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Turvey, N.G. 1994. Afforestation and rehabilitation of *Imperata* grasslands in Southeast Asia: identification of priorities for research, education, training and extension. ACIAR Technical Reports No. 28, 52p.

ISBN 1 86320 109 2

Typesetting and layout: Arawang Information Bureau Pty Ltd, Canberra, Australia.
Printing: Pirie Printers, Canberra.

Cover photo: *Acacia mangium* recovering from fire damage in *Imperata* grassland, Kemasul, West Malaysia. [J.W. Turnbull]

Afforestation and Rehabilitation of *Imperata* Grasslands in Southeast Asia: Identification of Priorities for Research, Education, Training and Extension

Nigel D. Turvey

1994

Foreword

THE Center for International Forestry Research (CIFOR) was established in 1993 by the Consultative Group on International Agricultural Research (CGIAR). It is the focus for forestry research within the CGIAR system of international research in support of sustainable natural resource management for the benefit of rural communities in developing countries. The Australian Centre for International Agricultural Research (ACIAR) has been CGIAR's implementing agent for the establishment of CIFOR and as part of that task, has undertaken a number of planning activities aimed at providing CIFOR's incoming management and scientific team with a foundation for research program development and implementation.

Within the current strategic planning framework, set out in its provisional medium-term plan (1994–98), CIFOR is establishing a 'program of research on degraded and depleted lands (which) will deal with forestry systems for recovering the potential productivity of such sites'. These programs are intended to incorporate:

> policy, social science and economic aspects of strategic research for reforestation (as well as) ... the associated technical issues needed to improve the economic and financial production functions which feed into the policy studies.

The basic premise underpinning this approach is that restoration of forest cover and its management for the benefit of dependent rural communities is a desirable though not necessarily exclusive outcome.

The *Imperata* grasslands of Southeast Asia (alang alang) have attracted considerable regional interest for their development and sustainable management. These anthropogenic grasslands are largely derived from tropical forest and are subject to considerable agricultural and grazing pressures associated with population increase including migration. Shifting and shifted agriculture involving slash-and-burn are but two elements of alang alang systems. Rehabilitation via reforestation including agroforestry is one strategy being considered for the development of land-use systems for alang alang and to halt what is perceived to be regressive degradation under current land-use practices.

While there has been considerable research, observation and anecdote on alang alang land use, we lack a coherent statement upon which to define more precisely the problems and hence build management strategies to redress the issues. Research in the widest sense is necessary to support rational decision making, strategy development and operational plans for implementation of sustainable land-use practice.

As part of its role in assisting CIFOR to develop its research program, ACIAR commissioned a prefeasibility study of the problems associated with afforestation and rehabilitation of alang alang in Southeast Asia with a view to defining the constraints to development and the issues which might be amenable to research inputs in seeking relief from these constraints. The objectives of the study were:

- to identify the biological and socioeconomic constraints to sustainable management of *Imperata* grasslands in Southeast Asia;
- to assess needs and develop options for research on grasslands redevelopment through afforestation; and
- to examine long-term land use options for rehabilitated lands and their influence in the direction of the research agenda.

The study was conducted in the latter half of 1993 by Dr Nigel Turvey (FORTECH, Canberra) who has extensive field experience of alang alang afforestation in the region. This was a timely activity and complements other work on alang alang being supported by ACIAR through its bilateral program and in cooperation with the International Centre for Research in Agroforestry (ICRAF). While the field work associated with the study was for logistic reasons restricted in geographic scope to Indonesia, Philippines and Thailand, it is hoped that the study provides sufficient useful background information for the evolution of research initiatives not only by CIFOR, ICRAF and ACIAR, but also by other interested national, regional and international institutions with a commitment to sustainable development of the grasslands of the Asia–Pacific region.

Ian Bevege
Principal Adviser
ACIAR

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Abbreviations

ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
ANR	assisted natural regeneration
ANU	Australian National University
CBFM	community-based forest management
CDA	controlled droplet application
CDC	Commonwealth Development Corporation
CGIAR	Consultative Group on International Research
CIFOR	Center for International Forestry Research
DENR	Department of Environment and Natural Resources
DOF	Department of Forestry
ERDB	Ecosystem Research and Development Bureau (Philippines)
F/FRED	Forestry/Fuelwood Development project
FAO	Food and Agriculture Organization
FORTECH	Forest Technical Services Pty Ltd
FPL	Fiji Pine Ltd
GIS	geographic information system
IBSRAM	International Board for Soil Research and Management
ICRAF	International Centre for Research in Agroforestry
IFMA	industrial forest management agreements
IRRI	International Rice Research Institute
ITTO	International Tropical Timber Organisation
KBS	knowledge-based system
MPTS	Multipurpose Tree Species Research and Development Network
NARC	national agricultural research cooperators
NCDS	National Centre for Development Studies (ANU)
NGO	non-government organisation
ODI	Overseas Development Institute, U.K.
PICOP	Paper Industry Corporation of the Philippines
TLA	timber licence agreement
UNDP	United Nations Development Fund
UNESCO	United nations Educational, Scientific and Cultural Organization
USAID	United States Agency for International Development

Executive Summary

THIS paper touches on edaphic, climatic, ecological, silvicultural, agricultural, anthropological, socioeconomic, demographic and political problems associated with afforestation and rehabilitation of *Imperata* grasslands in Southeast Asia.

Imperata is a pandemic genus found on all continents from the tropics to just outside the subtropics. It is a rhizomatous perennial grass with a spreading habit; it is dispersed locally through the rhizome system, and more widely through wind-dispersed seed. In Southeast Asia *Imperata* grasslands occur in a wide range of humid, sub-humid and seasonal climates. In the humid tropics it forms single species stands when managed by fire. At higher altitudes and in areas of more seasonal climates *Imperata* forms associations with other grasses and herbaceous species. Of the estimated 20 million hectares of *Imperata* grasslands in Southeast Asia, 60% are in Indonesia.

Imperata grows in dense stands and will compete for light, water and nutrients with small seedlings. It can be readily controlled using herbicides, particularly glyphosate. Other methods of mechanical cultivation, pressing, or shading with tree species are used with varying success.

Imperata-dominated grasslands can form part of extensive agricultural systems. There exists in *Imperata* grasslands a matrix of human and ecological states, the coincidence of some of which causes problems of sustainable land use which are severe and require resolution. As the pressure of population increases, agricultural systems are required to become more intensive (fixed); the agricultural and economic options, present in the old extensive systems characterised by low population densities, are reduced in scope.

Imperata is a symptom, not a cause; it is an indicator of problems rather than a problem in itself. The attendant factors of low soil fertility and high population pressures are the cause of the problem, not the incidence of *Imperata*. There is a clear need for a spatial inventory of *Imperata* grassland areas and their environmental and demographic status. These factors can be coordinated on a geographical information system (GIS) which should provide the vehicle for identification of critical combinations of edaphic, climatic and demographic factors, and hence aid the spatial definition of problem areas. This should result in a focus away from *Imperata* as the source of the problem, and towards the location of the combined set of critical factors underlying the problem.

It is unreasonable to expect successful establishment of utilisable trees on degraded landscapes without auxiliary inputs of weedicide, soil cultivation, and fertilizers. However, there needs to be research in policy areas to devise acceptable methods of financially supporting farmers in the crucial problem of the initial cost of improved practices on land which otherwise would become un-farmable.

The greatest problems for timber plantations established on *Imperata* grasslands, and the most pressing research tasks, stem from issues of land tenure and security, and hence land policy and planning. The incidence of fire is also a major threat to the success of plantations on *Imperata* grasslands. This problem can also be minimised by resolution of tenure issues and establishment of 'ownership' of the land and/or trees or products.

Activities required to resolve problems of growing trees in *Imperata* grasslands have been articulated as five Grasslands Projects, namely:

- *Grasslands Project 1.* Definition of priority research areas using a GIS-based spatial definition of the extent of *Imperata* grasslands, and coincidence of critical edaphic and socioeconomic indicators of problems associated with *Imperata* grasslands.
- *Grasslands Project 2.* Research into policies for resolving the problems of land and resource tenure and the incidence of fire in *Imperata* grasslands.
- *Grasslands Project 3.* Research into policies to

assist purchase of fertilizers and weedicides by farmers to aid successful establishment of trees in *Imperata* grasslands.

- *Grasslands Project 4.* Research into problems of present and long-term fertility of soils under *Imperata* grasslands.
- *Grasslands Project 5.* Establishment of a knowledge-based system (KBS) as a focus for synthesis of research into biophysical and socioeconomic factors in *Imperata* grasslands.

In addition to these research projects there is a need for improvement of information transfer, education, training and extension to ensure programs of establishing trees in *Imperata* grasslands are successful. The role of extension is to facilitate the communication process and to raise the level of understanding of the factors involved and the consequences of different actions by all parties so that the innovations and adaptations proposed by research workers are appropriate and applicable in the social milieu.

It is concluded that the principal technical problem is not a deficiency in the sum of technical knowledge about afforestation of grasslands; the problem is the dispersed locations of knowledge in cells remote from the body of people who can benefit most from its appreciation and application. New research should address the sociopolitical context within which the *Imperata* land systems are managed or mismanaged, and ensure that tree planting programs can be targeted appropriately in space and society. Research and policy analysis are the means to address socioeconomic factors inhibiting appropriate land use in *Imperata* grassland areas.

Acknowledgments

The author acknowledges the guidance and stimulation of a large number of people who have been involved in some ways with this study. Most of these people are listed in Appendix A. However, I would like to acknowledge the intellectual stimulation and support provided throughout this study by Dr Ian Bevege of ACIAR and Dr Neil Byron, formerly of the National Centre for Development Studies, Australian National University; their ideas and inputs have been gratefully received.

CHAPTER 1

Introduction

Background

There are estimated to be 20 million hectares of *Imperata* grasslands (alang alang) in Southeast Asia (Vanderbeldt 1993). In the Philippines degraded grasslands, including *Imperata* and other species, cover more than 5 million hectares (de la Cruz 1993) while in Indonesia the total area of grasslands, mainly dominated by *Imperata*, is 10 million hectares with a further 20 million hectares of bush/scrub-covered land associated with shifting cultivation (Tjitrosoedirdjo 1993). In Malaysia, *Imperata*-dominated grasslands are found mainly in western Sabah (on the island of Borneo) and total 1 million hectares. There are no large areas of *Imperata* grasslands in Sarawak or on Peninsular Malaysia (Shi 1993).

Although statistics are not available, it is likely that the greatest geographical concentrations of *Imperata* grasslands are in Indonesia on the island of Sumatra and in both Kalimantan (Indonesia) and Sabah (Malaysia) on the island of Borneo. These are predominantly anthropogenic in nature and large areas now cover land which was once under closed forest. The conversion of large tracts of closed forest to grassland, through the processes of logging, shifting cultivation, and continued burning, is seen by many governments and international organisations as detrimental. This is because of several perceptions: the forest is considered to be innately more productive and valuable in an ecological sense than the grassland; maintenance of the grassland by fire is seen as environmentally detrimental; and the resultant grassland biotype is classed as 'wasteland' by both governments and external agencies.

The opinions of governments and international organisations have generated attitudes to grasslands which have given rise to the perception of such ecosystems as problem ecosystems identified by the presence of *Imperata*. Such perception does not extend to *Imperata*-dominated grasslands dotted with occasional fire tolerant tree or herbaceous species which are generally considered in biogeographical terms to be savanna woodlands and of intrinsic ecological value (Bourliere and Hadley 1983). The perception of treeless tropical grasslands as wastelands has generated notions of weed-infested lands requiring reclamation. For example it has been proposed (Grainger 1988) that '...two thirds of the estimated area of alang alang (*Imperata* spp.) infested grasslands in Southeast Asia...' would require 'conversion' to hardwood plantations to meet the demand for tropical hardwoods by the end of the present century. Similarly:

> Governments and donor agencies have recognised the waste of leaving these expanding grasslands idle, and have funded numerous schemes to 'reclaim' them or to bring them into some kind of sustainable production. ... These efforts have been backstopped by a considerable investment in research by national, regional, and international forest institutions (Vanderbeldt 1993).

Although in many cases the land covered by *Imperata* is newly converted from closed forest, informal land allocation[1] is made by members of the occupying communities. Thus, in most cases, lands dominated by *Imperata* grass are occupied and not considered to be wasteland by the occupants. Occupation covers a range of tenures from: grazing lease holders, long-term established communities and land holding structures, medium-term community ownership, and recent opportunistic migrants. Thus tenure ranges from well established and moderately prosperous communities to 'marginal people on marginal land'. There is a mix of acceptance both within and between governments of 'illegal' land occupation. The occupants of *Imperata* grasslands in Southeast Asia cover a very wide spectrum of belief systems and cultural approaches to land and environment.

[1] Land allocation is informal in the sense of not coinciding with government allocation of land, but it is usually formal within the community and recorded formally by the community leader. Loss of such land by a community member then requires compensation to the 'informal' owner. Government attitudes differ on the interpretation of this concept.

In general, *Imperata* grasslands in Southeast Asia are occupied or utilised by communities with very low income and who subsist with little opportunity to capture cash income. Attempts at conversion to commercial cropping have been linked to loan/debt spirals (e.g. cassava growing in Thailand). In general the more wealthy middle class in the community uses the land for cattle (buffalo) grazing, and in the Philippines, grazing lands are often tenured by absentee landlords. In many cases, *Imperata* land is used as a component of extensive land use. The occupants of the grasslands use other resources peripheral to the grassland which has resulted in some instances of the problem of over-exploitation of remaining resources. As population densities increase from relatively low levels, over-exploitation of other resources can occur.

