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# Technologies for Sustainable Agriculture on Marginal Uplands in Southeast Asia

**Proceedings of a seminar held at**
**Ternate, Cavite, Philippines, 10–14 December 1990**

*Editors*: **Graeme Blair and Rod Lefroy**

Co-hosts:
Australian Centre for International Research (ACIAR) and
Regional Center for Graduate Study and Research in Agriculture (SEARCA)

# Contents

# Foreword

The Australian Centre for International Agricultural Research (ACIAR) and the Southeast Asian Research Centre for Graduate Study and Research in Agriculture (SEARCA) jointly sponsored a workshop on 'Technologies for Sustainable Agriculture on Marginal Uplands in S.E. Asia' in the Philippines, December 10–14 1990.

The purpose of the workshop was to:

a) report on challenges, opportunities and technologies developed to enhance the productivity and sustainability of agriculture in upland areas, with special reference to technologies emerging from ACIAR projects;

b) review research needs and alternative technology options for marginal upland areas; and

c) identify research gaps for future programs.

The participants in the meeting consisted of researchers and development experts from national and international agencies and NGOs concerned with upland areas. National program representatives included research administrators, extension leaders and officers from planning agencies.

A common feature of all countries in Southeast Asia is increasing population and a consequent increase in pressure on land resources. The environmental consequences of these changes are creating concern amongst a number of countries in the region.

This, together with a desire by some national governments to expand and diversify agricultural production, has resulted in increased utilisation of sloping lands. Whilst such development in some instances has resulted in an increase in productivity and living standards of the local population this has often not been the case. Commonly the inputs required to maintain the new system have not been sustainable. Considerable research and development activity has been focused on lowland, high input, areas with generally high success. By comparison, R and D activities on the non-irrigated hilly land that is now being called into production have been far fewer.

A considerable number of national and international projects have reached the point where results should be extended to development agencies and national programs in the region. It was believed that these efforts, together with other national and international R and D activities would benefit from an exchange of ideas and experiences; hence this workshop.

Areas of low productivity can be broadly divided into two categories:

a) those which, in their natural condition, are of low but maybe stable productivity, and

b) those which, because of man's influence, have become unstable and of low productivity.

Examples of a) include acid sulfate and coastal sandy and saline soils and peat areas and of b) sloping and infertile inland areas that have been generally cleared of forests.

The workshop was confined to the areas that fall within b) above because it is in these areas where productivity has fallen or is declining, and that degradation has consequences for agricultural and urban areas downstream. Therefore the meeting was focused on upland areas with freely drained mineral soils which have been developed for agriculture and/or forestry.

The workshop was planned by an advisory committee consisting of

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| Dr. Graeme Blair | ACIAR/University of New England (Chairman) |
| Dr. Eric Craswell | ACIAR (Chairman until November 1989) |
| Dr. Arturo Gomez | SEARCA, Philippines |
| Dr. Ibrahim Manwan | Research Co-ordinating Centre for Food Crops, Indonesia |

| | |
|---|---|
| Dr. Aminuddin bin Yusoff | MARDI, Malaysia |
| Dr. Percy Sajise | UPLB, Philippines |
| Dr. Thanit Yingvanasiri | Royal Forest Department, Thailand |

The local Organising Committee was chaired by Dr. Arturo Gomez, Director, SEARCA.

The workshop program included a review of the resources and problems associated with the sustainable development of upland areas in Indonesia, Malaysia, the Philippines, Thailand and the region as a whole. The program also included reports on technologies emerging from research on the problems of different production systems. The last day of the meeting was devoted to working group sessions to consider the relevance and applicability of the technologies and identify research gaps.

The papers presented at the meeting and the outcome of the workshop sessions are contained in this volume.

Graeme Blair
ACIAR Forage Program Co-ordinator

# A message from SEARCA

It is certainly a great pleasure for SEARCA to co-host, with ACIAR, a workshop such as this. We are meeting in a venue that will be conducive to good discussion on matters of sustainability.The workshop has been structured with a bias towards inland hilly agriculture. I acknowledge that in some of the papers it is difficult to differentiate and sub-divide the total system, nevertheless, we hope that by giving a focus, we can move ahead more rapidly than by tackling all the major problems in all systems.

It is about one year ago that we started planning for this workshop. I would like to recognise some of the people who have been a part of this planning process like Dr Graeme Blair of ACIAR, Dr Craswell of TAC, CGIAR, Dr Percy Sajise of EISAM-UPLB, Dr Aminuddin Yusof of MARDI and Dr Ibrahim Manwan from Indonesia who is, unfortunately, not here with us today.

In planning the workshop we organised to visit Baguio, but because of the earthquake that struck the Philippines last July, this visit is not possible. Our second alternative was Cebu but again, this is not possible because Cebu was hit by a typhoon only last month. We will now visit Batangas and Laguna.

SEARCA, has only very recently changed its mandate to put agricultural sustainability as the main focus. It is for this reason that we are clearly pleased to be with you this morning. SEARCA receives about 20% of its resources from the Australian government, though not from ACIAR directly.

As an institution concerned with agriculture and natural resources, the Department of Environment and Natural Resources has been a continuing partner in our work. The presence of Undersecretary Ricardo Umali of the Department of Environment and Undersecretary Carlos Fernandez of the Department of Agriculture and the officials of these two ministries here in this workshop is clearly a manifestation of this interest. We hope that the workshop can provide some solutions to the nagging problems that are presently facing us in agriculture.

I wish everyone good luck, I hope that we all will have a very good workshop.

Dr Arturo A. Gomez
SEARCA Director

# A message from the Australian Government

I'M very glad to be here with both official and personal interests.

I happen to have been, at one stage, a geographer and after many years of doing other things, I haven't lost the taste for it, although I've lost a lot of the current state of the art.

Australia sees an enormous need for programs which address the question of sustainable development, particularly for upland areas. We have spent a lot of time in the Philippines focusing on sustainability related issues through various activities in AIDAB and ACIAR and within other activities in our embassy.

Anyone who has been in the Philippines will know how urgent the task is to try to improve the constant 'eating' into hilly, forested areas, particularly in kaingan and swidden agriculture.

I was in a helicopter in the T'boli Lake Cebu area of Mindanao recently and not only did we find farmers working incredible slopes, but they were also burning-off. This leads one to contemplate the environmental cataclysm that will likely result. I'm sure you will spend a great deal of time talking about this kind of situation. It appears to me that in a lot of the discussions over these questions, we don't always get the perspective right as we tend, because of our different disciplines, to look at things in boxes.

Certainly in the Philippine context, I would urge those of you who are talking about these issues not to lose sight of the marketing and distribution of crops and the role of the middle man which are both essential if we are going to make progress in this area. Experience in Australia suggests that the change agents happen to be in these areas more than in the research and farming areas. Because of this I would urge that people do not lose sight of this aspect in these discussions. But having ventured the toe into the academic water, I will retract and listen to what you have to say.

Let me say again that I wish you all, on behalf of our government and the various organisations that are interested, a fruitful and productive meeting. I hope that at the end of this workshop we can make some further progress towards helping alleviate the difficulties that many of the people in Southeast Asian countries are now suffering, having been forced into lands that are not very productive.

I wish you all well. Thank you very much.

His Excellency Mr Mack Williams
Australian Ambassador to the Philippines

# A message from the Department of the Environment and Natural Resources

Good morning ladies and gentlemen and welcome to all on behalf of the Department of Environment and Natural Resources (DENR).

Much of the Philippines is hilly or mountainous with the uplands covering about 15.5 million hectares or 54% of the national territory. The uplands are the location of the remaining forested areas and for most of the watersheds which sustain lowland agriculture and secure the water supply for population centres and industry.

In the past, the uplands have been regarded as marginal areas unsuitable for crop cultivation or suitable only for forests or grazing. The fact is, less than half of the Philippines remain under significant forest cover and a significant upland area is already being used for agricultural purposes.

Also, population pressure due to high growth rate in Southeast Asia is resulting in more intensive use of natural resources leading to deforestation. Soil erosion, losses in agricultural productivity, environmental deterioration and a massive movement of population from rural to urban areas, and from the lowlands to the uplands. The Philippines upland population now stands at around 18.8 million, including some 8.5 million upland dwellers occupying forest lands who comprise the country's poorest of the poor and are the main focus of development programs and activities of DENR.

Unlike the lowlands, the uplands probably cannot sustain a highly intensive form of agriculture. Thus, as population pressure increases, the most likely eventuality is that there will be further incursions into whatever accessible forest lands are left if there are no other means of livelihood or if their farms cannot be made more productive.

We have learned, from over a century of experience, that legal sanctions and punitive measures do not prevent our people from converting forest lands to agricultural use. The heart of the problem is poverty, which has driven our people into the uplands to clear the land of trees and raise food crops to survive. What we must do is involve the upland population in the productive management of the uplands and institute a system that would allow upland farmers to sustainably earn a living from their cultivations, thus dampening the need to expand or transfer to other areas.

Upland farmers are now recognised by government as effective partners in the rehabilitation, development, and protection of marginal upland areas, rather than as agents of destruction. Keeping in mind the slash and burn farmers, other occupants, and communities dependent on public upland areas for livelihood, the DENR has initiated a number of 'people-orientated' programs and accompanying policy and institutional reforms, with sustainable development as the underlying philosophy. These include the Integrated Social Forestry Program (ISFP) and the National Forestation Program which involves nine other line departments and their agencies: the Community Forest Program; contract reforestation with a Forest Land Management Agreement; and the Comprehensive Agrarian Reform Program (CARP) in the uplands, among others.

Our focus is on CARP and the ISFP areas since agriculture is the predominant land-use concern. CARP is expected to distribute 7.3 million ha to some 3.6 million farmer–beneficiaries and their families. The ISFP is a sub-program (Program D) of CARP which does not effect land transfer, but provides rights of use to some 1.88 million ha of public upland areas suitable for agroforestry. The program starts from the recognition that food, not forestry, is the chief priority of upland dwellers. Thus, by promoting agroforestry with emphasis on food crops and the introduction of conservation methods as well as new sources of livelihood, the program seeks to minimise the damage caused by inappropriate farming techniques, shifting cultivation, and forest exploitation.

As to be expected there are constraints, particularly on support systems and agroforestry technology. There is need for more farm to market roads, subsidies for seeds and seedlings, farm inputs, health and extension services, and technology transfer. Upland farmers are also in need of on-site and off-site training in technical aspects of agroforestry, as well as on entrepreneurial skills. They also need training designed to re-orient their values and attitudes towards forestry and the environment, and to educate them on the harmful effects of kaingin-making and other destructive aspects of some upland agricultural practices.

We are thankful for the continuing assistance provided by the various donor countries and the bilateral and multilateral agencies as well, for the implementation of foreign assisted projects, which to a large extent, are supporting the Government efforts to overcome the constraints to our upland development efforts. These have been providing much needed lessons and experiences to complement past and existing initiatives, which would surely prove invaluable in our future endeavours.

Of note are USAID and the 'Rainfed Resources Development Project' component focusing on the rehabilitation and development of selected upland areas nationwide; UNDP and the 'Strengthening of the ISF Program'; GTZ and the 'Philippine–German Cebu Upland Project'; ADB and the 'Development Project in Ilocos Norte' and the 'Palawan Upland RP–Japan Forestry Development Project' research activities on social forestry techniques; and the Australian Government through AIDAB and the 'Natural Resources Management and Development Project' (NRMDP) activities involving agrarian reform and integrated social forestry. I would also like to take this opportunity to thank the Australian Government for the proposed assistance, for the human resources development component of NRMDP to implement the urgently needed training of DENR's Social Forestry personnel, who frontline our upland development efforts.

A common denominator of the foreign assisted projects is the fact that it is now imperative to take into account not only the need and resources to feed, clothe and shelter our upland population, but also of the type of technology which will make this possible without degrading the environment. A question of balancing population and resources. I believe that the knowledge and technology essential to the sustainable management of the upland ecosystems exists. It is a matter of determining under what circumstances, including land quality, climatic conditions, market accessibility, status of watersheds, and slope criteria, among others, should various parts of the uplands be put to different uses, including crop cultivation.

It is indeed an honour to be here today with respected researchers, planners, and development experts from national and international agencies and NGOs concerned with upland areas, professionals in related fields and other dignitaries. This, in itself, is an assurance that this workshop can evolve sound agro-ecological strategies to sustain the development of our upland marginal lands.

Thank you and good day.

Undersecretary Ricardo M. Umali
Department of Environment and Natural Resources

# A message from the Department of Agriculture

I would like to thank the organisers for the opportunity to be with you this morning.

This message from our Department will not dwell on past accomplishments but rather take the form of a call for assistance and commitment in the Department's efforts to pursue its work in attaining sustainable agricultural development. As an anthropologist and rural sociologist I intend to raise some questions and issues that normally agriculturists stay away from.

If pessimism is noted in the message, I would like to assure you that pessimism, to my mind, is informed optimism.

An agri-system that can evolve indefinitely toward greater human utility and more efficient resource-use in an environment that is favorable to both human and other species, is the most recurrent definition of sustainability one would find in textbooks.

Our concern is the responsiveness of any working framework to the public agenda and linking that agenda to policy and policy to development programs and projects.

We believe that the public agenda must be national, time-specific and people-driven. In many countries, farmers and scientists are not the sole, or even the major determinants of what is sustainable. Their major role has been reduced too often to technology development.

We in the Department of Agriculture are looking for some sort of consensus that agriculture must be increasingly productive and efficient in the use of its resources, particularly in the face of a fast growing population. Biological processes must be within the system not externally controlled or manipulated through the use of fertilizers, pesticides and other external elements. Nutrient cycles should be treated as closed systems. We would also like to seek consensus on a premise that at this time in our history, it should be a farmer's strategy first. Let the people lead and let the experts follow.

The Department of Agriculture classifies upland areas as those not used or suitable for lowland irrigated rice production, elevations above 38 m and slopes in excess of 3%. The upper limits are open because the Department of Environment and Natural Resources (DENR) delineate the beginnings of the public forest lands. The position, however, and the policy taken by the Department, is that it should provide assistance to all tillers of the land regardless of tenural status, and the areas that they occupy. The uplands, in the Philippines, constitutes in excess of 70% of total arable land. The prime irrigable lands of the country, as defined by the Bureau of Soils and the Department, are about 23% of total arable land.

In the past three decades, much of our efforts in research, training and infrastructure development in the Department has been biased in favour of the lowlands. This implies quite clearly that we have neglected the remaining 70% of total arable uplands.

On the point of the commitment we seek, our efforts are tampered by Mencken's warning: 'For every human problem, there is a solution that is simple, that is neat, and that is very wrong'.

Sustainable agriculture in the uplands is not in search of quick technological fixes. Such a technological fix has not been able to satisfy the needs of sustainable upland agriculture. In the uplands we also have to reckon with a different kind of mental framework, with major differences between lowland and upland systems such as:

1) The diversity of the geo-physical factors of the uplands;
2) The diversity of the biotic life of the uplands;

3) The diversity of the human communities that reside therein; and

4) The fact that the key to sustainable agriculture in the uplands is to preserve diversity.

We need to understand upland agriculture in its own terms not in terms of making lowland farmers out of the upland occupants.

I anticipate that in the next decade the crises in agriculture are going to be soils and water-related. Rather than re-working nature, we have to re-orient our projects, programs, research and extension systems, to work with nature. We all realise that short-term solutions breed long-term problems, yet we still want to provide a simple 10% solution to a complex 100% problem.

Farmers need to know and to understand the returns and the rewards of sustainable systems of upland farming. What are the costs of sustainable agri-systems to society and the burden we must bear?

The settlement of the uplands in the Philippines has essentially been a battle between the large and small. Government allocation of concessions has often not helped. In Mindano and Palowan for example allocation of land under timber leases, mining concessions, minor forest product concessions, government reservations and corporate agribusinesses has resulted in an average of three concessions per unit of land yet only 12% of agriculture holdings are titled.

At any one point in our history, various sectors of society will be staking their claims — often conflicting claims over resources and history has been consistent in that. The big claimants win and the small claimants lose.

To date we have not come to grips with the macro or micro economics of upland agriculture and we must do this if sustainable uplands are to be developed.

In developing the uplands we must face the problems of equity and to consider the social costs and returns, social organisation, government and others. Will new technologies result in increased productivity yet create displacement or dislocation of upland communities?

It is possible to ensure that what we do in the uplands strengthens the capability of these communities to identify and protect their collective interest? Can we be sure that what we do in the uplands will enhance the peoples ability to mobilise their resource, so that even if the Government doesn't assist them they will not starve to death? Can we ensure that whatever we do in the name of upland agricultural development will enhance their ability to bid for participation? Choice is not a simple process. We often talk about felt needs and all too often we second read those needs. Where we are remiss, is in understanding the fact that good decisions are made on the basis of good options and that good options are made on the basis of good information. Too often, we don't have that information. It used to be a decade or so ago that our slogan was 'Listen farmers, we have the answers'! It's about time we turn that around and it should now read 'Speak and we listen, lead and we will follow'.

There is increasing interest in exploring problems together and working out a wide range of solutions. If this is now valued, then a question that faces bureaucrats like myself is 'What will be the new faces of research, extension and planning in the upland communities?'

The Department of Agriculture welcomes the efforts and the concern of the governments of the Netherlands, Australia, New Zealand and Canada in shoring up the efforts of private NGOs in the field of rural development, in particular, the uplands. In addition, there are several notable innovative efforts by private companies, in pushing for sustainable development thrusts with upland communities. We would like to see more of this. The new buzz word is to add sustainable agriculture in our publications and our proposals. I think the question that runs foremost in my mind being an academic is: 'Is commitment to be equated with accounting and is commitment to be indicated by the size of the project's budget or by the balance between high-tech and non-tech?'

A commitment is needed to those whose hands till the soil, not to those who hold the pen, nor the chalk, or those who control the cash register. We have seen many innovative studies being undertaken by scientists on farms. I think the Philippines has a very good comparative advantage in converting people's farms into a truly people's learning centre. Our track record in doing this is good but insufficient.

Finally, I think the question that remains will be this:'Will the people commit themselves to sustainable agricultural efforts in their respective areas?' To their own agenda, yes. To a joint agenda, maybe. To an agenda imposed from the outside, I think the response can be summarised from a quote from political detainees in this country not too long ago which reads:'There are times when we must be like cultural minorities and reject plans made for us, without us'. Thank you.

Hon. Carlos A. Fernandez
Philippine Undersecretary for Special Concerns
Department of Agriculture

# A message from ACIAR

UNDERSECRETARY Ferandez, Undersecretary Umali, Ambassador Williams and Dr Gomez, thank you for providing such an appropriate opening to this workshop.

If I can use an analogy it would seem the task before us is to paint a very large picture. But, as Undersecretary Fernandez has pointed out, the dimensions of the total picture, which is analagous with the definition of sustainability, are not important. What is important is the correctness of the detail and the harmony within the picture.

The four messages this morning have each, albeit in a different way, directed us toward answers to the problem of sustainability by highlighting the many and varied elements that are involved. It is the understanding of each of these elements, and perhaps the almost magical harmony between them, that will open the way to seeing in place truly sustainable agricultural systems.

I, like many of you, come from a biological-agricultural background. And you like me have now probably reached the conclusion that when innovative technologies have failed to live up to expectations it is because we have failed to identify the mechanisms which bring those technologies into harmony with the social needs of a particular society.

The Australian experience is not so different to that of the Philippines. We too are experiencing the consequences of inappropriate land management. In the 200 years since European settlement in Australia we have effected remarkable change in the environment and much of that change has led to degradation. Large-scale development of fragile lands is not sustainable.

At ACIAR we can see the benefits of forming partnerships to tackle problems and we hope that one of the outcomes of this particular meeting might be further ideas for projects — particularly those that emphasise the social aspects which are so important.

The organisers of this workshop have deliberately focused on lands where degradation has emerged as a problem due to human intervention rather than lands with low inherent fertility such as the acid soils of the coast, peat areas, sandy areas and so on. Given other sustainability initiatives underway at present, I trust you agree that this is potentially a most productive focus.

I join with SEARCA Director Arturo Gomez in thanking those who have assisted in organising this meeting, and similarly thank our distinguished guests for providing such an appropriate opening to the workshop.

Dr George H.L. Rothschild
ACIAR Director

# Balancing Cost-Benefit Analysis and Ecological Considerations in Developing Priorities in R and D in Upland Agriculture

Geoff Edwards*

*Abstract*

The first section of the paper considers the use of cost-benefit analysis (CBA) of projects and of changes in policies which have ecological or environmental effects. It is suggested that CBA is most fundamentally a framework within which all pluses and minuses of projects and policy changes can be considered. Ecological effects need to be included in CBAs, even when it is not possible to assign dollar values to them. The discipline of ecology, being a positive study, does not provide a basis for making decisions on whether courses of action will advance community wellbeing. Public projects or changes in policies are most likely to pass a CBA test when market failure due to such factors as information deficiencies, capital market imperfections, land tenure problems, and external diseconomies exist or when there are inefficiencies due to government failure caused for example by pricing policies and subsidies.

In the second section some new ideas on sustainable development are discussed. Ecologists have not provided a clear definition of sustainability. Not surprisingly, therefore, agreement on the operational requirements for sustainable development, in agriculture or more broadly, is lacking. The suggestion by Pearce et al. (1990) that the central condition for sustainable development is that the stock of natural resource capital does not diminish is noted and some questions are raised concerning the interpretation and acceptability of this condition.

In the third section some ideas on the economics of research are noted. It is pointed out that research which offers the largest gains in economic efficiency may not be the research which contributes most to desired changes in the distribution of income, or to other objectives. The importance of the specification of a system for defining sustainability and for determining agricultural research priorities is emphasised. For systems at the farming and marketing levels, as opposed to the plant level, improvements in markets and other social institutions are crucial. Much of the research which is important for promoting efficient development in agriculture is therefore in the social sciences area. This includes research concerning land tenure, credit, the development of storage and trade, information flows, use of common property resources, and externalities.

THE topic that has been assigned to me is very broad and somewhat daunting! While economists and ecologists share the professional objective of using resources well, they often do not agree on the meaning of efficient resource use or of sustainability. Some reasons for this disagreement are mentioned in the paper. But it would be wrong to suggest that the definition of and the requirements for sustainable development is a settled issue in economics; it is not. An already big topic is made even bigger by the inclusion of research priorities! Given the breadth of the topic this paper concentrates on some important general concepts and questions.

— Ideas from conventional economics.

— New ideas on sustainable development.

— Ideas on the allocation of resources to research.

My terms of reference said I should take a theoretical and international perspective. In presenting some ideas on the three areas a number of illustrations are presented from around the world.

## Ideas from Conventional Economics

### Are ecological effects beyond the scope of economics?

Economics is often defined as the discipline concerned with the allocation of scarce resources. In the minds of

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some critics of the economic approach, the scope of economics is limited to the subset of scarce resources which is traded in markets or — not the same thing — which can be assigned money values without too much difficulty. If this view were accepted, it would indeed be reasonable to speak of economics versus ecology (or the environment). But this interpretation of economics does economists an injustice. After all, economists devote much effort trying to determine the value of such goods as pollution abatement, species preservation and wilderness areas.

Cost-benefit analysis (CBA) is best viewed as a framework for investigating systematically the pluses and minuses of projects (and of changes in policies). It appears to be most common to assess costs and benefits from a national perspective, though sometimes a broader (multinational or global) or narrower (state or regional) approach is taken. Dumsday et al. (1990) distinguish five steps in a CBA:

—specification of the project, which also requires explicit elaboration of the 'no change' or 'base case';

—identification of each class of costs and benefits arising from the project;

—assigning money values to those classes of costs and benefits for which this can reasonably be done;

—provision of information in physical terms for those cost and benefit items which cannot be given money values;

—testing the sensitivity of total money benefits minus total money costs to changes in important assumptions, such as commodity prices and the discount rate used to convert benefits and costs accruing in the future into present values.

