} year^{-1})	DLI&IL3	IL1		
		Class I	Class II	Class III
Total income	33,487	49,623	25,896	15,337
Milk income	20,809	34,773	20,858	14,194
Meat income	12,678	14,850	5,037	1,142
Income from milk	62	78	83	95
Income from meat	39	22	17	5
Total income (Rs. animal^{-1} year^{-1})	1,321	5,173	3,053	2,567

(Source: Survey data, 1994)

Table 12.8. Costs incurred in cattle and buffalo farming - NWP (Rs. farm^{-1} year^{-1})

Cost Component	DL 1 and IL 3	IL 1 Class I	IL 1 Class II	IL 1 Class II
Feed	238.5	1977	1214	1055
Medicine	53.6	195	270	229
Fuel	3.4	-	15	-
Maintenance	21.8	534	151	160
Utensils	126.0	231	209	199
Hired Labour	33.4	645	128	-
Total	512.8	4123	1997	1650

(Source: Survey data, 1994)

Some Conclusions

Cattle and buffalo farming practices in the NWP are well-integrated with the agro-plantations. There is a consolidation of profit-oriented, multi-species livestock enterprises with economies of scale through contract grower schemes and traditional agreements. Farming efficiency is variable using moderate to high levels of technology. The availability of agro-industrial by-products such as coconut 'poonac', rice bran, etc, has promoted the use of concentrate rations. However, these are only marginally adequate to meet the nutritional requirements of improved cattle and buffalo. Modern veterinary facilities are easily accessible in urban centres, but difficult in the rural sector where farmers use indigenous technologies. No attempts have yet been made to upgrade the indigenous animal health welfare facilities for dairy cattle and buffalo production in the NWP. An increased milk extraction rate >65% from the coconut triangle is a positive feature for milk marketing, but the sale of live animals remains within the informal sector in the hands of the middle operators.

Farming practice is of significance with reference to the national goals on dairy development and strategies could be introduced to:

- establish the desired cattle/buffalo gene pool to match the resource availability from the available vegetation, since efforts to grow improved fodder/pasture species have failed to cover the opportunity costs under limited land resources;

- develop feeding options, including the feeding of urea-molasses based multi-nutrient feed supplements to reduce feeding costs and promote under-utilised resources such as rice straw; and

- increase the herd size within the limited land holdings through better management.

Results and Discussion: The Central Province-Nuwara Eliya District

Nuwara Eliya District (Appendices 12.4 & 12.7) in the Wet Zone at elevations above 2,000-2,500 m, receives an annual average rainfall of 1,500-2,500 mm. It is well known for its salubrious environment, and it was selected in colonial times as ideal for the temperate breeds of *Bos taurus* and for tea growing. This alteration of the ecological balance spelt disaster to the traditional hill country and furthermore, the importation of plantation workers from South India resulted in major socio-economic and political problems. The changes in soil management certainly gave rise to high erosion hazards in 27% to 32% of the up-country land areas. Currently, only 37% of the land is suitable for agriculture, while 28% is unsuitable for any agricultural use. In some places water has become a scarce resource!

The Village and Estate Sectors

Investigations of the cattle industry within the estates, villages and the Government and NGO farms in this District has indicated a generally low farming efficiency, with milk yields well below the acclaimed production potential of temperate cattle. There are many reasons for this position. Although the temperature is highly favourable for *Bos taurus*, the prevailing high humidities and strong winds predisposes cattle to diseases. Severe land scarcity requires husbandry management under intensive zero-grazing regimes. The cattle feeding systems are dependent on naturally-growing grass species such as Guinea A and B (*Panicium maximum*), Kikiyu grass (*Pennisetum clandestinum*) and patana grasses like *Chrysopogon* and *Arundinella* spp. High quality leguminous fodder such as alfalfa or fodder

sorghum, maize or silages are, however, absent in the feeding regimes. The use of high level concentrate rations for milk production is in vogue, but not cost effective, due to the prevailing unrealistic milk price and concentrate price ratios in the market. Supplementation with concentrate rations is essential due to the high water content of natural vegetation in the up-country Wet Zone.

In the up-country villages, 61% of the farmers are involved in the dairy agri-business with an average of 2.1 cows household^{-1} and 62% of these being *Bos taurus* breeds. The use of concentrates is in the range of 0.5 kg milking cow^{-1} day^{-1} and the milk yields are low, 3-5 litres cow^{-1}. Small scale dairy development schemes are operated by the Milk Co-Operatives, Government and Non-Government Organisations so as to consolidate milk production in the marginal villages.

In the estate sector, the plantation workers are encouraged to keep good quality dairy cattle through soft loans, a support infrastructure and veterinary facilities, which are not available to cattle owners in the village sector. Seventy three percent of the milking cows are pure *Bos taurus* breeds and 67% of the farmers provide concentrates, at a level above 3.8 kg cow^{-1} day^{-1}. Two point nine percent of the farmers use superior diets involving protein by-pass materials in the rations, reaching up to 8 kg cow^{-1} day^{-1}. Milk yields are in the range of 13-16 litres cow^{-1} day^{-1}. On the Government farms the average herd milk yield stands at 9 litres cow^{-1} day^{-1}. The highest yields are reported in NGO dairy farms. Cattle ownership in the estate sector (2.8 cows household^{-1} on average), indicates a reduction of 26.6% from that reported a decade ago.

The population estimates indicate 19,720 milk cows with a production potential of 39 million litres year^{-1}. The extraction rate exceeds 60%. All cattle under the up-country estate production system are insured, whereas the farmers in the village sector know little of cattle insurance.

The production of milk and cow dung (much in demand for vegetable growing) are two of the farmers' major objectives. Sale of excess heifers and bull calves provides regular cash incomes due to the high demand for exotic dairy cattle from the Intermediate Zone. The progressive genetic decline observed within the existing exotic breeds is a significant finding. The socio-cultural and religious habits of the plantation workers, and their dairy

enterpreneurial skills, are highly favourable for the milk industry in the up-country Wet Zone.

The costs and returns on milk production in the village and estate sectors vary widely. The economic parameters show similarities with Class I, II and III farmer groups of IL1, in the Kurunegala District (see Tables 12.6 and 12.7).

SUMMARY

In this region the production skills of Class I farmers (intensive to semi-intensive, with improved breeds) offers only little advantage when comparing the annual net returns with those of Class II and III farmers (semi-intensive with improved breeds and with local breeds, respectively). In fact, the high input systems add additional risks which farmers are not willing to absorb. Thus, the profitability of Class I farmers is highly sensitive to changes in the milk yield of cows and the major cost component, i.e. the concentrate ration (calculated to cost Rs. 14.59 per 3.55 kg unit). In all these systems the roughage is derived free, using family labour, indicating again the dependency on the natural vegetation, as with traditional practices elsewhere.

Within this context, it is not surprising that milk yields in general, have hardly increased over the past few years. Strictly speaking, increased milk collection in the island has only been accomplished in areas where efficient milk procurement systems are operational and where milk production is based on minimal cash expenditure by the farmers, especially with regard to concentrate rations.

PROSPECTS AND PROPOSALS FOR THE EXTENSION OF ANIMAL SYSTEMS WITH AGROFORESTRY IN SRI LANKA: A SUMMARY

Profitability is Essential

The farming systems reviewed indicate that farmers' objectives are of considerable significance in determining the economic returns in both the

animal agroforestry and the agro-plantation sectors. The profitability of the production system is a key issue.

The Extensive Grazing System has Promise

In the traditional systems a farmer has multiple objectives in keeping cattle. This is the predominant practice in the Dry Zone, with extensive free grazing of indigenous zebu cattle and water buffaloes. The milk production potential is low and depends purely on the availability of natural biomass resources including trees and shrubs. The extensive grazing system is advantageous as it uses only unproductive lands for free grazing. The social costs of grazing scrublands and fallow paddy lands over an average of 8.4 hours day^{-1} is considered marginal, provided the grazing pressure does not exceed the carrying capacity of the common property resources. Crop damage and conflicts with cropping practices are major social costs but, in the absence of a policy to protect crop cultivation, animals have to migrate to alleviate grazing pressure, and this inevitably results in crop damage, creating additional costs to cattle owners.

The potential of the extensive system could be further exploited by adopting a land alienation policy for cattle herding. This would have to allow access to feed resources from the natural biomass and to fodder from agroforestry practices and agro-plantations. There is also a need to resort to simple feeding regimes so as to optimise the use of all potential resources.

Recommended indigenous woody perennials could be planted to increase the availability of leafy or pod fodder on common property resources, and agreements on their use undertaken. However, the *ad lib* use of tree leaves is not possible due to the presence of tannins and toxins, such as mimosin in *Leucaena leucocephala,* which decrease crude protein absorption and digestibility in ruminants. This factor is not a concern under free grazing management due to voluntary controls by the animals on feed intake. Under intensive feeding systems adverse effects may be corrected by the use of calcium and mineral supplementation.

Livestock Farming has Become Less Important in the Intermediate Zone

In the Intermediate Zone, integrating cattle and buffaloes under perennial tree crops has been practised traditionally. Cattle owners receive a modest payment for the manure left in the plantations. However, livestock farming has become less important due to the fragmentation of lands. Where milk production is the primary objective, farming continues with relatively small herds of cattle of improved genotypes, managed under semi-intensive systems involving tethering and free grazing of animals. The inability to match the improved cattle gene pool to the biomass resource availability is a major problem. The under-utilisation of coconut lands for cattle production is a characteristic feature in the Intermediate Zone.