In identifying and focusing on the problems attendant with the occurrence of *Imperata* grasslands, it is important that some widely stated universalities are challenged. Some of the more commonly postulated universalities which will be examined in this study are:

- shifting agriculture is the cause of the spread of *Imperata* grassland;
- traditional farming systems are intrinsically sustainable;
- the soil is degraded under *Imperata*;
- *Imperata* grasslands require rehabilitation;
- *Imperata* grasslands are 'infested', 'empty', 'idle' or 'wasteland'; and
- *Imperata* is not an integral part of agricultural systems and is 'unusable'.

Definitions

The use of trees in grassland systems has been variously termed reforestation, afforestation, and rehabilitation of wasteland. There are some inherent problems in using such terminology universally:

- *reforestation* implies the previous existence of forest;
- *afforestation* implies the creation of a forest which may not be pertinent in an agroforestry context; and
- *rehabilitation* implies a pre-existing state of degradation.

Moreover, wasteland is a pejorative term which is not necessarily pertinent to either the biological or cultural context of the *Imperata* grassland ecosystems of Southeast Asia; the land may be poorly productive from an anthropocentric viewpoint, and largely devoid of trees. In this context, afforestation and rehabilitation are terms which can be applied usefully to the process of planting trees to improve soil fertility, community well-being and wealth, and maintaining or improving biodiversity of the landscape.

Geographical Scope

The geographical scope of this study encompasses Southeast Asia, but principally Thailand, Malaysia, the Philippines, and Indonesia. This geographical context provides a sufficiently broad spectrum of landscapes, climates, ethnic groups, population pressures and social systems to begin to identify the fundamental problems associated with *Imperata* grasslands, and from which to begin to generate useful principles which may be applicable in a wider geographical context.

Methods

The principal source of guidance for the study was discussions with some fifty people in governments, private industry, universities, research institutes, and bilateral and multilateral aid agencies in Australia, Indonesia, Philippines and Thailand. These people were canvassed for their perceptions of the problems which inhibit successful establishment of trees on *Imperata* grassland. Input was also received from a meeting of some thirteen researchers which was convened in Canberra to assist in the definition of socioeconomic research requirements and how they may be addressed. The individuals in both groups are listed in Appendix A. Surveys of the literature and abstracting services were also used to provide source information for particular points in the study.

CHAPTER 2

Imperata Grasslands: Biology, Use and Control Strategies

Biological Features

Botany

Imperata is a pandemic genus found on all continents from the tropics to just outside the subtropics. It is a rhizomatous perennial grass with a spreading habit. It is dispersed locally through the rhizome system, and more widely through wind-dispersed seed. The genus previously included some 10 species (Henty 1969) but has now been divided into two sub-genera: *Imperata* with two stamens per flower; and *Eriopogon* with one stamen per flower. There is only one species in the *Imperata* sub-genus, *I. cylindrica*, which has been divided into the varieties *major*, *africana*, *europea*, *condensata*, and *latifolia* (Tjitrosoedirdjo 1993). In this paper the genus *Imperata* is used to denote grasslands dominated by *I. cylindrica* var. *major.* The botanical characteristics of *Imperata cylindrica (*L.) P. Beauv. (Syn. *I. arundinacea* Cyr.) are detailed in Table 1 and a wide range of common name synonyms from around the world are listed in Appendix B.

Ecology

In Southeast Asia *Imperata* grasslands occur in a wide range of humid and sub-humid and seasonal climates. In the humid tropics it forms pure single-species stands when managed by fire. At higher altitudes and in areas of more seasonal climates it forms associations with other grasses and herbaceous species such as *Themeda gigantea, Sorghum serratum* and *Arundinella setosa* (Blasco 1983). *Imperata* also forms successions with *Ischaeum pubescens* and *Eriachne pallenscens* in areas of deforestation and erosion in lowland New Guinea, and is favoured by burning in the succession of *Phragmites/Saccharum/Imperata* associations to *Paspalum/Chrysopogon* associations in India (Whyte 1968).

Imperata grows on a wide range of landscape types from flat and gently undulating to steep and erodible. It also grows across a wide range of altitudes. It grows on a wide range of soil fertilities from acid to alkaline soil types; it does not tolerate soils inundated for long periods of time. The soils under *Imperata* maintained by burning for a long

Table 1. Botanical features of *Imperata cylindrica* (L.) P. Beauv. (Syn. *I. arundinacea* Cyr.)

Feature	Description
Life form	Perennial, spreading and rhizomatous
Culm	Usually erect, 50–150 cm tall
Leaf	Blade is linear, usual range 15–50 cm (max. 150 cm) long and 4–8 mm wide Ligule is 0.5–1 mm, membranous and truncate Sheath margin is often hairy
Flower	Usual range 7–20 cm (max 60 cm) long pseudospike composed of short, appressed branches (racemes). Spikelets are binate, 3–6 mm long, surrounded by silky hairs and have a pedicel. Glumes are equal, membranous, 3–9 nerved

Source: Hafliger and Scholz 1980

time are characterised by low organic matter in the surface horizons, reduced soil structure, and reduced water infiltration. This is due more to the management of the grasslands through frequent and continued burning rather than due to the grass species itself. The biomass of *Imperata* tends to reflect the fertility of the site. The fertility requirements of *Imperata* appear to be much less than that of other vegetation and it will colonise soils which are acidic, strongly weathered and low in nutrients. On very fertile soils *Imperata* will colonise effectively when assisted by fire, and will restrict light and water and nutrient availability to other potential colonisers.

Succession and fire

If regeneration by woody species is not inhibited by frequent burning, woody species, which are the progenitors of the secondary forest of the region, can recolonise incipient *Imperata* grassland areas provided that degradation of the soils has not progressed too far and buried germplasm is available, or the forest margin is in close proximity. *Chromolaena odorata* (Syn. *Eupatorium odoratum*) is a relatively recent woody weed of Southeast Asia (Dove 1986) and will colonise *Imperata* grasslands if fire is excluded. *Chromolaena* is also associated with termite mounds in South Kalimantan, and its distribution in continuously burned grasslands is coincidental with the socially determined distance between termite mounds.[2] *Imperata* grass is associated with shifting cultivation only where the site is in close proximity to a source of *Imperata*; sites of shifting cultivation well within the closed forest will recolonise to forest species.

One of the main problems of establishing trees on *Imperata* grasslands is the management of fire in the landscape; this is more a problem of land tenure, ownership of trees and their products and community attitudes than the flammability of grass.

One researcher considered fire to be the main cause of perpetuation of *Imperata* in southern Sumatra, and that '...much may be done if the native indifference to fires can be corrected by education and punishments.' (Danhof 1940). Careful use and control of fire by the community can be achieved if the users of fire have a vested interest in the resource, such as a plantation, which may be placed at risk by fire. Once control of fire is accepted by the community, the next major problem becomes one of introducing the technology which will make the establishment of trees successful for the objectives of the growers. This involves very careful evaluation of the objectives of the enterprise, the end use of the trees and hence selection of appropriate species, the agricultural systems employed by the farmers, and the resources available within the community.

Biodiversity is very low in *Imperata* grasslands at a macro- and micro-level. On more fertile sites where the grass may grow as tall as two metres, *Imperata* may be burnt to provide feed and cover for deer and other game (Seavoy 1975).

Use

The utilisation of *Imperata* grass is out of proportion to its areal extent. It is traditionally used for roof thatch and in some areas has been cultivated for such use; it is also of ceremonial importance in some communities (Dove 1986). It is used for grazing cattle following burning and regeneration of palatable shoots, but *Imperata* grasslands are poorly productive when considered from the point of view of conversion into animal protein (Soemitro 1991). Small amounts of *Imperata* are harvested for conversion to cattle fodder by a process of protein enrichment (R.E. de la Cruz[3], pers. comm.). Small amounts of *Imperata* grass are also used for low-quality paper making, but this process is dependent upon proximity to processing facilities and technological advice.

Competition with Trees

Imperata grows in dense stands and will compete for light with small seedlings. It is likely that when water becomes limiting, the extensive root system of *Imperata* will access water more effectively than planted tree seedlings. However, Richards (1967) showed that in subtropical Queensland *Imperata* competed with *Araucaria cunninghamii* principally for nitrogen, not water.

Eussen (1978) has shown some extracts from *Imperata* to have inhibiting effects on the growth of maize and sorghum. However, there appear to be no marked allelopathic effects of *Imperata* detritus or mulch used in agricultural systems.

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[2] This was a personal observation of the author while working in the *Imperata* grasslands in the coastal districts of South Kalimantan. It is not known whether the distribution so found is a result of seed storage by termites or a protective environment provided by the termite mound.

[3] Director, Philippines National Institute of Biotechnology and Applied Microbiology, Los Baños.

Eucalyptus planted in *Imperata* grassland in Riam Kiwa, South Kalimantan, have been found to be highly sensitive to competition from *Imperata* and did not recover if weed control was delayed. *Acacia mangium* was also sensitive to *Imperata*, but recovered growth if weed control was implemented (Vuokko 1991). In trials on Pulau Laut, South Kalimantan, competition from *Imperata* was so severe that *Eucalyptus urophylla* grew very slowly indeed (3.8 m^3/ha) in its presence, but grew at a rate of 40.5 m^3/ha in the first 10-months on sites where *Imperata* had been killed with glyphosate (Turvey 1993). In the same trials, *Acacia mangium* was more tolerant of competition from *Imperata* and grew at 10.8 m^3/ha, but when *Imperata* was controlled with glyphosate *A. mangium* grew at 29.1 m^3/ha in the first 10 months.

Pinus species such as *P. caribaea, P. merkusii, and P. taeda* have been found to compete moderately well with *Imperata* in Queensland, Indonesia, Fiji and Papua New Guinea (Dr D.I. Bevege, ACIAR, pers. comm.).

Control

Many methods of controlling *Imperata* have been published and some are examined below. The methods can be classed as: competitive control (shading by woody species), self mulching (rolling and pressing the grass), physical destruction (intensive hoeing or mechanical cultivation), and chemical control (weedicides). Methods of controlling *Imperata* recommended in Indonesia by Departemen Pertanian (Indonesian Government 1984) and Balai Teknologi Reboisasi (Sagala 1988) include:

- hoeing in the dry season;
- mechanised ploughing to 30–40 cm in two directions, followed by a further double cultivation three to four weeks later;
- spraying with dalapon; and
- spraying with glyphosate.

Eradication through shading

Imperata may be controlled through protection from fire so that it senesces, and planting a shading cover crop such as *Gmelina arborea, Paraserianthes falcataria, Gliricidia sepium* and *Leucaena leucocephala* (Barnard 1954; Anoka et al. 1991; Aken 'Ova and Attah-Krah 1986). *Acacia mangium* has also been proposed as a species which will eliminate *Imperata* (Pohjonen 1992). However, the cover crop is prone to shading by the *Imperata* itself, and it is a race for dominance between the grass and tree species.

The principal weakness in such methods of eradication by competition is the need to exclude fire from the target area, and the vigorous nature of competition from *Imperata*.

Mulching and pressing

If fire is controlled, senescent *Imperata* may be mulched to effectively inhibit its further germination. Flattening or pressing mature *Imperata* with light rollers (Bourgoing and Boutin 1987) or boards (Drilling 1989) can inhibit growth of *Imperata*, but this is labour intensive and must be done when the grass is dry and the stem breaks, otherwise it is ineffective.

The method of pressing is being applied in test programs of assisted natural regeneration (ANR) of indigenous forests in upland areas of the Philippines and Indonesia (Drilling 1989). The ANR program uses human interventions to assist the growth of woody species in ecological processes of secondary forest succession. The results from ANR are relatively slow to be achieved and prone to biological risk (as is the natural succession itself), but the advantage of ANR is that it reduces or eliminates the costs associated with seedling germination, transport and planting and avoids the costs of herbicide application or mechanical cultivation if no funds are available (Jensen and Pfeifer 1989).

Cultivation and herbicides

Cultivation exposes the roots of *Imperata* to desiccation in the dry season (van Wijk 1950). However, control is temporary, and *Imperata* will regenerate from rhizomes following rain. Control of *Imperata* by cultivation permits a window of limited competition in which fast growing plantation species can become established (Anon 1954). If successful, such species will shade *Imperata* and reduce competition. Tjitrosoedirdjo stressed 'the importance of timing, rotation, climate, appropriate adjustments to prevailing conditions, and above all, persistence, to achieve the best results' from cultivation for eradication of *Imperata* (Tjitrosoedirdjo 1993). Cultivation can also increase the competition from *Imperata* and other weed species. In plantation establishment trials in South Kalimantan, cultivation of *Imperata* resulted in a greater biomass and complexity of weeds in plots cultivated three times than in control plots which had not been cultivated (Turvey 1993).

The effect of cultivation on controlling *Imperata* is complicated by the enhancing effect of cultivation on tree growth by reducing soil density and promoting mineralisation of organic matter and root proliferation. Combining deep cultivation (to 1 m) of soil under *Imperata* in the dry season, followed by killing of germinated *Imperata* with glyphosate prior to planting in the wet season resulted in an increase in growth of 10-m^3/ha of *Acacia mangium* in the first 10–months over untreated control plots in South Kalimantan (Turvey 1993).