When all costs and benefits can be given money values, a project or policy change is said to pass the CBA test if total money benefits exceed total money costs. This is not the case when some costs and/or benefits are listed without having money values attached to them. It is then necessary for the decision-makers, who will usually be members of the political process rather than economists or other technical people, to make judgements about whether the project passes the CBA test. A hypothetical example is given in Table 1. The clearing of a forest to develop new farms is assumed to give net benefits of $3 million in present value terms for the items which can be given money values. The analysts who conducted the CBA report that there is also expected to be an increase in soil erosion of x tonnes a year, causing additional silting problems. It may be possible to provide further help to decision-makers – for example, to tell them that the extra silting would in ten years reduce by half the storage capacity of a dam supplying urban water. Clearly, the information on erosion and silting, even though it is not expressed in dollar terms, is useful to those decision-makers trying to reach a judgement on the overall benefits and costs of the project. This is not to deny that some decision-makers may be influenced only by the effects of the project on particular groups on whom they rely for political support. However, this political reality prevails also in situations where all benefits and costs are valued in dollars.

**Table 1.** Hypothetical summary of a CBA for the clearing of a forest to develop new farms.

| | Values assigned $M | Values not assigned |
|---|---|---|
| Benefits | 10 | None |
| Costs | 7 | Additional soil erosion of x tonnes/ yr, generating silting of dams and irrigation channels |
| Benefits-Costs | 3 | |

It is a fact that in both developed and developing countries there is often a great deal of uncertainty about the ecological or environmental effects of projects and of changes in government policies. This is true of transport projects, water development projects and projects to develop agriculture, forestry and fisheries. It is true also of policies to change the prices of energy, fertilizers and water. This uncertainty about environmental effects does not justify ignoring them in CBAs, as too often occurs. The corollary is that scientists need to have input into CBAs where there are environmental effects. This existence of uncertainty about ecological effects does not mean that in analysing projects and policy proposals the assessment of those effects should be viewed as separate from the cost-benefit analysis. After all, uncertainty is usually a feature also of parameters such as output and input prices which affect the size of calculated net dollar benefits.

An important feature of CBA is that a cost or benefit of $x 1, 10 or 100 years in the future is assigned a lower value than a cost or benefit of $x now. The further into the future the cost or benefit occurs the smaller is its equivalent current or present value. This process of discounting future benefits is sometimes said to increase the attractiveness of projects and policies which have harmful long-term environmental effects – for example, through pollution and through the elimination of species and ecosystems.

However, even among those who have argued that inadequate attention has been given to the environment in economic analyses, the idea that what is needed is a radical change in discounting procedures – the abandonment of discounting – is often rejected. Thus Pearce et al. (1990) argue: ' the environmental critique that discount rates are in some sense "too high" reflects real concerns. But these are better dealt with not by adjusting discount rates, but through other means'.

One way to improve CBAs of projects or policies with long-term environmental consequences follows from recognising that future environmental damage, or even the risk of such damage, involves a current cost as well as a future cost. People experience a loss of utility now from the knowledge that the future quality of the air or water is under threat, and from the knowledge that a forest or an animal is in the process of disappearing. These costs, which encompass values arising from the mere existence of natural things which give pleasure and from keeping open options for enjoying them in the future (see for example Common 1988, Pearce 1990) can be brought into consideration in a CBA. This can be done in a quantitative way if values can be assigned to the costs concerned by direct questioning or other methods, or in a descriptive way if values cannot be assigned. An alternative to CBA, the Safe Minimum Standard, for providing help to decision-makers when a project or policy involves substantial environmental losses, especially of an irreversible nature, is considered later.

Sometimes an environmental impact assessment (EIA) is carried out for a project in addition to a CBA. When this is done the only satisfactory way to bring all the resulting information into consideration for decision-making purposes is to summarise the environmental pluses and minuses, along with the other pluses and minuses, in CBA format. The CBA framework allows this to be done. By definition, the EIA framework is concerned with environmental benefits and costs, and does not provide the comprehensive framework for assisting decision-makers that CBA does. Furthermore, ecology being a positive study it is hard to see how it could substitute for CBA as a normative aid to decision-makers. In the words of Dumsday (1987): 'While the [CBA] framework has a number of weaknesses it does not appear to have any serious competitors from other disciplines and is likely to be increasingly applied to evaluation of environmental issues'.

On the nature of the values that count in CBA and in the policy prescriptions of some who claim to be informed by ecology, Harris (1985) writes: 'Economics is based on society's preferences or values. The values of "deep ecology" for example, imply an infinite value for environmental resources. Economists doubt that society as a whole would give such values to natural resources as a whole.' And well they might doubt, some may add, since resource decisions in the areas of health, transport and welfare in all societies imply decidedly finite valuations for human life and limb!

## Why does wasteful use of labour, capital and natural resources occur?

The starting point for much economic thinking about inefficiency, including inefficiency in the use of land, forests, energy, air and water, is the search for factors which cause it. Economists distinguish two classes of such factors. The first class is factors which are inherent in real economic systems; these are commonly referred to as sources of 'market failure'. The second class of factors causing inefficiency is government policies; this source of inefficiency in the use of labour, capital and natural resources is often designated 'political failure' or 'government failure'.

Among the causes of inefficiency present in many economies are:

*Deficiencies in the knowledge of producers.* A local example is provided by Anderson (1987). In discussing the numerous Filipinos relocated to the uplands in recent decades Anderson writes: 'Once in the uplands, the former lowland tenants and agricultural laborers encountered ecosystems whose cultivation demanded skills that were unknown to them'. The direct way to remove inefficient resource use that results from ignorance is to provide information to the decision-makers concerned.

Poor information in farmers' possession does not always work to worsen the environmental damage that they cause. If the lack of information stops them growing cassava, a crop which places relatively small demands on the land resource in many situations, then the effect is to worsen pressures on the environment. But if farmers lack knowledge of an opportunity to increase net income at the expense of extra environmental damage, the ignorance is beneficial to the environment.

*Capital market imperfections.* In developed and developing countries, inefficiencies in capital markets can limit the resources available for the development of productive investments, including investments that conserve natural resources. Many researchers and extension workers in developing countries regard the provision of appropriate credit facilities as an essential part of the package needed to make farming more productive on a sustainable basis. Inefficiencies in capital markets often appear to be due ultimately to information problems (Stiglitz 1989). It is necessary to caution that attempts to reduce the 'high' rates of interest charged small farmers by moneylenders are likely to have the unwanted effect of limiting the amount of credit provided to them.

*Land tenure conditions.* In many countries, tenure conditions are widely seen as a cause of inefficiency, including inefficiency in the form of insufficient conservation of natural resources. The conditions under which vast areas in the arid zone of Australia are leased to sheep and cattle farmers have been criticised for inducing overstocking and deterioration of the land resource (Young 1987). In many developing countries tenure conditions are viewed as an impediment to productive investment, soil conservation and the development of capital markets.

*Externalities: the distinction between 'on-site' and 'off-site' environmental effects.* Conventional economists have made much of the distinction between private costs that are borne by the decision-maker concerned and external costs that are experienced by other parties. The existence of external costs in such forms as traffic congestion, noise and the pollution of water and the atmosphere is accepted as a major rationale for government intervention in economic and social activities. In the case of the erosion of soil from a farmer's holding, the private cost may take the form mainly of a reduction in productivity, though if the erosion causes on-site scarring the farmer may also experience a loss of utility on account of the reduced attractiveness of his land. Off-site or external costs caused by erosion of one farmer's soil may take a number of forms, including silting damage to private and public property, off-site erosion due to the uncontrolled flow of water from the farm where the externality is generated, and problems caused by the presence of fertilizers and pesticides in eroded soil. Pearce et al. (1990) report a study by the World Resources Institute for Java of the costs of accelerated human-induced erosion in agriculture. The results are shown in Table 2. On-site costs in the form of lost productivity are estimated at US$324 million, the great bulk of the estimated costs of erosion. These on-site costs represented about 4% of the value of the six main rain-fed crops grown on Java. It should be noted, however, that Pearce et al. (1990) drew attention to the difficulty of accurately estimating off-site effects of erosion.

**Table 2.** Soil erosion: losses and costs in Java ($million per annum)

| | |
|---|---|
| On-site | 324 |
| Off-site | |
| irrigation system | 8–13 |
| harbour costs | 1–3 |
| reservoirs | 16–75 |
| Total | 349–415 |

Source: D. Pearce et al. (1990)

Conventional economics suggests that farmers who own their land will not knowingly let their soil resource wash away, so long as the benefits from stopping the erosion are greater than the costs. No-one wishes to see the income-producing capacity and the capital value of their assets fall. The benefits and costs that a farmer considers in deciding on action to reduce soil loss is likely to extend somewhat beyond the on-site effects: the farmer does, after all, have to continue to live with his close neighbours! But it is unlikely that a farmer will act voluntarily to reduce external costs that erosion from his land is causing well away from his property — even if the nature and size of those effects were clear. Sometimes this will not matter. A farmer who acts in his own interest to reduce his productivity loss from erosion will, incidentally, reduce the off-site costs of erosion also. It may not be profitable for a farmer to reduce erosion to the level that is socially optimal when allowance is made for the external costs of erosion. But the possession by farmers of good knowledge of the consequences of different cropping choices and management practices on their future productivity, together with a wealth incentive to maintain their productivity base, provides conditions very favourable to reducing the external damage from soil erosion. This is especially so when, as in the example for Java, the on-site gains to farmers from reduced erosion are estimated to be a multiple — at least three — of the savings in external costs.

Where farmers are unaware of the impact of soil loss from their holding on future productivity, or where their conditions of land tenure provide little or no incentive to maintain soil productivity, it is not possible to be so confident that the self-serving decisions of individual farmers will give a satisfactory outcome for the broader community. In these circumstances, changes in tenure arrangements and/or extension programs on soil conservation may be necessary conditions for reducing on-site soil erosion costs and soil erosion externalities.

It is fortunate that there are grounds for expecting that much soil erosion can be eliminated by ensuring that farmers have property rights conducive to wealth creation, and knowledge on the effects of their land use practices on the soil resource. This is because it is extremely difficult to create efficient incentives to reduce soil erosion externalities. A major reason for this is that, unlike most industrial pollution, soil erosion is a non-point externality. That is, it is difficult and costly to measure soil loss from individual areas of land. Many textbooks on the economics of pollution have virtually nothing to say on non-point pollution. An implication of the difficulties of measuring soil loss is that taxes, subsidies and regulations directed at reducing erosion cannot be targeted at soil loss — the variable of direct concern — but must operate indirectly through policy measures targeted at commodity outputs, inputs or management practices. This involves formidable problems because of deficiencies in information — in developed countries as well as developing ones — about relationships between the input- output- management system and soil loss (Chisholm 1987). Moreover, the most efficient feasible policy instrument or mix of instruments varies from farm to farm, with physical factors such as slope and soil type and with feasible crops and management practices.

*Government failure.* Although much of mainstream economics is predicated on the assumption that government is benevolent and is concerned to correct market failures in the 'public interest', the reality is that policies implemented by governments are the cause of many inefficiencies. The 'private interest' interpretation of government sees these inefficiencies as a consequence of governments using their power to redistribute income in an attempt to maximise their own political support (e.g. Stigler 1975).

Many examples from around the world of government policies which generate wasteful use of labour, capital and natural resources could be mentioned. Among these are: subsidies and price supports on agricultural commodities; subsidies on agricultural inputs such as fertilizers and water; government-set tenure conditions (already mentioned); regulations which increase farmers' costs disproportionately to the social benefits; and misallocation of resources in agricultural research. This is not to say that agricultural price supports and subsidies are always wasteful when all benefits and costs are taken into account; but they nearly always are! In some countries, especially developing ones, the overall efficiency of resource use is reduced by taxation and exchange rate policies which hold down prices for agricultural commodities.

In some countries, especially in Africa, the actions of governments towards agriculture have been marked by special ineptitude. The recent famine in Ethiopia had less to do with weather than with forced resettlement, government attempts to control marketable grain supplies, and the concentration of public investment on state farms producing less than 5% of agricultural output (Griffin 1987). In situations such as this improvement in the performance of government is the main requirement for progress in agriculture.

### The relevance of market and government failure to CBA

The presence of a failing in a market or on the part of a government should be regarded as a necessary condition for investing resources in a CBA. Consider the case of soil conservation. The claim that soil erosion is 'excessive' in a particular situation has more credibility if there is evidence that market failure (e.g. ignorance or external economies) or government policies (e.g. pricing or subsidy policies that encourage the growing of crops or the use of practices that are especially exploitive of the soil) are contributing to soil loss. The existence of a particular cause of excessive soil loss gives direction to a CBA that would otherwise be lacking. The objective of 'carrying out a CBA of reducing soil erosion' is vague. The meaning of 'a CBA of an extension program to increase farmers' awareness of productivity losses from erosion or to make farmers pay the external costs to which their farming gives rise' is much clearer and more action-oriented.

## New ideas on sustainable development

Some non-economists have suggested that economists are being forced to consider for the first time the long-term consequences of demands on renewable and non-renewable natural resources. Of course this is incorrect. The notion that economic growth might be constrained as a result of population growth in the presence of a fixed supply of resources, especially land, was discussed at length by Malthus (1798) in his Essay on Population and by Ricardo and other classical economists in the nineteenth century. In recent decades theoretical economists such as Solow (1974, 1986) and Hartwick (1977) have taken up the classical economists' concern with long-term resource availability. These recent analyses have been couched in terms of intergenerational equity. A central result is that intergenerational equity is achieved when consumption and the stock of capital, including natural resources, is kept constant over time. However, the relevance of this result to the real world is questionable in view of the assumptions which underlie it. Among the assumptions are constant population, no technical change, and known resources of depletable natural resources.

In the last decade or so 'sustainable development' has received much attention internationally of a more popular and less rigorous kind than the economists have afforded it. Probably the most influential publication has been Our Common Future prepared by the World Commission on Environment and Development set up by the United Nations and chaired by Mrs Gro Brundtland, Prime Minister of Norway. The key aim of the Brundtland Report, published in 1987, was to establish development policies which '...ensure both sustainable human progress and human survival ...It [sustainable development] contains within it two key concepts:

—the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given, and

—the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs'.

The authors of the Brundtland Report make it clear that they consider some natural resources are being overexploited. They argue that natural resources such as forests and fisheries should not be exploited beyond the level of their maximum sustainable yield, taking account of effects throughout the resources' entire ecosystem. For non-renewable resources such as fossil fuels and minerals use inevitably reduces the stock of resources. For these resources 'the rate of depletion should take into account the criticality of that resource, the availability of technologies for minimising depletion, and the likelihood of substitutes becoming available. Sustainable development requires that the rate of depletion of nonrenewable resources should foreclose as few future options as possible'. In the case of land it is said that this resource 'should not be degraded beyond reasonable recovery'.

Two books by Pearce et al. (1989, 1990) represent significant contributions to the recent debate on sustainable development. These are Blueprint for a Green Economy and Sustainable Development: Economics and Environment in the Third World. In the latter book Pearce et al. (1990) argue:

> We summarise the key necessary condition (for sustainable development) as 'constancy of the natural capital stock'. More strictly, the requirement is for non-negative change in the stock of natural resources and environmental quality. In basic terms, the environment should not be degraded further but improvements would be welcome.

An implication of the 'constant natural capital stock' condition is that a development project which reduced the natural capital (for example, destroyed an area of forest) could only be carried out if a 'compensating project' which correspondingly added to the natural capital was also undertaken.

Although much has been written and spoken about 'sustainable development' in recent years, it cannot be said that there is a rigorous definition of the concept. This no doubt has something to do with limitations in the contributions of the natural scientists. Tisdell (1988) asks: 'Since ecologists and biologists put so much store on sustainability why is this concept not more carefully defined and measured by them?' However, perhaps the idea of sustainable development, like the notion of a fair world, embraces too many elements on which opinions differ. 'Therefore, not surprisingly,'say Pearce et al. (1990), "efforts to 'operationalize' sustainable development into practical decision-making have been few and generally unpersuasive".

Focusing on the idea of non-decreasing natural capital, there are a number of questions to be asked about sustainable development:

—At what level should the rule of non-decreasing natural resource capital apply– global, national or local? Clarke (1990) suggests that the rule might be more easily rationalised for a resource-rich country such as New Guinea than for Bangladesh. The existence of trade between regions of a country and between countries weakens the argument that exhaustible resources and renewable resources should be conserved at the regional and national level.

—In the context of rising population, is it total or per capita natural capital that is not to be allowed to fall? What is the implication of the answer for the incentives of countries and individuals to add to the population?

—Does the natural capital that is to be maintained relate to each natural resource or to natural resources in aggregate? If the latter interpretation is accepted as the more reasonable, would it follow that degradation of a country's land resource would become a less serious concern if the country discovered a new fishery resource or if the value of its fossil fuel or forest resources in world markets experienced a long-term increase? Or if technological developments enhanced the capacity to use sunlight or wind to generate electricity?

—What incentives would be appropriate to ensure that the desired conservation of natural resources occurred? Would these be consistent with efficient use of the overall set of labour, capital and natural resources available to a society? To what extent would it be feasible for 'small countries' to depart from the realities of world markets in determining policies on the use of natural resources?

—Perhaps the most fundamental question of all is would the welfare of present and future generations always be advanced by insisting that the stock of natural resource capital never fall? What if a small decline in natural resource capital meant a large increase in present and future incomes? Could not some addition to capital in the form of machinery, buildings or knowledge offset a given reduction in natural resource capital? Although a broad interpretation of the non-decreasing environmental capital condition allows substitution between different natural resources, it rules out substitution between natural and man-made capital if the result is a decrease in the stock of the former. The case made by Pearce et al. for disallowing such substitution is likely to be viewed by many as arbitrary and unreasonable. In this context the argument of Solow (1986) is relevant: 'whether productive capacity should be transmitted across generations in the form of mineral deposits or capital equipment or technological knowledge is more a matter of efficiency than of equity'.

*Sustainability as resilience.* Conway (1985) has suggested that the essential behaviour of agroecosystems can be described by four system properties: productivity, stability, sustainability and equitability. This is depicted in Figure 1. Sustainability of a system in response to external shocks and internal stress is called resilience.

Resilience to stress and to shocks is a desirable feature of economic as well as ecological systems. Resilience is associated with diversity and, in turn, with the avoiding of irreversible choices (Pearce et al. 1990). Irreversible events such as the loss of natural species and irreparable damage to environmental functions reduce diversity and the performance of economic systems under conditions of stress and shock. This productivity argument, together

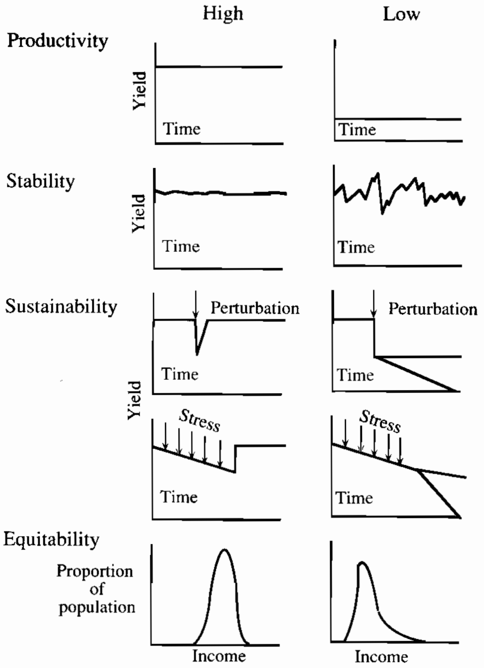

**Fig. 1.** The system properties of agroecosystems (Conway 1985).

with the argument for caution in cutting off future options, has been used in support of the Safe Minimum Standard (SMS) approach to decision-making where irreversibilities are involved. The Safe Minimum Standard approach is due to Ciriacy - Wantrup (1952) and Bishop (1978). It is 'the risk-averse, conservative criterion which states that society should ensure the survival of species, habitats and ecosystems unless the costs of doing so are "unacceptably large". What is unacceptably large is a social decision to be made through the political process' (Batie and Shugart (1989).

To make the operation of the SMS approach clearer, consider the following example, adapted from Chisholm (1988). The entries in Table 3 show the losses associated with each of two strategies. One strategy (D) involves developing a natural resource, in the process of which a natural species is made extinct. The other strategy involves preserving the resource, and saving the species (P). With each strategy, the size of the loss depends on the 'state of nature'. In state 1 there are no losses to society if the species becomes extinct, while in state 2 there are significant losses because the species turns out to be valuable in combatting a disease. With the development strategy, the worst outcome occurs if nature plays state 2; the loss is then Y. Under the preservation strategy, the loss (in the form of development benefits foregone) is largest if nature plays state 1; this loss is X.

**Table 3.** Matrix of losses.

| Strategy | States | | Maximum losses |
|---|---|---|---|
| | 1 | 2 | |
| D | O | Y | Y |
| P | X | X–Y | X |

The SMS approach is interpreted to point to following the preservation strategy if Y (the maximum loss with development) is greater than X (the maximum loss with preservation). As emphasised by Chisholm (1988), Batie and Shugart (1989) and others, the SMS is a very conservative decision criterion. The maximum possible loss from making any species extinct is extremely high (and not quantifiable), but the probability that nature will play the state that generates this extremely high loss is extremely low. It can therefore be suggested that routine use of the SMS criterion in decision-making where natural resources are concerned could well reduce sustainable income levels even if it did result in the preservation of some species or ecosystems which turned out to have very high values. It should be noted also that the maximum loss from development will often be many times higher if a global perspective is taken than if Y is assessed from a national view.

## Ideas on the Economics of Research

In this section, especially, a note of tentativeness is appropriate. At a general level, some statements about the role of research can be made confidently. But there are many questions concerning the appropriate contribution of research to such specific even if poorly defined objectives as enhancing sustainability of marginal upland agriculture in Asia.

The economic case for governments to undertake or support research in order to prevent market failure is not disputed. In explanations of why government involvement in research is in the public interest emphasis is usually placed on the public good characteristics of research findings (the availability of results to persons other than those making the discoveries). Sometimes the riskiness of research is also adduced as a reason for government to be involved.

From an international perspective, there is another argument for governments to cooperate in advancing research. This relates to international spillovers from research (Edwards and Freebairn 1984; Davis et al. 1987). These spillovers may arise because successful research in one country reduces farmers' costs in other countries and/or because cost reductions in one or more countries may reduce commodity prices in world markets. In their empirical study Davis et al. (1987) reported: 'The contribution of spillover effects from regions where research is conducted to other regions with similar agroecologies and infrastructure were shown to be substantial. Between 65% and 82% of total international benefits from agricultural research on the 12 commodities considered so far were estimated to come from such spillovers'. On the argument that national governments ignore these spillover benefits there is a case for international action by governments — and by private research funding agencies — to facilitate an agricultural research effort that is closer to optimal from an international viewpoint.

Although governments have a big part to play in achieving efficient agricultural research systems, this is not to say that governments always play their part well. Political and bureaucratic considerations are important in the establishment of research systems and in determining research priorities, just as they are in other areas of policy. Moreover, so long as the choice of research activities is influenced by relative prices, government interventions in commodity and input markets will have an impact on the direction of research. For example, Ruttan (1982) gives evidence of over-allocation of resources to rice research in Japan as a result of price supports. In Brazil and India differential exchange rates and subsidies resulted in excessive allocation of research effort to mechanisation (Ruttan 1982). Mechanisation was especially beneficial to larger landowners, while it imposed a burden on hired labourers.