Dairying in the Wet Zone

In the Wet Zone hill country both plantation workers and village farmers have taken up dairying to supplement incomes during the lean periods, and as a source of nutrition. This is a unique system where specialised dairy breeds (*Bos taurus*) are maintained under varying degrees of stall feeding and management. The system has high labour requirements, and requires the provision of feeds and veterinary inputs. Although productivity per unit is higher in comparison to other systems in other Zones, the net returns are low. The high incidence of infertility of *Bos taurus* breeds and their crosses enumerated by this study is attributed to inadequate feeding and micro-nutrient deficiencies. The high cost of production is not compensated for by a higher farm gate price, but the demand for cattle manure for horticulture also determines the profits. The objective of milk production appears to increase calf mortality in all the systems (by 23%) as less milk is allowed to calves, and calf weaners are not used.

Integration of Cattle and Buffaloes

The present degree of integration of cattle and buffaloes in agroforestry practices is highly variable. In the Hambantota District only 3.2% of the

buffaloes are used for farm power, whereas in the Kurunegala District the usage is high, some 51-61%. The demand for cattle manure in the Nuwara Eliya District also reflected the comparative advantage of integration.

The Milk Sector

Implications, overall in the milk sector that can effect production systems can be summarised as follows:

- lack of a coherent policy for dairy development through the integration of cattle and buffaloes in the agroforestry or agro-plantation sectors;
- poor Government, NGO, and private sector infrastructure for dairy development;
- a failure to understand the specific needs and the perceptions of the farmers in the diverse farming systems;
- low consumer preference for dairy products, together with high prices to consumers;
- a failure to exploit the multipurpose potential of indigenous cattle and buffaloes within the animal agroforestry farming systems adopted by the farmers;
- a disregard for actual milk production costs in the different production zones when considering pricing policy;
- the inherent low production of small-farmer operation and the lack of commercialisation of the milk production sector *viz-a-viz* the processing sector; and
- adverse effects of multinational operations in the dairy sector under open economic policies.

The problems enumerated urgently require policy interventions to ensure substantial profits from diary farming. State policy favours the importation of cheap quality milk powder produced under lucrative farmer subsidies or under high cost, high tech models in the industrialised world by the multinationals. This has effectively reduced domestic milk production. The nature of small scale production and the poor profitability from dairying

has not received due attention. The direct involvement of multinationals in the procurement, processing and marketing of milk is also supported by State subsidies, and this has further aggravated the position. Indigenous milk producers are subjected to competition in the milk procurement network.

A direct involvement of multinationals to increase in-country milk production is essential if the animal agroforestry/agro-plantation milk production systems are to benefit from simple improvements to the traditional practices. Given a firm commitment to supportive policies the prospects for further development is promising, as long as the problems are dealt with urgently and with a long term commitment. A beneficial feature is the existence of a still-active dairy farming population, despite losses and poor profitability.

Village Tank Systems in the SEDZ: Farmer Organisation is Needed

The implementation of model animal agroforestry complexes in the existing ecosystems of the SEDZ offers considerable promise. Improvements can and should be made to the existing traditional cattle and buffalo production systems, based on tank village agroforestry or agro-plantation sectors. Much could be achieved by developing the organisational capacity of the farmers using farmer-centred holistic approaches. Hitherto, the organisational capabilities and the leadership abilities of livestock farmers have not been identified or encouraged. The development of organisational capacity for production, processing and marketing through collaborative linkages is essential because project-based development models have failed, so far, to produce the desired results.

Profit orientation of the production system by directly targeting the consumer, according to market demands, can only be achieved by reorganising the livestock-owner/farmer organisations under a properly constituted structure such as a livestock company. Such a company, constituting the livestock owners themselves, would independently ensure the correct inputs and necessary requirements to secure the advantages for more effective animal production in agroforestry. What is needed, here, is to improve organisational capabilities at the managerial, technical and operational levels.

Advance in Participatory Technology Needed

Finally, lack of co-ordination within institutions and the line agencies responsible for the integration of animal, agriculture and forestry production systems have been major constraints to increased farmer incomes in Sri Lanka, but this situation can be remedied. The re-organisation and integration of resource use under these systems, combined with existing traditional practices, falls very much in line with modern day approaches to participatory technological advance throughout agriculture in general and agroforestry practices in particular. Indeed, farmers that depend on animals for their subsistence are often principal social groups that already favour agroforestry production practices.

There are many opportunities to incorporate new thinking so as to integrate scientific methods of animal production within the existing traditional production systems. In this, we need to take into account the experiences from successful animal agroforestry/agro-plantation production systems in the SEDZ/NWP. There has to be a proper integration of the major landuse components: forests and plantations; general agricultural production; and animals for production and service roles. Agroforestry practices could be the means by which modern technology and indigenous knowledge systems can be successfully moulded for the benefit of Sri Lankan farmers[†] .

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Appendix 12.1: Distribution of irrigation tanks during the Pre-KOISP period



Appendix 12.2: Indigenous knowledge about the management of domestic animals

- *Herd identity*: cattle/buffalo breeds are identified (Nama Gothra) by their colour differences, individual names and by branding with specific patterns.

- *Herd ownership and duties of herdsmen*: a differentiation exists through a caste system for herdsmen and herdowners (Chronicle Mahawansa).

- *Herd nutrition*: dietary supplementation with sesame oil cakes/broken rice gruel is given during lactation.

- *Use of labour:* there is supervision of small herds using family labour and of large herds by hired herdsmen, through a Rajakariya ('payment-in-kind') system.

- *Herd management and production:* herdsmen are required to follow specific herd management procedures such as rotational grazing of pastures once in 5-7 days; fallowed agricultural fields and woody trees in forest reserves are used during droughts; animals have to be watered without damage to water sources and irrigation channels; the task of selecting animals for breeding is assigned to a specialist among the herdsmen referred as the 'Patti Widane'.

- *Herd health:* preventative treatment such as udder sanitation before milking is carried out and herdsmen are required to acquire indigenous knowledge about material and spiritual medications for treating common diseases; access to a local specialist for emergent diseases may be required. A major area well-documented in the ancient palm leaf manuscripts illustrates how IKSs are used in the maintenance of animal health and husbandry. Under this system both spiritual (invisible) and material (visible) medications, moxibustion of vital

points and bleeding are performed by specialists as well as by herdsmen in order to provide instantaneous remedies to cure animal diseases (Jayatileka, 1993).

- *Herd welfare:* special attention is given to the herd bull, or the lead animal, to ensure the well-being of the herd, and by watering the young animals first during seasonal droughts.

Appendix 12.3: The old terminology used in the operation of the traditional 'tank' (wawa) systems

- *Vana*: spill level, fixed at two thirds the height of the bund.

- *Bisokotuwa*: a device that controlled irrigation water and indicated the storage capacity. The 'bisokotuwa system' is yet to be analysed by modern technology.

- *Madahorowwa*: a sluice gate to remove fermented mud rich in nutrients to fertilise paddy fields.

- *Horowwa*: the main sluice that opened to the 'bisokotuwa'.

- *Thaweilla*: the end of the catchment area which became muddy and offered wallowing for buffaloes. Specific areas with running water were also used as buffalo wallows. The buffalo wallow was rich in cow dung which promoted the growth of inland fish species in the tank. The existence of 'Kumbuk' (*Terminalia arjuna*) tree belts, in association with running water, indicated the use of IKSs to prevent soil erosion and purify the water. The seeds of the 'Ingini' (*Strychnos potaturum*) tree and charcoal were also used to filter muddy water.

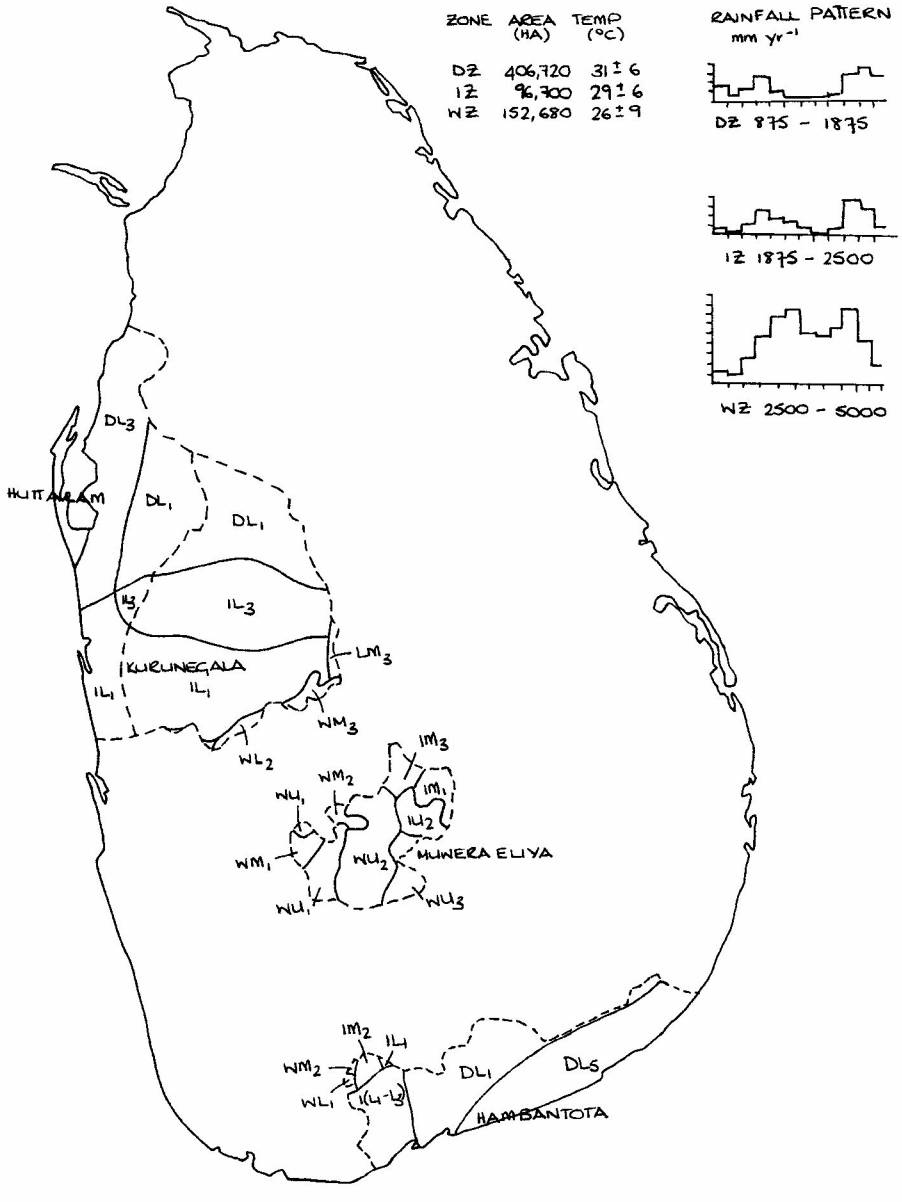
- *Wew'pitiya*: a parkland area which offered rich pasture grazing due to soil-enrichment from flooding in the rainy season.