Chemical control of *Imperata* now includes the herbicides dalapon, glyphosate, glufosinate and imazapyr (Tjitrosoedirdjo 1993). Of these, glyphosate appears to be the most environmentally and occupationally safe, effective and versatile herbicide if applied in consideration to the growth stage of the plant, prevailing weather conditions, and the quality of the water supply.

Glyphosate (Roundup) works by translocation through the target plant's leaves to the root system; it has no residual effect in the soil or plant residues and has an extremely low toxicity for human beings (Monsanto Agricultural Products Co., Berthet), and with controlled droplet application (CDA) protective clothing requirements of the sprayer are minimal (Lee and Chung 1985). The action of glyphosate is affected by the age of the plant and its growth activity; more actively growing plants are killed more readily. Similar to many other herbicides, the action of glyphosate is reduced if sprayed just before rainfall. The action of glyphosate is also reduced if the water for application contains suspended clays or organic matter; this can be minimised by the use of controlled droplet application in which very small volumes of water are required (Teoh 1985). These factors are important in ensuring the success of herbicide use, and may explain apparent poor performance of glyphosate on *Imperata* in some instances.

Since glyphosate has been found to be very effective in controlling *Imperata* and other weeds of timber plantations, it may be strategically important to implant genes for glyphosate resistance into plantation trees which are also susceptible to glyphosate, as has been done experimentally for tobacco and canola. Such a gene transfer could simplify the application of glyphosate in plantations. The research is in its infancy and attendant problems of tree crop sterility and the inherited tolerance to glyphosate concentrations are yet to be resolved (A.R. Griffin[4], pers. comm.).

In a comparison of mechanical clearing of *Imperata* and zero tillage using dalapon or glyphosate, little difference in soil fertility and structure was found between the treatments, and the main advantage of the minimum tillage system was economic (Anwar and Bacon 1986). Similarly, in a comparison of control of *Imperata* for the establishment of crops, it was found that 'In economic terms, herbicides to control *Imperata*, followed by rubber or coconuts intercropped with food crops using zero tillage were effective' (Mangoensoekarjo et al. 1987).

Research needs

Appropriate use of glyphosate by farmers can eradicate *Imperata*. The cost of glyphosate inhibits its use, particularly by smallholders. This is despite demonstrated increases in yield of crops due to eradication of *Imperata*. This problem is magnified in the case of tree plantings and the long lead time before a return on investment.

Research is required into policies needed to provide subsidies to users of effective but costly technology, such as weedicide and fertilizers, to ensure the success of tree planting endeavours.

[4] Shell International Petroleum Company

CHAPTER 3

Problems of People and Resources

Human Communities in *Imperata* Grasslands

There exists in *Imperata* grasslands a matrix of human and ecological states; the coincidence of some of which causes problems of sustainable land use which are severe and require resolution.

Dove (1986), and others (DHV/ACIL/SIMONS 1992), have shown that *Imperata*-dominated grasslands can form part of extensive agricultural systems. In some cases the grassland plays the role of the preferred fallow cover, in others regeneration of *Chromolaena* in *Imperata* grassland is preferred as the fallow vegetation. *Imperata* may also be maintained as the preferred vegetation and burned frequently to provide grazing fodder. The yield from these systems is supplemental to or an integral part of systems which produce plant or animal proteins and cash. In South Kalimantan, the *Imperata* grassland becomes part of an extensive land-use system which includes grazing cattle on the young grass shoots, harvesting old grass for thatch, growing rice in wet lowland spots and fertile upland spots, growing fruit trees and/or coconut trees in fertile spots, harvesting products from the forest margin, fishing, and alluvial mining (DHV/ACIL/SIMONS 1992).

The problem of *Imperata* grasslands then can be placed in the context of ecological and agro-economic continua. If the soils are fertile, then *Imperata* becomes a problem in permanent agriculture because of its productivity; its biomass needs to be controlled and soil fertility channelled instead into crop biomass. Such ecosystems present few problems and can support well managed fallow systems or permanent agriculture. *Imperata* growing on soils of low fertility is used in extensive agricultural systems to capture what little productivity the soils can support. Once population pressures begin to increase, the lands with low productivity become the weak component of the agricultural system.

As the pressure of population increases, agricultural systems are required to become more intensive (fixed), and the agricultural and economic options, present in the old extensive systems characterised by low population densities, are reduced in scope.

The question of population density and population growth are very important components of the problem of land use that this topic encompasses. The problem becomes easier to identify when the focus is on population growth at the small scale of communities rather than a regional scale. For example, in South Kalimantan,[5] the rate of population growth for the province between 1980 and 1990 was 2.3%, but within the Kabupaten covering the relatively newly formed grasslands and transmigration areas of Kotabaru and Tanah Laut, the population growth rates were 4.7 and 4.1% respectively, with population densities of 23.5 and 85.3 people/km^2.

Population increase in *Imperata* grassland areas consists of spontaneous migration of population to relatively newly available land areas, and government sponsored migration as in the case of transmigration in Indonesia. Such mechanisms do not exist in isolation, and in many areas conflicts arise because of government designation of land tenure over tenure determined at a local level.

As population pressures increase, then the following problems arise on all soils, but become most critical on soils of low fertility:

- fallow systems break down as land is returned to cropping more quickly;
- soil physical and chemical fertility becomes further degraded;
- the productivity of permanent cropping systems becomes more vulnerable;
- land tenure issues become more vital;
- additional options for cash income become more important; and
- pressures increase on the remaining natural forest resource.

[5] Kal Sel Dalam Angka 1990; Sensus Penduduk Kal Sel 1990.

As population densities increase, the use of fire as a tool for managing *Imperata* becomes more of a hazard than an asset, and protection of dwellings, gardens and fruit trees consumes more labour.

The problem of increasing both the quantity and reliability of food production from more intensive permanent agriculture is exacerbated in areas with more seasonal climates and when attempts are made to increase productivity on soils on unstable (steep and erodible) landscapes. Thus in a pan-tropical context the most severe problems are those areas which have the following attributes:

- soils of low fertility
- unstable landscapes
- strongly seasonal climates
- high population density
- increasing population growth
- insecurity of land tenure
- few options for income enhancement.

***Imperata* is a symptom, not a cause; it is an indicator of problems rather than a problem in itself.**

The act of planting trees in *Imperata* grassland will not solve the socioeconomic, sociopolitical and demographic problems which created the grassland. Similarly, tree plantations in such grassland environments are vulnerable to failure if they are not planned with community participation.

Research needs

There is a clear need for a spatial inventory of *Imperata* grassland areas and their biophysical and social status (Pohjonen 1992; Vanderbeldt 1993)[6].

This should be coordinated on a geographical information system (GIS) which should provide the vehicle for identification of critical combinations of edaphic, climatic and demographic factors, and hence aid the spatial definition of problem areas. This should result in a focus away from *Imperata* as the source of the problem, and towards the location of the combined set of critical factors underlying the problem.

The collection of information and implementation of a GIS is a procedural problem which requires definition of the means with which the objectives can be accomplished. This in turn should lead to a geographical framework within which research can be conducted in a more focused way.

[6] The need for a spatial definition of *Imperata* grasslands was echoed many times by researchers and administrators throughout the course of this study.

The Natural Forest Margin

Increasing population pressures on cleared land puts greater pressure on the natural forest margin which is pushed back. This often is coincident with logging and subsequent opportunistic occupation of degraded secondary forest. It has been stated that 'Slash and burn agriculture is the principal and proximate cause of tropical deforestation...' (ICRAF et al. 1991). Concern within the scientific and science policy arena over deforestation of the humid tropics is frequently articulated. The two main concerns are:

- the overall contribution to global warming from deforestation over the next decade is expected to equal or exceed that from combustion of fossil fuels by the second or third decade of the 21st century; and
- deforestation is decimating the world's largest repository of plant and animal diversity (ICRAF et al. 1991).

Poore (1989) adds concerns over:

- the rate of disappearance of tropical forests;
- the effects on soil, water, climate;
- the loss of potential supply of economic products;
- unsustainable uses of land converted from forest;
- forest destruction is for no ultimate benefit; and
- forest-dwelling people are arbitrarily displaced.

The two concerns of global warming and reduction of biodiversity are far removed from and largely incomprehensible to migrant farmers in the humid tropics. However, the main strategy to alleviate these two main concerns is to change practices of, or the need for, clearing the natural forest.

At low population densities the forest recovers rapidly from shifting agriculture which has a similar ecological effect on the forest as a gap caused by a tree death; patches of forest cleared for shifting agriculture are returned to on a slowly revolving cycle as long as 15–20 years. The land area under swidden cultivation should not be confused with the land area required for cycles of cultivation and fallow. On the island of Sumbawa, Indonesia, Dove (1984) estimated that although LANDSAT imagery indicated that only 4% of the land area of the island was being cultivated, some 36% of the island was being used for swidden cycles of cultivation and fallow if an average fallow period of 8 years was assumed. At low human population densities swidden agriculture is a productive use of the forest, and Dove (1983) has highlighted the mythical perception that swidden agriculture *per se* is wasteful and destructive and results in barren useless grassland successions. As human population densities increase, areas previously cleared for shifting agriculture are revisited more frequently, the frequency and areal impact of burning vegetation increases, invasion of *Imperata* grass is more rapid and more persistent, soil degradation increases at a more rapid rate, and the capacity for recovery of the forest cover from germination of buried or transported seed is greatly reduced.

It has been argued by Kummer (1992) that in the Philippines loss of the natural forest cover in the last half century has been due principally to the combined effects of commercial logging and the influx of migrants into upland areas to practice small-scale predominantly permanent agriculture. In this case the conversion to arable land was a two-stage process with commercial logging converting the closed forest to degraded secondary forest which could then be readily converted to farmland by migrants. This two-stage process is applicable to large areas of the tropics since population influx follows roads constructed for timber harvesting. Kummer points out that deforestation is not primarily the result of intensified shifting agriculture or increased population, but is statistically related to the increase in the commercially allowable forest cut. Whilst this thesis can be argued cogently, it does not negate the clear impact that the influx of migrants into an area will have on increasing the pressure on the existing forest margin for both timber and non-timber products. It does however highlight the historical problems of the general paucity of adequate and sustainable forest regeneration following logging, and the uncontrolled influx of migrants to logged areas.

The pressure on, and resultant pillaging of, common forest resources by competing upland communities in the Philippines in an 'us-before-them' resource-use pattern has been clearly demonstrated by Fujisaka (1993a). This study highlights the conflicts which can arise between long-term residents and newly arrived migrants over the rights to utilise common resources of the natural forest.

From the above it is clear that there are multi-layered objectives for reducing forest clearance and retaining an indigenous forest cover. The focus on the global scale is on global warming and biodiversity. At an ever increasing local scale the focus is much more on: maintaining sustainable forest industries and key areas of national ecological heritage for the national benefit, maintaining catchment integrity for clean water supplies for the regional benefit, providing timber and non-timber forest products at a community level, and providing land and agricultural systems to provide food at a family level. Attainment of all these objectives relies on satisfaction of each underlying demand.

Thus the means to preserve indigenous forest cover begins with provision of secure land tenure and sustainable farming systems at the family level.

The role of forestry in this hierarchy of wants is to provide alternative sources for timber and non-timber forest products which are integrated with innovative sustainable land-use systems. It is also to provide scientific and policy methodologies for sustainable use, or where necessary the preservation, of the indigenous forest.

The Problem of Degraded Land

The process of continued frequent burning of grassland results in loss of organic matter from the soil, a reduction in soil structure, reduced water infiltration, and continued soil degradation by surface runoff of water. In temperate climates, biological activity in grassland soils can be greater than that in forest soils, but the inverse is true of tropical grassland soils. Soil nitrogen mineralisation in tropical grasslands is limited by the relatively small amounts of easily assimilable carbon (Kaiser 1983). Species diversity of soil fauna is much lower in tropical grassland soils than in tropical forest soils. Many species of soil fauna are greatly disadvantaged by conversion of forest to grassland, and many species such as earthworms have limited potential for adaptation to grasslands (Lavelle 1983).

In more fertile soils, soil biology is more resilient and the systems well buffered chemically so that the deleterious effects of burning are not so obvious. The role of the fallow is to restore physical structure and chemical fertility of the soil. The problem of soil degradation is exacerbated and the context of the extensive agricultural systems is changed dramatically once population pressures increase in the area, agricultural systems become intensive, and fallow systems cannot be supported. This is not a new finding by any means, and it was the subject of Project 1 of the UNESCO Man and the Biosphere Programme almost 20 years ago:

> One of the major aims of the project is to determine the ecological bases of choice of rotations or agricultural practices in view of maintaining soil structure and fertility, so that the soil can be utilised under some system of permanent agriculture (McAlpine 1975).

One focus on research to reduce soil loss and improve soil fertility is the International Board for Soil Research and Management (IBSRAM) ASIALAND Management of Sloping Lands network which is active in South China, Indonesia, Malaysia, the Philippines, Thailand and Vietnam. The network was established because an estimated 54% of the land area of Southeast Asia has soil that is acidic and of low fertility (Myers 1993). The various objectives of the network program are: to validate the effectiveness of improved technologies in reducing soil runoff and land degradation, to determine the recovery of soils due to changes in crop management, to identify agricultural options which are cost effective for farmers, and to demonstrate successful farming technologies through extension and demonstration (IBSRAM 1993). Currently IBSRAM in association with national agricultural research cooperators (NARCs) has established experiments on nine sites spread over five countries. The sites include a range of soils, climates and management systems. The nature of the research is long term, since soil improvement through management techniques is not rapid.