The important effect of a country's resource endowments, reflected in the pattern of relative market prices on the direction of its research, has been clearly established. Japan, with its scarcity of land, turned earlier to chemical and biological research directed to raising output per hectare than did the United States, Canada and Brazil; these land-abundant countries found it more economic to develop mechanical technology that would add to labour productivity (Ruttan 1982). Looking to the future Ruttan saw the market-induced interpretation of technological progress pointing as follows: '...the close of the fossil fuel frontier join[ing] with the close of the land frontier to drive technical change along a path that entails the emergence of a much larger role for biological and information technology'.

The best discussion known to the author of agricultural research for sustainable agriculture is provided by Lynam and Herdt (1989). These authors point out that 'previous criteria [for evaluating agricultural technology] have included production, technology for small farmers, welfare of low income consumers, technology for women, diversification and stability. Sustainability is the latest twist in the continuing elaboration of criteria by which agricultural development is defined and agricultural technology evaluated'. It is only possible here to give a sample of the careful thinking that is reflected in the Lynam-Herdt paper.

An important argument in Lynam and Herdt concerns the specification of a system. 'Much of the confusion in the discussion of sustainability reflects a mixing of system levels, namely the lack of recognition that a plant photosynthetic system is embodied in a plant system which is embodied in a cropping system which is part of a farming system, which is embodied in a regional or national agricultural marketing system, which lies within the international market system ...Except for the highest system level, i.e. the international market, each of the lower systems is, except under quite special circumstances, open to influences from outside. Openness creates the very difficult problem of determining when sustainability is an inherent property of the defined system, dependent on endogenous system relationships as for Conway, or when sustainability is so dependent on external forces that the system level should be upgraded in order to define sustainability adequately'.

Although they do not claim that economists have always given the maintenance of ecological capital adequate attention, Lynam and Herdt suggest that ecologists can learn from economists about '...the role that markets and social institutions play in system sustainability, from the farming systems level up.' This general point is illustrated with reference to famine. 'However, probably famine is the ultimate indicator of the unsustainability of a food system. Famines are more common in rural areas than in urban areas and in rural areas they are more likely in those regions not integrated into market systems — certainly this is the case in sub-Saharan Africa. Trade and stock management are buffering mechanisms for marginal agro-climatic regions and in a sense preserve farming systems in regions where they could not exist independently.' Their discussion leads them to 'a rather interesting and perhaps unsettling second proposition: sustainability is first defined at the highest system level and then proceeds downward; and as a corollary, the sustainability of a system is not necessarily dependent on the sustainability of all its sub-systems'. It follows from the approach of Lynam and Herdt that research directed to developing social institutions such as information systems and markets has an important role to play in enhancing the sustainability of marginal farming systems and societies.

In the view of Ruttan (1982) 'institutional innovation is both a more powerful and a more reliable instrument of reform than technical change'. Examples have already been given of agricultural research which had unfavourable distributional effects. In the international study by Davis et al. (1987) it was found that the highest prospective economic returns were available from extra research into rice but that research into bananas/plantains and sweet potato could give a more favourable distribution of research benefits. It is widely accepted that agricultural research has serious limitations as a means of achieving socially desired redistribution of incomes. More efficient methods of achieving redistribution, such as social welfare policies, are widely used in developed countries, but these are understandably not a feature of developing countries. In the view of some, including Ruttan (1982), institutional changes concerning education and the ownership of resources offer considerable potential for socially-desirable reform in developing countries, including reform conducive to the wider sharing of research benefits among farmers.

Hopper (1987) gives examples of World Bank projects which failed because they were incompatible with the culture of the society concerned. One of these was the provision of funds to allow government to introduce piped rural drinking water, with charges to recover costs, on the North Indian Gangetic Plain. With a tradition of free drinking water for all from the thousands of private wells on the Plain, '...an ancient social compact is broken, a cultural institution embodying society's responsibility to insure each person's access to drinking water is violated. The obvious cultural response is to forego payment of the water charges, or, if need be, to let the new foreign system decay'.

One concern under the sustainability rubric relates to the exploitation of common property resources such as fisheries, streams, oceans, the atmosphere, and sometimes grazing land and forests held in common or under open access. As noted by Lynam and Herdt (1989), sustainability of these resources has more to do with social arrangements for controlling access and use than it does with production technologies. Institutional innovations in such forms as taxes, subsidies, regulations and education are also important in dealing with external diseconomies, such as the soil erosion case discussed earlier. Incidentally, research directed to reducing external diseconomies in such forms as silting of public sector dams and damage to roads may be less likely to lead to a leakage of research benefits to other countries than research that directly reduces the costs of growing agricultural commodities. This consideration suggests that research into some externalities could yield a higher national payoff, other things being equal, than cost-reducing commodity research. More generally, it has been argued that the system of property rights in a society needs to evolve as knowledge emerges of new relationships (e.g. between the use of agricultural chemicals and the quality of groundwater), as new social preferences emerge (e.g. a stronger demand for a high quality natural environment) and as technologies change. See Braden (1982) and Bromley and Hodge (1990) for discussion of developments in the institution of property rights consistent with the broad objective of using a society's resources efficiently.

An implication of the important role for institutional change in enhancing the long-term efficiency of systems involving the use of natural resources by people earning their living is that much research needs to be social science in nature rather than scientific or technical. The development of tenure arrangements, credit, storage, transport, trade, education, and information channels requires substantial research efforts from economists, anthropologists and sociologists. So does the development of institutional changes to improve the use of common property resources and to deal with externalities. The importance of research to ensure that resources are not wasted on projects that do not fit with the culture of a society is evident from Hopper's paper. The task of social scientists in carrying out and reporting on their research can be made more difficult when government policies which benefit powerful interest groups are major barriers to raising the productivity and incomes of marginal farmers. The less free is the society the greater this problem is likely to be. Of course this is not to deny that sustainable progress in improving the lives of large numbers of people in agriculture will depend also on the efforts of natural scientists.

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# Cost-Benefit Analysis and Ecological Considerations: Implementation into National Upland Agriculture R & D Programs

**Marian S. delos Angeles***

*Abstract*

To examine the implementation of cost benefit analysis cum ecological considerations in national R & D programs on upland agriculture a cursory research review is presented. The review shows that basic research that would allow valuation of intertemporal and offsite effects of upland agriculture (and alternative land uses) is necessary. Valuation methodologies have been developed for incorporating ecological considerations into economic analysis while tools for exploring the basic problem of optimal upland use allocation are available. In the case of direct benefits and costs of upland agriculture, more uniform studies are called for upon which policy formulation would be based.

## Conceptual Framework

THE following natural resource economics framework is presented through which an analysis of the implementation of cost benefit analysis and ecological considerations into upland agriculture R & D, is made. Any activity that is largely based on natural resources such as soil and timber in the upland ecosystem may be reckoned in terms of the net social benefits of producing a good or service with the following four components (delos Angeles 1986):

a) the satisfaction derived from the consumption of the good or the use of the service (revenue or welfare);

b) the production cost for complementary inputs, or the expenses incurred in paying for the other (non-land) factors of production (i.e. direct costs);

c) the user cost on the soil-based resources 'on site' which are not being replenished or are not able to regenerate; and,

d) the negative impact on environmental services previously provided by the disturbed ecosystem.

When goods are produced the benefit that society derives from them is determined by the satisfaction gained from consumption by users, less the costs involved in production. Conversely, when such goods are not produced, society foregoes the consumption value and does not accrue the costs involved.

The costs include both the direct production costs and the indirect costs composed of those which affect direct future resource users or item (c), the intertemporal cost, and those that affect off-site users, or item (d), the environmental cost.

Since upland agriculture is one of many land uses at least two steps need to be undertaken. The first involves determining the optimum area for upland agriculture; the second pertains to examining competing land uses. For these the following economic principles are important:

a) Optimum use level for a given activity is achieved when the present value of marginal costs is equal to the present value of marginal benefits .

b) Allocation among alternative uses is optimum when the present value of marginal net benefits per unit area is equal across uses.

The implementation of economic analysis on upland agriculture (such as benefit cost analysis), that incorporates ecological considerations, thus requires accounting for both direct and indirect costs. However, for many developing countries, lack of information, shortage of funds, and a strong bias for increasing current consumption levels usually result in public decision-makers' exclusion of future and off-site effects. Further, even when society does account for such costs, individual users tend to attach varying importance to them, depending on specific socio-cultural, economic, and institutional relationships.

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Comparing the three costs, for example, we find that while production costs are spent during the time of resource use, user costs are experienced in the future. Thus unless the present user also happens to be the future user, or the present user values other future users' welfare, they need not be concerned with intertemporal costs. Consideration of future costs would hence characterise only: (a) current users who have secure access to future net benefits from the same resource stocks, a condition that would prevail under secure rights over resource use; or (b) current users, who, despite not having secure, future access to the resource, consider other users' welfare. The latter case, where social concerns are incorporated in the private decision-making calculation, would characterise closely-knit societies.

With respect to off-site, environmental costs, private decision making under a market economy would likewise disregard these unpriced effects. The nature of these costs is such that others bear them, they tend to be non-mutually exclusive or non-rival, and attribution of the cause is no easy matter.

Overall, the private user's non-incorporation of the negative externalities , whether off-site, or intertemporal, or both, arises because the market insufficiently accounts for the welfare of future individuals and the off-site effects. This leads to two divergent effects: (a) for destructive upland agriculture practices, privately determined use rates are much too high from the public's point of view; on the other hand, (b) for resource-conserving upland agriculture systems use rates are much too low compared to those based on societal perspectives.

Thus the question of determining the optimum carrying capacity of the upland ecosystems through upland agriculture needs to be explored, from both individual users' and societal concerns.

## A Cursory Research Survey

How have we fared so far in terms of R & D in upland agriculture? A brief review shows that few economic valuation studies on alternative forest land uses including upland agriculture have been carried out so far. They include feasibility studies which are generally conducted from the private investor's point of view, as well as watershed management studies, which are implemented for public projects or as input to policy formulation.

### Net benefits of upland agriculture: the private perspective

Numerous studies exist on the gains from various upland uses by communities. For purposes of this paper, we highlight only those where insights may be learned on the concepts of optimum upland agriculture use presented earlier.

Most of the often termed, 'socio-economic' studies of activities which are based on upland resources (including the soil) focus on characterising upland users, whether on an individual or community basis. Indicators on the quality of life are often formulated to depict various aspects such as housing conditions, participation in the labour market, health status, the degree of organisation and the like (e.g. Samonte 1980; Ellevera-Lamberte 1983; Sevilla 1983).

With respect to the economic gains to upland-based livelihood, cash income is often used as a measure, such as in studies conducted by Corpuz (1984) and Saplaco (1984), whose analyses are based on observations made on few (one or two) upland users. Though these researches are similar in approach to the numerous case studies employed by the works of other social scientists (e.g. anthropologists, as presented in Olofson, 1981) they differ from the latter in terms of their focus on technologies which have differential impacts on soil (and water) conservation.

These economic studies, by their nature, produce detailed measurements of farm produce and inputs, including labour, and thus enable computations of net returns to factors of production and viability of upland farms. The findings of Corpuz (1984) for example, indicate similar gains from traditional *kaingin* and modified cropping which earned net present worth of PH 16622 and PH 17674 respectively; in contrast, tree farming yielded lower net benefits of PH 1185 due to the time lag in harvesting the tree product and the effect of discounting. Corpuz also tackles future, on-site farm productivity decline by calculating the cost of buying back the fertility of the soil to its original level The amount of nutrients found in the sediment yield was multiplied by the corresponding fertilizer costs. The figures so derived indicate the following order of soil erosion: tree farming (least erosive), traditional *kaingin*, and modified cropping systems. A shortcoming of the study, however, is that data were gathered from a few years' observation, and thereby do not capture possibly declining farm productivity over time, as well as shifting to other fields.

Saplaco (1984) investigated returns to an 'improved' farming system (e.g., pilot agroforestry on a demonstration farm) in Villarica, Pantabangan, Nueva Ecija. The study was conducted on a pilot agroforestry farm where ideal conditions prevailed in terms of the level of input-use; income measurements here therefore tend to be on the optimistic side.

Since these studies focused on a few upland farmers, detailed recording of inputs and output allowed computation of farm production and income with inclusion of labour costs. This variable has not normally been measured by other social scientists who have relied more on surveys of larger groups of farmers (e.g. Samonte, 1980, Duldulao et al. 1979, 1980). Thus, non-costing of labour particularly that contributed by the farmer, his household members, or other community members tends to result in overstated upland farm incomes.

The importance of assigning positive opportunity costs to labour in upland farming is, in fact, implied by earlier studies which show that, based on time allocation, upland residents do not have slack time or labour surplus, and are economically productive with diverse, albeit subsistence, sources of livelihood (e.g. Estioko-Griffin and Griffin 1981; Cadeliña 1981; Nguu and Corpuz 1979).

Another rationale for valuing household-contributed labour is the role that it plays in soil-conserving upland cropping systems which are usually labour intensive. Latter studies which do account for such labour costs such as those of Corpuz et al. (1987) and Cruz et al. (1987) indicate subsistence farming in most upland areas.

The work of Corpuz (1987) shows that when labour costs are accounted for, net return to communal tree farming is negative, either on a per farm or on a per hectare basis, amounting to –PH 739 and –PH 637, respectively. Furthermore, non-cash expenses, primarily labour, comprise, on the average, some 72% of total production costs of 147 farmers in nine communal tree farming project sites located in various parts of the country . A major factor contributing to the seemingly non-viable farms is that yield from the tree component of the farms was either minimal, or yet forthcoming, even five to six years after the introduction of communal tree farming projects. Futhermore, insufficient information on future yields expected from trees planted in farms deterred calculation of net present value of benefits from communal tree farming.

On valuation of farm output, since most of the earlier socio-economic research focused on cash income, only those products which are traded in the market are accounted for while those which are consumed by the farming household are not estimated. Notable exceptions are studies by Floro (1980), C.J. Cruz et al. (1987) and delos Angeles (1990) who quantified imputed income, or the value of farm output which is consumed at home.

Another source of underreporting of upland-based production is income from the sale or home use of fuelwood, a forest product whose gathering from public forests is considered illegal under various rules on wood cutting. Ono (1982), for instance, reports that income from fuelwood gathering accounts as the most significant income-in-kind underreporting in official surveys.

Thus, early socio-economic studies have tended to undermeasure labour costs, undervalue farm produce that is home consumed, underreport fuelwood use, and underestimate tree yields. More complete accounting of an upland farming system thus implies looking at upland occupants as integrated household consumption-production units. This is most marked in communities which are distant from market centres, and where self-reliance is more important.

Furthermore, researchers need to consider the interaction among the social, economic, institutional, and natural environment systems. Though this has long been the focus of various case studies by anthropologists, they were usually conducted with minimal quantification and focused mostly on members of cultural minorities. More recent research, which attempts to measure such interrelationships, includes upland migrant communities, and covers larger observation units.

Among those who have used survey-based data gathering on single sites were Capistrano (1984) who quantified the socio-economic institutional relationships in Pantabangan, Tapawan (1981) who measured environmental factors-cropping system interactions in Antique, Hyman (1981) who analysed smallholder forestry or tree farming in Surigao del Sur, delos Angeles (1986) who examined factors explaining the practice of resource conservation in Pantabangan, and Pulhin (1988) who analyzed compliance with stewardship requirements in Region IV in terms of variations in cash farm income, level of living, and incentive/government support services.

In addition, integrative analyses of data gathered on various sites have yielded information which could serve as stronger bases for national policymaking (versus local policymaking which should likewise draw from site-specific studies). Noteworthy are the works of Aguilar (1986) and delos Angeles (1983) on the process of planned change ; Ellevera-Lamberte (1983) on upland poverty; Cruz (1986) on population and migration; Cornista et al. (1986) on land tenure and resource use; and Cruz et al. (1987) on upland production systems, their relationships with the agroecosystem and their interaction with the rest of the local economy.

More recent work has focused on the measurement of the effects of improved upland agricultural systems such as Rola's (1987) work on agroforestry in Rizal and delos Angeles'(1990) study of upland agricultural sites in the Central Visayas Region.

The findings of these researches have specific relevance to the direct costs and benefits of private use of soil resources by upland farmers.

A basic question that remains to be pursued is the optimum carrying capacity of the uplands under varying population, agroforestry and institutional mixes. Upland population estimates of Cruz (1988) highlight increasing pressure in the uplands. Recent studies by Cabrido (1989) on Palawan calculated upland population carrying capacity based on the assumption that income would be solely derived from the farms. More analyses need to be conducted to simulate alternative upland agricultural systems and combinations of income sources.

Another important dimension is the role of organisations in the adoption and implementation of soil conservation measures. Though anthropologists have long documented the importance of organisations in the survival of cultural minority groups, it was only but recently that the same importance was recognised for the involvement of the rest of the upland-based communities in soil-conservation oriented projects. Delos Angeles (1985) documented such importance in the conduct of a pilot agroforestation project in Pantabangan, while Aguilar's (1986) summary of eight case studies also indicates how crucially dependent community building is in the progress and success of upland-based development. The question of optimum carrying capacity is in fact one that needs to be assessed also in terms of the alternative institutional requirements under which production systems are organised and through which benefits and costs are shared.

Related to the interaction with the economy is the question of local trade and marketing studies which are notably lacking, except in the case studies on fuelwood by Cruz (1986) and Maligalig (1983).

## Net social benefits of upland agriculture

With respect to the societal perspective of upland resource use few quantitative studies have been conducted. Consideration of the intertemporal effects of lower resource stocks including soil, agriculture and timber, though implied in the numerous field trials of natural scientists, have yet to be translated into economic values.

Although growth and yield prediction models for natural forests have long been developed for determining future timber scarcity at the national level (Revilla and Bonita 1977; Revilla 1984) and assessing the private costs of commercial forestry (Cruz 1982, 1988), these have yet to be conducted for upland agricultural crops including farm trees and the like.

Cruz et al. (1987) examined both the on-site and off-site effects of activities in two major watersheds, Pantabangan and Magat. On-site effects of soil erosion were measured in terms of lower agricultural productivity arising from on-site loss of soil fertility. This approximates what we earlier described as 'user cost', which is incurred by upland farmers who experience decreasing crop yield over time. Off-site effects of soil erosion were valued in terms of irrigation losses and the need to build larger reservoir structures or dams to allow for large sediment yields. The study is a major contribution in terms of its use of hydrologic information provided by David (1987), its use of various valuation methodologies, and its findings on in situ conservation losses. Major results include the following:

a) The annual sedimentation cost in Pantabangan reached PH 593/ha and PH 366/ha in Magat. This translates into a unit cost per tonne of sediment of PH 30 and PH 18 for the two watersheds, respectively.

b) On a per hectare basis, the estimate for on-site loss of soil fertility which was made for Magat, however, translates into higher losses, of the magnitude of PH 1068/ha of affected land.

c) Due to the large area affected by the two watersheds, however, the off-site losses still turn out to be considerable in absolute (rather than on a per unit ha basis) amounts.

Several lessons may be derived from these results, apart from the methodologies developed. First, is the importance of on-site lossess, particularly when we consider the fact that poor farmers bear such losses in soil fertility, in terms of foregone future productivity. Second, the large benefits that would be earned with proper soil conservation measures applied in the two watersheds, as measured by the off-site damage that would be avoided, justify the need for society to promote soil conservation through subsidies to the upland farmers. Third, since the estimates were made at the time when the watersheds were already used for crop production rather that for timber, the on-site losses are conservative estimates. If restoration of forest cover through tree planting were to be encouraged, more subsidies are, in fact, warranted, because of the long gestation period of trees. When trees are planted more for rehabilitative purposes rather than for production, the case for subsidy becomes even stronger.

### *Related studies*

Clearly, there is a need to investigate alternative upland-use schemes. Few researches have attempted this. Noteworthy is Hodgson and Dixon's (1988) analysis of a logging ban on parts of the Bacuit watershed in El Nido, Palawan. The results show higher present value of benefits from a logging ban due to increased fish production and tourism activities in the corresponding coastal ecosystems in the area. The study however does not account for direct production costs of the alternative activities so evaluated; the conclusion thus derived by the authors holds if, and only if, direct log production costs are not less than direct fishing and tourism costs.

The results of these studies are specific to their sites; similar valuations need to be conducted for the forest use allocation decisions that have yet to be made at both local and regional levels.

Recently, the Forestry Master Plan included calculations of environmental benefits arising from the recommended forest land use —this is probably the first attempt at sectoral development planning cum environmental considerations with quantitative estimates of environmental damages avoided through the restoration of appropriate vegetative cover to forest lands. The environmental valuation so conducted was done at the macro level and was added onto standard net present value (benefit cost analysis) prepared for the study. This implies the following shortcomings: incorporation of environmental considerations in a quantified manner was first not conducted on alternative upland vegetative covers; thus the scales of land uses recommended are not necessarily economically optimal. Although the Plan is conservative in the sense that it recommends that remaining old-growth forests be preserved, more work needs to be done to determine areas to be (sub)allocated for the preservation of gene pool diversities (for their option value), conservation of tribal lands for both their intrinsic value to the tribes as well as for bequest (heritage) sake. Concomittantly the areas for timber production, upland agriculture and industrial tree plantations, though broadly defined according to concepts such as minimizing direct on-site costs, need to be examined in greater detail at lower levels of aggregation (regional, provincial, local) where conflicting claims and uses would have to be resolved.

### *Models for optimising Philippine tropical forest allocation*

There is no shortage of tools available for examining tropical forest land allocation. Various attempts at determining optimum forest use allocation have included the application of mathematical optimisation models and economic valuation of alternative land uses. Among the land-use modelling programs are Camacho's (1983) linear programming model for forest-based industries at the national level, Balangue's (1979) goal programming model for the Mt. Makiling forest, Arano's (1985) interactive programming study for the Cagayan Valley Region, Contreras'(1985) STEM algorithm application and Gregorio's (1990) logit decision model for land use allocation.

Although the usefulness of these models for resolving forest land-use allocation problems yet remain to be seen beyond their contribution as academic studies, their conduct has resulted in the generation and organisation of important land-resources information. With recent attempts at improving such information, (e.g., geographic information systems, etc.) similar studies may likewise be conducted in the near future for purposes of exploring alternative forest uses.

## Conclusion

The inventory of studies in terms of the economic framework of upland use presented here indicates the need to support more research which would be useful not only in terms of user-groups and localised policies, but also from the perspective of society and national policy making as well. The determination of optimum use of upland soil resources, including timber and agricultural crops, necessitates the conduct of studies on parameters affecting revenue, direct costs, user costs and environmental costs.

There is a need to conduct more site-specific studies in a more uniform manner. Similar accounting for direct costs (including labour) and income (including imputed income), is important for comparability and to allow more generalizations to be made upon which policies would be based. Incorporation of intertemporal effects and off-site impacts on the environment is still at its pioneer stage; more studies by natural, biological and engineering scientists are required that would yield basic information upon which economists could base their economic valuation.

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# An Overview of Upland Development in the Philippines

**Percy E. Sajise* and Delfin J. Ganapin Jr. ****

## *Abstract*

The uplands constitute a large portion of the Southeast Asian landscape. It is a very heterogeneous and fragile resource base that exists in a continuum with the lowland and aquatic ecosystems.

The upland classification in the Philippines contains the elements of slope, elevation, land classification, vegetation cover, availability of water, soil type and dominant human activity practiced by upland communities. This classification varies by sectoral concern and project orientation. However, there is a general recognition of the serious problems associated with deforestation, soil erosion, declining agricultural productivity, loss of biodiversity, off-site impacts, the increasing poverty and the social costs associated with the bio-physical and ecological instability in the uplands. The goals of upland development are defined in the context of these problems as well as the concern for sustainability of the upland resource base. Strategies involving appropriate technology, enhanced farmer participation and effective extension programs based on research and development work in the uplands are identified. On-going research activities related to major factors affecting upland sustainability are also enumerated including possible new research opportunities and long-term development strategies.