- *Gas gommana*: this term referred to large circular or oblong highland areas containing trees which were spaced in such a way as to act as efficient windbreaks and shelters within the surrounding exposed lowlands. The micro-flora, fauna and the topoclimate created within the 'Gasgommana' were essential elements needed to sustain the crops and animals in the whole ecosystem.

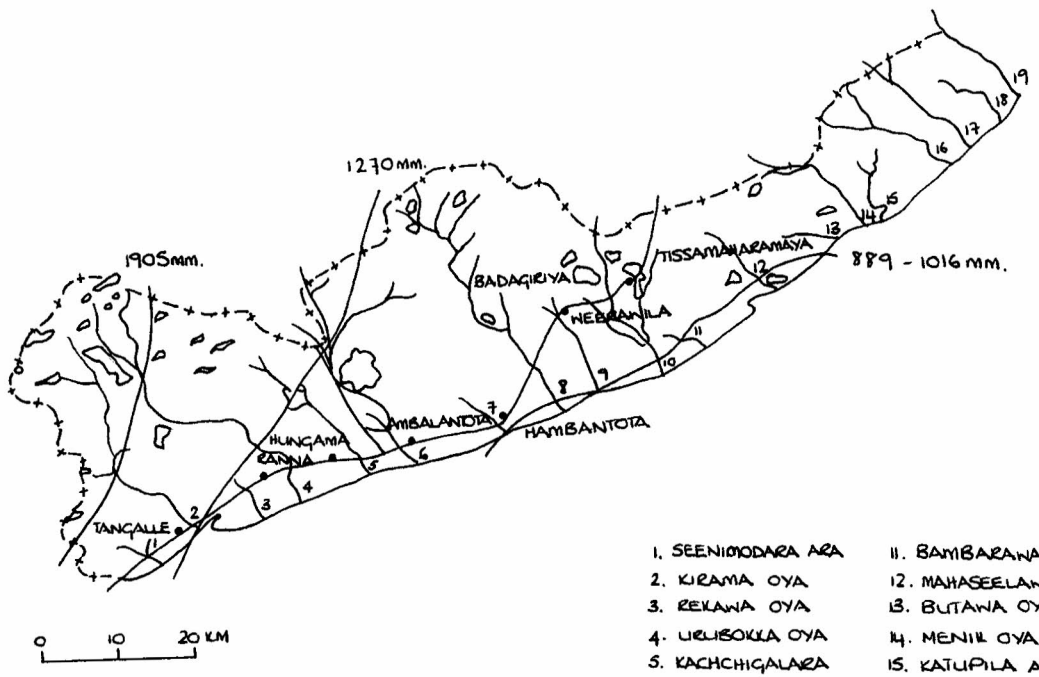
- *Thisbamba*: an area 60 metres from the tank which comprised both marshy lowlands and highland parks. This area was specifically reserved for cattle and buffalo grazing. Woody permanent tree species (*Prosopis* spp. etc.,) were grown to provide shade as well as fodder. It comprised natural grasses and leguminous tree species of the genera *Tephrosia, Mimosa, Cassia, Acacia, Bauhinia 'Maila'* important for cattle and buffalo production, as well as succulent weeds, medicinal herbs and a variety of other shrubs. The knowledge to plant indigenous tree species and herbs known to reduce soil alkalinity and salinity (kivula) were remarkable features. 'Lunu midella', 'Lunuwarana', 'Walbeli' or 'Gam Sooriya', were common trees ('Walbeli' is a well known tree fodder relished by ruminants). Reef grasses and weeds, such as 'Pan' and 'Hambu', 'Lunuwila', 'Atwara', that are known to remove salinity, are common in the marshes. The scrublands offer a variety of indigenous species preferred by cattle and buffaloes such as 'Batadella', 'Girapala', etc., for scrub grazing. This 'Thisbamba' area was the principal source of soil nutrients transported by run-off and subterranean water flows to the tank system (see Dhamasena; this volume).

Appendix 12.4: Agro Ecology and Study Areas

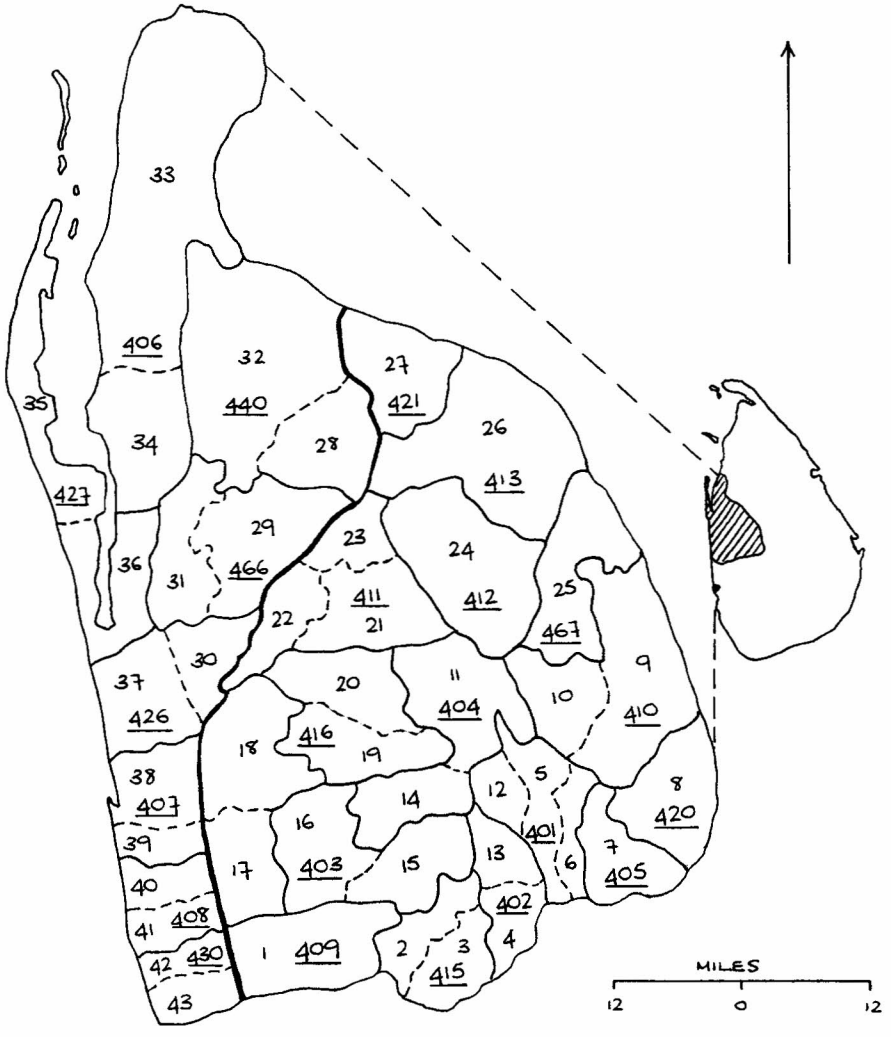
(Source: Research Data Adopted From Dept. of Census)