As population pressures increase, land which was previously considered too steep for agriculture comes under cultivation. Loss of fertile top soil from these lands is severe and results in unsustainable land use. Soil loss due to farmers' traditional practices of ploughing up and down the hill have been monitored by the ASIALAND network at 224 t/ha/yr in northern Thailand on land of 25–50% slope, and as high as 102 t/ha/yr in Malaysia on slopes of 10–15% (Sajjapongse 1993). In the Philippines (Siebert 1987) intensified land use reduced fallow periods and continuous cropping in some areas has led to a monitored loss of the top 3 cm of soil, or 489 t/ha/yr. As soil is lost, soil fertility declines, and food crop production declines. The result is either abandonment of the land and/or clearing of forested land for cultivation.

The problem of soil acidity is due to the occurrence of one or more factors including: low pH, high exchangeable Al and Mn, low cation exchange capacity, low Ca, Mg and K, low base saturation, low available P, low organic matter, low water-holding capacity, compaction and erosion (Myers 1993). The practices used to control and repair the effects of soil loss are well established soil management techniques. They include the application of lime, organic matter, fertilizer, together with land management practices of contour alley cropping, grass strips, hillside ditches, and agroforestry practices. These have to be combined to provide sustainable land-use practices which are acceptable to farmers. It is important to note that such adaptive research includes the introduction of both tree and non-tree systems.

The work of the ASIALAND network shows that soil science which is well understood in both developing and developed world institutions can be applied together with soil conservation techniques, the functioning of which are also well understood, to address severe problems of sustainable productivity from and conservation of marginal soils. The science is well understood, but the adaptation of the principles to the site require experimentation. This adaptive research is common to the solution of many applied problems. Once adaptive research is successful, demonstration and extension to other farmers becomes the most pressing problem.

Research needs

A wide network of sites is required to provide the data for simulation modelling (Myers 1993) so as to better tailor practices to sites. Moreover, the implementation of best farmer practices is not a technological one, but one of how a farmer who has little or no capital finds the financial resources to purchase the necessary inputs to turn around the detrimental processes operating on his marginal farm land.

There needs to be research in policy areas to devise acceptable methods of financially supporting farmers in the crucial problem of the initial cost of improved practices on land which otherwise will become un-farmable.

As proposed by Myers (1993), collaborative research is required on root dynamics in acid soils, soil physical properties, soil microbiology, and simulation modelling. There is a continuing need for the type of adaptive research which is being done by the ASIALAND network with respect to reversing soil acidity and inhibiting soil loss and erosion; much of this research involves the use of trees.

The effective use of fertilizers by both tree and non-tree crops often depends upon mycorrhizal symbioses between the root systems of the plants and soil fungi to make the most effective use of applied fertilizers. With respect to land dominated by *Imperata* and continuously burnt, there is little understanding of the soil biology under such grasslands. A greater understanding of the extent of degradation of soil biology, both macro- and microbiology, is required to aid plantation establishment and efficient use of fertilizers.

Table 2. Factors affecting adoption of new technology by farmers.

Reason why new technology not adopted	Factors
1. The innovation addresses the wrong problem	• farmers do not face the problem • the innovation addresses what is not the key problem • the problem is incorrectly identified
2. Farmers practice is equal or better than the innovation	
3. The innovation does not work	• the innovation works under some circumstances but not others • the innovation creates other problems • the innovation works against another farm solution
4. Extension fails	• extension may not correctly demonstrate an innovation • extension may target the wrong farmers
5. Innovation is too costly	• labour, material or opportunity costs are too high • costs are immediate, benefits are risky and accrue in the future • benefits may have been overestimated
6. Social factors	• insecure land tenure • farmers may be mining common resources • the innovation may have negative social connotations • war

There is a clear requirement for effective demonstration and extension of 'best farmer practice' technology to other farmers. This requires skilled extension officers and effective training of such staff, and close cooperation between research and extension staff in identifying and demonstrating best practices.

Adoption of Technology: Lessons for Research and Extension

Site specific research can provide technologies to resolve land-use problems, but such technologies may not be adopted successfully. Fujisaka (1993b) examined why farmers did or did not adopt new technologies offered by research and extension in upland environments in the Philippines. The reasons included one or more of the factors shown in Table 2.

Six conclusions which affect research directions and the effectiveness of extension programs can be drawn from these results.

1. Problems and target farmers must be properly identified.
2. Innovations must work under target conditions.
3. Current well-being should be assured before promoting risk.
4. Institutional strengthening is required to ensure communication of innovations from research through extension to farmers.
5. Policies are needed to strengthen security of land tenure.
6. Adoption is facilitated by farmer participation.

CHAPTER 4

The Role of Trees

There is a role for trees and herbaceous vegetation in improving the productivity of the land base in an agroforestry sense. Trees improve soil physical and biological factors, provide shelter for crops, provide timber products for construction or fuel, and provide non-timber products such as fodder, litter and fruit. There is also a role for timber, rubber, oil palm, coconut or other plantations to provide cash income for the local inhabitants through labour hire or through more integrated commercial timber systems owned and operated by the community.

Planting nitrogen fixing trees in *Imperata* grassland is one method to alleviate and rectify the damage to soil caused by past land management. It is by no means suggested that tree planting is a universal panacea; it is an option that should be used in an appropriate context, and there is a role for research to define the appropriate contexts for the use of trees. A clearly appropriate context of planting trees is to establish a successful timber-based industry; this commercial objective sometimes becomes lost in the mission to 'rehabilitate' and change land-use practices.

The problems of changing existing cropping practices become magnified where it is expected that communities can grow trees with little or no financial input apart from the provision of seedlings.

It is unreasonable to expect successful establishment of utilisable trees on degraded landscapes without auxiliary inputs such as weedicide, soil cultivation and fertilizers.

Nitrogen and phosphorus fertilizers play essential and interdependent roles in the establishment of sustainable successional tropical agro-ecosystems (Ewel 1986). Such inputs have been considered essential by the Department of Transmigration in Indonesia in the establishment of commercial agricultural smallholdings, and governmental assistance is being formulated to this end. However, there is a problem of financing the minimum acceptable silvicultural treatments required for successful establishment and growth of trees. Assistance programs which promote a successional approach to colonisation of grasslands by trees (selection of trees which survive fire and competitive stress) are prone to problems of slow tree growth, mortality of trees, unacceptable end products, and lack of acceptance by land users; the objectives of planting trees must be defined before the methods are employed.

Importance of Fallow

Fallow periods are an essential component of shifting cultivation which, in various forms, is called ladang, chena, kaingin, milpa, and is synonymous with swidden agriculture and 'slash and burn' agriculture (Blaut 1960). This system involves the destruction of a small patch of primary or secondary forest, generally by cutting and burning, and the establishment of a food garden. The process of burning woody debris provides a pulse of readily available nutrients in ash to the soil. After the production of one or two cropping cycles, the cleared patch is abandoned and a new garden is established in another area. The patch is abandoned because of declining crop yields; this can be due to either increasingly vigorous weed competition from the regenerating forest on fertile soils, or from declining available nutrient reserves on less fertile soils. The original patch is left fallow for a period of some years and then cleared again.

The role of the fallow is to restore organic matter and nutrients in the surface soil through the woody succession which accumulates nutrients in organic matter through litter fall and mineral cycling (Richards 1966). The capacity of the woody fallow to return mineral fertility to the soil has been well documented (Nye 1958, 1961; Nye and Greenland 1960; Charley 1983).

It is clear that shifting agriculture becomes a problem which requires addressing when the agriculture ceases to shift.

The importance of fallow periods in subsistence agriculture on marginal land are encapsulated by a quotation from Fujisaka (1991) concerning northern Laos:

> ...weeds, low and possibly declining soil fertility, intensification of the cropping cycle, rats (plus birds, wild pigs), and insects lowered rice yields or reduced system sustainability. The forest ecosystem has been degraded by logging, burning and rice monocropping; and potential for environmental rehabilitation through natural succession are minimal. Farmers cannot adopt high labour and cash cost innovations; and improved fallow is needed as an intermediate step prior to crop diversification, adoption of agroforestry technologies, and sedentary agriculture.

In a study of four fallow systems in Indonesia, Dove (1986) found that the peasant view of the fallow species (secondary forest, *Chromolaena*, or *Imperata*), determined their view of each species as a weed. The type of species desired for the fallow depends on the length of the fallow period. The longer the fallow period the more woody vegetation was desired. This reflects also the labour requirements for clearing the fallow. Woody fallow species require less labour to clear and are preferred in areas of low population density and labour availability. Such systems are extensive in nature and conserve labour rather than land.

Agroforestry Systems

Agroforestry has been considered by Raintree and Warner (1986) to be a reorganisation of the basic elements of shifting agriculture into a more intensive and sustainable land-use system. However, the adoption of trees into agricultural systems is dependent upon the intensification of shifting agriculture required by population density and sustainable soil fertility. Some conceptual alternatives are shown in Figure 1. Economically enriched fallows require trees of greater economic value than the natural fallow; biologically enriched fallow is designed to speed the recovery of soil fertility over that of the natural fallow; and alley cropping is a form of continuous fallow with crops grown between rows of trees.

As systems of greater land use intensity are required, tree crops become more pertinent and land use becomes more permanent.

Although research workers can draw conceptual links between agroforestry systems and systems of shifting agriculture, such conceptual links are not necessarily easily seen by the target population of farmers. Changes in species and planting systems will be seen as innovations by farmers irrespective of the conceptual links with traditional systems. Moreover, traditional farming systems which

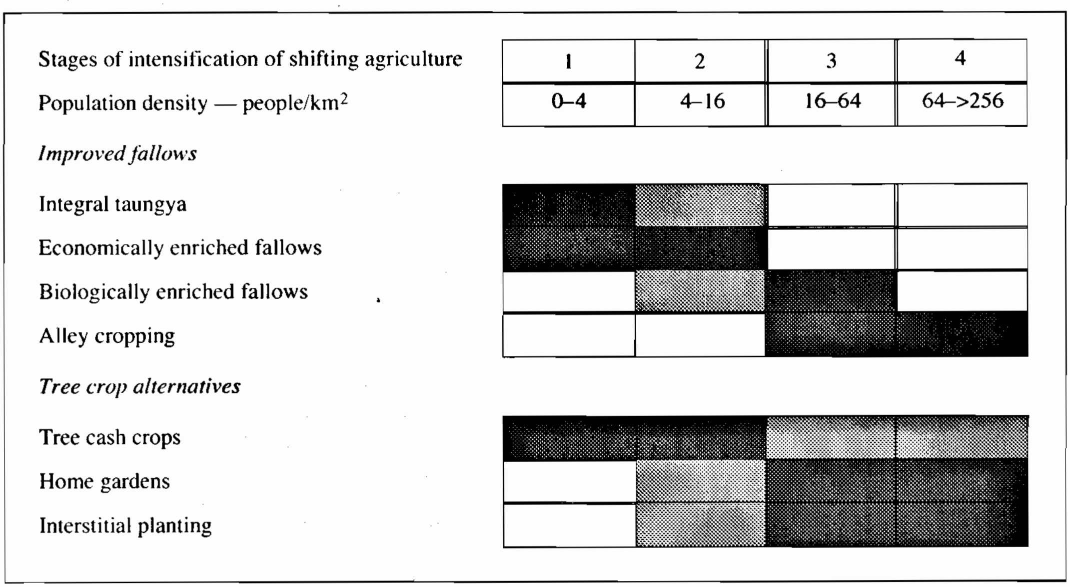

Figure 1. Stages in the intensification of shifting cultivation and agroforestry options with increasing population densities. Higher shading intensity indicates greater feasibility or priority. (Source: Raintree and Warner 1986)

include agroforestry components or concepts are not necessarily transportable between communities within cultures or between edaphic environments within cultures (Fujisaka 1989). Migrant farmers will carry with them and adapt known techniques to their new environment and as such they are practiced innovators (Fujisaka and Wollenberg 1991; Denny Hidyati, pers. comm.[7]). However, this does not mean that techniques practiced are innately sustainable, or that they are immune to technical innovation.

Agroforestry systems which combine woody perennials with herbaceous plants and animals have been classified by Nair (1985) into *agrisilvicultural* (crops with trees), *silvopastoral* (pasture and animals with trees), and *agrosilvopastoral* (crops, pastures with animals and trees) systems. There is a great number of tree and crop species combinations which can be grouped together under the umbrella of agroforestry, and agroforestry systems are as varied as their roles and outputs. However, Nair (1990) points out that appropriate scientific intervention can raise the productivity and sustainability of agroforestry systems.

It is easy to get overloaded with information about the extremely long list of trees and crops that have been used in agroforestry systems; what is important is to consider the requirements of the agro-economic system into which trees are being introduced, the benefits that the tree can bring to improving biological sustainability of the systems, and the wood or non-wood products which will be derived by the grower. If restoration of soil fertility is the goal, it does seem appropriate that nitrogen fixing trees should be the first consideration for planting because of the supply of nitrogen rich organic litter. The adverse effects of soil acidification by nitrogen fixing trees (Crocker and Major 1955)[8] is seldom mentioned, and in some cases such acidification can have an adverse effect on the mobility of trace metals in the soil (Helgar 1976), and mobilise aluminium which dominates tropical acidic oxisols and ultisols (Lathwell and Grove 1986).