## Background

AGRICULTURE, broadly covering the areas of crop and animal production, fisheries and some aspects of agroforestry is a major concern of many countries of Southeast Asia. Its development is the backbone of rural and national programs designed to support a continuously growing population.

Rambo and Sajise (1985) suggested division of the Southeast Asian landscape into two general areas for research and development based on topography, dominant land use and human activities. The core areas are where large scale monoculture rice production predominates and the hinterlands which are generally sloping lands are where small scale mixed farming, grazing and forestry occurs. These areas constitute only 2–16% of the total area of most countries in Southeast Asia (Table 1). Agricultural development will necessarily require a mutually reinforcing strategy of utilising both the core and hinterland areas on a sustainable basis. Such developments will need to consider the whole landscape which constitutes the rural resource base.

The Philippine population growth rate of between 2.7% to 2.8% for the past decade is considered the highest in Asia. With an estimated population of 63.8 million today, there is a crisis of land and resources and this will greatly increase in the coming years. The need for sustainable upland development therefore, is foremost in the national agenda. In its various forms, it is an important facet of the Philippine Strategy for Sustainable Development (PSSD) which was just recently formalised and adopted.

## Prevailing Land Use System in the Philippines

Land use systems and plant cover in the Philippines have recently been estimated by the Swedish Space Corporation under contract with the World Bank in a study entitled fFARM. SPOT imagery on a scale of

**Table 1.** Area (million ha) of 'core' productivity in Southeast Asia.

| Country | Total land area | Total rice area | % of total area |
|---|---|---|---|
| Burma | 65.774 | 5.500 | 8.40 |
| Indonesia | 181.130 | 7.564 | 4.20 |
| Kampuchea | 17.652 | – | – |
| Laos | 23.080 | 0.524 | 2.30 |
| Malaysia | 32.855 | – | – |
| Philippines | 29.817 | 3.010 | 10.10 |
| Thailand | 51.177 | 8.230 | 16.10 |
| Vietnam | 32.536 | 5.170 | 15.90 |

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1:100000 was used for this purpose and data was obtained in 1987 and reported in 1988. The categories of land-use were forest (7 types), extensive cultivation (open forest, grassland, and mixed), fishpond, lakes, and others. This was also broken down by provinces and regions. An inventory of forest cover was also compiled by the RP-German group in 1988. Results of the Swedish study are shown in Tables 2 and 3. Although, there are some shortcomings of the study such as inaccuracy due to cloudiness, inability to distinguish closed versus open forest cover with confidence relative to the RP-German study, the data have the following obvious implications:

1. Forest cover is low (only 23.9%) compared to an ideal cover of 54% based on slope consideration. There has been a reduction of 52% in forest cover in 38 years based on a 75% value estimated during the 1950s. Lowest forest cover occurs in Regions 7 (3%), 5 and 6 (7%), Region 1 (14%) and Regions 3 and 4 (16% and 19% respectively). Adequate forest cover is found only in Palawan (54%) (Table 3).
2. Intensive and extensive cultivation areas cover a very high 71.78% of the country. There has been an expansion of extensively cultivated areas which consist of low productivity grasslands and plantation areas.

**Table 2.** Land use/land cover classification of the Philippines. (Source of data: Swedish Space Corporation, Mapping of the Natural Conditions of the Philippines, Solna, Sweden, 1988).

| Land Use/Land Cover | | Area ('000 ha) | % of Total |
|---|---|---|---|
| A. | Forest | 7 226 | 23.92 |
| | Pine | 81 | 0.27 |
| | Mossy | 246 | 0.81 |
| | Dipterocarp | 6 629 | 21.94 |
| | closed | 2 435 | 8.06 |
| | open | 4 194 | 13.88 |
| | Mangrove | 149 | 0.49 |
| | Other | – | – |
| B. | Extensive cultivation | 11 958 | 39.58 |
| | Open in forest | 30 | 0.09 |
| | Grassland | 1 813 | 6.00 |
| | Mixed grass, brush, plantation, etc. | 10 114 | 33.49 |
| C. | Intensive cultivation | 9 729 | 32.20 |
| | Plantation | 5 336 | 17.67 |
| | Coconut | 1 133 | 3.75 |
| | Other | 91 | 0.30 |
| | Coconut and cropland | 3 748 | 12.40 |
| | Other and cropland | 365 | 1.20 |
| | Cropland | 4 392 | 14.54 |
| D. | Fishponds | 205 | 0.67 |
| | Fishpond from mangrove | 195 | 0.64 |
| | Other fishponds | 10 | 0.03 |
| E. | Non-vegetable areas | 101.4 | 0.34 |
| | Eroded areas | 0.7 | 0.002 |
| | Quarries | 8.0 | 0.02 |
| | Riverbeds | 81.0 | 0.27 |
| | Other barren land | 10.0 | 0.03 |
| F. | Other | 439 | 1.45 |
| | Built-up areas | 131 | 0.43 |
| | Marshy areas | 103 | 0.34 |
| | Lakes | 205 | 0.68 |
| G. | Unclassified | 546 | 1.80 |
| | Total | 30 205 | 99.96 |

3. To restore overall productivity and sustainability of natural ecosystems (both terrestrial and aquatic), large portions of extensively cultivated areas should be converted to production and protection forests. Particular attention and priority should be given to the regeneration of protection forest on critical watersheds.

**Table 3.** Forest cover by region (Source of Data: Swedish Space Corporation, Mapping of the Natural Conditions of the Philippines, Solna, Sweden, 1988).

| Region | % Forest Cover |
|---|---|
| 1 | 14 |
| 2 | 42 |
| 3 | 16 |
| 4 (Excluding Palawan) | 19 |
| Palawan | 54 |
| 5 | 7 |
| 6 | 7 |
| 7 | 3 |
| 8 | 26 |
| 9 | 20 |
| 10 | 37 |
| 11 | 31 |
| 12 | 34 |

## Trends and Changes in Land Uses and Their Effects on the Uplands

Land use changes have been shown to be driven mainly by population pressure, economic forces (both internal and external) and technology. As forestry and agriculture are the dominant land use in the Philippines, these two systems were examined against a population backdrop (Table 4). Deforestation rates, total forest land and cultivated areas obtained from the data of the Swedish Space Corporation are shown in Table 5. It can be seen that those regions with a high deforestation rate (Regions V, VI, VII & IX) have already depleted their forest cover to low levels. These forest covers have been converted to permanent or shifting agricultural use as evidenced by the higher percentage of total cultivated areas.

Table 6 is a correlation analysis of deforestation rate, total forest area for 1980 and 1987, total cultivated area and upland population density (1948-1988) as well as forest population zone density for 1980.The population density was used here as a parameter because it simplifies comparisons between regions. Upland population density growth from 1948 to 1988 shows that higher densities correspond to regions with high deforestation rate (Regions V, VII, IX) and regions with relatively lower deforestation rate (Regions I, II, IV) have lesser population density values. The forest zone population density, 1980, follows the same pattern, with generally a higher deforestation rate associated with higher population

**Table 4.** Upland population data

| Region | Total upland area ($km^2$) | Forest zone land area ($km^2$) | 1948 | 1960 | 1970 | 1975 | 1980 | 1988* | Growth from 1948 to 1988 | Forest zone population density (1980) units |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 15 122 | 13 586 | 50 | 64 | 80 | 87 | 96 | 111 | 61 | 92 |
| 2 | 23 437 | 21 088 | 17 | 25 | 36 | 41 | 48 | 61 | 44 | 48 |
| 3 | 6 119 | 4 125 | 47 | 67 | 103 | 121 | 138 | 169 | 123 | 147 |
| 4 | 23 062 | 15 062 | 18 | 29 | 42 | 49 | 56 | 72 | 54 | 65 |
| 5 | 7 188 | 6 024 | 69 | 103 | 127 | 137 | 147 | 165 | 96 | 151 |
| 6 | 10 080 | 8 499 | 85 | 106 | 117 | 135 | 147 | 167 | 81 | 135 |
| 7 | 7 892 | 6 124 | 131 | 154 | 185 | 208 | 233 | 280 | 149 | 204 |
| 8 | 8 538 | 7 763 | 66 | 77 | 93 | 101 | 111 | 128 | 61 | 97 |
| 9 | 5 520 | 4 178 | 36 | 50 | 76 | 84 | 103 | 145 | 109 | 73 |
| 10 | 11 762 | 9 354 | 33 | 47 | 74 | 89 | 107 | 142 | 110 | 110 |
| 11 | 21 282 | 16 318 | 15 | 32 | 58 | 71 | 86 | 118 | 104 | 76 |
| 12 | 9 698 | 7 308 | 16 | 36 | 63 | 70 | 77 | 89 | 73 | 80 |

***Estimated population on projections from 1975–80 level.**

Source: Ma. Concepcion Cruz and I. Zosa-Feranil,'Policy Implications of Population Pressure in Philippine Uplands' (1988).

density levels in the upland and forest zones. It can therefore be deduced that the population in the upland and forest areas directly affects the deforestation rate. The simple and strong relationship that can be deduced from these data is that forest conversion to agricultural land is driven by population pressure.

## The Regional Setting and Some Implications for Agricultural Development

The division of the agricultural resource base in Southeast Asia into the core and hinterland types has some profound implications for our thinking of agricultural development.

**Table 5.** Forest and non-forest land uses. (Source: Swedish Space Corp 1988).

| Region | Deforestation rate (%) | Total land ('000 ha) | Total forest ('000 ha) | | Total cultivated ('000 ha) | |
|---|---|---|---|---|---|---|
| I | 0.8 | 2157 | 289 | (13.4%) | 810 | (37.55%) |
| II | 0.6 | 3640 | 1470 | (40.4%) | 928 | (25.49%) |
| III | 2.3 | 1823 | 294 | (16.1%) | 815 | (44.70%) |
| IV | 2.3 | 4840 | 1334 | (27.6%) | 1692 | (34.96%) |
| V | 5.2 | 1763 | 118 | (6.7%) | 1000 | (56.72%) |
| VI | 3.9 | 2022 | 140 | (7.0%) | 974 | (48.17%) |
| VII | 4.6 | 1495 | 45 | (3.0%) | 685 | (45.82%) |
| VIII | 3.4 | 2142 | 559 | (26.1%) | 782 | (36.51%) |
| IX | 4.2 | 1868 | 318 | (17.0%) | 729 | (39.02%) |
| X | | 2833 | 1040 | (36.7%) | 862 | (30.43%) |
| XI | | 3169 | 975 | (30.8%) | 1108 | (34.96%) |
| XII | 3.2 | 2329 | 523 | (22.5%) | 932 | (40.02%) |

**Table 6.** Correlation analysis

| | Deforestation rate | Total forest area 1980 | Total cultivated area 1987 | Upland population density | Forest zone population density 1980 |
|---|---|---|---|---|---|
| Deforestation rate | 1 | | | | |
| Total forest area 1980 (% of total land) | – 0.66546 | 1 | | | |
| Total cultivated area (% of total land) 1987 | 0.77404 | – 0.87334 | 1 | | |
| Upland population density (1948–1988) | 0.61891 | – 0.71800 | 0.61086 | 1 | |
| Forest zone population density (1980) | 0.60393 | – 0.83295 | 0.77457 | 0.81266 | 1 |

Critical Value (1–tail, 0.05) = +/– 0.55240
Critical Value (2–tail, 0.05) = +/– 0.62972

Relationships:

1. Total forest area is smaller with larger deforestation rate and vice versa — negative correlation.
2. Total cultivated area is larger with larger deforestation rate — positive correlation.
3. Deforestation rate is positively correlated with upland population density under the (1–tail, 0.05) test but not significantly related with the (2–tail, 0.05) test.
4. Deforestation rate is positively correlated with the forest zone population density under the (1–tail, 0.05) test but not significantly related with the (2–tail, 0.05) test.
5. Total forest area is strong negatively correlated with the forest population density.

Fujisaka and Sajise (1986) compared the process of agricultural technology generation for the core and hinterland areas (Table 7). Agricultural development activities necessarily differ between the core and hinterland areas. Compared to the core areas, the hinterlands are more heterogeneous in terms of physical factors such as slope, aspect, soil resources, temperature, and in terms of people and cultures. As a result, a mosaic of 'micro-patches' must be considered in developing agricultural systems in the hinterland. As the core areas are most often well studied, homogeneous and accessible, the strategy for developing agricultural systems for these areas can rely heavily on 'packaged technology' generated by research stations located usually within these areas. In contrast, since the hinterlands are remote, highly diverse, and rapidly changing, the strategy for agricultural development necessarily requires that it should be adaptive, flexible and sustainable. Innovative planning methods and assessment are needed in agricultural research and development. Such methods include Rapid Rural Appraisal (RRA), Agroecosystem Analysis (AE), Process Documentation (PD), Upland-lowland interactions, Farming Systems Research and Extension (FSRE) and Sustainability Assessment with a Human Ecology perspective. These methodologies are the most commonly used in agricultural research and development.

## The Uplands Defined

There is no consistency in the definition of what constitutes an upland. In Malaysia, upland areas are circumscribed by a set of conditions which include relatively steep topography but emphasis is given to problematic soil conditions. In Indonesia, uplands include marginal and sloping areas ordinarily not subjected to intensive agriculture. In Vietnam, uplands include both the midlands (i.e. the middle zone between the lowland delta and the mountain areas) as well as the mountain areas.

In the Philippines, definition of the uplands is highly sectoral depending on the government agency or the kind of project involved. According to the Department of Environment and Natural Resources (DENR) which has jurisdiction over most upland areas in the country: '...uplands are hilly to mountainous landscapes of slopes greater than 18% including the tableland and plateau lying at higher elevations which are not normally suited to wet rice unless some form of terracing and groundwater exists. These are mainly classified as public land'.

Both DENR and the Department of Agriculture (DA) agreed on the coverage of the uplands for the Rainfed Resources Development Project (RRDP) funded by USAID: '...uplands are areas that are rainfed or are not benefited by irrigation. These can be both private or public land'.

The DENR in its Upland Stabilisation Program (USP) in Palawan, which is funded by ADB, adopted the following definition: '...uplands are hilly to mountainous areas where ecologically destructive human activities are being practiced resulting in loss of vegetation cover, excessive runoff, soil erosion and declining agricultural productivity'.

If a slope of greater than 18% is used to classify upland areas, 17.6 million ha or 59% of the total area of the country can be considered as uplands. This constitutes about 5.6 million ha or 38% of alienable and disposable lands and approximately 11–12 million ha of areas classified as forest land. Cagayan Valley, Northern and Southern Mindanao provinces have more upland areas relative to other areas in the country.

The recent estimate of upland population in the

**Table 7.** Upland and lowland technology generation compared (Fujisaka and Sajise 1986).

| | Characteristic | Lowlands | Uplands |
|---|---|---|---|
| 1. | Variability | Relatively homogeneous; some micro environmental variations | Very heterogeneous |
| 2. | Baseline data | Considerable; available | Very little |
| 3. | Obtaining information for design of appropriate technologies | Standard survey<br>Extension agents<br>Research stations | Adaptive ethnographic method<br>RRA, AE |
| 4. | Technology generation work | Heavily based on research station knowledge | Heavily based on indigenous |
| 5. | Technology | 'Packaged' | 'Menu' type |

Philippines is 17.8 million or 3.18 million households. It is projected that there will be an additional 2.5 million persons/year who will occupy the uplands. At a population growth rate of 2.6%, it is projected that by year 2025, an additional 5.24 million ha of forest lands will be cleared to accommodate the increasing population (Cruz and Zosa-Feranil 1988). Population growth rates near logging concessions is presently 3.5% (Ganapin Jr., pers. comm.).

Viewed in this light, the uplands are of considerable importance for the following reasons:

1. The area contains the tropical rainforest ecosystem which is the oldest productive and protective ecosystem on earth.
2. It is a dynamic and highly interactive landscape component of the rural system and is the life support system of the lowlands and aquatic areas.
3. It is a place where our increasing population of the 'poorest of the poor' lives and one which is expected to absorb more of the expanding population.
4. It contains untapped mineral deposits.
5. It is a destabilising force in the peace and security situation of the country if environmental and socioeconomic conditions are not improved.
6. Properly developed, it is a key to sustainable development and socioeconomic progress. It can be a major government strategy to attain greater social stability.

## Goals of Upland Development

Generally, the goals of upland development will vary because of the different needs of people and the varied bio-physical conditions in various upland areas. During the time when most of the upland areas in the tropics were covered with tropical rainforest vegetation, and sparsely populated, upland development was not a major concern. The tropical rainforest is a very productive and sustainable type of ecosystem which yields varied products that satisfy the basic needs of human society. It is also a soil and nutrient conserving system that has been able to regenerate itself for over 30 million years. However, with increasing human population, together with the indiscriminate exploitation of the tropical rainforest, the uplands became marginal and less capable of sustaining productivity and supporting the basic needs of human society (Sajise 1986).

In considering upland development the following goals should be considered:

a) increased productivity and income;

b) enhanced sustainability through soil, water and nutrient conservation;

c) community participation; and

d) increased equitability.

These goals have bio-physical, socio-cultural and physical dimensions.

When we consider upland farming or farming systems, we refer to the combination of enterprises (cropping pattern, animals or other ventures of a single farm) and their management and interactions within the system, between it and its environment. Upland farming, therefore, can be considered as the centerpiece of upland development.

The goals of upland development can not be measured solely in terms of increased productivity or income for various reasons:

1. Because of the fragile nature of the uplands, stability and sustainability needs to be taken into account.
2. As the upland occupants have already been shown to be the poorest of the poor, the goal of equitability should be a component of the development process. As a goal of upland development, productivity is not difficult to comprehend. It represents products of the upland farming system useful to man. It can be represented as:

a) Biomass/unit area/time

b) Energy yield (calories)/unit area/time

c) Riboflavin/unit area/unit time

d) Carotene/unit area/unit time

e) Yield/unit input (labour, cash, nutrient etc.)

f) Net return/cash input/unit time

Stability as a goal for upland development is also not difficult to assess. It represents the ability of the system to recover from minor and regularly occurring stresses, i.e., rainfall, temperature, etc. A comparative study of factors affecting stability of upland farming systems, from the intensive commercial vegetable areas in Central Cordillera in Luzon, Philippines to the Chiangmai Valley and dryland farms in North and Northeast Thailand and the intensive home gardens of Java in Indonesia, has been conducted jointly by the Environment and Policy Institute, East West Center and the Southeast Asian Universities Agroecosystem Network (SUAN).

The main factors identified as important were:

a) rainfall or water supply

b) pests and diseases

c) typhoons

d) floods and drought

e) fertilizer supply and cost

f) market price

g) credit availability

Equitability reflects the eveness of distribution of productivity among the human beneficiaries. Factors affecting this are land tenure and differential access to factors of production such as land, labour and capital.

The goal of sustainability is a more problematic one for upland development. In the general sense sustainability is equated to the words 'maintain' and 'prolong' which is easy to comprehend. In its operational context, however, this goal is more difficult to comprehend. Sustainability refers to 'the ability of the system to recover from major and cumulative perturbations, i.e., major droughts, volcanic eruption, soil changes etc.' The definition proposed by the World Commission on Environment and Development (WCED) on sustainability is 'meeting needs of the present without compromising the ability of future generations to meet their own needs' is too general to provide an operational framework.

The operational aspect of sustainability as a goal is made difficult because of the following :

1. It has biological, physical and social dimensions. It involves bio-physical processes such as nutrient cycling and soil quality maintenance, biotic diversity, biotic stability, hydrologic cycle and water conservation and biomass production. Social processes involved are participation, social structure/organisation, economic viability, incentives, information flow, needs orientation and institutional linkages.
2. Sustainability forces may operate at different hierarchical levels in the system and they are time bound. For example, if one takes an individual farm, cultivated in the traditional shifting cultivation system, it is not sustainable. A farm has to be abandoned after 3-4 years of cropping depending on site quality. However, at the watershed level, shifting cultivation is sustainable as there is enough time allowed for soil nutrient build-up. Sustainability is, therefore, attainable if there is complementarity between social and ecological processes thereby allowing system recovery and continued development.

Overall, upland development can also be viewed at micro and macro hierarchical levels:

At the micro level (farm/farm household and watershed/community level), sustainable upland development will occur when the upland farmers and the community have the technical and managerial skills to make rational changes which will improve their lives. Upland development should incorporate the elements of increased productivity, sustainability, stability and equity.

In terms of a macro or hierarchical level (regional and national) upland development will occur through the creation of an increased demand for labour. This can come about by establishing highly productive, labour-intensive agri-based industries which encourage upland farmers to move down from the steep slopes. These critical areas can then be placed under protection and production forest.

*Issue: The major issue facing the sustainable development of upland areas is massive infusion of resources for upland development which attracts more people into the uplands.*

*How do we bring about a balanced area development where uplands and lowlands have a synergistic effect in the overall process of rural development?*

## Current Knowledge of Upland Development

Several studies conducted in the Philippines, Thailand and Indonesia provide some ideas of the factors affecting the dynamics of upland farming systems (Tapawan 1981, Soemarwoto and Soemarwoto 1984, Grandstaff 1988).

Upland land use and farming systems are characterised by change and this process needs to be understood in order to promote upland development.

A shifting cultivation upland farming system type may shift to a 'Talun-kebun' system such as found in Indonesia or entirely to annual crops or monoculture forest plantations depending on whether water and the technology for managing water is available or as a result of a shift from subsistence to cash-orientation. With these shifts in upland farming systems, tenurial forms may also shift from a communal type to private ownership or a mixture of these two. An overall force that can initiate this change is also population and demographic forces. In terms of factors affecting the attainment of the goals of upland development the following are some key findings:

*Increased productivity and income.* This is affected by site quality, especially the presence of water and soil fertility levels. Installation of soil-water and nutrient conservation measures are important, not only for increased productivity, but also for sustainability.

Our experience with the Rainfed Resources Development Project (RRDP) at DENR and also based on the studies of Carson (1989) indicates that some factors affecting adoption or non-adoption of soil conservation measures are:

a) land tenure,

b) percentage of off-farm versus on-farm employment,

c) cash crop versus subsistence orientation,

d) profitability of the farming system,

e) potential for increasing profitability,

f) presence or absence of cooperation and labour exchange mechanisms, and

g) confidence in the extension agent.

The factors that contribute to an increase in the adoption of soil-water and nutrient conservation measures are a more secure land tenure, greater reliance on on-farm income, cash-orientation, high profitability and a more rapid return on labour and financial investments, presence of mechanisms for group labour such as 'hilo,' 'hunlos,' 'tiklos,' 'bayanihan' and credible extension agents.

Increased productivity and stability of upland farms is also attained by a strategy whereby the households increase their landholding through adoption of mixed tenurial systems. However, in situations where households of one hectare or less and no means of increasing the area of the farm, rely more on off-farm income sources. The design of the cropping system will also determine its susceptibility or vulnerability to pests and diseases or to market fluctuations. A diverse farm tends to be more stable than a less diverse one.

As landholdings become more fragmented, and as population continues to increase, a vital issue will become prominent.

*Issue: What mechanisms will buffer the influence of typhoons, diseases and other calamities in the uplands? One may raise the question that everybody is subjected to the same perturbations but this is exacerbated in the uplands by the marginal conditions of the households and their inaccessibility to basic services such as health and education.*

## What Upland Technology Works

Several years of experiences in upland farming systems development have shown that the following needs to be considered in identifying upland technology that will work:

1. Technology 'baskets' should be promoted instead of 'technopacks'. The highly variable conditions in the uplands require a process instead of a packaged technology. The process should involve rapid assessment, identification of constraints and opportunities and the farmer's decision to try the most appropriate technology.
2. The technology in the uplands must be soil, water and nutrient conserving. This is a must in order for the farming system to be sustainable. This role in the original tropical rainforest is assumed by the large tree biomass and the multi-layered diverse structure of the forest community. Where farm land has replaced forest, this role can be jointly assumed by leguminous tree and annual crops and the animal component and composting. Such can be enhanced by market incentives.
3. Technology introduction should be one step or one component at a time. Farmers tend to shy away from complicated technology.
4. The technology should fit the site and socio-cultural conditions of the area.
5. The upland technology should provide immediate benefits and answer the basic needs of farmers.
6. Indigenous technology should be assessed and promoted if found to be well adapted to a range of upland situations.
7. Proper support systems should be provided such as technical, land tenure security and reliable supply of good animal stock and planting materials.
8. The upland farming system technology should fit a desirable overall land use plan. We have seen cases in Davao and Camiguin Island where forest was cut to establish Sloping Agricultural Land Technology (SALT). This should be avoided.