Appendix 12.5: Hambantota Study Area, Southern Province



Appendix 12.6: Kurunegala Study Area, North Western Province

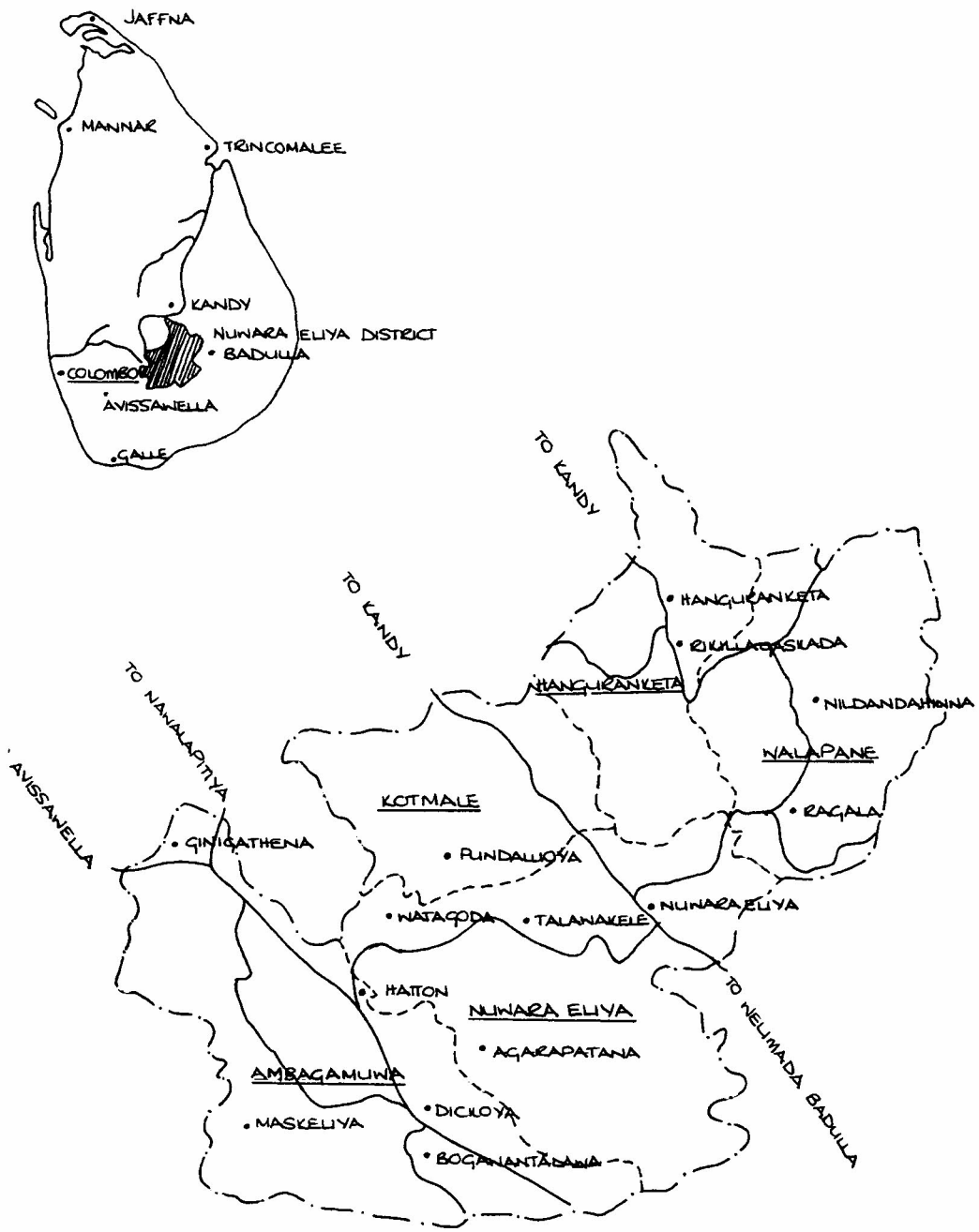


KURUNEGALA DISTRICT

409 - 1	PANNALA	403 - 9	KULIYAPITIYA	466 - 1	ANAMADUWA
415 - 2	NARAMMALA	414 - 10	BINGIRIYA	426 - 2	PALLAMA
402 - 3	POLGAHAWELA	416 - 11	HETTIPOLA	440 - 3	KARUNALAGASWEWA
401 - 4	KURUNEGALA	411 - 12	NIKAWERATIYA	406 - 4	PUTTALAM
405 - 5	MAWATHAGAMA	412 - 13	MAHO	427 - 5	MUNDALAMA
420 - 6	RIDIGAMA	467 - 14	POLPITHIGAMA	407 - 6	CHILAW
410 - 7	IBBAGAMUWA	413 - 15	GALGAMUWA	408 - 7	MAHAWEWA
404 - 8	WARIYAPOLA	421 - 16	GIRIBAWA	430 - 8	DANKOTUWA

PUTTALAM DISTRICT

Appendix 12.7: Nuwara Eliya Study Area, Central Province



13. Analog Forestry: A Strategy to Reverse the Loss of Rainforest†

A. Palinawadana

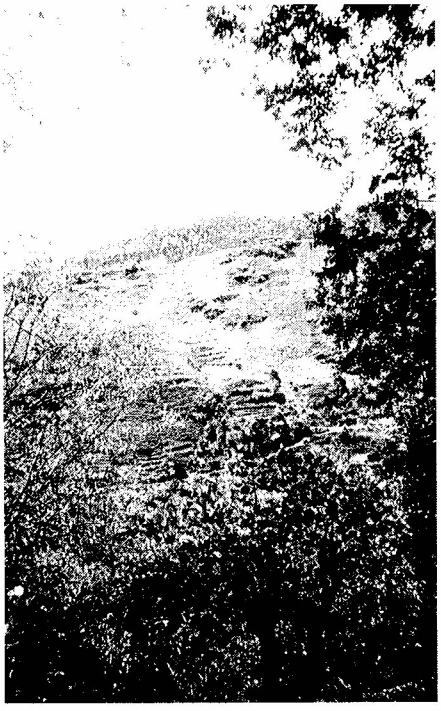
FORESTS AND FORESTRY

'Forests' can be defined as a continuous stand of trees at least 10 m tall with their crowns interlocking. But there are many kinds of forest and many other forms of wooded land cover ('woodland', 'bushland', 'thicket', 'shrubland', etc.), with transitional types as well. We may view such communities from various viewpoints: the provision of various products, their ability to provide habitats for wild creatures, the diversity of species of birds and so on. A most important factor to remember is that forests and similar communities, left undisturbed, are *sustainable natural formations*. Sri Lanka has a population of approximately 18 million with a growth of 1.8% $year^{-1}$. This means that the increase in population on this small island is about 900 people day^{-1}. Naturally this rapid growth results in an increasing demand for land and in great pressure on forested areas.

'Forestry', on the other hand, has all to do with man. It is the art and science of managing forests. As human impact on natural ecosystems increases, the heavier becomes the burden upon the practitioners of this science to ensure that the stability on the biosphere conferred by natural forests continues uninterrupted. This is accomplished through two routes. The first is by the conservation of natural forest resources, the second by creating man-made forests. To be successful the latter need to be carefully designed. Foresters tend to concentrate on producing wood and this has led to monocultural plantings of fast-growing tree species (Fig. 13.1). Such has been the major response to deforestation worldwide. However, the negative impact of plantation forestry at both the social and ecological levels has been well documented; in most cases these monocultures have amplified environmental

† An introduction presented by Mr. Agantria Palinawadana on behalf of Dr. Ramil Senanayake (Director) preceding a short video presentation on 'The Forest Garden' and 'The Neosynthesis Research Centre'.

problems and created social dislocation. The replacement of natural forests with exotic monocultures has not provided adequate solutions. The problems created by *Eucalyptus* plantations in Portugal and India, or those brought about by *Pinus* plantations in Sri Lanka, are examples. In all these cases the local population and native biota have been negatively affected.



(Photo: P.A. Huxley)

Fig. 13.1.
View over experimental 'Analog Forest' at Bandarawele (Intermediate Zone) to old chena lands on far slope. A *Grevillea robusta* plantation (monoculture) caps the far hill and abandoned terracing can be seen lower down.

Tropical Rainforests

The loss of tropical rainforests has reached critical proportions and, especially, the extinction rate of rainforest species is of increasing concern (Myers, 1982; and see FAO's 'Forest Resources Assessment Project', 1990). It occurs through two routes: a) the destruction of habitat together with the introduction of biocides, and b) the reduction of size of remnant patches of forest, which are often physically too small to retain the full complement of species that were found originally.

Natural forests possess an architectural form that creates a varied and equitable environment. This form, consisting of a closed diverse canopy, extending well above the soil surface, which mitigates erosive effects of rainfall by breaking the force and frequency of raindrops (see Fig. 3.1). It also reduces the desiccating effects of direct sunlight and wind, and regulates the ambient temperature of the environment below the canopy, so reducing the amplitude of diurnal/nocturnal temperature fluctuations. It is this modified or 'organism controlled' environment, free of sudden severe environmental stresses, that allows most plant and animal rainforest species to maintain their populations. The other feature that is characteristic of the tropical rainforests is its great diversity of species. The diversity of plants allows the evolution of a wide array of herbivores, and thereby, a corresponding diversity of carnivores and detritivores.

Thus, any attempted response to compensate for the loss of tropical rainforest needs to include these requirements of architectural structure and diversity of species if the original character of a forest is to be retained or simulated.

Traditional Forestry

'Traditional Forestry' involves the functional use of tree crops by rural communities. Native species may be used, as in the case of the farmers of the 'Puna' zone of the Peruvian Andes, or exotics, as with the farmers of the west coast of Sri Lanka (Senanayake, 1987). The particular choice of tree species needs to provide the highest degree of agricultural sustainability in that environment. Another characteristic of these traditional forestry systems is the great diversity of species and age classes usually found. Traditional forestry encompasses the diverse forms of tree farming termed 'village forest', 'forest gardens', 'mixed tree farming', and so on. This type of activity, recorded in many traditional societies, seeks to develop its models based on the functional or utilitarian features of trees.

Analog Forestry

Large areas of Sri Lanka's highlands have been planted to tea but, because some of this was done on unsuitably steep slopes, the land has become eroded. One solution adopted in order to restore such degraded lands has been afforestation with monocultures of pines or *Eucalyptus* spp. with the purpose of producing high yields of timber in the shortest possible time. Unfortunately, the leaf litter from both these species tends to accumulate to the detriment of good cover plants, especially where fire is also a hazard. Vegetation is in no way as ecologically diverse as natural forest cover.

It is possible, however, to create a simulation of natural forest. 'Analog forestry' is just such an attempt, developing from a traditional paradigm. It is a forestry technique that allows the creation of a physical structure akin to the climax forest that, as a consequence, recreates a similar modified environment allowing many animal species of the original forests to extend their habitat range (Senanayake, 1989). It attempts to create a physical structure and a set of ecological relationships that are analogous to the natural climax state, or end condition, of the ecological process termed succession (Fig. 13.2). It uses trees and plants that support and/or simulate the natural structure but that are useful to man as crop plants.

An example of the dynamics involved in such a succession can be seen on any piece of recently-cleared forest land. At first, the environment is exposed and the soil can become eroded. Succession begins on this newly-cleared land with fast-growing weedy species, 'colonisers', that begin to change their immediate soil and surface environment. This change creates a microclimate amenable to the growth of other woody, longer-lived species. These latter species, in their turn, create microclimates suitable for the seeds and seedlings of larger trees to survive. This process continues until no further changes occur, usually culminating in a mature forest termed the 'climax state'.