[7] Javanese migrants in South Kalimantan adapted to a changed resource base and adopted techniques of fish farming from the indigenous Banjarese.

[8] In this study, soil pH under *Almus crispa* fell from a little over pH 8 to a little over pH 5 over a 40-year period of natural succession on post-glacial morainic debris.

Research needs

Systematisation and classification of agroforestry practices leads to some order if the classification is based on function rather than form. Here the problem is that many agroforestry systems are multi-functional with respect to their biological effects and their products.

For advances in agroforestry to be made pertinent to the problems of increasing population densities on soils of declining fertilities, research needs to be focused rigorously on the biological and agro-economic functioning of the systems, rather than anecdotal descriptions of soil tree and crop systems.

Research in agroforestry requires a systems approach with rigorous scientific input from tree and plant physiologists, soil scientists, agriculturalists, horticulturalists, wood scientists, socioeconomists, ethnobotanists and anthropologists, to list some of the more obvious disciplines. This is a problem of research definition and coordination so that the research that is done becomes more widely useful and less anecdotal. This is encompassed in the research program identified by the International Centre for Research in Agroforestry (ICRAF) both generally and for Southeast Asia (ICRAF 1992a,b).

Considering the relatively fledgling status of agroforestry and the plethora of species and systems being used and experimented with, there is a pressing need to establish order in the information process. Once this is achieved research can progress with clear objectives. One such objective which will follow naturally from adoption of systems is improvement of the tree crops by selection and breeding.

Farmers are unlikely to invest labour in agroforestry systems which have long-term benefits if they do not have secure tenure of the land. Similarly, they will not invest in systems which have long-term 'abstract' benefits such as reduction in pH or increasing soil organic matter, without evidence of return for effort invested and possibly return for production foregone in the short term. This is a function of technical skills and education of the farmer and community sophistication. These factors needs to be addressed through skilled use of extension and demonstration techniques and are a feature of the dissemination role perceived of itself by ICRAF (ICRAF 1992b). Agroforestry research needs to be well linked to extension. It should be recognised that the transfer of technology, or extension, is a teaching discipline which requires trained people to be effective. There needs to be a two-way flow of information and innovation between farmers and researchers. Too often agricultural extension is the weak link between research and its application because of the low emphasis on the discipline and the concomitant low esteem in which extension workers are held in many agricultural organisations.

Timber Plantations

Timber plantations have most frequently been proposed as the means of 'rehabilitating' 'degraded' and *Imperata*-'infested' lands. In some instances the rationale behind such proposals has been the elimination of *Imperata* as an end in itself (Pohjonen 1992[9]).

There is a role for timber plantations as an appropriate land use, but this is not necessarily because of the presence of *Imperata* nor the incidence of degraded soils, but rather because of a perceived market for the wood, land available for planting, and benefits to regional and local economies.

Tree plantations are appropriate for the purposes of: production of sawn timber, pulpwood, reconstituted wood products, fuelwood, round timber for construction or mining; landscape protection; catchment water management; restoration of indigenous forest resources; and the production of non-timber products such as litter, fodder, fruits, and restoration of soil organic matter and nutrient status. The purpose of the plantation and the available land for planting should determine the species planted and the silvicultural management of the plantation (Evans 1982).

The question appropriate to this study is what role do plantations have in the context of *Imperata* grasslands in the humid tropics? Plantations have been proposed for *Imperata* grasslands because of the perception that the grasslands are empty and the land degraded. It has been shown above that this perception of the land is not entirely appropriate. The question should then be what is the role of tree plantations in areas of soil degradation, disappearing indigenous forest, increasing population densities and inadequate farming systems.

In some areas *Imperata* can be seen as an indicator species for lands and farming systems under stress; in such cases tree crops may be a solution to alleviate that stress.

[9] Pohjonen proposed plantations of *Acacia mangium* as a sacrificial crop on *Imperata*-dominated land to improve soil fertility before conversion to agricultural cropping.

Plantations of other tree or herbaceous species such as rubber, oil palm, coconut and coffee are commonly considered conceptually as quite distinct from timber plantations. Moreover, such crops, once established, provide an annual income whereas timber plantations traditionally provide income only at the time of harvest. When compared to planting trees in close spatial arrangement with food crops or animals, as in agroforestry, tree plantations have some of the following attributes or requirements:

- greater labour force for establishment;
- less labour per tree for planting and tending;
- less maintenance per tree during its life;
- greater capital investment;
- greater spatial continuity;
- greater impact on the landscape;
- greater impact on water yield;
- greater risk from spread of disease due to extensive nature;
- greater potential to benefit wildlife;
- greater investment in infrastructure;
- larger area to be managed for protection from fire and damage;
- trees are harvested in large contiguous groups rather than individual trees; and
- benefits of net harvested crop is realised rather than benefits of individual trees.

The decision to establish a plantation on a degraded grassland area is one which can be taken at several different levels for different purposes. It can be made at a government level, a private industry level, or a community level. The problems of establishing plantations are not unique to *Imperata* grasslands. The problems include:

- obtaining sufficient land to provide a sustainable supply of harvested material, or obtaining sufficient contiguous land for the purposes of land or water protection;
- obtaining sufficient capital for plantation establishment and maintenance in a climate of biological risk surrounding the returns on investment and the time lag between investment and returns;
- provision of a trained labour force for plantation establishment and maintenance;
- selection of species for the desired objective;
- determining fertiliser requirements for successful establishment and optimum yield;
- controlling grass competition;
- controlling fire;
- controlling disease;
- establishing tree crop yield improvement programs;

- provision of a trained labour force for safe harvesting and transport of the crop;
- provision of infrastructure for safely transporting the crop; and
- provision of infrastructure for processing the crop.

The problem of fire is perceived as the greatest problem militating against the success of timber plantations on *Imperata* grasslands.[10] Moreover, the problem of fire is perceived as one generated by and controllable by people.

Resolution of the problem of fire can be achieved by the inclusion of communities in a perceived ownership or 'stake holding' of either the land and/or the timber resource.

Under examination here is the identification of problems which inhibit the establishment of timber plantations on *Imperata* grasslands on degraded or infertile soil on land with a population with usufruct rights.

If competition from *Imperata* can be controlled, soil fertility offset by use of fertilizers and management of organic matter, and appropriate species selected for the desired plantation product, then the most pressing problems of establishing timber plantations are the issues of land tenure and ownership of the product of the plantation.

Land issues for plantations

Some of the issues concerning land and people as they affect timber plantations on grasslands are discussed below for Indonesia, Thailand and the Philippines.

Indonesia. One aim of the forestry program of REPELITA V (planning period 1989–90 to 1993–94) was the establishment of 1500000-ha of industrial tree plantations (*HTI*). The objective was to establish plantations on cut-over and depleted natural forest areas. The establishment of plantations was to be done by private and state-owned forestry companies (*BUMN*) assisted financially from the reforestation fund (*DR*) financed principally from timber royalties.

In Indonesia, natural forest managed to supply timber is termed production forest. If the forest has been depleted severely it is transferred at some stage into conversion forest status, and subsequently alienated by permit to agricultural production. Land classified as production forest may be under *Imperata* grassland, but destined to be replanted at some stage. However, the greatest areas of grassland are classified as conversion forest land, or already alienated to private companies, sometimes speculatively in advance of viable operations.

The establishment of timber plantations becomes problematical on large areas of grassland. This is because once under grass the land has most likely, although not necessarily, been changed in status from production forest to conversion forest. The term conversion forest applies to the land rather than the vegetation, hence conversion forest land may have no trees on it. It is permissible to establish plantation crops such as rubber and oil palm on land classified as conversion forest once a permit to grow an agricultural crop is issued; once this occurs the land passes out of the jurisdiction of the Department of Forestry and into that of the provincial government or Department of Transmigration depending on the nature of the land use. If under the jurisdiction of the Provincial Government, it then issues permits for occupation for agricultural production , and subsequently adds the alienated land to its taxation base. In the case of a private investor, it is left to the investor to determine de facto land ownership and compensation. Compensation can be paid to de facto land occupiers according to the improvements they have made and relative to a scale of compensation payments issued by the government.

Plantation timber crops are considered to be forest production, and it is expected that forest production will take place on land allocated as production forest; this is normally logged natural forest, but may already have passed to grassland. Forest plantations are expected to replace wood production from the natural forest once the supply of standing timber in the natural forest becomes unsustainable (less than 20 m^3/ha merchantable timber).

This set of land classes does not recognise the possibility of timber plantations being established on, nor of being used to 'rehabilitate', *Imperata* grasslands. In order for a timber plantation to be established on *Imperata* grassland once the grassland has been classified as conversion forest, the land has to be re-classified from conversion forest back to production forest. This process involves passage in reverse order through government departments at both national and provincial levels; moreover it represents a depletion of the taxable base of the provincial government. Such a classification of land use promotes the establishment of

[10] This was the most commonly stated threat to plantations perceived by those people interviewed (shown in Appendix A) in Indonesia, the Philippines and Thailand.

timber plantations on cut-over and depleted natural forest, but inhibits the establishment of timber plantations on grasslands.

The Philippines. In the Philippines, the change from timber licence agreements (TLAs) to industrial forest management agreements (IFMA) has taken some 20-years to evolve. Administration of the TLAs favoured irresponsible logging and resulted in ecological deterioration of the forests. The IFMAs, begun in 1991, are designed to promote community involvement in the management of remaining forest resources and the establishment of plantations. The IFMA participant has to pass a technical capability evaluation by the Department of Environment and Natural Resources (DENR) in order to qualify for loan finance (Hugh Speechly[11], pers. comm.). People-based forestry has begun under prototypes of community-based forest management (CBFM) programs, but there is confusion over one of the key areas of the proliferation of land tenure instruments. Resolution of land tenure is a key component for the successful implementation of tree plantations. It is recognised that training and extension are key components for the future success of the CBFM programs. Critical research areas include: generation and verification of plantation technologies, approaches to community organisation, extension, harvesting and processing of forest products, product development, biodiversity enhancement, and improving the financial and economic viability of CBFM interventions (Guiang 1993).

Thailand. It is clear that the reforestation targets and the requirements for agricultural land do not coincide in Thailand. The Government of Thailand proposed to award land to occupiers if they had evidence that they had taken it into production between 1968 and 1975. This created uncontrolled land clearance and encroachment on the natural forest (Sargent 1990). All land in Thailand which is not owned privately or by state corporation is legally classed as crown forest estate, even though a considerable proportion of this land has not had a forest cover for many years (Arentz 1993a). It was expected that plantation establishment in Thailand would be done by private consortia, but the Asian Development Bank proposed nucleus estate plantings in which the private investor creates an estate which becomes the focus for small growers. However, the establishment of timber plantations in Thailand has been of very limited success and is likely to remain so for some time. This has been due to the loudly voiced concerns of NGOs over the perceived socioeconomic and ecological effects of exotic plantations, and in part to commercial interest in preservation of the status quo.

Communities in plantation projects

The concept of wood being grown by smallholders for a central privately-funded processing industry depends upon the sophistication of the community, smallholders and the industry in appreciating the problems of assured returns for wood and assured markets. Such understanding and acceptance by both smallholders and the industry can happen in time, but such cooperative arrangements will not flourish before trust and appreciation is developed by all parties. In the initial stages of plantation development, devolution of wood supply by the industry to third parties is unlikely to be more than 10% of the planned resource[12]. Large privately-funded projects are likely to be at odds with the objectives of community forestry, but community forestry can benefit greatly from the presence of privately funded projects in providing markets and expensive infrastructure.

Two often cited examples of community involvement in growing and owning plantations are that of Fiji Pine Ltd (FPL) and the Paper Industry Corporation of the Philippines (PICOP) (Bass 1993). In the first example of FPL, the plantations were initially planned and financed for establishment on 'unused grasslands' and marginal lands with community involvement by the predecessor of FPL.

In the case of PICOP, the stimulation for involvement of 'outgrowers' came from PICOP's partner, International Paper Company, and was modelled on timber growing on private lands in the southeast of the United States. Under the PICOP program 5300 farmers operated a total of 20000 hectares of plantation grown on their own lands (Picornell 1985). Following the initial program, some farmers grew wood speculatively outside of the PICOP harvest zone. The program has been successful for PICOP, providing a steady supply of timber at low overhead and labour costs.

[11] Team Leader of the Industrial Forest Plantation Programme, Forest Management Bureau, DENR, Quezon City, The Philippines.

[12] This figure was proposed informally in discussion by members of the timber industry in Indonesia during the course of this study.

Research needs

When placed in the spectrum of problems of plantation establishment, most land covered with *Imperata* presents few problems which are peculiar to such an environment. In many cases the biophysical aspects of establishing trees on such landscapes are simplified by the narrow weed spectrum. Problems of plantation establishment are exacerbated by steep and erodible slopes, but such problems are neither unique to grasslands nor insurmountable. Soil fertility and soil structure are problems which can be overcome by cultivation and judicial use of fertilisers and appropriate tree crops.