## Factors to Promote Farmer Participation

Based on more than ten years of extensive work in upland development, the following factors have been identified as influencing upland farmer participation in development schemes:

1. Provision of access to land and other resource base such as the Certificate of Stewardship Contract (CSC) given by DENR.
2. Proper identification of community needs with the use of RRA or other assessment methods.
3. Availability of properly identified animal stock and planting materials. This is culturally and environmentally dependent.
4. There is a proper fit with the farmer's socio-cultural circumstances i.e. labour supply, traditional beliefs, health conditions etc.
5. Credibility of implementing agency. There should be no previous bad record of the implementing agency with the community. If project staff stay on the site with the community, this will create good rapport between the project and the community.
6. Utilisation of indigenous or existing organisations as a vehicle for decision-making and implementation of the project.
7. Adoption of heterogeneous units or social organisations for different project activities such as work groups, kinship circle, womens groups, youth groups and others.
8. Promoting linkages with local officials and appropriate government line agencies.

## Extension Strategies That Work

The following are some upland extension strategies that have been found to be effective in various upland development programs in the Philippines.

*1. Cross Farm Visits.* This is an extension strategy where farmers are brought to another location with a similar situation to their own where a viable technology has been developed. The farmers interact, and in the process, an immediate transfer of technology takes place. This works very well but requires considerable planning.

*2. Farmer-Based Extension System.* Farmer leaders are trained to become extension workers based in the area. This works very well both for NGO's as well as government projects.

*3. On-Farm, Farmer-Run Field Trials.* The extension worker and the farmers join together in assessing existing problems, technology and formulation of hypothesis related to upland farming system. Consequently, the farmers try to test the hypotheses by conducting their own field trials. Results are immediately translated into action which has the added effect of strengthening the confidence of the community in exploring ways of improving their own farming system.

*4. Learning by Showing or On-the-Job Training.* This is a more effective method than lectures. Farmers readily adopt new methods if they are shown how, and especially if results are visibly observed.

## Strategies for Attaining Goals of Upland Development

Borne out by various experiences in upland development, the following are some strategies which can hasten the attainment of the goals of upland development:

*1. Diversification.* This has an ecological and economic dimension. Diversification here implies not only crops or animals or a combination but also enterprises other than those involved in farming.

*2. Use of Traditional Knowledge as the Basis for Planning.* This is socio-cultural in nature based on the fact that the upland situation is so diverse and that there is an occurrence of adaptive co-evolution between the social and natural system over time. In the process of upland project planning, local knowledge as regards technology, social processes, and beliefs should be incorporated.

*3. Participatory Strategy.* This strategy will promote sustainability.

*4. Enhancement of Ecological Functions.* Strategies such as soil-water-nutrient conservation, biotic conservation and prevention of environmental pollution will promote sustainability.

*5. Promotion of Sectoral and Spatial Integration.* To attain the macro-level goal of appropriate land use planning and synergistic upland-lowland interaction, this administrative goal should be attained. In the Philippines, and in many other countries of Southeast Asia, this is a significant issue.

*Issue: What strategy will promote sectoral and spatial integration for upland development?*

*6. Policy Support.* This is an administrative strategy which should emanate from the higher hierarchical levels. Upland development will need appropriate policy support for land tenure, decentralised decision making and greater local autonomy.

## What is Currently Being Done

Recently, Garrity and Sajise (1990) conducted an assessment of sustainability problems and issues in the uplands and a synthesis of the findings is presented in Table 8, which divides the uplands into two subsystems: gently sloping drylands of <18 % slope, with moderate fertility, on which productive agricultural systems are generally feasible; and the hilly lands, predominantly strongly acid and infertile. Some production systems are common to both sub-ecosystems, but the land use systems and their sustainability problems often differ between sub-ecosystems. Massive settlement of lowland populations in the uplands is occurring in response to a critical shortage of land. The upland population in the Philippines living in areas of 18% slope or greater, was recently estimated at 17.8 million or about 30% of the country's total. The growth rate of the upland population is much higher than that of the already high lowland population. The prevalence of absolute poverty is also much higher. A similar trend is evident in Thailand and Vietnam. In Indonesia, settlement on the infertile uplands of the outer island is proceeding very rapidly due to spontaneous migration and a massive government sponsored transmigration program.

Food crop systems present the greatest sustainability problems in the uplands, particularly on sloping acidic Ultisol soils. This sector is characterised by a very large number of small-scale farms, where subsistence food production is of vital importance. These systems are therefore based predominantly on the production of upland rice or maize.

Land and labour productivity in small-scale food crop production is very low. Since most upland farm families have limited access to capital they are trapped with very little capacity to bear the considerable risks associated with diversification into less environmentally destructive perennial tree crop enterprises.

The gently sloping, higher fertility landscapes of the region have now been completely occupied. The new waves of economic migrants are attempting to farm the much larger areas (180 million ha) of hilly, infertile hinterlands. These areas were traditionally farmed successfully only by shifting cultivation. Farm density has increased in many parts of the region to the point where fallow cycles are reduced to a few years at most. Farmers rotate among fields within their land holdings. Fallow vegetation does not develop beyond a grass or scrub stage before cultivation is renewed. As settlement density continues to increase, farm sizes are reduced further, and fallow is replaced by continuous cropping. Because these soils are highly deficient in available nitrogen and phosphorus, their productivity cannot be maintained without imported nutrients, but fertilization is practiced to only a limited extent.

Upland farmers have a distinct preference for clean cultivation of their fields. This is manifested in numerous tillage operations per year in animal powered systems

**Table 8**. Overview of sustainability research on upland (Garrity and Sajise 1990)

| | Sub-ecosystem | Production system | Dominant pests | Market orientation | Major sustainability problems |
|---|---|---|---|---|---|
| 1.Uplands | Gently sloping<br>Moderate fertility | Food crops | Corn ear-worm and borers, rats and birds | Subsistence and commercial | Monoculture food crops.<br>Yield decline due to nutrient extraction.<br>Hard pan development |
| | | Coconuts | Beetles, centre rot, 'Cadang-cadang' | Commercial/cash | Low productivity/ low/income/ insecure land tenure |
| | | Vegetables | Diamond-back moth, bacterial wilt, thrips | Commercial | Low productivity<br>Insect and disease epidemics<br>Soil erosion<br>Water supply |
| | | Pastures/forage systems | Nematodes, fire | Commercial | Low productivity<br>Soil erosion<br>Insecure land tenure |
| | | Plantation field crops: sugarcane banana, pineapple | Mites, nematodes | Commercial/cash | Pollution<br>Soil erosion<br>Water quality<br>Soil chemical imbalance |
| | Hilly<br>Strongly acid<br>Infertile | Food crops and agroforestry | Corn borer and rice blast psyllid | Subsistence | Declining productivity<br>Soil erosion<br>Nutrient depletion<br>Insecure tenure |
| | | Rainfed | Rice bug, stem borer, birds, rats | Subsistence | Low productivity |
| | | Coconut | Beetle, centre rot 'Cadang-cadang' | Commercial | Declining productivity<br>Cutting of old trees without replanting |
| | | Native grassland | Chromolaena Weed | Cash | Low productivity |
| | | Forestry and forest plantation | Canker Baricose borer | Cash | Low productivity<br>Soil nutrient loss<br>Low diversity |
| | | Industrial crop | | Cash | Soil nutrient depletion<br>Low diversity |

**Table 8.** (cont'd)

| | Sub-ecosystem | Production system | Dominant pests | Market orientation | Major sustainability problems |
|---|---|---|---|---|---|
| 2. Highlands | | Commercial vegetable systems | Bacterial wilt<br>Nematode<br>Thrips<br>Diamond-back moth | Cash/commercial | Declining water resources<br>Soil chemical inbalance<br>Chemical pollution<br>Erosion<br>Market fluctuation |
| | | Irrigated rice | Rice bug | Subsistence | Water supply<br>Competing land use<br>Labour supply |
| | | Coffee | Stem borer<br>Rust | Cash/commercial | Market |

(e.g. 5–6 cultivations annually in the Philippines). In human-tilled systems, as in Indonesia, multiple hoeings and clean weedings are practiced. These practices are applied on slopes from 8% to 60%. Short term soil erosion losses are enormous, often being reported in excess of 1 cm of topsoil per year.

The insecurity of land tenure in the uplands has a major role in encouraging the continued implementation of cropping practices on sloping lands that are obviously inappropriate to sustain productivity.

A number of research institutions in the regions are engaged in serious research to develop sustainable small-holder food production systems. The work has two major facets: research on technologies and their integration within the constraints of current farming systems, and research to overcome the social and institutional constraints to implementation of appropriate forms of land tenure and group organisation.

Minimising soil erosion in ways that are compatible with small-scale farmers' food production goals is the primary sustainability imperative. Work on contour hedgerow farming systems is underway in numerous institutions. Installation of contour hedgerows has profound effects on the entire farming system. Five major types of systems are being investigated:

- Hedgerows with cash perennials
- Hedgerows with forage crops
- Hedgerows with tree legumes
- Hedgerows with 'inert' species
- Combinations of the above

International collaboration among institutions on hedgerow systems is stimulated through the Asian Farming Systems Network (ARFSN), International Network on Soil Fertility and Sustainable Rice Farming (INSURF), the Australian Centre for International Agricultural Research (ACIAR) and the International Board for Soil Research and Management (IBSRAM), which has initiated a network for research on acid upland soils. Many studies are also being conducted independently by national institutions and non-governmental organisations (NGOs).

A second strategy to sustain food crop production on slopes is zero or minimum tillage systems. Although these systems have been spreading in temperate regions, they have had virtually no impact in tropical farming systems. There are numerous constraints. Weed control (cover crop or herbicide management systems) is the foremost problem, followed by crop establishment methods (planting through thick mulch), pest control (rats and soil insects thrive in trash), and nutrient management.

Systems research in zero tillage is constrained by weak component technology, but the Visayas State College of Agriculture in the Philippines, and the Department of Land Development and the Highland Agricultural and Social development program in Thailand have done some promising work.

The evolution of social forestry concepts has resulted in a system of Land Stewardship Contracts in the Philippines. These recognise the tenurial rights of upland farmers to designated portions of sloping land that were previously protected from settlement by government.

Vigorous research on Integrated Social Forestry is now in progress to put institutions into place in upland communities that can effectively implement the concept. The Department of Natural Resources, several universities and institutes, and the Ford Foundation are collaborating in this process development and documentation.

*Coconut-based systems.* Southeast Asia is the world's dominant production zone for coconut. The country with the largest area under this crop is the Philippines, while Indonesia is also a major producer.

The coconut palm has several desirable characteristics that enhance its suitability in land use systems on sloping lands. Combined with an appropriate grass or legume ground cover, coconut systems provide satisfactory soil protection against erosion.

Coconut-based systems are in a period of serious threat. Because of an increasing preference for substitute vegetable oils with a lower concentration of saturated fats, a long term decline in world demand for coconut oil is projected. Therefore, sustaining the income levels of small-scale coconut holdings (the dominant sector of the industry) is a pre-eminent concern.

Coconut is a relatively open-canopied perennial, suitable for understory cropping. Research has intensified in the past decade on multistory cropping systems to improve the productivity of coconut palms. Several systems tested in the Philippines (UPLB and Bureau of Plant Industry) and in Indonesia (Centre for Soils Research) combining understory fruit trees, and other perennials and annuals, have proven compatible and profitable. Coconut-based livestock systems are also being developed in these countries.

Land tenure is a dominant barrier to more productive management of coconuts in the Philippines. Most farms are cared for by tenants, who are prevented by the owners from intensifying productivity . This is done to avoid future claims to permanent occupancy.

*Grassland Systems.* The extensive grassland areas in the region are a result of deforestation and the continuous and regular occurrence of fire, grazing, and shifting cultivation. This is promoted by marginal soil fertility conditions due to inherently acidic soil condition and to soil erosion. Many of these degraded grassland areas are also located in critical watersheds used for generating hydroelectric power or for irrigation.

Traditional use of the grassland in the region was for livestock production (viz. cow-calf ranching operations). The sustainability problem associated with this land-use is low productivity and soil erosion. At present, with population pressure increasing there are competing demands for those areas i.e., agricultural crop production and reforestation. Long-term prospects are favourable for the use of legume forage (herbaceous or tree species) and for the installation of soil-water and nutrient conservation measures.

Several institutions in the region are conducting systems-oriented research on grassland sustainability issues, i.e. nutrient cycling, integrated crop-livestock production and land use conversion. These institutions include, among others, the Institute of Environmental Science and Management (IESAM) at the University of the Philippines at Los Baños, and Biotrop in Bogor, Indonesia.

*Forest plantations.* Declining natural forests and population increase in the region, coupled with limited energy sources, has increased the demand for wood and wood products. This has provided the incentive for intensified establishment of forest plantations, consisting mainly of a monoculture of fast-growing tree species. The commonly planted species in the region are *Eucalyptus* spp, *Acacia* spp, *Leucaena* spp, and *Gmelina* spp. Forest plantations are also promoted as a strategy for generating watershed cover.

A major sustainability issue confronting forest plantations is the reduction of species and biological diversity. Monoculture forest plantations can lead to major problems. An example is the devastating effect of psyllid infestation on *Leucaena* spp. Another is the concomitant effects of fauna reduction and soil nutrient imbalance.

### Highland systems

The highland system is part of the upland continuum but with elevations normally exceeding 1000 m a.s.l.The dominant features of the highlands in the region, distinguishing it from the midlands or lower portions of the uplands, are cooler temperatures, cloudiness, and lower radiation.

The dominant land use is a mixture of subsistence cropping i.e. irrigated rice, rootcrops, and agroforestry and commercially based systems, notably vegetable growing. Livestock are also integrated in the subsistence cropping system.

While many of the traditional subsistence-oriented farming systems in the highlands manifest sustainability (and/or durability), the commercial vegetable system has many problems, such as pests and diseases, chemical pollution, soil deterioration and declining water supply and water quality. The risk factor shouldered by the farmer has also increased since many of the factors of production are no longer within his control.

There are a very limited number of institutions involved in systems research in highland environments. A notable example is the work of the Cordillera Studies Center of the University of the Philippines at Baguio, which has been studying the sustainability of highland commercial vegetable systems.

## Upland Development Questions Unanswered

There are some questions related to the goals of upland development that remain unanswered. These are research and development questions:

1. What are the resource management strategy and possible impacts of mixed upland tenure systems?
2. What are the different types of upland farmers and under what conditions are they engaged in a productive and sustainable upland farming system?
3. Analysis of the legal framework of property and use rights vis-a-vis customary practices in the uplands and its impact on productivity and sustainability.
4. Analysis of land tenure systems in pasture lands and timberland concessions.
5. Strategies for rural institution building in the uplands.
6. Policy incentives for crop diversification in the uplands.
7. Diversified cropping and policy on sharing land rights especially of new and permanent crops being introduced by government programs in the uplands.
8. How do you keep and avoid Certificate of Stewardship Contracts (CSC) from being abused, transferred and lost from the original owner-tillers?
9. What will be the long term impact of the new and emerging groups of tenants and 'labour for hire' in the uplands?
10. What is the best way of administering a multi-agency and multi-sectoral program in the uplands?
11. How do we conserve and promote local or indigenous species for hedgerows, fuelwood, fodder and soil amelioration in the uplands?
12. How to determine the appropriate land size for allocation to Integrated Social Forestry participants?
13. What is the methodology o43!·‡sessing alternative income-generating technologies in the uplands which consider economic, social and ecological adaptability?
14. What are the economic options which will provide incentives for upland conservation?
15. What methodology can be used to evaluate off-site impacts of upland development?
16. What is the potential and the best technique for implementing enriched fallow and assisted natural regeneration techniques for effectively regenerating the upland?
17. Species interaction in agroforestry systems.
18. Upland farming technologies and farmer/farm household typology.
19. What is an effective mechanism of bridging the gap between upland research and upland policy formulation and implementation?
20. What is the most effective training program for upland development projects?

## Long Term Upland Development Issues

There are some long term issues that will determine the sustainability, productivity and equitability of the uplands. These issues are the following:

*1. 'Shrinking Land—Increasing Population'*. The country, in the long run, cannot rely solely on its agricultural base. Land-based resources will not be sufficient to support projected population increases. This scenario will require increasing alternative for off-farm or off-the-land sources of income.

*2. Inheritance Pattern.* The present inheritance pattern tends to promote land fragmentation and expansion of cultivation into forest land. This is also related to the issue above.

*3. Tenurial Forms.* At present the government is in the process of evolving various tenurial forms which are appropriate for specific cases and situations. The issue, however, is the lack of a sufficient time and research data to support and identify the appropriate tenurial forms.

*4. Appropriate Education for Productive and Sustainable Uplands.* At present, indigenous knowledge and cultures are 'eroded' by the so called 'modern' educational system. This will have long-term consequences in the development of the uplands.

*5. Empowerment.* The highly varied and inaccessible conditions of most upland areas will require highly flexible and localised decision-making in the implementation of upland programs. It will also require the maximum use of indigenous knowledge in planning. This will require empowerment of local communities. How can we effect this need in the present organisational set-up of government line agencies?

*6. Equity.* It is just a matter of time before land consolidation will again be in the control of those who have money and power. CSCs, although they cannot be legally sold or transferred except to immediate kin, find their way into the hands of money-lenders and unscrupulous individuals. In the long run, this will influence upland equity and will undermine the objectives of Integrated Social Forestry.

*7. Upland-Lowland Interaction.* As a consequence of highly sectoral programs, upland development or lowland development are often seen as isolated from each other. In reality, however, the upland and lowland of the rural landscape are interacting and this should be considered in rural resource management. The worsening conditions of the uplands is caused by conditions that emanate from the lowlands. Politics and economics in the lowlands in turn are caused by internal factors and external influences i.e.:

- Foreign debt and resource degradation. As long as almost 50% of our national budget goes to foreign loan servicing, demand for natural resource exploitation will most often win against conservation.
- Export-oriented agriculture causes increased environmental and social problems.

*8. Militarisation in the Uplands.* Presence of undisciplined military personnel and military operations cause displacements and loss in confidence among upland farmers. This further aggravates the gap between government and uplanders and results in a loss in farm productivity.

*9. Penchant for 'neutral' and 'bankable' programs in the uplands.* The continuing use of 'bankable criteria' such as return on investments, profitability and others in the upland will jeopardize the inclusion of marginal upland farmers into the mainstream of economic development.

*10. Upland policy confusions.* At present, there are major policy confusion and issues in the uplands, i.e. parks and occupancy, conservation and protection strategies, ISF and contract reforestation. These need resolution.

## Conclusion

In the final analysis, upland development will be propelled by committed, credible and experienced men and women who can influence institutional, experiential and popular support for the attainment of the goals of upland development. This does not mean only college graduates, but more so the involvement of upland farmers themselves who have accumulated generations of experience which has enabled them to survive the vicissitudes of a dynamic and often harsh upland environment.

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# Resources and Problems Associated with the Development of Upland Areas in Indonesia

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## Abstract

The development of upland agriculture has a significant effect in increasing agricultural production and farmer welfare in Indonesia. It is estimated that there are 19.4 million ha of upland area available for development. Various constraints have been identified which restrict sustainable development in these areas. Soils in upland areas are generally acid, deficient in nutrients, have low water-holding capacity and are susceptible to erosion and soil degradation. Current farming systems practiced in upland areas generally ignore soil and water conservation practices which result in declining productivity and also cause sedimentation and disruption of water regimes in lowland areas.

Socioeconomic constraints to development are capital, cultural, marketing, institutional factors and risk aversion by the farmers. Appropriate technologies to increase and to sustain agricultural productivity are available, but the transferability and development of these technologies have faced many problems. To promote the adoption and extension of appropriate technologies, farmer groups, extension workers and regional authorities should be involved in on-farm research. Integrated farming systems, consisting of perennial crops as a major commodity, livestock, food and forage crops, seem to be a better approach to sustain soil productivity and farmer income.

INDONESIAN agriculture is basically composed of lowland mostly irrigated agriculture, upland agriculture predominantly rainfed and agricultural sub-systems in swampy and reclaimed tidal swamp regions.

Agricultural development programs have been carried out systematically in Indonesia within Five Year Development Plans since 1968–69. One of the major accomplishments in agricultural development in the last decade was the achievement of self sufficiency in rice in 1983–84. The production of rice has increased from 12.3 million t in 1969 to 44.8 million t in 1989 which is made up of 42.4 million t from lowlands and 2.4 million t from upland areas. This success has been achieved through massive intensification programs concentrated mainly in well irrigated areas.

The upland regions play a very important ecosystem role in increasing agricultural production. Therefore, it is considered that the proper management of upland areas is a key issue for the successful utilisation of land resources for agricultural development.

The most common problems encountered in upland agriculture are improper soil and water conservation management (erosion and drought problems), low soil fertility and productivity, lack of appropriate technology and production factors such as good seeds and credit.

A farming systems approach should be developed for the development and improvement of productivity, stability and sustainability of upland agriculture.

This paper presents the resources, research results and technology and problems associated with the management of upland agriculture for future agricultural development in Indonesia.

## Resources and Resource Use

### Land, topography, soils and climate

*Land*

The total land area of Indonesia is approximately 192 million ha with some 162.6 million ha, or 84.9%, in the islands of Sumatra, Kalimantan, Sulawesi and Irian Jaya. More than half of the total land (approximately 115.5

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**Table 1.** Land area in four major islands outside Java according to its topography (in million ha).

| Island | Swamp | Level (0–3%) | Undulating (3–8%) | Rolling (8–15%) | Hilly mountainous (>15%) | Total |
|---|---|---|---|---|---|---|
| Sumatra | 8.5 | 10.9 | 5.2 | 2.6 | 20.1 | 47.3 |
| Kalimantan | 8.7 | 5.1 | 6.1 | 4.1 | 30.0 | 54.0 |
| Sulawesi | 0.2 | 1.9 | 1.3 | 1.0 | 14.7 | 19.1 |
| Irian Jaya | 11.5 | 4.9 | 3.0 | 1.0 | 21.8 | 42.2 |
| Total | 28.9 | 22.8 | 15.6 | 8.7 | 86.6 | 162.6 |

Source: Central Bureau of Statistics (1988)

**Table 2.** Great Groups of Indonesian soils and their distribution and area '000 ha*

| Classification | | Topography | Areas | |
|---|---|---|---|---|
| CSAR | USDA Taxonomy | distribution | ('000 ha) | % |
| Organosol | Histosol | Flat | 24 000 | 12.57 |
| Aluvial | Entisols, Inceptisols | Flat | 19 628 | 10.28 |
| Regosol | Entisols | Flat-hilly | 4 300 | 2.25 |
| Renzina | Mollisols | Hilly | 1 782 | 0.93 |
| Grumusol | Vertisols | Flat-undulating | 1 886 | 9.99 |
| Andosol | Inceptisols | Mountainous | 6 491 | 3.40 |
| Mediteran | Alfisols | Flat-hilly | 8 525 | 4.46 |
| Latosol | Inceptisols, Ultisols | Flat-mountainous | 17 856 | 9.35 |
| Red Yellow Podzolic | Ultisols, Oxisols | Undulating-hilly | 31 960 | 16.74 |
| Brown Podzolic | Inceptisols | Mountainous | 16 757 | 9.78 |
| Podzol | Spodosols | Flat-mountainous | 5 603 | 2.93 |
| Complex/ miscellaneous | Complex | Flat-mountainous | 52 158 | 27.32 |
| Total | | | 190 946 | 100.00 |

*East Timor is not included
Source: Centre for Soil and Agroclimatic Research (CSAR)

million ha) is swampy and hilly to mountainous (slope > 15%), most of which is unsuitable for agricultural development (Table 1).