Studies in some tropical countries suggest that a process mimicking ecological succession is, indeed, practised by landusers in many rural areas.



(Photo: P.A. Huxley)

Fig. 13.2. Visiting students from the Forestry Unit, University of Sri Jayewardenapura walking through the Analog Forest at Bandarawela. It's multistrata nature is readily apparent. Such a system is built up over time. At the start 'key' tree species that will be compatible with lower-storey plants (such as *Erythrina lithosperma*) are selected or planted. Consideration is given to vertical as well as horizontal diversity and the possibilities of compatability between species is watched carefully. The process starts by enclosing an area of patana (grass) and stall fed animals are introduced. Eventually a system may have over 60 useful species.

Here the natural sequence of stages is undertaken and species of use to man are substituted for some of the forest species. While much of the hill zone villages of Sri Lanka possess rudiments of such forest analogues, its potential for development was not recognised until 1980, when experiments on design and development of these analog forests were begun at the NeoSynthesis Research Centre (NSRC), Mirahawatte (NeoSysynthesis Research Centre Annual Reports, 1986, 1987, 1988). These experiments confirmed the ecological and economic validity of such plantings. Analog forests create a multistrata system where useful plants, such as cardamom, jackfruit, avocado and many others, occupy different levels (Fig. 13.3).

A question in creating such an analog forest is 'What do farmers do who have to make their living on a day-to-day basis growing short term crops?' Regular crops like beans, carrots, potatoes or tomatoes can be grown but, at the same time, the first fruit tree crops can be planted out along with them. Species such as papaya, banana, citrus or macadamia nut will be taller than the crop plants and they will give a relatively early return. As these tree

crops grow, lower storey shade increases and agricultural crops are replaced with more of the higher-strata components, whilst retaining shade-loving plants in the lowest storeys. Over time the analog forest becomes more and more complex and even high value spices can be added. Eventually, there is a highly profitable and productive permanent system to take the farmer into the future.



(Photo: P.A. Huxley)

Fig. 13.3.
Some of the lower storey plants, cardamom, coffee, etc.

Creating the Infrastructure

The establishment of National Centres capable of testing and designing a wide array of tree crops to fit into the economic, social and ecological needs of communities will be required if the data now emerging from current activities are to be more widely tested and introduced. But more is needed. It is clear that the term 'forestry' has to be extended to any human endeavour that seeks to establish a tree crop dominated ecosystem on any landscape, but if this

broad definition is to be made meaningful a reappraisal of the present administrative structure would seem essential. One suggestion would be to create a forestry sector structured in such a way that is was served by three departments: one dealing with Conservation Forestry, another with Industrial Forestry and the third with Analog Forestry. The concerns are as follows:

- *Conservation forestry* refers to the management of wild or natural areas, the planting of endangered species, planting forests to protect water catchment areas and so on. Conservation forestry protects and preserves genetic stocks and sustains particular plant associations.

- *Industrial forestry*, using commercial forest tree species, still remains the fastest way in which to produce fuelwood and timber on a large scale.

- *Analog forestry* concentrates on the development of tree crops and cropping systems that produce ecological and environmental benefits as a part of the design. Activities are relatively intensive, concentrated around the village, and the designs are based on ecological concepts.

The utility and applicability of such an approach to the forestry sector is summarised in Table 13.1.

Table 13.1. The provision of national needs by different kinds of forestry

Potential for:	**Forest Category**		
	Conservation	**Analog**	**Industrial**
Sustainability of genetic resources	x		
Sustainability of the environment	x	x	
Non-timber income	x	x	
Fuelwood production	x	x	x
Timber production		x	x
Timber production over the shortest time			x
Human habitation		x	

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Senanayake, R. (1987) Analog forestry as a conservation tool. *Tigerpaper Journal*, FAO, Bangkok, 25-29.

Senanayake, R. (1989) The planting to cutting ratio (R). In: Jayal, N.D. (ed), *Deforestation, Drought and Desertification.* INTACH: New Delhi, pp. 141-144.

Editors' Note: Readers may also wish to refer to:

Oldeman, R.A.A. (1983) The Design of Ecologically Sound Agroforests. In: P.A. Huxley (Ed.) *Plant Research and Agroforestry*. ICRAF: Nairobi, pp. 173-207.

Appendix 13.1

The Neosynthesis Research Centre, Bandarawela, Sri Lanka.

"In an age dominated by environmental concern the need to assess global biodiversity loss, particularly that of forest resources, is considered to be of paramount importance. In addition, it is accepted that conservation projects in this area are most beneficial where they are within the boundaries of localised ecosystems, while contributing to social and economic development. One organisation that encompasses this approach, and whose primary goal is the promotion of forestry systems analogous to natural forests, is the Neosynthesis Research Centre (NSRC) situated in the highlands of tropical Sri Lanka. The Neosynthesis Research Centre (NSRC) was established in 1982 as a non-profit community organisation and is registered as a non-governmental organisation in Sri Lanka. The NSRC is located on a diversely cultivated estate that stands in contrast to the tracts of denuded, degraded and badly-managed land that surround it.

The major objectives of the NSRC are the reversal of forest loss and environmental degradation, as well as the encouragement of sustainable agricultural production and sensible land management. These objectives are pursued in a programme of activity such as raising the awareness of local cultivators, general research and the introduction of Analog Forestry in particular. Analog Forestry is a system of silviculture pioneered in Sri Lanka by NSRC that replicates the structure, ecology and function of natural forests. Analog Forests are created by planting ecologically compatible and economically viable species of plants that are adaptable to the soil and climate of a particular area. The advantage of the Analog Forests are numerous and it is an effective method of arresting loss of biodiversity. It also creates micro-habitats for a variety of fauna that were once confined to the rain forest. Furthermore, this system of silviculture can contribute towards the economic sustainability of rural communities by establishing forest gardens on the principals of Analog Forestry. A range of specialised high value crops can be grown that are appropriate to community level processing.

The NSRC co-operates with the National Certification programme that

precludes the application of pesticides and artificial fertilisers. This method of agronomic management ensures that the consumer receives the healthiest produce. This organic production system has been further developed into a Forest Garden Produce Certification Scheme. Other conservation projects include an arboretum and a forest nursery with some 80 species of plants that are provided to local cultivators. In addition there are several projects which are actively supported by the Humane Society of the United States. One is the establishment of a sanctuary for the elusive deer that come from the land adjacent to the NSRC. This project uses the deer as an indicator species to demonstrate the effectiveness of participatory conservation. The other project on the south coast of the island comprises a hatchery for several endangered species of turtle and an associated coastal ecosystem survey.

These are some of the ways in which the NSRC has contributed to the environmental stability and consequently the economic sustainability of local communities. And the potential of the NSRC is such that its pioneering concepts can have a considerable impact on the future of biodiversity conservation."

14. The Philosophy and Practice of Agroforestry Research

P. A. Huxley

THE RESEARCH PROCESS

Is Agroforestry Research Different?

Research is finding out what we do not know in response to questions posed by a specific set of objectives. In particular, agroforestry research is discovering the answers to questions that arise when we grow woody and non-woody plants together in a variety of ways. Like all research it involves perception and recognition (of the problem), understanding (of the system being investigated) and interpretation of the results of the research.

To be contained and structured research must, then, have clear objectives but, where different groups are involved, who decides what these shall be? What we would like to know *always* exceeds our capacity to find answers, so how do we best allocate scarce research resources? Who are the beneficiaries of research and what kind of costs and benefits can accrue from structured research activities? What should be the correct 'mix' of approaches to research ('basic', 'applied', 'adaptive')? Should research be conducted 'on-station' or 'on-farm'? And so on. These are all questions that should be settled, as we know, before any research begins, and agroforestry research is no different from any other in this respect. However, although these are all familiar questions we have been forced to reconsider them carefully in agroforestry for two reasons: (a) agroforestry involves working with systems that are more complex than those usually found in agriculture because they involve understanding and evaluating the interactions between woody and non-woody plant components; and (b) farmer preferences are top priority because multiple products *and* services are involved and, in this context, purely technical solutions are insufficient (Fig. 14.1).



(Photo: P.A. Huxley)

Fig. 14.1. Students from the Forestry Unit, University of Sri Jayawardenepura discussing a research problem with Dr. Hemanthi Ranasinghe and staff of the Field Crops Research and Development Institute, Mahailluppalama. Farmers, extension experts and researchers are all likely to have a different perception of a landuse problem.

Because of its complexities, agroforestry has forced us to re-explore the ways we can seek to learn. Perhaps we may do this unwittingly, but the sheer scope and complexity of some of the problems that we have to solve in agroforestry forces us to compare notes with other sciences and to remind ourselves of the remarkable progress that has been made in the past in agriculture and other forms of land use, through the application of simple, perceptive methods of investigation. Some of these are being applied in Sri Lanka today, and it would be wise to see what can be learnt from such examples.