The technology exists to establish plantations on landscapes dominated by *Imperata*; there are sufficient successful projects in Southeast Asia to underline this conclusion. The greatest problems for timber plantations on *Imperata* grasslands, and hence the most pressing research tasks, stem from issues of land tenure and security, and hence land policy and planning.

What Tree to Grow?

The question of *which tree* should logically follow the question of *why the tree should be grown*, i.e. the selection of *form* should follow the decision about *function*. However, this logical sequence cannot always be followed because of pre-existing site factors, and because of substitutability of function between species.

Indigenous species

Tree species from the closed Dipterocarp forests of Southeast Asia are generally slow growing and are very sensitive to the environment of regeneration. The problems imposed by grassland environments of high temperatures and light and water stress are generally too severe for planting such indigenous species. Some success has been found with pioneer species from the forest margin such as *Macaranga* and *Anthocephalus*; *Acacia mangium* is one of the most successful of the rainforest margin pioneer species in plantations. Research requirements for the use of indigenous species in plantations include: size and growth rates, reproductive phenology, seed supply and seedling propagation (Lim and Faridah-Hanum 1992).

Exotic species

Trees are exotic in an ecological sense when the species is exotic to the environment in which it is planted. Thus species such as *Eucalyptus deglupta, E. urophylla, Acacia mangium* and *A.-auriculiformis* are indigenous to Southeast Asia, but they are most often exotic in the environments in which they are planted.

When planting eucalypts in grasslands it is well accepted that effective chemical weed control is essential in order to obtain successful establishment and subsequent growth; eucalypts are quite intolerant of competition from *Imperata*. Under favourable conditions, eucalypts are very efficient at capturing light and water to maximise net primary production. However, their success has caused criticism in some areas, and research has been polarised into that trying to promote and that trying to discredit eucalypts (Kirk et al. 1990). The resolution is to promote understanding of the biology and use of eucalyptus species, and plant them where they are of benefit and acceptable.

Research needs

Several collections of recent research in the biology and silviculture of tropical acacias detail the advances in research that are being made (Anon 1983; Turnbull 1987, 1991; Carron and Aken 1992; Awang and Taylor 1992). It is difficult to excise, from these reviews, research which is particularly pertinent to the afforestation of infertile *Imperata* grasslands, since all research which improves the performance of nitrogen fixing trees in general is pertinent.

The list of topics requiring research from the 1991 Bangkok meeting (Haines et al. 1991) for tropical acacias included:

- reproductive biology;
- vegetative propagation;
- adaptation to climate and soils;
- pests and diseases;
- field identification keys;
- provenance research;
- seed supply;
- species evaluation;
- advanced breeding strategies;
- silviculture;
- utilisation; and
- communication.

Research into the aspects listed above is required if plantations of any type are to be successful in any environment; none are unique to establishment of trees on *Imperata* grassland.

CHAPTER 5

Research

Perceptions of Research Problems within Southeast Asia

People involved in research, planning and administration of forestry projects in Southeast Asia were interviewed for their perceptions of the problems they faced in establishing trees on *Imperata* grasslands; the people interviewed are listed in Appendix A. Amongst those interviewed within Southeast Asia, there was remarkable congruency of responses with three major problems being perceived.

- *Resolution of tenure.* It was almost universally accepted that it is necessary for communities to 'own' the land, trees, and products, and that this is a prerequisite to community control of fire.
- *Control of fire.* This was perceived as being linked implicitly to 'ownership' of the land and/or the project. There was also a perceived need for planning of projects in the landscape to minimise fire, and appropriate equipment and organisation for fire control. Without appropriate social and institutional infrastructure, technical innovation will be ineffective.
- *Transfer and adaptation of well known silvicultural technology.* It was widely recognised that successful projects of afforestation of *Imperata* grasslands exist. The lack of ways to transfer such technology to communities and even to private growers was seen as an impediment to success. The resolution of this lies in education, training and extension at all levels.

Other problems perceived to be of lower priority were:

- the extent and rate of expansion of *Imperata* grasslands (this is perceived as a lower priority from a local perspective but achieves greater importance in regional and global perspectives);
- what species to plant for what end use;
- weed control — the technology and cost of weedicide application;
- policy changes to subsidise initial cost of fertilizer and herbicide;
- nurseries and provision of good seedlings;
- how to grow indigenous species for reforestation of protected sites;
- site preparation on difficult sites;
- water yield;
- infrastructure for wood extraction and transport;
- utilisation and industry;
- non-wood products;
- reliability of markets; and
- reliance of community on market agreements.

From the preceding discussion of the problems of afforesting *Imperata* grasslands in Southeast Asia, a number of priority problem areas can be identified in which research strategies can be formulated (Table 3).

Problems Specific to *Imperata* Grasslands

Of the research programs listed in Table 3, it is clear that programs relating to the specific problem of afforesting *Imperata* grassland on soils of low fertility include:

- the planning program of spatial definition of the problem;
- the policy programs of land tenure;
- the policy/planning program of fire control;
- the policy program of fertilizer and weedicide subsidy;
- the edaphic problems of present and long-term soil fertility; and
- transfer of technology, information, education, training and extension.

Research Projects in *Imperata* Grasslands

Research projects specific to the problems of *Imperata* grasslands have been detailed in logical framework matrices and are shown in Appendix C. The titles of seven grassland projects are shown below.

- *Grasslands Project 1.* Definition of priority research areas using a GIS-based spatial definition of the extent of *Imperata* grasslands, and coincidence of critical edaphic and socioeconomic indicators of problems associated with *Imperata* grasslands.
- *Grasslands Project 2.* Research into policies for resolving the problems of land and resource tenure and the incidence of fire in *Imperata* grasslands.
- *Grasslands Project 3.* Research into the policies and planning methodologies to reduce and manage the incidence of fire in *Imperata* grasslands.
- *Grasslands Project 4.* Research into policies to assist purchase of fertilizers and weedicides by farmers to aid successful establishment of trees in *Imperata* grasslands.
- *Grasslands Project 5.* Research into problems of present and long-term fertility of soils under *Imperata* grasslands.
- *Grasslands Project 6.* Establishment of a knowledge-based system (KBS) as a focus for synthesis of research into biophysical and socioeconomic factors in *Imperata* grasslands.
- *Grasslands Project 7.* Improvement of information transfer, education, training and extension for programs of establishing trees in *Imperata* grasslands.

Table 3. Priority problem areas identified for research.

Area	Research program
Policy	• land tenure and traditional land use • fertilizer use and subsidy • weedicide use and subsidy • the underlying causes of migration to lands of marginal productivity • means of ensuring practices of silvicultural management and regeneration of natural forests are implemented
Planning	• spatial definition of problem areas • fire control • yield planning • infrastructure development: appropriate road construction to avoid erosion and siltation • appropriately engineered civil works • safety of workers, particularly in harvesting
Edaphic	• biology and fertility of tropical soils • the long-term effects of tree species on soil (deleterious or beneficial) • soil biology and tree interactions, particularly N fixation, nutrient uptake and mycorrhizas • site preparation techniques
Manipulative genetics	• multipurpose tree breeding strategies • selection for pathology and disease resistance • indigenous species programs • glyphosate resistance of crop species
Utilisation	• wood science studies of new species • appropriate technology for communities to process wood in small industries • yield and value of non-timber products • marketing of timber and non-timber products

A 'Knowledge-based System' as a Focus for Research

In order for tree planting projects to progress successfully, there is a need to examine previous afforestation and agroforestry programs and evaluate their successes and failures. There is a great deal of knowledge, distributed across a broad geographical range, about tree systems which did or did not function. Such knowledge could be accumulated into a computerised knowledge-based system (KBS). Such a system could bring together the contextually-based information from a wide range of experiences.

The objective of such a knowledge-based system is to create a generic conceptual decision-making model which is both culturally and geographically portable.

The size and sophistication of such a KBS depends on the quantity and type of information put into the system, whether it be public knowledge such as derived from published material, or expert knowledge in key areas such as plant physiology or edaphic factors, or private knowledge such as micro-economic modelling data; such concepts are shown in Figure 2.

Such a system could be in the form of an economic model for project analysis, but its inputs would not all be definable in an economic sense. Inputs will be derived from an analysis of successful and unsuccessful projects which have involved tree planting in *Imperata* grasslands across the countries in Southeast Asia. Some inputs may be in the form of decision triggers with outcomes derived from set conditions of key inputs. A type of decision tree which could result from collected inputs about farmers' decisions was derived by Fujisaka et al. (1993) and is shown in Figure 3.

The inputs to such a model should be the complexity of factors which surround the decision-making process about tree planting programs. By following the suggested model inputs, the user should address the factors pertinent to the decision, and hence the proposal to adopt tree planting will be appropriately formulated. As such the model should be an aid to decision making rather than a functioning econometric model.

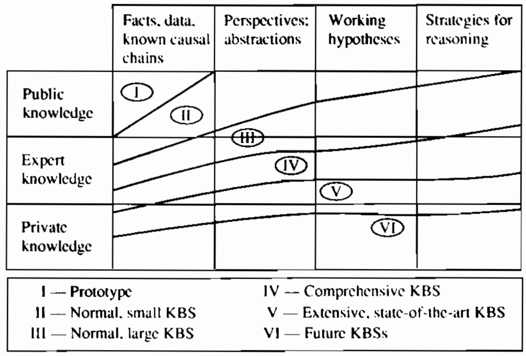

Figure 2. Levels of sophistication of knowledge-based systems (KBS). (Source: Wiig 1990)

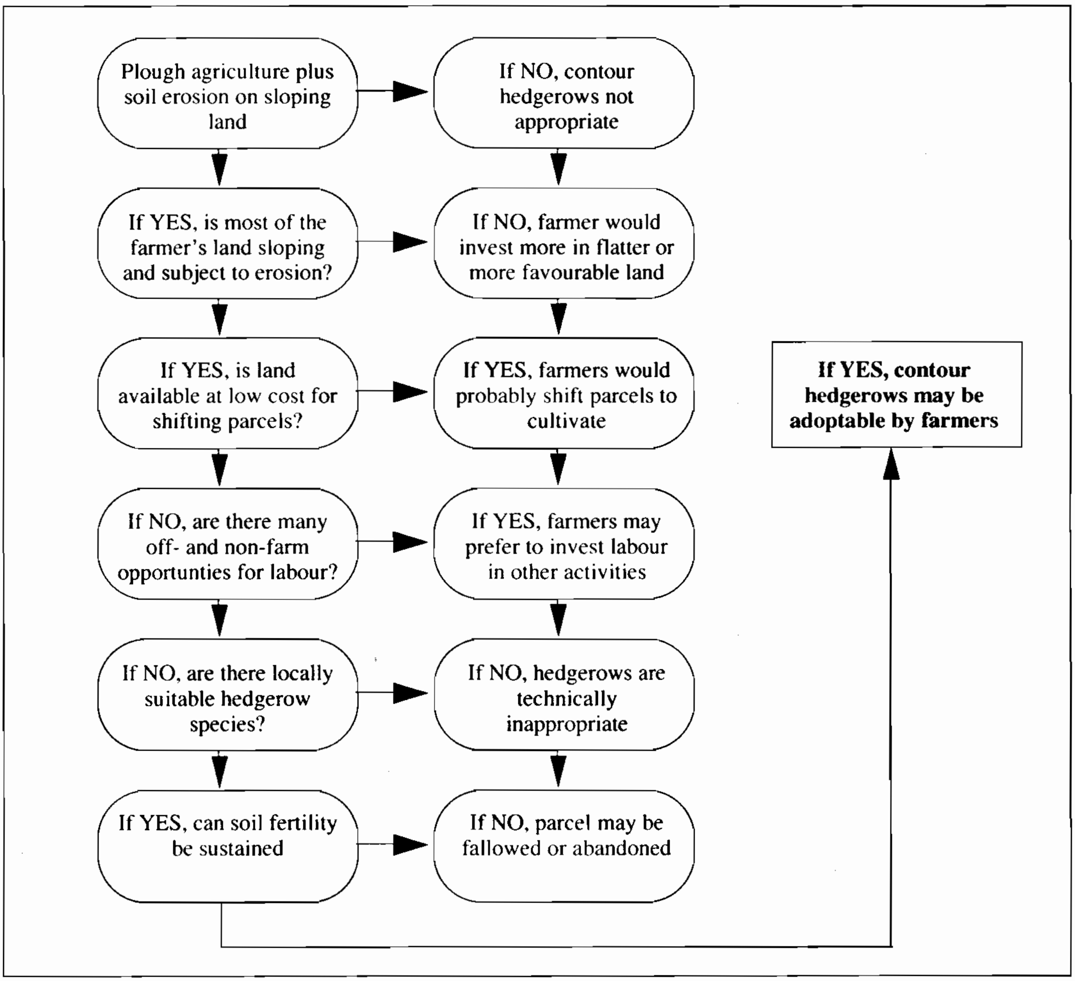

Figure 3. Decision tree: the minimum necessary criteria for sustainable adoption of contour hedgerows by farmers. (Source: Fujisaka et al. 1993)

The framework itself will identify socioeconomic research topics which will provide inputs into the model. The objective of the model is to provide a framework for systematic organisation of knowledge and experience to continuously question and challenge current 'understanding' and to rationalise apparent anomalies in the functioning of systems.

Inputs to the KBS will require synthesis of information from a wide range of sources. The means to achieve this could be through a purpose-built network; the role of networks is discussed in Chapter 6.