The total area of Java is approximately 13 million ha. Some 2.3 million ha of upland in Java presents severe problems in terms of agricultural productivity and income of subsistence farmers, as well as in terms of soil and water conservation. Because of a high population growth rate, increasing areas of the uplands are being subjected to intensive cultivation, often under inappropriate farming practices. This is resulting in decreased productivity.

The outer islands (Sumatra, Kalimantan, Sulawesi and Irian Jaya) which are relatively sparsely populated, have potential for the development of new agricultural areas. It is estimated that there are 17.1 million ha of uplands in Sumatra, Kalimantan, Sulawesi and Irian Jaya available for development. This area, has slope classes of 0–3%, 3–8% and 8–15%. In the outer islands there is an additional 15–20 million ha potentially available for cultivation of suitable tree crops or estate crops, if the upper slope limit of 15% is increased to 40%.

### *Soils*

These are formed from a wide range of parent materials under a range of climate and topographic conditions. There are 11 great groups of soil in Indonesia (Table 2) and their fertility is generally low to very low. The upland soils of the outer islands have been developed under humid tropical conditions from acid sedimentary rocks. The dominant soils in the upland area of the outer islands are Ultisols and Oxisols (Podzolic). These cover about 48.3 million ha, or 29.7% of the total land area of Indonesia. The total area of Podzolic soils suitable for agricultural development with slopes less than 15% is about 20.7 million ha, distributed over Sumatra (8.9 million ha), Kalimantan (7.9 million ha), Sulawesi (0.7 million ha) and Irian Jaya (3.2 million ha) (Table 3).

In addition to acidity, the soils are known to be deficient in P, K, Ca and Mg. The organic matter content and cation exchange capacity (CEC) are generally low and Al and Mn content are often high, causing toxicity in plants. The main physical constraints are low available water holding capacity and susceptibility to erosion and soil degradation.

These soils are considered marginal for the growing of annual food crops under the traditional agricultural system, but are suitable for tree or estate crops and pasture development. Mixed farming or silvipasture (tree crop-food crop-pasture) systems are possible alternative technologies for the management of these upland areas.

### *Climate*

Climate, topography and soils are factors which determine the land suitability for agricultural development. Since climate cannot be manipulated agricultural development should be adjusted to suit topographic and soil factors.

Rainfall distribution in Indonesia is governed by the monsoons with the wet season starting abruptly when the Northwest monsoon reaches Indonesia. This generally occurs in September in the Northwest and late December in the Southeast parts of Indonesia. The dry season starts more gradually, first in the Southeast and later in the Northwest.

### *Demography*

Table 4 presents the population distribution and its projection by major island. In 1990 the total population was about 182.6 million. With a growth rate of 2.01% per

**Table 3.** Distribution of Red Yellow Podzolic soils (Ultisols and Oxisols) in the four outer islands of Indonesia (million ha) (Muljadi, 1977).

| Islands | Slope<br>< 3% | 3-8% | 8-15% | >15% | Total | % |
|---|---|---|---|---|---|---|
| Sumatra | 5.1 | 2.7 | 1.1 | 11.7 | 20.6 | 43.5 |
| Kalimantan | 1.7 | 3.6 | 2.6 | 8.2 | 16.1 | 29.9 |
| Irian Jaya | 2.4 | 0.2 | 0.2 | 6.8 | 9.6 | 23.0 |
| Sulawesi | 0.3 | 0.2 | 0.6 | 0.9 | 2.0 | 10.3 |
| Total | 9.5 | 6.7 | 4.5 | 27.6 | 48.3 | – |

**Table 4.** Human population, density and labour force on the main islands of Indonesia.

| | Java | Sumatra | Kalimantan | Sulawesi | Nusa Tenggara | Maluku Irian Jaya | Total |
|---|---|---|---|---|---|---|---|
| Population (m) | | | | | | | |
| 1985 | 100.20 | 32.70 | 7.80 | 11.60 | 9.40 | 3.00 | 164.6 |
| 1990 | 109.20 | 37.90 | 9.90 | 12.70 | 10.40 | 3.50 | 179.1 |
| 1995 | 117.20 | 43.40 | 10.10 | 13.80 | 11.30 | 3.90 | 199.6 |
| Density/Population/sq km | | | | | | | |
| 1990 | 826 | 80 | 17 | 67 | 117 | 7 | |
| Growth rate (%) | | | | | | | |
| | 1.66 | 2.69 | 2.72 | 1.78 | 1.97 | 2.80 | - |
| Labour force (%) | | | | | | | |
| 1988 | 58.10 | 56.40 | 60.00 | 53.70 | 67.10 | 65.30 | |

annum the total population will be 199.6 million in 1995. The distribution of population throughout the islands is not uniform, and Java, with less than 7% of the total area, supports 59.8% of the total population. The population density in Java is 826/km$^2$, far beyond that on the other islands, even though the population growth rate is the lowest due to an intensive family planning program (Table 4).

The high population density in Java has created many problems because more agricultural land is being converted to other uses such as housing, factories, etc. This has resulted in increased areas of hill-land being opened up for intensive cultivation using inappropriate farming practices. This will undoubtedly decrease agricultural productivity and cause environmental degradation. Transmigration programs to the outer islands are needed.

Table 4 shows the labour force participation rate in 1988. This rate has increased since 1985. More than 50% of the population is categorised as labour force with an age of more than 10 and more than 80% of the labour force is between 35–49. About 55.8% of the labour force is working in the agricultural sector, an indication that Indonesia is an agrarian country. Approximately 70% of the total farm population are engaged in rainfed agriculture and they constitute the poorest strata of the rural population. The labour force data indicates the human resource potential available for future development.

## *Present land utilisation and agricultural production trends*

Land utilisation in the major islands is shown in Table 5. There are about 70.4 million ha of land being utilised for agricultural purposes including 8.1 million ha (11.5%) for lowland rice, 10.3 million ha (14.6%) for estate, 3.2 million ha (4.5%) for grasslands, and 22.5 million ha (32.0%) are classified as bare land/shifting cultivation/ utilised. These figures show that there is a vast abandoned land area which is available for agricultural development. These lands can be converted for agricultural development through the application of appropriate technology. The rehabilitation of these lands will reduce environmental degradation and is much cheaper than the clearing of virgin forest.

The present area harvested, production and average yield of food crops in Indonesia is presented in Table 6. Lowland rice covers 74.4% of the total area harvested.

Data of the planted area and production of estate crops are presented in Table 7 and indicate that the yield per ha of the smallholders is much lower than from estates. This is due to the low level of inputs and poorer soil and crop management. Attempts have been made to increase smallholder productivity through the smallholder nucleus estate system.

The livestock population in Indonesia (Table 8) indicates that the ruminant livestock population is very unevenly distributed with 95.5% of the dairy cattle, 46.3% of other cattle, 29.7% of buffalo, 61.7% of goats and 87.9% of sheep found in Java. During the 1986–1988 period the highest increase was in dairy cattle and cattle with rates of increase of 11.5 and 9.4 per annum respectively. The average increase in other livestock (buffalo, sheep, pig)

**Table 6.** Area harvested, production and average yield of food crop production in Indonesia

| Food crop | Area harvested ('000 ha) | Production ('000 t) | Average yield t/ha |
|---|---|---|---|
| Lowland rice | 10 452.7 | 42 417.7 | 4.28 |
| Upland rice | 1 142.2 | 2 361.5 | 2.07 |
| Maize | 2 910.1 | 6 213.0 | 2.14 |
| Cassava | 1 402.2 | 17 091.1 | 12.20 |
| Sweet potatoes | 228.7 | 2 126.4 | 9.30 |
| Peanuts | 612.3 | 615.3 | 1.01 |
| Soybeans | 1 186.9 | 1 300.9 | 1.01 |

Source: Central Bureau of Statistics (1989)

**Table 5.** Land utilisation (%) on the main islands of Indonesia

| | Java | Sumatra | Kalimantan | Sulawesi | Nusa Tenggara | Maluku Irian Jaya |
|---|---|---|---|---|---|---|
| Land utilisation | | | | | | |
| Lowlands | 26.7 | 4.9 | 2.3 | 4.1 | 3.6 | 0.1 |
| Estates | 5.7 | 11.4 | 3.6 | 5.7 | 2.3 | 0.7 |
| Dyke and ponds | 1.0 | 0.2 | 0.1 | 0.5 | 0.1 | 0.1 |
| Pasture | 0.5 | 1.5 | 0.7 | 3.1 | 11.0 | 1.0 |
| Unoccupied/ shifting cult. | 25.9 | 15.6 | 8.0 | 14.7 | 17.0 | 4.8 |
| Grown timber | 2.6 | 9.8 | 5.7 | 7.7 | 9.7 | 21.1 |
| Houses | 12.7 | 3.7 | 1.6 | 2.2 | 1.8 | 0.6 |
| Unclassified | 24.6 | 31.1 | 77.9 | 61.9 | 54.5 | 70.8 |

was about 1.4% per annum (Central Bureau of Statistics, 1989).

The principal constraints to increasing livestock production are low stock numbers in the outer islands, farm capital, farmers' knowledge and marketing. There are many opportunities to increase the livestock population in the outer islands through an integrated farming system approach.

The contribution of the livestock component to the overall viability of the farming system is very important. Livestock, especially small ruminants, offers not only supplementary employment opportunities but should be explored further as a principal source of income, particularly in areas with low soil fertility. Attempts have been made to introduce livestock into many transmigration areas, but these have often been unsuccessful due to problems of forage supply. The problem of insufficient feed could be overcome by silvipasture farming and the growing of forages on the edges of terraces and in waterways all of which would also be beneficial for erosion control.

**Table 7.** Planted area and production of several estate crops from estates and smallholders

| Crops | Planted area ('000 ha) | | Yield ('000 kg) | |
|---|---|---|---|---|
| | Estates | Smallholders | Estates | Smallholders |
| Rubber | 499.5 | 2 362.4 | 228.8 | 795.2 |
| Oil palm | 561.9 | 204.1 | 1 177.2 | 165.2 |
| Tea | 73.1 | 50.3 | 87.4 | 25.4 |
| Coffee | 47.9 | 908.6 | 25.9 | 358.6 |
| Cocoa | 54.5 | 115.7 | 19.0 | 25.8 |

Source: Central Bureau of Statistics (1989)

## Development Problems

### Environmental consequences of current land use

Traditional dryland agricultural techniques are generally inappropriate in an upland tropical environment with precipitation ranging from 1500 to well over 3000 mm/year concentrated in a 6 to 8 month period. Such techniques generally have poor soil and water conservation practices which results in reduced productivity in the uplands, and also causes sedimentation and disruption of water regimes in lowland areas. Unless corrective measures are undertaken by the Government the productivity of both upland and lowland agricultural areas, especially in Java, is likely to be seriously impaired within the span of few decades.

Although the problem is most acute in Java similar problems are beginning to occur in the outer islands such as Sumatra, Kalimantan and Sulawesi, because of a rapid increase in the opening up of new land for agriculture, often using inappropriate techniques. The rapid deterioration and destruction of tropical forest and natural vegetation, especially in the watershed regions, has serious consequences not only for Indonesia but for the world.

### Major constraints

The upland areas of the outer islands, which are considered as marginal land, have potential for increasing agricultural production. There are many constraints encountered in attempts to ensure the sustainable development of these areas, These can be classified as physical/technical or socioeconomic constraints:

—The physical/technical constraints include soil fertility and biological considerations, risk of erosion, soil and environment degradation.

—The socioeconomic constraints include limited skills and capability of the farmers to adopt the generated technologies, limited cash/capital of the subsistence

**Table 8.** Livestock population ('000) in Indonesia 1988

| Island | Dairy cattle | Cattle | Buffalo | Goat | Sheep | Pig |
|---|---|---|---|---|---|---|
| Java | 246 | 4.814 | 995 | 6.389 | 4.792 | 1.196 |
| Sumatra | 10 | 1.693 | 1.193 | 1.855 | 456 | 1.735 |
| Kalimantan | 2 | 265 | 122 | 173 | 7 | 874 |
| Sulawesi | – | 2.550 | 574 | 998 | 31 | 817 |
| Nusa Tenggara | – | 980 | 437 | 735 | 155 | 1.210 |
| Maluku + Irian Jaya | – | 98 | 20 | 201 | 6 | 630 |
| Indonesia | 255 | 10.402 | 3.341 | 10.355.2 | 5.449 | 6.464 |

Source: Central Bureau of Statistics (1989) farmers, cultural, acceptability by the farmers, marketing and institutional factors.

Studies have indicated that most of the physical constraints could be overcome relatively easily. Appropriate technologies to increase and to sustain agricultural productivity are available, but the transferability and development of these technologies have faced many problems due to the socioeconomic constraints and cultural and institutional factors. Thus the socioeconomic evaluation component, which is considered as a major aspect, should be developed along with the other research technologies. The transferability of packages of technology is considered very important since it will determine the impact of the generated technology in agricultural development.

In order to make maximum use of research findings, the selection of 'field sites' must be based on agroecological considerations. The site has multiple functions: the development of the agrotechnology package to support the agricultural development program, as a site for the interaction between research and extension workers to improve two-way communication, for supporting verification trials in farmers' fields and dissemination of appropriate technology to surrounding farmers.

## Development Strategies

Attempts have been made to utilise the upland areas outside Java for agricultural development since the Second Five Year Plan by carrying out component technology research. Most of the studies have been focused on physical aspects to overcome the constraints related to production sustainability, i.e. soil and crop management and integrated farming system approaches.

A summary of the results and the generated technologies are as follows:

### Soil fertility management

*Phosphorus management.* Among the major nutrients, P deficiency is the main constraint and in most cases P fertilizer efficiency is low due to the relatively high P retention capacity of the soil:

—the optimum rate of P for food crops is 20–40 kg P/ha (initial) and 20 kg P/ha per year for maintenance;

—no differences were observed due to method of P application and broadcasting is therefore recommended since it requires less labour than banding;

—organic matter application increased the efficiency of P fertilizer;

—the effectiveness of reactive phosphate rocks (RPR), a slow release and low water soluble P is better or equal to TSP and have greater residual effect than TSP;

—the economic return from P fertilizer application is very high.

*Potassium management.* Potassium is the second constraint after P in most acid upland soils:.

—upland rice and grain legumes respond markedly to K fertilization;

—the optimum rate for upland rice and maize is 80-120 kg K/ha and for grain legumes 40-80 kg/K ha;

—liming on highly acid soils increases K utilisation efficiency;

—organic matter application and returning crop residues will maintain high yields and decrease the need for K fertilizer.

*Soil acidity and liming.* Aluminum toxicity is a major constraint in most acid upland soils. The use of lime to overcome this constraint has shown that the critical Al saturation levels for various crops are as follows:

mungbean—5%
peanut—29%
soybean—15%
cowpea—55%
corn—28%
upland rice—70%

Upland crop rotation systems should consider liming for the most acid sensitive crop in the rotation. No lime is needed even for acid sensitive crops planted immediately after slashing and burning of the forest. Liming may be needed for the second or third crop.

*Organic matter management.* One of the problems encountered in cultivating acid upland soils is the decline of soil productivity due to declining soil organic matter. This decline occurs more rapidly when all crop residues are removed or burned, as is often practiced by farmers. Soil organic matter acts as a biological buffer and maintains a supply of available nutrients for the plant. Addition and management of organic matter are measures which can be used to improve the growth environment for plants and to increase the benefits of fertilizer applications. Soils which decline in organic matter content lose their buffering capacity and fertilizer efficiency decreases. Management to increase soil organic matter is therefore very important for promoting more efficient utilisation of fertilizer and in increasing soil fertility:

—long term experiments in Sumatra indicate that application of organic matter increases fertilizer efficiency and reduces lime requirement;

—proper management of organic matter in upland farming systems is a major key to sustaining soil productivity.

—the technique of alley cropping or hedgerows using fast growing legume trees to increase soil organic matter in situ can improve soil physical properties and soil productivity. The technique should be further developed for upland farming systems.

### Soil conservation and erosion control

The main soil physical constraints of most acid upland soils in Indonesia are low available water-holding capacity and susceptibility to erosion.

Soil compaction due to improper land clearing and low organic matter content and the loss of topsoil due to erosion and runoff are the main causes of soil productivity degradation of acid upland soils. Trials to establish the most appropriate erosion control measures and to improve soil physical properties have been conducted in many locations. Research results have shown that:

—on flat and sloping terrain mulching using biomass of the alley tree *Flemingia congesta* in combination with minimum tillage is better than full tillage without mulching (Table 9);

—a conservation method using a combination of grass and legumes strips can control erosion more effectively than only grass strip;

—bench and bunch terraces supported with grass in combination with mulching effectively reduce erosion;

—high input management, in combination with mulching, effectively reduce run off and soils loss;

—soil conservation management (returning crop residues and alley legume leaf) and terraces supported with grass and legume strips on undulating terrain must be the first priority in any farming system.

### Cropping systems for food crop

The crops in a soil conservation based farming system have canopies that cover the soil surface as much as possible to reduce raindrop impact, run-off and soil loss. They should be able to produce both a high yield and have a conservation value. Among the cropping systems tested, a combination of maize and legumes (maize + soybean, maize + peanut, cowpea (mung bean) proved to be the best. These systems produced high yield in terms of calories, protein, cash income and crop residues which can be used as mulch or fodder (Table 10).

**Table 9.** Effect of mulching and tillage on the yield of food crops on Oxisols and Ultisols Jambi, Sumatra (Suwardjo, et al., 1987).

| | | Yield (t/ha) | | | |
|---|---|---|---|---|---|
| | | Maize | Rice | Peanut | Maize |
| Slope | Treatment | WS | | DS | |
| Oxisols | | | | | |
| < 8% | F0 | 0.55 | 0.68 | 0.35 | 1.37 |
| | F1 | 1.36 | 0.80 | 0.82 | 1.58 |
| > 8% | F0 | 0.93 | 0.53 | 0.86 | 1.00 |
| | F1 | 1.15 | 0.85 | 0.97 | 1.05 |
| Ultisols | | | | | |
| < 8% | F0 | 1.31 | 0.52 | 0.77 | 1.87 |
| | F1 | 1.64 | 0.57 | 0.82 | 1.98 |
| > 8% | F0 | 2.29 | 0.36 | 0.77 | 1.74 |
| | F1 | 2.68 | 0.68 | 0.81 | 2.64 |

FO = Full tillage without mulching.
F1 = Minimum tillage + mulching (*F.congesta*)
Cropping pattern: maize + rice-peanut+maize

## Farming system research

Experiences and results of experiments indicate that food crop based farming systems on acid uplands are facing many constraints and risks. They need high inputs to overcome soil chemical and physical constraints and a lot of labour. Despite this production remains low and unstable due to pests and disease and climatic factors. For subsistence farmers it is nearly impossible to overcome these constraints without assistance in the form of subsidies from the government.

To solve the problems of upland agriculture, an integrated farming system should be developed to satisfy the needs of the farmer family, with perennial crops as the main commodity and the food crop component a sideline.

Various alternative integrated farming systems have been studied to produce alternative technologies for management of upland agriculture in Indonesia. The appropriate farming system should be adjusted to the local physical conditions. Pedo-agroecological zone data of key areas are urgently needed, so that the results can be transferred to other locations with similar characteristics.

A concept of an integrated farming system based on the maximum utilisation of land resources and solar radiation through an integrated soil conservation farming system is being tested in Jambi, Sumatra. The concept consists of (Fig. 1):

1. The tree crops are planted in east-west rows in several stages to avoid shading and to maximise the utilisation of solar radiation.

**Table 10.** The yield comparison in calories, protein and income of two cropping systems on sloping land in Jambi, Sumatra.

| | Yield | | Income |
|---|---|---|---|
| | Calories | Protein | |
| | (kg/ha) | | ('000 Rp) |
| A | 10 211.0 | 389.6 | 928.8 |
| C | 13 654.8 | 597.8 | 1136.5 |

A: maize + rice— maize + soybean—mung bean
C: maize + soybean—maize + peanut—mungbean

1st stage: coconut, oilpalm (connected with smallholder estates)

2nd stage : clove, cinnamon, nutmeg or mango

3rd stage: banana, orange, coffee, cacao, root/plants/ medicine herbs.

2. Food and feed crops are planted as the 4th stage while alleviating the physical constraints in terms of soil fertility, erosion control and biotic control, including cropping pattern and utilisation of crop residues.
3. Livestock are very important in an integrated farming system for the utilisation of agricultural by-products and wastes. Livestock raising supports the improvement and maintenance of soil productivity through organic matter recycling and by indirectly controlling erosion through planting grass on the edge of terraces for fodder. They also represent a capital investment and additional income and a source of power for the farmer.
4. Fish should be included if the soil and topography enable the construction of a pond which will catch the runoff water in the rainy season. The pond can also serve as a water source for irrigation.

## Rehabilitation of alang-alang (*Imperata cylindrica*) lands

Alang-alang land is considered another resource for the development of upland areas in Indonesia. As mentioned previously there are vast areas of abandoned land, covered with alang-alang grass, which have developed as a result of shifting cultivation or improper soil management. In 1975 the area was estimated at 16 million ha with an annual increase of 200 000 ha.

Unlike forested areas, alang-alang land already has some infrastructure and there would be only minor land clearing costs involved compared to virgin forest clearing. Because of this it should be far more economical to rehabilitate this land rather than clear virgin forest.

Rehabilitation of alang-alang grasslands through the use of legume (*Centrocema pubescens*) as a smother, and appropriate fertilizers, was reported from S. Sulawesi, Indonesia by Blair et al. (1978). Currently, demonstration trials on farmers' fields to test the use of reactive phosphate (RPR) in combination with fast growing cover crop *Mucuna* sp. and alley cropping for the rehabilitation of alang-alang land are being conducted at four sites in Sumatra. Mucuna sp. is planted as the first phase with a high application rate of RPR to suppress alang-alang, to protect the soil from erosion, to fix nitrogen and to transform some of the P into organic P. Preliminary results indicate that direct application of reactive RPR in combination with proper organic matter management is very promising for the rehabilitation of alang-alang land and have increased its productivity.