I mentioned earlier on ('Understanding Agroforestry') that, when ICRAF was established, we were unable to give satisfactory answers to many of the questions that farmers would put to us concerning choice of species, the best kinds of management and design, and so on. A decade and a half on we are often still unable to give precise answers to many such practical questions. In many cases, however, we have at least begun to reappraise the information that already exists about the processes and interactions between plants and soils and climate that can tell us how any landuse system might be expected to behave in any particular set of circumstances. A good example of this is the existing research available from the study of plant component interactions in

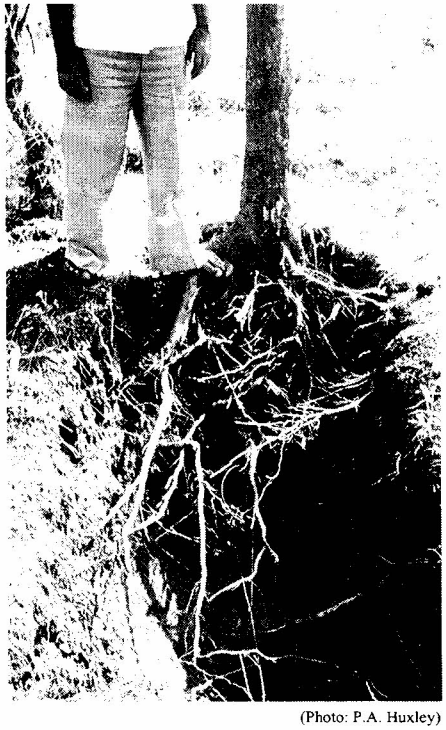
agricultural intercropping. This can form a sound basis for investigating the situations we find in woody/non-woody plant mixtures found in agroforestry, although it still needs adaptation and further development (Ong and Huxley, 1996) (Fig. 14.2). Similarly, the detailed knowledge of the processes involved in the degradation of plant residues which can be beneficial to adjacent plants in the short term, and to soil fertility over longer periods of time, has been assembled, explored and is being applied to agroforestry situations (Anderson and Ingram, 1993).

Thus the underlying nature of agroforestry research is not to explore unknown processes, but rather to evaluate the outcome of those which are known within the very different kinds of plant mixtures we have to deal with in agroforestry. This involves a much broader range of plant form, together with a wide choice of behavioural characteristics, than that found in conventional agriculture, with the complexities of differing scales of space and time that this implies. Thus, not the least of our difficulties is that the sampling problems in agroforestry can be awesome. In part, this is because agroforestry, itself, not only exploits 'patchiness', but helps create it.

Why Do We Need More Research?

Because there are many very different indigenous agroforestry practices to be found around the world (Nair, 1989), a question that is sometimes asked is whether we need any more research? Why not just distribute information about what is already known (George, 1993)? However, we can readily dismiss such a proposal. The reason for this, as stated above, is that mixtures of woody and non-woody plants interact to a high degree, and the interactions in such situations are highly site-dependent. It becomes increasingly difficult to predict what may occur, even if we change the management only slightly in any particular system and, certainly, if we transfer it to a different environmental situation. Similarly, if we change the species within a practice then there are a whole host of possible effects on the outcome in terms of productivity and/or sustainability. Medical researchers deal with complex human systems and undertake corrective procedures only after using a whole range of methods to establish a correct diagnosis. In agroforestry, this process

of 'Diagnosis and Design' (D&D) has been formulated, analogously, in order to help determine farmers' constraints and potentials. With its history of understanding indigenous agroforestry the application of 'D&D' can be most informative. However, the conclusions will all too frequently require further research to be done (Raintree, 1987).



(Photo: P.A. Huxley)

Fig. 14.2.
Investigating the character of the root system of *Casuarina equisitifolia* in a particular soil type under controlled management conditions (at Dharwad University, India). It is by examining carefully such *component interactions* (i.e., between plant-plant and plant-environment), that a detailed understanding of cause and effect can be built up. However, with the complexities found in agroforestry this will take a long time. An experiment on the whole, or part, of an agroforestry *system* (e.g., some form of 'alley cropping') is likely, if properly replicated and randomised according to accepted rigorous standards, to occupy a very large area and demand substantial resources if it is to be managed properly. Such attempts to learn about the way systems function, biologically, might often better be acheived through 'Prototype Trials' which purposefully attempt to simulate the system under study and manipulate or 'perturb' it so as to obtain some indication of how it is functioning, perhaps by critical observation (as here). Such an approach (and see the Chapter on 'Analog Forests') cannot reveal positive cause and effect, but it can be indicative, instructive and much less costly!

Again, in engineering research there is often a very pragmatic approach to development where, after having established the principles for a basic design, the research engineer will manipulate the system, adding to it and subtracting from it, or making changes, until it operates satisfactorily. In some ways we can see that this is mirrored in the 'analog forest' approach[†] .

† See 'Analog Forestry: A Strategy to Reverse the Loss of Rainforest', this volume.

Making Research Count

Perceptions and Viewpoints

Agroforestry research has to be useful. It does not matter whether it is 'high-tech', for example requiring the use of expensive equipment and considerable technical skills (as when investigating details of carbon assimilation in agroforestry systems); or whether it is 'low-tech', for example studying how best to plant out and establish MPTs (just by using hand tools). The critical issue are: 'when it is successfully concluded, how easily can the results be implemented?', and, 'what will be their impact?' In order to achieve success in these respects, agroforestry research needs to involve farmers in one way or another; but not all research problems necessarily demand active farmer-participation at all stages. A good example is the onset of *Leucaena* psyllid where pest identification, etiology, epidemiology, and damage assessment by experts were essential first steps. Later, research on the best methods of controlling the pest necessarily included farmer participation.

Many of our problems, however, *will* best be approached in a participatory way and, here, a perception of the problem may differ according to the particular group viewing it. Researchers can sometimes help farmers understand that they do actually *have* a problem (e.g., with virus diseases of plants). On the other hand, researchers tend to confront problems when, sometimes, farmers and extentionists may see ways round them, i.e. by changing management or output objectives. Also, there will be other groups that are, or should be, involved with research decisions. For example, administrators and decision-makers will be able to evaluate the impact of proposed research on the wider scale. Community leaders, if consulted, may see research requirements in a different light than that of individual farmers because tree planting can have an impact on the broad scale. Hence, the need for, and agreement on the value of, any particular research programme may differ. Understanding other peoples' viewpoints is essential, therefore, and in agroforestry there is an added dimension to research brought about by the long term nature of the woody perennial plant components. It is easy to see that the objectives of agroforestry research can be as difficult to determine, or more so,

than we find in agricultural land use!

Ways to 'Know'

Once clear objectives *have* been determined there are usually a number of methods by which we can fill in the gaps in knowledge which represent the research goals. There are many 'ways to know' but, basically, we can think of these as falling into two main groups: heuristic and algorithmic processes. Once we have 'perceived and interpreted' a problem we have to 'evaluate' it before executing any action. Often we may do this analytically, i.e., we work incrementally through deductive/inductive processes to formulate and test hypotheses. These processes form the basis of experimental science and are algorithmic in nature[†] .

There are, however, other ways of knowing which have also stood us in good stead, and these operate through heuristic convergence, that is we create a 'picture' of a situation perhaps because we recognise its intrinsic structure from similar 'models' or from past experience. Then from this cognition we are able to 'see' a solution to our problem. This is a common way for us to deal with everyday problems. In the research process it is here that there is a significant place for indigenous knowledge, and an opportunity to take a more flexible approach to acquiring the knowledge we seek, (e.g., see Giles *et al.*, 1993).

Certainly, in agroforestry research, there is a place for both algorithmic and heuristic approaches. Analytical, 'reductive' experimental research approaches can be unsurpassed in discovering causation. Other quantitative approaches, for example the results of surveys, can provide strong correlative evidence that can help us evaluate critically; but in many cases the resources required to undertake these may be considerable and the costs very high. Indeed, field experiments are best not undertaken at all unless several essential criteria are first satisfied: that there is a clear set of objectives; that those carrying out the experiment are familiar with the biological characteristics of the plant components that will be included, *and know how to manage them sufficiently well*; and that the experiment can be structured appropriately and

† An algorithm is a formula for doing something.

be large enough to ensure that it produces statistically valid results (Figs. 14.3 & 14.4).

Should the above criteria not be met then there are less rigorous but still very valuable methods to use; it is wasteful to use experimentation just to gather information that can be obtained in other ways more cheaply! Here in Sri Lanka, the 'analog forest' can, clearly, be a sound learning process, for example. Similar to this are 'prototype trials', as suggested by Huxley and Raintree (1987), 'high-density' plantings in India (Bavappa, *pers. comm.*), and 'systematic plantings' (Flores-Paitan, 1986).

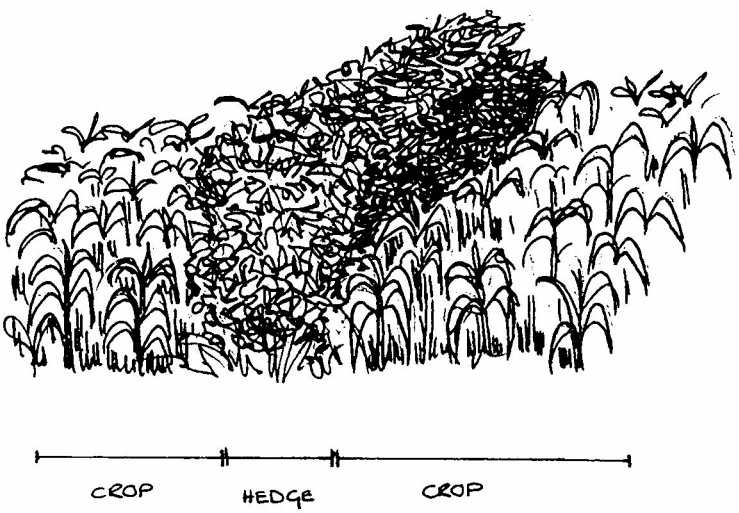


Fig. 14.3. The process of just adding a hedge to a simple plot very greatly increases the complexity of the experimental situation in terms of management, assessment, analysis and evaluation of the results (see also Fig. 14.4.)

These approaches all have one thing in common, i.e., they provide a perception about the way a system works rather than a detailed understanding of component interactions, and they demand a high level of experience and critical observation in order to make interpretative, useful inferences. Such approaches have a limitation, however, in that they will *not* inform us how the system under study will behave in a different environment.