CHAPTER 6

Education, Training, Extension and Communication Programs

The Need for Education, Training and Extension

There is a need for a two-way flow of information between proponents and planners of tree plantations, and the people in the communities affected by the planting. The role of research in this process is to identify the key biophysical and socioeconomic factors which require addressing, and to determine, from the systems available, appropriate means of facilitating and enhancing the enterprise. This applies to all levels of enterprise from smallholder agroforestry to large integrated plantation enterprises. The role of extension is to facilitate the communication process and to raise the level of understanding of the factors involved and the consequences of different actions by all parties so that the innovations and adaptations proposed by research workers are appropriate and applicable in the social milieu.

The role of education, training and extension in the current context is in:

- changing concepts held by government and industry planners about land tenure and traditional land use;
- transfer of well-established land and crop management technology to the end user;
- education of research workers to identify broader issues outside their own disciplines;
- training trainers: establishing the foundations for maintaining education processes;
- creation of a cadre of skilled and respected extension workers;
- community education about investment and long-term market vulnerability;
- community organisation in management and protection of resources;
- training plantation workers; and
- certified training of workers involved in harvesting.

These objectives have been incorporated into Grasslands Project 7 which is detailed in a logical framework matrix in Appendix C.

Networks for Research and Extension

Networks of researchers at the work-face are very important since such networks overcome regional political factionalism which can inhibit free exchange. Such networks can be enhanced through the strengthening of national research and teaching institutions. In Southeast Asia there are a wide range of networks operating in the broad sphere of afforestation. Networks which are working in the area and which have published material pertinent to afforestation include:[13]

- Regional Wood Energy Development Programme (FAO)
- Forestry Research Support Programme for Asia and the Pacific (FAO/FORSPA)
- Regional Project on Improved Productivity of Man-Made Forests Through Application of Technological Advances in Tree Breeding and Propagation (UNDP/FAO/FORTIP)
- Forests, Trees and People Programme (FAO/FTPP)
- International Centre for Research in Agroforestry (ICRAF)
- Nitrogen Fixing Tree Association (NFTA)
- National Academy of Sciences (NAS), USA
- CAB International (CABI)
- FAO–AGRIS/CARIS
- ASEAN–Canada Forest Tree Seed Centre (ACFTSC)
- Asian-Pacific Agroforestry Network (APAN)
- International Tropical Timber Organisation (ITTO)
- International Union of Forestry Research Organisations (IUFRO)
- Regional Community Forestry Training Centre Thailand (RECOFTC)
- Society of American Foresters (SAF)

[13] Part of this list was provided by James French (F/FRED, Bangkok) and is included in French (1993). Items were also derived from Arentz (1993b).

- Australian Centre for International Agricultural Research (ACIAR)
- Plant Resources of Southeast Asia (PROSEA)
- International Board for Soil Research and Management ASIALAND Network (IBSRAM–ASIALAND)
- Multipurpose Tree Species Research Network, Forestry/Fuelwood Development Project (MPTS–F/FRED)
- Southeast Asia Ministers of Education Organisation BIOTROP (SEAMEO–BIOTROP)
- Rural Development Forestry Network (ODI/RDFN)
- European Tropical Forest Research Network (ETFN)
- Edinburgh Centre for Tropical Forests (ECTF)

Most of the networks listed above produce publications in their field, and although the literature is often of value outside of the network much of it is difficult to obtain. The cause, and in some cases the problem, is that such networks are focused narrowly both in subject matter and audience. Many networks are restricted in their operation by budgets and cannot reach a wider audience without substantial reorganisation and expenditure.

As can be seen from the above list, there are many nodes of network organisations. Such networks can become a functional organism if the nodes are connected into a coordinated organism. There is a role for an organisation to act as a clearing house of such information pertinent to afforestation.

CHAPTER 7

Implementation of Research, Education, Training and Extension Programs

The previous sections have detailed the activities required to address problems of afforestation of *Imperata* grasslands. The objective of this section is to indicate the ways in which such activities may be implemented. The activities include research, education, training and extension in several countries in Southeast Asia, together with funding and coordination of such activities. The following non-exclusive listing suggests some of the organisations and institutions in the region which may be able to assist in funding and/or implementation of the programs.

Universities Conducting Forestry Research and Education

Indonesia

Institute Pertanian Bogor (IPB)
Universiti Gajah Mada, Jogjakarta (UGM)
Mulawarman Universiti, Samarinda

Malaysia

Universiti Pertanian Malaysia
Universiti Malaysia

Philippines

University of the Philippines Los Baños (UPLB)

Thailand

Kasetsart University, Forestry Research Centre

National Forestry Research Institutes

Indonesia

Agency for Forestry Research and Development

Malaysia

Forest Research Institute of Malaysia

Philippines

Department of Environment and Natural Resources, Ecosystems Research and Development Bureau (ERDB), Los Baños

Thailand

Royal Forest Department

Training Institutes

Indonesia

SE Asia Ministers of Education Organisation (SEAMEO)–BIOTROP Bogor

Thailand

Regional Community Forestry Training Centre, Bangkok (RECOFTC)

International Funding and/or Implementing Agencies

- World Bank
- Asian Development Bank (ADB)
- Australian International Development Assistance Bureau (AIDAB)
- Australian Centre for International Agricultural Research (ACIAR)
- Japanese International Cooperation Agency (JICA)
- German Technical Cooperation Agency (GTZ)
- Finnish International Development Agency (FINNIDA)
- Swedish International Development Authority (SIDA)
- Swedish Agency for Research Cooperation with Developing Countries (SAREC)
- Danish International Development Agency (DANIDA)
- Overseas Development Assistance (ODA)
- Canadian International Development Agency (CIDA)

- International Development Research Centre, Canada (IDRC)
- United States Agency for International Development (USAID)
- International Centre for Research in Agroforestry (ICRAF)
- International Bureau for Soil Research and Management (IBSRAM)
- International Rice Research Institute (IRRI)
- Centre Internationale Agriculture Development (CIAD)
- United Nations Development Fund (UNDP)
- Food and Agriculture Organization (FAO)

CHAPTER 8

Conclusions

THE problem of afforesting or rehabilitating *Imperata* grasslands is so large that it needs to be brought into focus by use of sorting land information through GIS applications. Research and implementation cannot address the more than 20 million hectares in Southeast Asia, let alone the other areas of the Pacific, Latin America and Africa, without good spatial information. Research needs to be focused, both geographically and functionally, on where the greatest gains can be made in alleviating rural poverty, promoting sustainable land use and conserving natural forest cover.

The implementation of research, education, training and extension initiatives requires evaluation of implementing agencies and funding sources and communication between the agencies so that the programs can be effective; this requires careful planning.

It is suggested that no new technical research is required for plantations to be established successfully on *Imperata* grasslands in Southeast Asia. This does not mean that research is unnecessary; rather it means that there is a sufficient body of technical knowledge and expertise to establish successful plantations in the same way that there is to manage the natural forest as suggested by Palmer (1989):

> The situation is not irreparable. Where forest still exists, good management can be applied now, today. It is not necessary to wait a moment longer for new research to be initiated or published before starting or improving management.

The principal problem is not a deficiency in the sum of technical knowledge about afforestation of grasslands; the problem is the dispersed location of knowledge in disconnected cells remote from the body of people who can benefit most from its appreciation and application. New research should address the sociopolitical context within which the *Imperata* land systems are managed or mismanaged, and ensure that tree planting programs can be targeted appropriately in space and society. Research and policy analysis are the means to address socioeconomic factors inhibiting appropriate land use in *Imperata* grassland areas.

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APPENDIX A

People who contributed to this study

Country	Organisation	Location	Contributor(s)
Australia	ACIAR	Canberra	Ian Bevege
			John Turnbull
			Heather Crompton
			Ken Menz
			Pam van den Heuvel
	ICRAF Board		Jim McWilliam
	CIFOR Board		Alan Brown
	ANU NCDS	Canberra	Neil Byron
			Kate McConkey
	ANU RSPacS	Canberra	Jim Fox
			Leslie Potter
			Deny Hidyati
	ANUTECH/ITTO	Canberra	Fran Arentz
	CSIRO Division of Forestry	Canberra	Khongsak Pinyopusarerk
Indonesia	CIFOR	Bogor	Jeff Sayer
			John Palmer
	SEAMO–BIOTROP	Bogor	Soekotjo
			S. Tjitrosoedirdjo
	DOF Badan Litbang	Bogor	Nana Supriana
			Agustino Tampubolon
			Dida Syamsuwida
	USAID	Jakarta	Jerry Bisson
	World Bank	Jakarta	Jim Douglas
	Inhutani II	Jakarta	A. A. Malik
			Purjudoko
	Astra International	Jakarta	T. Arifin C.
			Saronto
	Monagro Kimia	Jakarta	Tommy Sutomo
	CDC	Jakarta	Malcolm Hudson
			Duleep Cheddie
Philippines	Univ. Philippines	Los Baños	R. E. de la Cruz
	ERDB	Los Baños	Carlos Tombo
			Emilio Rosario
			Elvero Eusebio
			Lebi Florido
			Lavinia Tandug
	ADB TA 1578 PHI	Los Baños	Ted Mannion
			Ross Wylie
			Bryant Richards
			Maurice Williamson
	ADB TA 1577	Manila	Hugh Speechly
	IRRI	Los Baños	Sam Fujisaka

Country	Organisation	Location	Contributor(s)
Thailand	MPTS Network	Bangkok	James French
			Kamis Awang
			P. Venkateswarlu
	Kasetsart Univ.	Bangkok	Suree Bhumibhamon
			Buvong Thaiutsa
			Rungsit Suwanketnikom
			Somsak Vagnai
	IBSRAM	Bangkok	Bob Myers
	Dept Land Development	Bangkok	Manu Srikhajon
	Royal Forest Dept	Bangkok	Vichien Sumantakul
			Tinakorn
USA	E-W Centre	Hawaii	Michael Dove
	World Bank	Washington DC	Norman Jones

APPENDIX B

Common names for *Imperata cylindrica*

Americas	Cuba	yaguna
	United States	cogongrass
Europe	Cyprus	xiphara
	Spain	carrizo, cisca, marciega
	Turkey	koseli saz
	CIS	gyrjuk
Africa	Cameroons	baya, ndongo limba, sosongo
	Eastern Africa	swordgrass
	Egypt	ambarta, beni-esh-shaam, bodweya, heleiw, deil el-qott, halfa, hishka, sill
	Ivory Coast	nse, kazari, tiskan-cub, herbe baionette
	Kenya	nyeki, alang-alang
	Madagascar	manevika, tenina, tsevoka
	Mauritius	lalang
	Nigeria	ata, ekan, isa, gasa kigere, syo, speargrass, tibin, tofa, zarenshi
	Senegal	herbe bayonette, dole, fa lint, hada, dol
	South Africa	bedding grass, mohlorumo, silverspike, um tente
	Sudan	doiya, mayani
	Tanzania	chiambi, motomoto, sanu
	Tunisia	dis
	W. Africa	dole, gombi, hada, nounour, soyo
	Zaire	binkba, moto-moto, niaga
	Zimbabwe	ibamba, luwamba, silenge, silverspike
Asia	Bangladesh	ulu, chon
	Burma	kyet-mei, thekke, la lang
	Cambodia	sbauv
	China	mao-tsao, mau kan tso
	India	chero, dabh, dharba, dhub, modewa gaddi, ooloo, siru, tharpai pullu, thatch grass
	Indonesia	alang-alang, eurih, lalang
	Iran	satintail
	Iraq	blady grass, cylindrical ha, halfa
	Israel	meshian glili
	Japan	chi, chigaya, tsubana
	Malaysia	alang-alang, lalang
	New Guinea	auturra, kawva, kunaigrass, kuru-kuru
	Pakistan	dhub
	Philippines	buchid, bulum, gaon, gogon, goon, ilib, kogon, parang
	Sri Lanka	lalang grass, illuk, darbai pul, inanka-pilu
	Syria	halfa, meshian, sill, sulel
	Taiwan	pai-mao
	Thailand	yah ka
	Vietnam	co tranh
Oceania	Australia	blady grass
	Fiji	gi
	New Zealand	*Imperata*

APPENDIX C

Logical framework matrices for grassland projects 1–7

Logical framework for Grasslands Project 1: Definition of priority research areas using a geographical information system (GIS-based spatial definition of the extent of *Imperata* grasslands, and coincidence of critical edaphic and socioeconomic indicators of problems associated with *Imperata* grasslands.