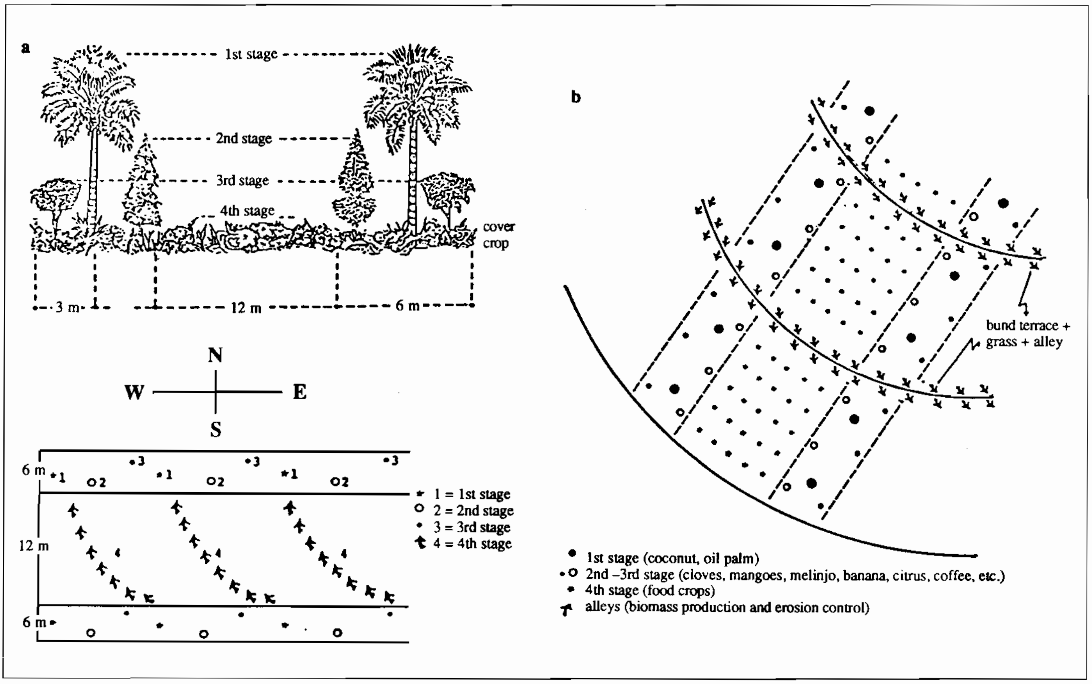

**Fig. 1.** The scheme of the concept of integrated farming system: **a.** on flat land; **b.** on sloping land.

## Transferability and Extension of Technology

The transferability and extension of packages of technology are very important since they will determine the impact of the new technology generated.

Studies carried out for more than 10 years have produced various alternative technologies for the sustainable development of upland agriculture in Indonesia. The extension and adoption of these research findings have faced many problems due to the socioeconomic and institutional constraints, i.e. ability of extension workers to transfer and the ability of farmers to adopt the technology, acceptance by the farmers and the availability of production factors (seed, fertilizers) and credit facilities.

In order to promote the transfer of technology, the linkage among the research and extension agencies and regional governments must be strengthened. Farmer groups, extension services and regional authorities must be involved in the on-farm research and the field sites should serve multiple functions.

## Conclusions

1. There are about 47.1 million ha of land resources with potential for agricultural development in Indonesia. About 45% is covered by Red Yellow Podzolic soil which is considered a marginal soil, acid, deficient in nutrients, has low water holding capacity, and is susceptible to erosion and soil degradation.
2. Sufficient human resources are available for the agricultural development of upland areas since more than 50% of the labour force works in the agricultural sector and about 70% of them are farmers dependent on rainfed agriculture. Uneven population distribution (approx. 60% are in Java with less than 7% of the total area) has created problems for agricultural development in the outer islands. Transmigration programs to resettle people from overpopulated Java to the sparsely populated areas in the outer islands have been promoted.
3. Research results show that high inputs are needed for the sustainable agricultural development of upland areas. These include P and K, and lime is required for sensitive crops such as corn, soybean and mungbean. Lime is not needed for the first crops after slashing and burning a forest but may be required for the second or third crop. Low organic matter content is one of the main causes of the low soil productivity. Application of organic matter from crop residues or alley cropping increases fertilizer efficiency, reduces lime requirements, improves soil physical properties and controls erosion. The use of *Flemingia congesta* as an alley (fast growing, Al tolerant and high biomass production) is promising. Integrated inorganic fertilizers and proper organic matter management are the main keys and the best management to overcome soil fertility constraints, increase soil productivity while maintaining high yield. Soil conservation techniques (mulching, terraces supported by grass and legume strips) should be the first priority in any farming system. Rehabilitation of alang-alang land has potential for agricultural development and is more economical than clearing of forests.
4. Food crop based farming systems face many problems and risks. Integrated farming systems consisting of perennial crops as a major commodity, livestock, food and forage crops seems to be a better approach to sustain soil productivity as well as farmers income.
5. To promote the adoption and extension of the new technologies, farmers groups, extension workers and regional authorities should be involved in on-farm research.
6. Coordination and cooperation among the involved institutions must be strengthened to achieve the goal of sustainable agricultural development which is one of the main targets in the Fifth Five Year Plan to support the development of the industrial sector.

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# Resources and Problems Associated with Sustainable Development of Upland Areas in Malaysia

**B.Y. Aminuddin*, W.T. Chow** and T.T. Ng*****

## *Abstract*

An overview of land, climate, topography and the nature of upland soils in Malaysia is given. About 68% of the total land area (or 22.5 million ha) is considered marginal and unsuitable for agriculture, and 80% of this area is found in the upland areas. The main agricultural limitations of the soils found in the area are shallowness, stoniness and steepness. The low pH, low CEC and kaolinitic nature of these soils do not seem to hinder the successful cultivation of adaptable crops like rubber, oil palm and cocoa.

With increasing population there are pressures to develop marginal uplands for agriculture. Indiscriminate use of steeplands in some areas for vegetable cultivation and intensive shifting cultivation has caused serious soil erosion problems. There is need to restrict use to a more sustainable tree crop system. In the state of Sarawak, such an attempt toward organised plantation is hampered by the existing unsuitable land tenure system, shortage of labour, and poorly developed infrastructure.

In Malaysia there has been a continuing generation of technology by various R & D institutions to support the main agricultural commodities of rubber, oil palm, cocoa, coconut, pepper and livestock. Technology generation for fruit tree cultivation is being intensified. The possible utilisation of highland areas for sustainable sub-tropical tree crops is being seriously investigated.

## Resource and Resource Use

### *Land*

Malaysia is located between latitudes 0° and 8° North and longitudes 99° and 120° East. The country has a land area of 33.03 million ha, and the percentages of land considered suitable and unsuitable for agriculture in various parts of the country are given in Table 1. It is evident that about 22.5 million ha of land is unsuitable for agriculture and more than 80% of this is located in the upland areas.

### *Climate*

Malaysia has a humid tropical climate. The year is commonly divided into the south-west and north-east monsoon seasons. The average annual rainfall in the Peninsula is about 2540 mm, with a higher total in Sabah and Sarawak. Ten different rainfall regions are recognised (Wycherley 1967). The average daily temperature varies from 21°C to 32°C. Humidity is high with a mean value of about 85%. At higher elevations, the climate has lower mean annual daily temperature and a slightly higher rainfall.

### *Topography*

The topography of Peninsular Malaysia is dominated by the Main Range which runs almost centrally along the middle of the Peninsula to a height of about 2000 m a.s.l. Secondary ranges fan out from this. From these mountain systems, many rivers flow towards the floodplains and the coast. The west coast is dominated by alluvial marine deposits while the east coast has exposed riverine deposits and sandy beach ridges. About 8% of the land area is swampland, mainly in the coastal depressions.

Sarawak and Sabah are generally mountainous and drained by an intricate system of rivers. Almost 70% of Sarawak consists of very steep areas. The highest peak is Mount Mulu (2371 m a.s.l.). The interior of Sabah has a series of mountain ranges and hills, the most prominent of which is the Crockers Range that rises abruptly to Mount Kinabalu (4175 m a.s.l.), the highest mountain in S.E. Asia.

### *Upland soils*

Upland soils are defined as those soils that are of sedentary origin or have developed from older alluvium. Owing to the intense weathering in the tropical environment these soils are highly weathered and have low cation exchange capacity and base saturation. They are dominated by

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kaolinites and sesquioxides of iron and aluminium, and are inherently infertile. They are mainly Ultisols and Oxisols, and also include skeletal soils.

Information on soil types in steepland areas in Malaysia is generally lacking. However, a wide range of soils is found in the steep lowland and highland areas. At low altitudes, both Ultisols and Oxisols are dominant whereas at high altitudes, Histosols and Spodosols are found.

Marginal upland soils are referred to as those that are unsuitable or marginal for agriculture. Soil limitations that are commonly encountered in upland areas of the Peninsula are outlined in Table 2 (Wong, 1986). In Sarawak, major limitations are steep slopes and shallow soil depth. As agricultural development in Malaysia progresses, more specific land suitability ratings for the various crops emerge. Chan et al. (1975) have developed a technical soil grouping for rubber which is directly related to rubber yields. The classification is largely based on soil physical properties and pH is the only chemical property considered. A few examples of soils in the various classes are given in Table 3. A similar classification is being attempted for oil palms and cocoa.

Paramanathan and Chan (1980) proposed that more soil chemical properties should be considered in soil suitability rating. They also proposed that the Fertility Capability Classification (FCC) of Boul et al. should be adapted. The kind and frequency of FCC limitations within 50 upland soils commonly mapped in Peninsular Malaysia are given in Table 4. These do not include soils in the steep highlands as they were not mapped. It appears that if this proposal is adopted, many of the Utisols and Oxisols would be classified as marginal soils.

Examination of data from 35 common upland soils (Law and Tan, 1975) indicated that all soils have structures and none are coarse textured. No upland soil has a cation exchange capacity (CEC) of less than 5 though many soils have a CEC below 7. Only a few Oxisols are somewhat excessively drained (due to aggregation of clays). These results show that based on the system of Wong (1986), these factors are not limiting in upland areas. Rather, limitations in the upland areas are mainly in the form of steep slope, stony and lateritic composition, and shallow soil depth.

**Table 1.** Distribution of suitable and unsuitable land for agriculture

| | Peninsula Malaysia | Sarawak | Sabah |
|---|---|---|---|
| Total area (million ha) | 13.16 | 12.24 | 7.63 |
| Total area suitable for agriculture (million ha) | 6.19 | 1.81 | 2.31 |
| Total area unsuitable for agriculture (million ha) | 6.85 | 10.43 | 5.25 |
| % of total area | 52 | 85 | 69 |
| Total upland areas unsuitable for agriculture (million ha) | 5.61 | 8.57 | 4.49 |
| % of total unsuitable area | 82 | 82 | 87 |
| Steepland (% of total area) | 36 | 70 | 22 |
| Slope in degrees | >20° | >33° | >25° |

**Table 2.** Soil limitations in upland areas

| Type | Very serious | Serious |
|---|---|---|
| Depth to compacted layer | 0–25 cm | 25–50 cm |
| Gradient | 20° | 12–20° |
| Nutrient | toxicity | – |
| | - | CEC <5 meq/100 gm |
| % Stoniness to 1 m | 75% within<br>0–25 cm | 50–75%<br>within 0–25 cm |
| Drainage | – | Excessive or very/somewhat poorly drained |
| Texture and structure | – | Coarse/fine textured and structureless |

(After Wong, 1986)

From the above data, it is felt that the suitability class of a soil should be crop specific. Ultisols and Oxisols would be marginal for many annual crops, but if adaptable crops are cultivated (like rubber and oil palm) a high yield is obtainable.

## Demography - Present and Future Trends

The estimated population of Malaysia in 1989 was 17.4 million comprising 14.3 million in Peninsular Malaysia, 1.6 million in Sarawak and 1.4 m in Sabah. A greater proportion of the population is found in the rural areas. However, during 1981–1985, the urbanisation rate increased rapidly. As a result, the urban population has increased from 34.2% in 1980 to 37.4% in 1985. It is expected to increase to about 7.3 million in 1990.

The population density in Malaysia is approximately 0.5 person per ha, comprising 1.1, 0.1 and 0.2 person per ha in Peninsular Malaysia, Sarawak and Sabah, respectively. The average national population growth rate for the period 1985 to 1988 is 2.6%. An increase of 1 million from migration is the main factor accounting for the high population growth rate in Sabah. In general, much of the steepland areas are virtually uninhabited or sparsely populated. The National Population Policy envisages a gradual increase in population to 70 million by the year 2000. This is to provide a base for demand and market of the local industrial products.

## Landuse and Related National Policies

### *Present land use*

About 72% of Malaysia is still under forest or swamp. The remaining land, mostly utilised for agriculture, is mainly under oil palm (*Elaeis guineensis*), rubber (*Hevea brasiliensis*), cocoa (*Theobroma cacao*), coconut and paddy (Table 5). In Peninsular Malaysia, the general pattern of land use is one of extensive cultivation in areas where the terrain is less rugged and easily accessible.

A large part of the the mountainous steep lands is kept under forest. Pockets of steep areas in the lowlands have been opened up in large scale agricultural development schemes. In Peninsular Malaysia about

**Table 3.** Examples of class and yield range for rubber (kg/ha), and yield of oil palm (ffb,t/ha) and cocoa (t/ha) per year on various soils

| Soil series | Classification | Class & yield for rubber[1] | Yield of oil palm[2] | Yield of of cocoa[3] |
|---|---|---|---|---|
| Munchong | Typic paleudults | I | 24 | 1.5 |
| Segamat | Tropeptic haplorthoxes | >1350 | | 1.1–1.2 |
| Harimau | Typic paleudults | II | | 0.8–0.9 |
| Batang-Merbau | Orthoxic tropudults | 1250–1350 | | 0.9–1.0 |
| Serdang | Typic paleudults | III | 24.4 | |
| Malacca | Plinthic haplorthoxes | | 23.2 | 0.6 |
| Durian | (Oxic) Plinthudults | 1100–1250 | 26 | 0.5 |
| Batu Anam | (Aquoxic) dystropept | IV | 24.3 | 0.6–0.7 |
| Seremban | Petroplinthic-paleudults | 1000–11001 | | |

[1] Chan et al. (1975)
[2] Ahmad Tarmizi et al. (1990)
[3] Thong et al. (1989)

**Table 4.** Frequency of soil limitations in 50 upland soils as considered in Fertility Capability Classification

| Limitations | % of profiles |
|---|---|
| Rock or root restricting layer within 50 cm | 6 |
| Heavy clays (clays>60%) | 16 |
| Al toxicity. 60% Al saturation of CEC within 50 cm | 84 |
| Low CEC (e.g. <7meq/100 gm by bases at pH 7) | 72 |
| K-deficient (e.g exch. K <0.2 meq/100 gm soil) | 72 |
| P-fixation (e.g free iron/% clay <0.2) | 26 |

**Table 5.** Areas under major crop types

| | Peninsular Malaysia | Sarawak | Sabah |
|---|---|---|---|
| Total cultivated area (million ha) | 4.4 | 0.5 | 0.6 |
| % of total area | 33.1% | 4% | 8% |
| Area by crop (million ha) | | | |
| — Rubber | 1.98 | 0.21 | 0.08 |
| — Oil palm | 1.32 | 0.04 | 0.23 |
| — Cocoa | 0.07 | 0.07 | 0.20 |
| — Paddy | 0.42 | Few | 0.04 |
| — Coconut | 0.44 | 0.06 | 0.06 |
| — Shifting cultivation | Small | 0.08 | NA |

5000 ha of steep mountainous land in the Cameron Highlands has been developed for tea, temperate vegetables and fruit trees. In Sabah and Sarawak, much of the cocoa and pepper are planted on steep lands. Other land use in steep areas is shifting cultivation, which is mainly found in East Malaysia. In Sarawak, this amounts to about 0.08 million ha (or 2.7 million ha, fallow area inclusive), where about 0.1 million ha is cleared annually for the cultivation of hill paddy and other food crops. The usage of lateritic soils, which are found in less steep areas, is more extensive despite their stony nature, indicating that the stony soil limitation is more acceptable to the farmers.

### *National policies*

The use of land for agriculture in Malaysia has been guided by the Land Conservation Act and Land Capability Classification reports (LCC). LCC reports and maps have been drawn up to summarise data on the relative capability of the land in Peninsular Malaysia for mining, agriculture, forestry, and other uses. LCC was also developed for Sarawak. Under the Act, no land above 20° slope in Peninsular Malaysia is recommended for agriculture. However, owing to increasing land pressure and also the lack of enforcement, this Act has not been strictly followed.

The National Agriculture Policy (NAP) was formulated in 1984 to set out guidelines for agricultural development up to the year 2000. Its main objective is to maximise income from agriculture through efficient utilisation of the country's resources. The principal strategies to achieve this objective are to develop new land, rehabilitate existing idle land, intensify land use, and organise group farming. Paddy production is aimed at 65% self-sufficiency and to be confined to granary areas. Through this, the country hopes to reduce its annual food import bill of about US$1.5 billion.

## Agricultural Production Trends

Agriculture still plays an important role in Malaysia's economy although the country is moving towards industrialisation. In 1986–1988 agriculture contributed an annual average of 22% towards the national Gross Domestic Product (GDP) and a share in total export earnings of about 31%. Agricultural GDP grew at a real rate of 5.4% per year during this period. The agricultural sector employed about 32% of the total labour force and it can be divided into two main categories, namely smallholders and estate sector (>40 ha). The smallholders include a small percentage of subsistence farmers, while the remainder is partially or fully commercialised. It appears that in the near future, the extent of subsistence farming will be reduced in favour of organised commercial farming.

The agricultural production trend in Malaysia is towards maintaining its present standing as a leading producer of palm oil, rubber, timber, cocoa and pepper in the international market. To overcome the negative effect of commodity price fluctuations, it is also the government's policy to encourage downstream industries where raw agricultural materials will be processed locally into value-added export goods.

The government is also commited towards agricultural diversification. Currently emphasis is being given for commercial farming of selected tropical fruits. In the highland areas, cultivation of subtropical fruits is envisaged mainly to cater for tourism and local needs. In addition, integrated farming of sheep under oil palm and rubber plantation is being promoted in tandem with the development of feedlot systems using agricultural by-products as feeds.

## Development Problems

### Environmental consequences of current landuse and policies

In general, farmers in steepland areas do not utilise good soil conservation practices, as they are usually motivated by short term profit. As such in the Cameron Highlands catchment, soil loss is more than 125 kg/ha/year. This has caused extensive siltation of the hydro-electric dam downstream, and shortened its life span to a mere third of initial projection. Moreover, the hydro-electric power generator cannot be operated during peak downpours as the sediment load is too high. The quality of drinking water is equally affected.

Indiscriminate farming in such an area cannot be sustained. In some places, soil has to be brought from outside areas to replenish what was lost by erosion after a period of about 30 years. The removal of forest has also caused an increase of the surrounding temperature by 1° or 2° C. However, in other steep areas, where cover crops are used, very low erosion rates are experienced.

The practice of shifting cultivation on steep land was found to be ecologically stable and sustainable when the fallow period was about 10–15 years. Recently however, the erosion problems have become severe as the fallow period decreased, in some cases to less than three years (Sinajin 1987). This is accompanied by yield decline from 2 t/ha of rice to as low as 0.3–0.4 t/ha (Hatch and Tie, 1979). Such a land use is unproductive and wasteful and a workable alternative farming system must be introduced. The extent of erosion resulting from different land uses is given in Table 6.

## Major constraints to development

### *The steep lands*

A major constraint in steep areas is the slope length. This, coupled with heavy tropical rainfall, causes excessive runoff and erosion. Proper choice of crops on steep areas minimises the developmental constraints. A technological package for growing rubber on such a slope is available. In contrast, such soils are not at all suitable for the cultivation of annual crops. Continued erosion under annual crops would reduce the soil depth and soil fertility as the organic matter and clays are removed.

Other technological constraints include unfavourable effects of land clearing. In land development projects, areas as large as 2000 ha are cleared at one time, mostly using heavy machines. Ling et al. (1979) showed that mechanical clearing resulted in a lowering of CEC, organic carbon and K content in topsoils. It also compacted the soil and reduced infiltration, making it more vulnerable to erosion.

From an economic viewpoint, a major constraint is seen in the added cost of development, especially the cost of conservation measures. Moreover, as machinery usage is not encouraged in very steep areas, higher costs are incurred during manual land clearing and terracing.

**Table 6.** Soil loss (t/ha/yr) under various land uses.

| | Soil loss* | Slope |
|---|---|---|
| Primary jungle | 0.25 | 25° |
| Secondary growth | 0.10 | 27° |
| Bare plot | 24.88 | 13° |
| Traditional hill paddy | 0.18 | 20° |
| Terraced hill paddy | 0.96 | 20° |
| Terraced pepper | 2.16 | 30° |
| Clean-weeded pepper | 94.36 | 25° |
| Rubber | 0.10 | 4–5° |
| Oil palm | 15.00 | 3–4° |
| Cocoa | 1.60 | 25° |
| Complete ground cover | 0.80 | 25° |
| Mucuna with mulch | 0.04 | 10° |

*F.H. Teck, 1987

### *The skeletal soils*

There are about 33 soil series classified as shallow and moderately deep skeletal soils in Peninsular Malaysia. They are characterised by the presence of lateric or quartz gravels (Table 7). The limitations to crop growth on these soils are determined by the percentage content of gravel as well as soil depth.

These soils have a low water-holding capacity, normally less than 10%. They also have low CEC and can cause Al and Mn toxicity to sensitive crops. Due to soil limitations, the yield of oil palm on lateritic soil is reduced by half as compared to the normal soils, and the palms commence yielding 12 to 24 months later.

### *Land tenure status*

The Native Customary Reserve (NCR) status of extensive areas of the Sarawak hinterland is a major impediment to land development. This category of land is granted to the indigenous people. As the land is unsurveyed, disputes among rural communities over boundaries and ownership are common. Probably because of fear of losing land ownership, it is difficult to persuade remote communities to resettle elsewhere. Illegal settlements (squatters) pose another common problem. Unending negotiations between development agencies and the incumbent squatters over compensation payment follow in order to reach agreement. These land tenure problems deter private investors from participating in agricultural development.

### *Shortage of farm labour*

Shortage of efficient and disciplined local farm workers is a common problem faced by the agricultural plantation sector, especially in Sarawak. Recruitment of foreign workers has become necessary. A seasonal labour shortage frequently occurs during farming, festive and fruit seasons. In general, the local workers find it difficult to adapt to the regimental lifestyle as expected of them in the plantation environment.

**Table 7.** Types of skeletal soils

| Description[a] | No. of soil series identified in Peninsular Malaysia. |
|---|---|
| Shallow in situ lateritic soils | 5 |
| Moderate in situ lateritic soils | 4 |
| Shallow reworked lateritic soils | 8 |
| Moderate reworked lateritic soils | 9 |
| Moderate soils with quatz gravels | 2 |
| Shallow older alluvium | 2 |
| Moderate older alluvium | 3 |

[a]Shallow = 0–50 cm, Moderate = 50–100 cm

### *Socio-economic problems of rural communities*

Illiteracy, preservation of traditional values, a reluctance to change, poverty and malnutrition are all parts of a cycle propagating problems associated with the rural communities in Sarawak, especially those in the interior of the state. The complexity of these problems will remain as great challenges to rural development experts for a considerable period.

### *Poorly developed infrastructure*

The road system to the hinterland is at present poorly developed. Development of such infrastructure is extremely expensive because of dissected terrain. It is also difficult to justify when rural settlements are so widely scattered. As a result, farm inputs and basic human necessities are costly to deliver to these communities. Extension efforts to them are equally costly, arduous and inefficient.

## Development Strategies

### Research and technology generation

In the development of the cultivable uplands, a considerable amount of technological information has been generated for the tree crop system (cocoa, oil palm and rubber), particularly on the effect of land clearing, terrace construction, cover crop establishment and farm management. Sufficient information also exists on the extent of erosion resulting from various land uses (Table 6). However, there is still a need to find shade tolerant forage covers that can survive and conserve soils under mature tree crop plantations.

In the tree crop system, observation shows that crop productivity is reduced by 10–20% during the first replanting, due partly to soil erosion. Should this trend continue for the subsequent replantings, economic sustainability is questionable and needs to be researched. Soil conservation measures have been shown to improve the yield of oil palm by about 20%. Apart from the benefits due to soil conservation, this could also be partly due to the beneficial effect of moisture conservation. Effects on other crop types, especially in the drier region, need to be monitored.