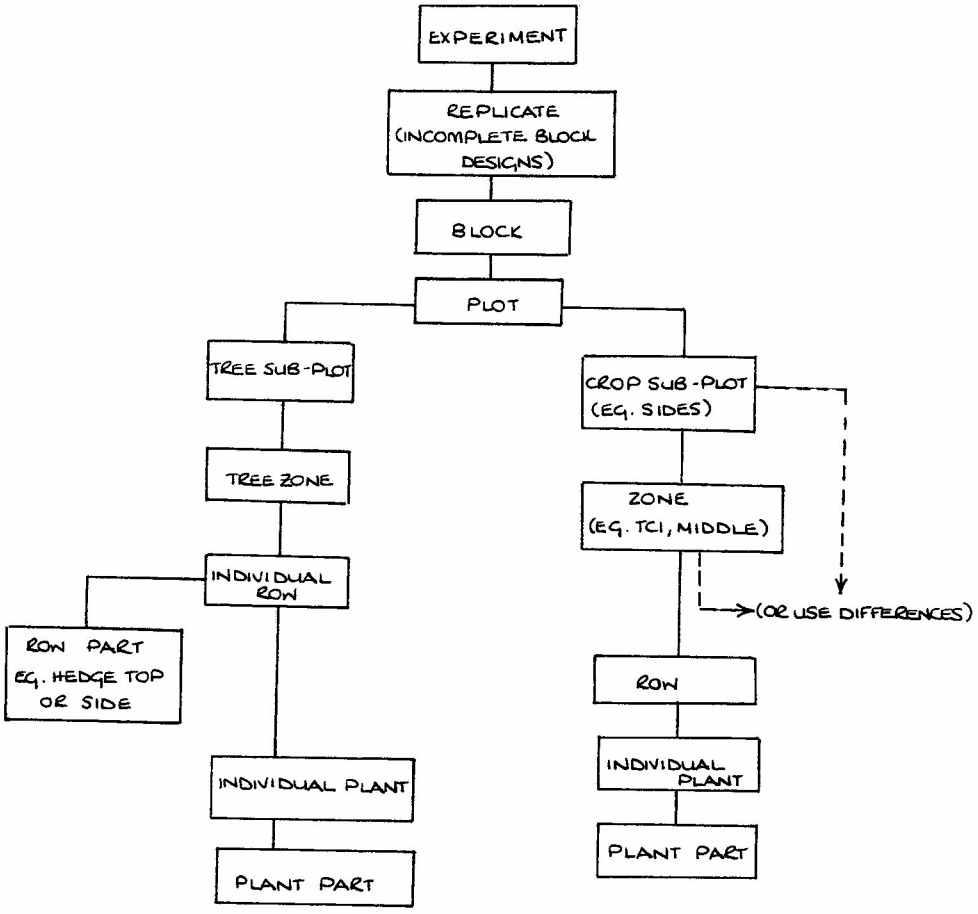


Fig. 14.4. The various experimental strata that may need to be investigated in a plot as shown in Fig. 14.3.

Because they are manipulating systems, such investigations necessarily include a high level of complexity and 'patchiness'. Both biotic and abiotic factors are involved and at different times various of these will be limiting. There will be linear and non-linear responses in such systems, with a large number of interactions and, probably, feedback loops. In many cases the level at which we can discriminate changes will only be those that can be made

visually, rather than those which can be measured; so that results will be observational and not very precise. Nonetheless, the strength of such approaches lies in testing the operation of a *complete system*, and in discovering the ways in which it can change when management, or various of its components are changed. Observing the resilient behaviour of the system when it has been perturbed in these ways can often be most informative.

AGROFORESTRY EXPERIMENTATION

When the objectives warrant it and it is feasible to do so, well-planned and well-controlled field experiments may be the only way to establish cause-and-effect, should we require to establish this. The common foundation for any type of field experimentation is randomisation, adequate replication, and the avoidance of bias. Agroforestry experiments are no different. However, there are special problems as follows[†] :

- *Choice of Site.* Where tree species are deep rooting it is clearly critical to establish what the underlying soil profile is like; particularly with respect to soil depth and the presence of impermeable soil layers. Many experiments may have to be carried out on sloping land and the control of water movement across the soil surface in such circumstances is important. Because agroforestry experiments may be larger than those normally found in agriculture, finding a homogenous site can be difficult. There are, however, appropriate designs (e.g., lattice and generalised lattice ('alpha') designs; Walker, 1896) that can handle blocks containing different numbers of treatments. Incomplete block designs, generally, can be very useful to help contain experimental size and limit within-block variation (Fig. 14.5). Additionally, sets of plots within blocks can be located apart in order to site them on suitably homogenous parts of the site.

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† As discussed in: Huxley, 1987; Roger, 1988; Huxley, 1989; Rao and Roger, 1990; Roger and Rao, 1990; Shepherd and Roger, 1991.



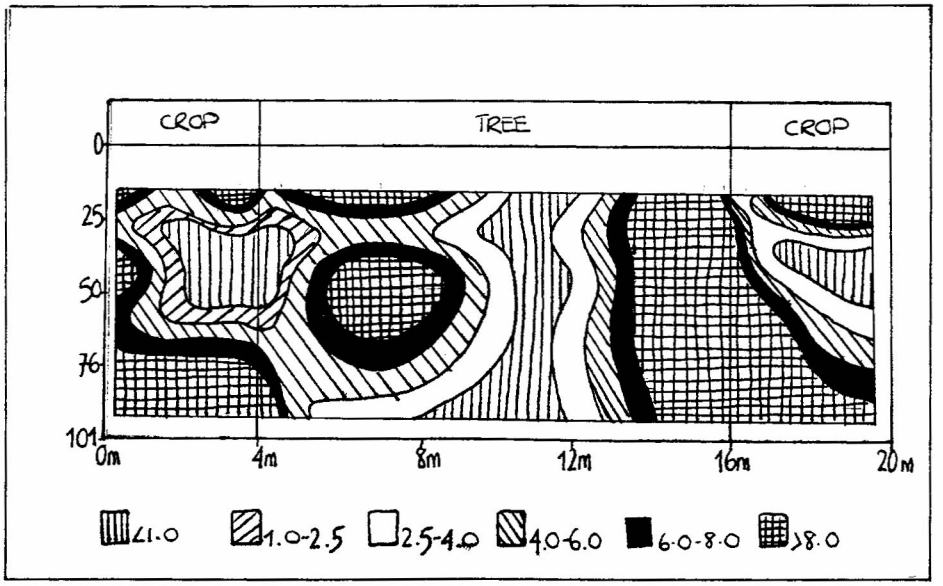
(Photo: P.A. Huxley)

Fig. 14.5. Incomplete block designs ('α designs') can be extremely useful for certain agroforestry field experiments because they allow for varying numbers of treatments per block. Because of the nature of woody plants it is best to use non-contiguous plots (so that tree roots in one plot do not reach below another). An understanding of the locational variability across the experimental area is essential if blocks are to be allocated so as to take this into account. In some cases, as with the *Gliricidia sepium* provenance trials at ICRAF's Field Station, Machakos, some blocks were fragmented to allow for this.

- *Selection of treatments.* In order to have sufficiently circumscribed objectives agroforestry field experiments, unlike prototype trials, deal with plant components and their interactions. Even so, there are invariably a large number of factors and levels which might form the basis of the experiment. Even though with a factorially arranged trial this can lead to greater statistical efficiency, the underlying difficulty we have is in limiting the number of treatments in order to keep the overall *size* of the experiment within bounds. This is necessary for two reasons: (a) in order to have a feasible chance to fit the experiment into what may often be a restricted amount of reasonably uniform land, and, (b) in order to be able to manage it well.

- *Specification of plots.* Here plot size is the first consideration. Obviously, where woody perennials are grown plot sizes may need to be relatively large. This particularly applies where we are not

growing hedgerows but mature trees. On the other hand, some research may lend itself to relatively small plot sizes for example, tree-crop interface experiments (Figs. 14.2 and 14.6). A second consideration also relates to the inclusion of trees in plots because we may find that even after only a short time, the root systems of the woody plants have become extensive. Thus, if plots are placed close together, i.e. just separated by pathways, there may be considerable interference and the interpretation of treatment effects may be impossible. Plots should, therefore, be non-contiguous.



(Photo: P.A. Huxley)

Fig. 14.6. The difficulties of experimenting with plots that contain both trees and crops is exemplified by this diagram showing the residual soil water in the profile under a plot of close-planted *Senna siamea* trees that had had maize grown immediately adjacent to them on either side. A very complex pattern of stored water remains in the dry season (February, at ICRAF's Field Station, Machakos, Kenya). > 8.0 = Field capacity; < 1.0 = Wilting point.

- *Overall size of the experiment.* Clearly, the overall size of an experiment is going to depend on all the above factors; together with the number of replications that are needed. Replication may be purposely limited in order to keep the overall size of the experiment down but, if this means, that statistically significant treatment differences cannot be obtained, then there may be no sense in carrying out the experiment in the first place. Statistical differences will emerge only if uncontrolled variability is small in relation to replication. Usually this can be done by prior investigation of the site variability, as well as by clarifying the likely variability that will result from the components themselves as they are to be managed in that system. Sadly, in agroforestry research we often do not pause to learn enough about these important sources of variability to be able to predict what they might be! Experimental sites in the tropics are almost always highly variable (and seldom completely flat), and *any* experiment containing out-crossing tree species is likely to contain genetically dissimilar plants and also suffer from variability imposed from planting them out, at least in early years. Inexperience in managing woody plants can also, sometimes, devalue what might otherwise be a successful experiment.

  All this suggests having as many replications as possible, but then the experiment grows to an unmanageable size. One way to help limit the number of replications is to reduce the level of probability at which one wishes to make statistical tests (i.e. in agriculture, conventionally, better than a 95% probability). To do this in no way abrogates the principles underlying the test, and it may be more realistic to adopt this course of action. If some lower percentage level is used the results are judged, as before in terms of probability, but on a different scale, and one that is, perhaps, more feasible.