NARRATIVE SUMMARY	INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
• *GOAL* • Definition of the interaction of critical components for the focus for research interventions in *Imperata* grasslands in Southeast Asia	• Definition of research programs and objectives • Changes in the areal extent of *Imperata* grasslands and the extent of natural forest boundary • Changes in economic well being of communities in grasslands	• Effective research programs in place • Rate of areal increase of *Imperata* grasslands • Changes in land use & boundaries from remote sensing program • Economic indicators of household status	• Data sources for areal extent of *Imperata*, edaphic, demographic and socioeconomic readily available • Governments agree to data exchange • Funding agency endorses program
• *PURPOSE* • Define geographical extent of *Imperata* grassland in Southeast Asia, and its coincidence with critical edaphic, demographic and socio-economic indicators	• Feasibility study for establishment of GIS in core centre • Creation of overlays for: *Imperata*, forest boundary, geology, soils, topography, climate, population density and structure, economic indicators • Establishment of program for data coordination across Southeast Asian countries	• Feasibility study report • Well focused research programs implemented	• Data have been collected and are available available • Networking and information transfer possible across national borders • Governments receptive to program needs • Possible to establish core GIS centre in Southeast Asian region • Research institutions have capacity to act on information derived
• *INPUTS* • Objectives agreed by contributing govern-ments and agencies • Effective program management • Skilled technical staff • Funds to implement program • Computer hardware/ software and infra-structure • Spatial data from contributing countries • Effective management of dissemination and publication program	• International agreement on contribution of data • Establisment of GIS centre • Appointment of management and technical staff • Purchase and commissioning of equipment and infrastructure • Implementation and dissemination of publication channels	• Documentation of international agreement • Management teams and technical staff in place • Computer purchases in place • Infrastructure in place • Ground truthing of remote sensing data • Ground truthing of edaphic, demographic and socioeconomic data • Critical levels for indicators and their coincidence with *Imperata* grassland defined for research programs • Network for dissem-ination and publication established and launched	• Agreement by governments can be achieved with little loss of time • Funding sources are available

Logical framework for Grasslands Project 1: cont'd

NARRATIVE SUMMARY	INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
• *OUTPUTS* • Spatial distribution of *Imperata* grasslands in Southeast Asia • Definition of critical human indicators • Spatial location of indicators and coincidence with *Imperata* and natural forest boundary	• Publication of maps • Publication and dissemination of supporting information on coincidence of critical factors in *Imperata* grassland • Reports to international meetings • Adoption into research programs	• Adoption of criteria by NRCs • Adoption of criteria and maps by research-communities as shown in publications • Well focused research programs in *Imperata* grasslands in Southeast Asia	• Publication and dissemination process is effective • NRCs have capacity to act on information received • Funds are available for effective publication and dissemination program

Logical framework for Grasslands Project 2: Research into policies for resolving the problems of land and resource tenure on *Imperata* grasslands.

NARRATIVE SUMMARY	INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
• *GOAL*			
• Resolve problems of tenure of land and resources so that tree planting programs in *Imperata* grasslands have community support and hence are viable in the long term and viable commercially	• Success of tree planting programs • Incidence of fire escapes from *Imperata* grasslands • Attitudes of government instrumentalities to issues of tenure	• Changes in policy effected • Establishment of tree planting programs • Community agreements for sharing common resources • Changes in the areal extent of *Imperata* grassland	• Governments are receptive to the problems and its resolution • Communities are receptive to cooperative enterprises • Conflicts between traditional owners and migrants can be resolved
• *PURPOSE*			
• Identify conflicts between de facto and de jure land tenure systems • Identify veracity of claims for ownership of land and planted resource • Propose resolutions to tenure problems • Establish viable tree planting programs in *Imperata* grasslands	• Research programs articulated • Research teams in field • Acceptance of tenure concepts by government instrumentalities • Community tree planting programs established • Cooperation between industry and community	• Research into tenure systems published • Research into policy issues published • Information disseminated to governments and communities • Policy changes enacted by governments • Tree growing agreements entered into	• Governments will act on research recommendations • Information transfer will be effective • Community agreements can be achieved • Industry is receptive to cooperation
• *INPUTS*			
• Research programs focused on: • Traditional land tenure systems • Expectations of traditional owners and migrants • Expectations of governments • Tenure requirements for successful tree planting	• Research program leader appointed • Research team appointed • Research programs established • Working groups established with industry and government instrumentalities • Effective extension to communities initiated	• Program progress reports • Publication record • Records of meetings with governments, communities and industries	• Research programs can be established across across widely differing ethnic groups in Southeast Asia • Funding available for policy research programs
• *OUTPUTS*			
• Changes to tenure requirements for successful tree planting programs on *Imperata* grasslands • Changed policies to implement tenure requirements • Effective communication and planning with tenure issues between communities, governments and industries	• Policy changes implemented by governments • Tree planting programs initiated	• Publication and dissemination of research findings • Published policy changes by governments • Cooperative agreements between communities and industry	• Publication, dissemination and extension programs are effective • Funds are available for dissemination and extension programs

Logical framework for Grasslands Project 3: Research into the policies and planning methodologies to reduce and manage the incidence of fire in *Imperata* grasslands.

NARRATIVE SUMMARY	INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
• *GOAL* • Elimination of fire threat to tree planting programs in *Imperata* grasslands	• Loss of planted trees to fire • Community management of fire in *Imperata* grasslands	• Area and age of planted trees in *Imperata* grasslands	• Communities recognise the effect of fire on loss of trees planted • Communities accept that destruction of planted trees constitutes a loss of a resource
• *PURPOSE* • Define policy changes required to provide communities with 'ownership' of planted tree resource • Educate communities about fire management • Equip communities to effectively control fire in *Imperata* grasslands	• Benefit/cost study of fire control in *Imperata* grasslands • Heightened community awareness of importance of fire control • Community fire protection response structures and equipment	• Publication of benefit/cost study • Change in area of successfully planted and maintained trees • Accession of community owned fire protection equipment	• Governments accept policy changes are necessary • Communities accept concepts of protection of communal resources • Sources of financing of fire protection equipment
• *INPUTS* • Research into policy changes required • Extension to demonstrate techniques of fire control • Define community management structures to control fire in *Imperata* grasslands	• Research program leader appointed • Research teams established • Extension officers trained • Extension programs initiated • Community management programs initiated	• Publication of research into policy requirements • Effective extension materials created and disseminated	• Funding agencies support extension services • Funding agencies provide community fire protection equipment
• *OUTPUTS* • Policy changes to affect tenure of resources in *Imperata* grasslands • Reduction in the incidence of loss of planted trees to fire • Increase in successful longer term planting of trees in *Imperata* grasslands • Community cooperative structures	• Policy changes implemented by governments • Extension programs effective in increasing community awareness and response • Community cooperation structures implemented • Increase in area of successfully established trees on *Imperata* grasslands	• Program reporting • Policy documents published • Evaluation of community attitudes to fire and effects	• Community attitudes sustainable • Fire protection structures sustainable • Rare events of extended dry season fires are controllable

Logical framework for Grasslands Project 4: Research into polices to assist purchase of fertilizers and weedicides by farmers to aid successful establishment of trees in *Imperata* grasslands.

NARRATIVE SUMMARY	INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
• *GOAL* • To facilitate use of fertilizers and weedicides for establishment of trees on *Imperata* grasslands	• Tree plantings by small holders • Use of technology by small holders	• Policies on subsidies for small holders • Areal extent of small holder tree plantings	• Governments are receptive to problem and its resolution • Extension is available to ensure effective and safe use of fertilizers and weedicides
• *PURPOSE* • To provide the policy environment which permits subsidies to small farmers to enable them to purchase fertilizers and weedicides for planting trees on soils of poor fertility under *Imperata*	• Feasibility study completed on economic background to issues • Identification of research program priorities	• Publication of feasibility study • Drafting of proposal for research program and cooperative interactions	• CIFOR • Funding available for feasibility study
• *INPUTS* • Identification of key sites (edaphic and socioeconomic) for study • Determine benefit/cost to farmer of using weedicides and fertilizers for growing trees • Research into government policies • Extension programs for effective and safe use of weedicides and fertilizers	• Research program leader appointed • Research program formulated • Study sites selected • Data for benefit cost analysis collected • Policy research initiated • Extension program formulated • Extension staff active in field	• Program reports • Research publications • Publication of benefit–cost analysis • Extension material disseminated	• Executive agencies can formulate cooperative research programs • Government instrumentalities accept importance of extension services to ensure effectiveness of subsidy programs
• *OUTPUTS* • Policies which permits subsidies of establishment costs of trees to farmers • Successful establishment of trees by small holders in *Imperata* grassland	• Distribution of tree establishment subsidies • Change in quantity of weedicides and fertilizers used by small holders in establishment of trees • Change in area of trees established by small holders	• Published policy changes • Economic indicators • Fertilizer and weedicide sales in target areas • Remote sensing of changes in *Imperata* grassland	• Channels of subsidy to small holders are not corrupted • Fertilizer and weedicide supply infrastructure is adequate • Funding available for effective extension services

Logical framework for Grasslands Project 5: Research into problems of present and long-term fertility of soils under *Imperata* grasslands.

NARRATIVE SUMMARY	INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
• *GOAL* • Ensure the long-term sustainable use of soils under *Imperata* grasslands	• Abandonment of land after cultivation • Changes in soil fertility indicators over time • Changes in economic indicators	• Remotely-sensed surveys of changes in land use • Monitoring of soil fertility in key target areas • Economic surveys	• Work already in progress by IBSRAM is incorporated into this program • Cooperative programs can be developed
• *PURPOSE* • Establish key research locations • Establish criteria for evaluation of soil fertility • Monitor changes in soil fertility • Evaluate impact on soil of changes in land use	• Definition of soil physical and chemical research programs	• Program reports	• Completion of Grasslands Project 1 on spatial definition of problem areas • Laboratory facilities of research quality exist in the region for soil chemical and physical analyses
• *INPUTS* • Cooperative research program management • Soil sampling programs • Soil analytical programs • Extension programs to implement alternative land use practices	• Appointment of research program leader • Formulation of research teams • Identification of key study sites • Identification of laboratory facilities • Extension program formulated	• Research establishment report • Extension materials prepared	• Funding available for sampling and analysis programs
• *OUTPUTS* • Understanding of management and inputs required for sustainable use of soils under *Imperata* grasslands • Incorporation of trees into sustainable land use systems	• Adoption of improved land use practices • Economic indicators	• Research publications • Extension material disseminated • Changes in land use from remote sensing program	• Funding available for publication and dissemination program

Logical framework for Grasslands Project 6: Establishment of knowledge-based system (KBS) as a focus for synthesis of research into biophysical and socioeconomic factors in *Imperata* grasslands.

NARRATIVE SUMMARY	INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
• *GOAL* • Improve the understanding of biophysical and socioeconomic factors and their interactions which are critical to the success of tree planting programs	• Success of tree planting programs • Focus of research programs • Success of extension programs	• Changes in land use and extent of *Imperata* grasslands • Research publications • Economic trends	• Executive agency endorses concept as research program
• *PURPOSE* • Create a generic conceptual decision making model which is both culturally and geographcally portable	• System feasibility and design study undertaken	• Contract let to undertake feasibility study • Feasibility study report	• Successful outcome of KBS feasibility study
• *INPUTS* • Program management and synthesis • System design • Computer hardware and software • System management and maintenance • Research to evaluate previous projects • Information codification and entry	• Program manager appointed • System manager appointed • System designed • Support staff appointed • Computer hardware and software purchased • Information processing initiated	• Annual report • Research program report • System design and program plan disseminated	• Funding for equipment, maintenance and infrastructure readily available • Acceptance by host of importance of establishment and maintenance of data gathering and encoding
• *OUTPUTS* • Well focused research programs • Well targeted extension programs • Successful tree planting programs in *Imperata* grasslands	• Dissemination of program to user centres • Network of users and contributors created • Research program definition enhanced • Effective extension responses • Planting programs adopted	• Publication of KBS structure and function in international meetings • Network listing • Changes in land use from remote sensing program	• Acceptance by international research community as a research tool

Logical framework for Grasslands Project 7: Improvement of information transfer, education, training and extension for programs of establishing trees in *Imperata* grasslands.

NARRATIVE SUMMARY	INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
• *GOAL* • Appropriate establishment and use of trees in sustainable land-use practices by farmers and industry through implementation of established technology	• Gap between well proven existing technology for establishing and maintaining trees and use of such technology	• Change in area of *Imperata* grassland planted to trees	• Executive agencies acknowledge goals as pertinent to their function
• *PURPOSE* • Change land tenure concepts held by government and industry planners • Transfer technology from research to the user • Broaden awareness of research workers • Train and empower extension workers • Provide communities with sufficient knowledge to make informed decisions about resource development • Train timber workers in safe work practices	• Acknowledgment of information gap by government and industry • Innovation by potential end users of technology • Success of extension programs • Focussed research programs • Effective community decision making structures • Reduced fatality and injury in forest harvesting and transport	• Enrolment of government and industry staff in short top-up courses • Adoption of innovation proposed by extension workers • Reported communication processes in developing research programs • Well targeted research programs • Community education programs publicised • Industry health and safety statistics	• Governments receptive to problems of education, training and extension • Substantial funding available for multi-level education programs • Industry health and safety statistics are kept and are available
• *INPUT* • Feasibility study of technology transfer problem, its magnitude and cost requirements • International coordination of technology transfer programs • Management of programs • Trained trainers • Team to monitor effectiveness of programs	• Contract let to conduct feasibility study • Program coordinators and managers appointed • Trainer programs established • Enrolment programs formulated • Monitoring team established	• Feasibility study report • Staff contracts negotiated • Course schedules • Enrolment schedules • Evaluation reports	• Funds for coordination of programs will be available • Training institutions will have the capacity to provide services
• *OUTPUTS* • Widespread adoption of technological innovations • Improved establishment of trees in *Imperata* grassland • Enhanced economic well being of communities	• Health and growth of planted trees • Change in area of *Imperata* grassland • Economic indicators	• Measured productivity rates of planted trees • Changes in land use from remote sensing program • Reports on economic conditions	• Capacity to coordinate evaluation program exists

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