- *Assessments.* There may be many more assessments needed than would be the case, for instance, in an agricultural experiment with a sole crop. This is because there will be several plant components but, also, any experimental plot may be considered to have different areas of interest, for example across the tree/crop interface, near-to and away-from the trees. In addition, agroforestry experiments are likely to last for a number of years and what is happening to the soil may also be of interest (Anderson and Ingram, 1993). Thus, there can be a very large number of assessments made over time on even quite a 'simple' agroforestry experiment (Rao and Coe, 1992). In order to manage the accumulating data from different components and from different experimental 'strata', ICRAF developed a computer soft-ware programme (DATACHAIN) that helps with the compilation, manipulation, storage and retrieval of such complex data sets (Roger and Muraya, 1990).

- *Analysis.* Standard methods of statistical analysis are appropriate. There is often a need to consider the outcome of data collected over time (Langton, 1989), and sometimes rotational experiments (Huxley *et al.*, 1987).

These additional problems demand that we make quite sure before embarking on an agroforestry field experiment that it has a good chance of being carried out successfully. That is, that we can contain variability due to the site and the plant materials being used; that the treatment differences are likely to be sufficiently large and not, themselves, likely to greatly increase variances in some cases; and that an appropriate high level of management and management skills are available over the whole life of the experiment. The difficulties that can arise in satisfactorily carrying out robust and rigorous agroforestry field experiments means that there is often only a small chance that they can be successfully carried out on-farm. On-farm experiments are almost always relevant, but often non-rigorous. On-station experiments are invariably more rigorous, although sometimes less relevant.

RESEARCH FOR SUSTAINABILITY

Finally, the interest we now have in sustainable landuse systems means that agroforestry research, itself, has to have this as a consideration. Interactions between the plants/animals *and* the resource base in agroforestry practices therefore become an issue. Measuring changes in the resource base will influence the size and scope of any field experiment; it will also mean additional assessments. Although we understand the processes involved, precisely what to measure is still under debate (Huxley, 1995). When our knowledge of this subject is more complete there will be undoubtedly be a place for computer modelling to assess and predict both productivity and sustainability in agroforestry systems.

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15. Some Recommendations for Action in Improving Agroforestry Practices in Sri Lanka†

Agriculture

There needs to be provision of security to farmers in respect of land tenure and rights to agroforestry products. Proper and timely land lease arrangements are essential for the success of agroforestry. Land and tree tenure issues are constant constraints to tree planting. Farmers with insecure tenure to the land they farm and the trees they plant may be unwilling to participate in the adoption of agroforestry.

Forestry

Amendment of forest policy and legislation are required in order to lift the legal restrictions on the transport of timber products and deal with the uncertainty of the legal status of lands, also to create a supportive policy for agroforestry activities. Much has still to be done with respect to forestry policy, legislation and institutional support so that farmers will wish to adopt agroforestry systems. The constraints on the development of agroforestry and private tree planting centred round uncertainty about the legal status of land and supportive policies.

Co-ordination of Government Agencies

A mechanism is required through which Government agencies concerned with agroforestry development can co-operate in agroforestry development. There are a variety of Governmental agencies which are already engaged in certain agroforestry development aspects. However, there is no co-ordination of policy development and implementation of agroforestry activities among the agencies and this leads to conflict and the duplication of efforts.

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† A summary of the outcome of the various Working Groups compiled by Dr. D.M.S.H.K. Ranansinghe.

National Landuse Planning

Agroforestry needs to be incorporated into the overall structure of National Landuse Planning on a District and agro-ecological zone basis, and be established on a firm scientific foundation.

Soil and Water Conservation

Emphasis should be given to the roles that agroforestry can play in soil and water conservation. Particularly in view of the known effects that trees and shrubs can have on environmental amelioration. For example, through microclimatic changes (wind barriers, shade), and beneficial soil physical and chemical changes. Diversification of cropping to include perennial tree crops, and semi-perennials in appropriate mixtures and arrangements can both increase cropping intensities and improve soil and water conservation.

The Need for Incentives

There is a need to formulate subsidy schemes that can play a stimulatory role, from start to finish, in agroforestry development. For example, Sri Lanka is a world leader in developing productive forms of homegardens yet, when compared with seasonal cropping systems, those managing homegardens are not well off in financial terms, especially during the first few years of establishment. Homegarden models are eventually very productive, but their establishment costs are very high, both in terms of material and labour; this applies to some extent to all tree-growing enterprises. Therefore to promote tree growing requires the provision of both economic and non-economic incentives. Economic incentives could include fiscal measures, provision of services (e.g., investment in infrastructure, education and technical assistance), and socially-oriented investments (e.g., improvements in land and tree tenure, technical training and raising awareness of benefits and available opportunities). Non-economic incentives include the establishment of public, private and farmers' institutions for promoting tree growing, research to create

technology that will increase the benefits, and policies and laws that encourage and do not impede tree planting and harvesting.

Extension Programmes for Agroforestry

Suitably documented and technically sound packages are needed to extend appropriate agroforestry practices to farmers. Unlike forestry, agroforestry extension requires information and advice from a wide range of disciplines, yet it should reach the farmer, or contact group, through a single unified agency. Forestry, horticulture, and the cultivation of coconut, rubber, food crops, export crops and fodder, the maintenance of small ruminants, and other enterprises, must all be catered for in a truly unified extension service. The interaction between line agencies, village bodies, NGOs and schools needs to be strengthened. Tree-growing often requires additional skills so that, especially early on, technical advice is needed (along with any necessary benefits, as mentioned above), so as to enable farmers to overcome the critical first few years before the perennial crops begin to produce marketable outputs. The content of any field extension programme should be based on farmers' needs, and its implementation should be carried out in an essentially participatory way, rather than as a top-down approach.

The Use of Mass Media

Positive extension to farmers needs to be supplemented by a mass-media component using radio, newspaper, magazines, television, motion pictures, slide shows, exhibits and printed educational promotional materials on agroforestry. Together with other agricultural extension messages these will help reach large numbers of people quickly and provide a contribution to general awareness and adult education.

Distribution of Planting Materials

The timely availability of improved seed and quality planting materials, in adequate quantities, based upon agro-ecological regions and fitting farmers'

preferences, is essential. This will require a co-ordinated effort from both Governmental and non-Governmental organisations, and it will require adequate supervision.

Indigenous Species

It is important to explore the possibilities of including indigenous species by balancing the use of endemic and exotic tree species in a more meaningful way. Exotic species are generally popular worldwide, often because of their fast growth and short rotation. However, concern has often been expressed about their possible detrimental effects (weediness, over-competitiveness). Careful thought should be given to the choice of species and also local wisdom should be heard or, better, the local people should be given more chance to express their choice of species.

Germplasm Conservation

There is a need to establish a centre to preserve wild and indigenous varieties grown in traditional homegardens in Sri Lanka for future crop improvement programmes. Agroforestry can offer a chance to increase biodiversity and help prevent genetic erosion by maintaining a broader range of species and varieties than would be the case in agricultural monocropping.

Local Nurseries

Farmers should be given the necessary know-how and other support and facilities required to establish their own village nurseries. Decentralisation of nurseries for tree seedlings can create employment, provide an economic way of raising trees and supplying farmers with their requirements, but nursery entrepreneurs may require support (training, credit and access to quality germplasm being very important).

Agroforestry Research

This is a broad subject which was addressed by all the Working Groups. In general:

- Further research in the field of agroforestry is essential. In particular, it is necessary to identify the potential technical and socio-economic benefits of agroforestry practices, traditional or otherwise, and quantify them. Research information currently available, and relevant to agroforestry practices in Sri Lanka, needs to be collated and tested under farmers' situations, and with their participation, through adaptive research and/or on-farm research, as early as possible. Soundly-based recommendations are urgently needed by the extension services' line agencies and by the NGOs.

Specifically, research is needed in the following areas:

- There is a dearth of information on the socio-economics of agroforestry practices. As agroforestry is related to social tree planting, or tree planting schemes with mass participation, the social acceptability and economic viability of specific agroforestry initiatives needs to be examined and evaluated. In particular, the underlying mechanisms for the implementation of agroforestry practices, i.e., social organisation, target groups, interest groups and market facilities, has to be adequately evaluated. Certainly, much more research has to be done on markets and marketing as these are very important bottlenecks in the success of all agroforestry practices in Sri Lanka.

- Socio-economic research should also include analysis of existing agroforestry practices with regard to problem areas and restraints such as land and tree tenure; the effects of size of an economic farm unit, taking into consideration the family size; time of crop harvesting and marketing opportunities; credit and subsidy facilities; and any other areas in which support may be needed.

- Investigations are required to explore the extent of potential benefits of various agroforestry practices on soil rehabilitation and for general soil fertility improvement. The value of different MPT species needs to be assessed and, especially, their long-term environmental impact, (including micronutrient transfer to the topsoil, and additions from leaf litter).

- Pest and disease incidence in woody/non-woody plant mixtures has to be recorded, and the establishment of suitable low-cost pest management practices addressed.

- Currently, there is more emphasis, worldwide, being placed on understanding the interactions between the plant components being used in agroforestry, both above- and below-ground. Results of such work on environmental resource capture, and utilisation, and on competition and complementarity, need to be compiled, assessed and circulated. Appropriate research relating to specific problems of component interactions/systems function in Sri Lanka would be of considerable value in formulating appropriate extension advice.

- The possibilities for including animals, especially small ruminants, in various agroforestry practices needs to be explored more fully; particularly as agroforestry practices can lend themselves to the provision of animal feed/fodder. The quality of tree fodder from different MPT species, and the ways in which these can best be used in different farmers' situations to supplement and extend the feed profile are areas in which research is needed.

- The medicinal, pesticidal and industrial use of trees which can be utilised in agroforestry in Sri Lanka should be explored further to include non-leguminous species.

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