Research has also been conducted on the cultivation of rubber and oil palm on lateritic soils. A larger than normal planting hole is required, and the frequency of fertilizer application is increased because of the low soil CEC. Tan and Thong (1975) recommended that planting density be increased by 50%, from 148 to 222 palm/ha. Ng et al. (1984) found that rubber is more suitable than oil palm on these soils, giving a yield of between 1200–1700 kg/ha/yr. Under improved agronomic practices the yield of oil palm is between 17–20 t/ha/yr. The scope for cocoa and hybrid coconut on these soils seems limited.

Pepper is recognised as the most remunerative cash crop for smallholders in the hilly interior. Demonstration plots of terraced pepper have been established in many localities. Whilst the practice is found to reduce soil erosion considerably, the high labour input requirement is again a deterrent to its adoption. The use of leguminous cover such as *Centrosema pubescens* has been found to be a more acceptable soil management practise on steep slopes. Research by Wong (1989) and extensive on-farm studies in major pepper growing areas have shown clearly that ground cover management can save both fertilizer costs and offer soil protection.

In Peninsular Malaysia, little emphasis is given to research on the cultivation of annual crops and subsistence farming on steep lands. In Sarawak, research on the development of a permanent hill paddy cropping system was attempted (Chai, 1983), but it was found that terrace construction was too expensive, and paddy yield could not be sustained on a continuous cropping basis (Tie et al. 1989). Research on other permanent cropping systems, based on fast growing leguminous trees and shrubs, is being carried out.

Recently, renewed interest has been shown in farming the highlands, mainly to increase the production of subtropical crops. It was soon realised that basic data on the climate and soils of these areas were lacking. Soils need to be surveyed and delineated according to their suitability for agriculture. Areas that are unsuitable for agriculture under the present technology should be protected from development. Climatic data are more difficult to generate and in the meantime, simulation of climatic characteristics is the next best solution. All the climatic factors need to be correctly matched with crop requirements in order to identify suitable tree crops and their successful cultivation.

### Extension

Extension is the responsibility of the Department of Agriculture (DOA). Efforts are taken to impart commercial and financial management skills in order to make farmers more commercially minded and self-reliant. Besides this, the main objective of extension is to increase productivity of the farm through effective transfer of farm technology, and effect changes in the attitudes of farmers to be more willing to adopt new technology.

Extension is carried out through the Training and Visit (T & V) system. Under this system, service areas have been identified and farmer groups established. Each group of farmers operates collectively, receiving technical and other inputs through its leader. The immediate impact of this system has been the gradual rehabilitation of land which was previously abandoned.

In addition, DOA also sets up integrated crop demonstration plots on farmers' land to introduce as well as to update farmers' knowledge on new technology, particularly with regard to the cultivation of paddy, vegetables, fruits, cocoa, coffee and maize. In 1987, a total of 5500 ha of land involving 11440 farmers in Peninsular Malaysia was involved in such demonstrations. The DOA in the different states also conducts various courses of different duration for farming communities in order to teach farming techniques and home economy. Short visits to successful farms are also organised.

### Policy and institutional arrangements

Whilst it is the Government's policy to accelerate commercialisation of agriculture through the development of the plantation sector, village-based smallholder agriculture remains a significant sector in the socio-economic and political context which needs Government's attention. In view of this, DOA, Malaysian Agricultural Research and Development Institute (MARDI) and various other institutions within the Ministry of Agriculture, and other agencies such as the Rubber Research Institute (RRIM) and Palm Oil Research Institute (PORIM) have jointly formulated various programs which aim at reducing poverty in the rural community. Basically, the strategies are to raise farm and non-farm incomes (e.g. through cottage industries), and to find ways of attaining food sufficiency.

Because of the complexity of problems in upland areas, there is a need to view upland development from a more holistic way. In these areas, development needs to be approached on a catchment basis, as well as from the point of view of competitive land use. Thus, decision makers have to choose the optimal land use desired for the area, which includes forestry, water catchment and agriculture. Should agriculture be chosen, adaptable crops must be identified to ensure its sustainability.

Sustainable development of the marginal upland areas is a formidable task. It takes great patience and innovative minds on the part of agriculturists, rural development planners and the policy makers to overcome the complexity of problems as discussed in this paper.

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# Resources and Problems Associated with Sustainable Development of Uplands in Thailand

**Samrit Chaiwanakupt* and Chaleo Changprai****

*Abstract*

Located in the tropical zone of Southeast Asia with annual rainfall ranging from 800–4000 mm, Thailand's uplands are covered by soils with an ustic soil moisture regime. These soils cover 46% of the total land. The poor productivity and the deterioration of the Ultisols, which account for 78% of the total upland soils, have been aggravated through misuse and mismanagement by smallholder farmers. Their rehabilitation would relieve pressures in upland areas. Multidisciplinary research, supported by both government and private sectors, as a means to overcome the problem is discussed in a socio-economic context.

THE Kingdom of Thailand lies in the tropical zone of Southeast Asia between approximately 5° and 21° latitude North and between 98° and 106° longtitude East. The total land area of the country is 51.3 m ha which is geographically divided into four regions, namely; the Central Plain (9.7 m ha), the Northeastern (16.9 million ha), the Northern (17.0 million ha), and the Southern regions (7.7 million ha).

The tropical monsoon climate has two major rainfall distribution patterns; a monsoon type with distinct wet and dry seasons in the majority of the country and an equatorial type with indistinct short to very short dry seasons in the Southeast Coast and Peninsula Thailand.

Major high rainfall zones are Peninsula Thailand and the Southeast Coast, with an average higher than 2000 mm and up to 4000 mm in some areas. The low rainfall zones are found in the rain shadow of the Western Continental Highland, where the average annual rainfall is less than 1000 mm. The peak of the rainy season falls from August through to October.

At the lower elevations, mean monthly temperature of the cool season in January ranges from 26°C to 28°C. During the hot season in April the averages are from 28°C to 32°C, and for the rainy season, the values are intermediate. This type of climate results in an Ustic soil moisture regime in most parts of the upland areas, a Udic regime in Peninsula Thailand, the Southeast Coast and in high altitude areas, and an Aquic regime in most of the lowland areas.

According to The Office of Policy and Planning (1988), the total population of Thailand was 53.9 million with an annual growth rate of about 1.5%. It is expected that the total population will be 61.1 million by 1998. In 1988 the agricultural population accounted for 64.0% of the total population. However, the size of the agricultural population is declining due to the rapid growth of industrial sectors in the country. The population by region during 1983–1988 is shown in Table 1.

## Physiographic Features and Soils

Physiographically, the country can be divided into six regions, the North and West Continental Highlands, the Central Plain, the Central Highlands, the Northeast Plateau, the Southeast Coast and Peninsula Thailand. However, according to the General Soil Map of Thailand (Soil Survey and Land Classification Division, 1979) the general topography of the country can be classified into three broad physiographic features; lowlands, uplands and highlands.

The lowlands cover approximately 12.7 million ha or 24.8% of the total land. They are generally fertile alluvial soils occupying flat to slightly undulating topography. Slopes are mostly less than 3%. They are characterised by fine textured, poorly or slowly permeable soils well suited to flood irrigation, or medium textured, moderately well drained soils suited to non-irrigation annual cropping. Most of the low-lying alluvial soils are used for submerged rice cultivation, while upland crops and fruit trees are grown on elevated parts of the flood plain or on natural river levees.

The uplands, which cover about 23.6 million ha or 46% of the total land area, are composed of moderately well

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Table 1. Population (millions) by region during 1983 to 1988. (Office of Interior Policy and Planning 1988)

| Region | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|---|
| Central | 17.52 | 17.31 | 17.67 | 18.22 | 18.66 | 19.04 |
| North | 8.56 | 8.82 | 8.97 | 9.07 | 9.42 | 9.23 |
| Northeast | 16.72 | 17.22 | 17.64 | 18.06 | 18.28 | 18.88 |
| South | 6.05 | 6.17 | 6.30 | 6.44 | 6.60 | 6.72 |
| Total | 48.85 | 49.52 | 50.58 | 51.08 | 52.96 | 53.87 |

drained, and excessively drained soils derived from older alluvial deposits They are developed in situ from various parent rocks and occur as series of terraces to approximately 500 m above sea level. These are described later in the definition of the uplands.

The highlands, which cover approximately 15.0 million ha or 29% of the total area, are confined to areas with an altitude exceeding 500 m above sea level. The area consists of elevated flat plateaus or mountains with steep-sided valleys, some with the valley floor representing less than 1% of the area. The surface soils in the highland zone are variable in terms of textural and depth classes as well as slope classes. In the highland area, slopes are mostly greater than 35%. Therefore, slope is the major limitation for the use of these relatively fertile soils for agricultural purposes other than forestry or related tree cropping. Soil erosion is a serious problem in the highland where slash and burn cultivation is commonly practiced by the indigenous hill-tribe farmers. The physiographic types and land area are shown in Table 2.

Table 2. Areas according to physiographic types. (Measured by weighting method from the General Soil Map of Thailand 1979)

| Physiographic types | Area million ha | Area % of total land |
|---|---|---|
| Lowland < 3% slopes | 12.73 | 24.82 |
| Upland 3–35% slopes | 23.62 | 46.03 |
| Highland > 35% slopes | 14.96 | 29.15 |
| Total | 51.31 | 100.00 |

## Upland soils

Upland soils in Thailand, which cover an area of approximately 23.6 million ha or 46% of the total area, are widely distributed throughout the country, and occupy 45%, 22%, 19% and 14% of the total land in the Northeastern, Northern, Central Plain and Southern regions respectively. The taxonomy of the upland soils falls into eight soil orders. Ultisols, the most extensive order, account for 78% of the total upland soils, followed by Alfisols 10%, Inceptisols 4%, Entisols 3%. Vertisols and Mollisols account for 2% each. The rest are Oxisols and Spodosols (Table 3).

In terms of soil texture, the upland soils of Thailand are dominated by light-textured soils: 49% loamy, 34% skeletal, 13% clayey and 4% sandy in texture

Table 3. Distribution of upland soils (order) by region (km$^2$) (Verapattananirund, 1986)

| Soil orders | Region<br>Northeastern | Northern | Central plain | Southern | Whole Kingdom | % |
|---|---|---|---|---|---|---|
| Entisols | 4880 | 187 | 1337 | 1318 | 7762 | 3.3 |
| Inceptisols | 3546 | 3139 | 1735 | 825 | 9245 | 3.9 |
| Mollisols | 271 | 2222 | 2531 | - | 5024 | 2.1 |
| Alfisols | 5083 | 11539 | 8208 | - | 24830 | 10.5 |
| Ultisols | 92632 | 33944 | 27825 | 30081 | 184482 | 78.1 |
| Vertisols | 371 | 407 | 3348 | - | 4126 | 1.7 |
| Spodosols | - | - | 76 | 516 | 592 | 0.3 |
| Oxisols | - | - | 144 | - | 144 | 0.1 |
| Total | 106783 | 51438 | 45244 | 32740 | 236205 | |
| Percentage | 45.2 | 21.8 | 19.1 | 13.9 | 100.0 | |

(Chaiwanakupt, 1986). The soils of the upland area in Thailand, which have been developed by deforestation rapidly lost their fertility when planted with arable crops. With continuous cultivation, it is clear that soil productivity decreases through the depletion of physical, chemical and biological resources. According to Verapattananirund (1986), 64% of the upland soils are low in inherent potential, moderately acid, low available P status, coarse texture, low CEC, low base saturation and contain predominantly low-activity clay.

In addition to the light textured soils, some 17.4% of the uplands are covered by skeletal or sandy soils or old mines and tailings (Table 4).

**Table 4.** Problem upland soils (General Soil Map of Thailand 1979)

| Problem soil type | Physiographic position | Area (ha) | % of total land |
|---|---|---|---|
| Skeletal soils | upland | 8 382 200 | 16.4 |
| Sandy textured | upland mostly | 988 400 | 0.9 |
| Old mines and tailings | upland | 24 450 | <0.1 |
| Total | | 9 395 050 | 17.4 |

## Land Utilisation and Agricultural Production

### Land utilisation

Land use in Thailand has been drastically changed during the past decade because of the increasing demand for crop production as well as the national policy of agricultural production diversification. The upland cultivated area has increased over 70%, resulting in the ratio of lowland cultivated to the total cultivation area decreasing from 60 in 1976 to 50 at the present time. The expansion of upland cultivation has resulted in most of the forest land being excessively encroached and destroyed. Forest area was reduced from 17.5 million ha or 34% in 1978 to 14.3 million ha or 28% in 1988 (Table 5). The cultivation area accounts for 23.6 million ha or 46% of the total land. Approximately, 50% or 11.8 million ha is in the uplands and 11.9 million ha under lowland paddy rice.

In the upland areas, the cultivation of annual field crops, fruit trees, vegetables and ornamentals, and pasture accounts for 5.7, 3.1, 0.1 and 0.8 million ha respectively (Table 6).

The government announced a policy on land use and land ownership in 1961. The national land policy has been in existence since the period of the First Economic and Social Development Plan. Land allotment for agriculture, residential and related purposes amounted to 50% (25.6 million ha) of the total land. The other half was allocated to forest land. Within the 25.6 million ha allowed for agriculture, the policy allotted only about 20 million ha or 39% of the total land for private holdings and the remaining 5.6 million ha for public use.

In 1988, however, studies showed that 23.6 million ha or 46% of the total land was used for agriculture under private holdings. This indicates that more areas were used for agriculture than was allowed for in 1961. The additional area taken up by agriculture came from the portion assigned for forest land and private use.

### Agricultural production

The agricultural statistics of Thailand indicate that agricultural exports produced 65% of the total export earnings in 1984 and that this gradually decreased to 48% in 1988. The produce from crops is still the major export commodity. The principal crops grown for export are rice, maize, cassava, sugarcane and pararubber. There are also considerable areas of kenaf, cotton and some grain legumes (Table 7).

The contribution of agriculture to GDP has fallen from 24% in 1977 to 13.8% in 1987 (Table 8). Crops, livestock, fisheries and forestry contributed 61.1, 11.4, 7.2 and 4.6% to the total value of the agricultural products respectively.

**Table 5.** Land utilization in 1978, 1983 and 1988. (Agricultural Statistics of Thailand 1978–79 and 1988–89)

| Land use | Year<br>1978 | <br>1983<br>million ha | <br>1988 |
|---|---|---|---|
| Forest land | 17.52 | 15.40 | 14.38 |
| Agricultural land | 18.63 | 19.88 | 23.64 |
| Low land | 11.78 | 11.79 | 11.87 |
| Upland | 6.85 | 8.09 | 11.77 |
| Unclassified land | 15.16 | 16.03 | 13.28 |
| Total land | 51.31 | 51.31 | 51.31 |

**Table 6.** Agricultural land use in 1988 (Agricultural Statistics of Thailand 1988–89)

| Land use type | Area (million ha) | Percentage |
|---|---|---|
| Paddy | 11.87 | 50.2 |
| Field crops | 5.72 | 24.2 |
| Fruit trees and trees | 3.12 | 13.2 |
| Vegetable and Ornamental | 0.13 | 0.5 |
| Pasture | 0.76 | 3.2 |
| Idle land | 1.23 | 5.2 |
| Housing and others | 0.81 | 3.4 |
| Total | 23.64 | 100.0 |

**Table 7.** Planted area and total production of major crops in crop years 1978, 1983 and 1988. (Agricultural Statistics of Thailand 1983–84, 1988–89)

| Crops | Area ('000 ha)<br>1978 | 1983 | 1988 | Production ('000 t)<br>1978 | 1983 | 1988 |
|---|---|---|---|---|---|---|
| Rice | 10.70 | 9.92 | 10.35 | 17.47 | 19.59 | 21.26 |
| Maize | 1.38 | 1.69 | 1.83 | 2.79 | 3.55 | 4.67 |
| Cassava | 0.85 | 1.40 | 1.62 | 11.10 | 19.98 | 24.26 |
| Sugar cane | 0.51 | 0.58 | 0.66 | 20.56 | 23.87 | 36.67 |
| Soybean | 0.16 | 0.16 | 0.40 | 0.16 | 0.18 | 0.52 |
| Cotton | 0.07 | 0.10 | 0.07 | 0.07 | 0.12 | 0.11 |
| Kenaf | 0.32 | 0.20 | 0.14 | 0.34 | 0.23 | 0.17 |
| Mungbean | 0.42 | 0.49 | 0.47 | 0.26 | 0.29 | 0.33 |
| Peanut | 0.10 | 0.12 | 0.12 | 0.13 | 0.15 | 0.16 |
| Sorghum | 0.17 | 0.26 | 0.18 | 0.22 | 0.33 | 0.21 |
| Rubber | 1.51 | 1.62 | 1.69 | 0.43 | 0.59 | 0.86 |

**Table 8.** Value of gross domestic product and percent contribution of agriculture 1979–1988. (Agricultural Statistics of Thailand 1988–89)

|  | GDP in nonagriculture | GDP in agriculture billion baht[a] | Total GDP | % GDP in agriculture |
|---|---|---|---|---|
| 1979 | 425 | 134 | 559 | 24.00 |
| 1980 | 506 | 153 | 659 | 23.32 |
| 1981 | 597 | 163 | 760 | 21.44 |
| 1982 | 663 | 157 | 820 | 19.13 |
| 1983 | 724 | 186 | 910 | 20.39 |
| 1984 | 973 | 175 | 1149 | 15.25 |
| 1985 | 1014 | 170 | 1184 | 14.34 |
| 1986 | 1095 | 181 | 1276 | 14.18 |
| 1987 | 1234 | 198 | 1432 | 13.84 |

[a] US$1 = 25 baht; billion = thousand million

During the Fifth Plan (1982–1986) the growth rate in the agricultural sector was only 2.1% per year, compared to the target of 4.4% per year. In an ongoing Sixth Plan (1987–1991) the target growth rate is 2.9% per year.

The increase in production during the past has been primarily based on the expansion of the cultivated land rather than increasing farm productivity. Since irrigation can be provided for only 20% of the total cultivated area, rainfed agriculture is still the dominant system in the country. Continuous cultivation and little or no supply of plant nutrients has resulted in rapid deterioration in productivity in most of the upland cropping areas. Even though the average yield of crops has recently increased slightly, the average yield of most crops is below world average (Table 9).

## Definition of the Uplands

In Thailand, the uplands can be distinguished from the lowlands on the basis of internal soil drainage, land use pattern and elevation. They often occur in a series of river terraces in specific geographic regions. The uplands, therefore, consist of the moderately well drained, well drained and somewhat excessively drained soils which are not saturated for a long period during the year. This is shown by the wetness condition in profiles and the lack of chrome mottles (2 or less) occurring within 75 cm. of the soil surface. The upland soils are found on the upper terraces and on erosion surfaces, lying between the tributaries of the main rivers and along the foothills of the ranges. The elevation does not exceed 500 m above sea level and the land is undulating to hilly with slopes ranging from 3% to 35%. Therefore, upland soils are commonly cropped under non-submerged conditions.

## Impact of Current Land Use

Since more and more agricultural land has been utilised for urbanisation and industrialisation, the land obtained through forest encroachment had to be put into cultivation. Land clearing by slash and burn practices, together with improper land use has caused rapid land degradation.

Soil erosion caused by rainfall is rather serious in Thailand not only in the steep areas, but also in undulating terrain. High to severe erosion occurs in the areas under upland crops, forest/upland crops and the area affected by slash and burn practices. Panichapong and Vijarnsorn (1985) reported that the eroded area accounted for 25.5% of the total area with annual soil loss ranging from 125 to 6000 t/ha/year. Chaiwanakupt (1986) reported that cassava cultivation in undulating terrain with 5-9% slope in the relatively dry southeast province resulted in soil loss up to 67 t/ha/year.

Soil erosion has resulted not only in a deterioration of soil productivity, but has also affected the environment through sedimentation of water courses and reservoirs. Suspended sediments from all watersheds are estimated to be 27 million tonnes annually which costs a large amount in reduced reservoir and river capacity and clogged navigation channels (Suebsiri 1984).

Ratanawaraha (1989) pointed out that the most crucial effect of the deforestation of the upland area has been the frequency of drought and the irregularity of rain. There is evidence that the average annual rainfall in the last six years has been 8-14% less than that recorded in the previous 30 years.

Misuse and mismanagement of land can result in disasters like that in Southern Thailand in 1988, where a sudden flood and landslide resulted in large loss of lives, destruction of property and considerable landscape degradation.

**Table 9.** Average yields of major upland crops in 1978, 1983 and 1988 (Agricultural Statistics of Thailand 1978–79, and 1988–89)

| | Yield (kg/ha) | | |
|---|---|---|---|
| Crops | 1978 | 1984 | 1989 |
| Maize | 2012 | 2269 | 2619 |
| Cassava | 12 631 | 14 968 | 15 231 |
| Sugar cane | 40 281 | 44 544 | 55 600 |
| Soybean | 981 | 1150 | 1319 |
| Cotton | 1087 | 1194 | 1500 |
| Kenaf | 1056 | 1106 | 1281 |
| Mungbean | 612 | 644 | 718 |
| Peanut | 1206 | 1212 | 1387 |
| Sorghum | 1231 | 1306 | 1237 |

## Major Constraints to Development

### Physical aspects

The soils and climate are considered to be the major factors hindering the development of upland agriculture in Thailand.

The amount and distribution of rainfall are both erratic from year to year and unpredictable within a given season. In addition, there is always uncertainty regarding the start of the wet season which can significantly shorten the growing season. Further, there are sometimes brief but critical inter-monsoon dry spells in June or July which can substantially reduce the productivity of the main crops.

There are extensive areas of problem soils in the upland and highland zones. They are sandy textured and skeletal (shallow) soils with low inherent fertility and high acidity. The skeletal soils limit root depth and increase the erosion hazard. They are also low in water-holding capacity which results in crop damage by drought during dry spells.

### Technological aspects

In general, upland agriculture in Thailand is considered to be of low and unstable productivity. Low yields of crops are primarily due to soil constraints and uncertain weather. Whilst irrigation would remedy much of the problem it is generally not possible in upland areas. Soil fertility reduction caused by cropping is often difficult to correct economically. Insects and diseases are also major production constraints. The availability and application of production and conservation technologies is limited.

Most of the technologies developed under the national research program have been either commodity or discipline oriented. The majority of resources have been devoted to crop improvement research programs aimed towards varietal improvement, cultural practices, pest and disease control and fertilizer usage. Recently, the DOA established the Farming Systems Research Institute (FSRI), to conduct integrated research in cropping/farming systems. Research on soils and crop management for sustainable production is carried out by various agencies and projects, but these research findings need further development before they can be adopted by farmers.

Existing soil and water conservation measures are rarely accepted by farmers because they are uneconomical. In the past, soil and water conservation planning emphasised the use of mechanical measures and agronomic measures were generally overlooked (TDRI 1986).

### Socioeconomic aspects

Most of the upland farmers are small farm holders with an average of 4.5 ha of land. They are generally economically deprived and face problems of insecure land tenure, low production and income. Rapid population growth has resulted in population pressure on land, which in turn led to the expansion of agricultural activity on to less suitable lands, including much land that is, at best, marginal. As a result, rapid deterioration of land quality can be anticipated, leading to a decline in the productivity of an already economically precarious existence for the people who have settled it. Seasonally unemployed farm labour is another problem due to the limited choice of cropping patterns, particularly during the dry season.

The government has acted to counter these problems through enhanced family planning, improvement of infrastructure and educational opportunities. An attempt to guarantee farm income by imposing minimum farm gate prices for certain crops, together with a credit scheme for agricultural input, are economic incentives given by the government. However, such economic support programs have not been very successful. One of the major constraints is a shortage of financial resources which limits the scope and continuity of the plans.

Formation of farmers' groups in the form of co-operatives is still limited. At present, agricultural co-operative members make up only about 40% of the total farm households. Most of the existing cooperatives lack financial and bargaining power over market negotiations and hence receive low output prices.

## Technology and Relevant Research

The high risk of rainfed upland agriculture is the major constraint preventing farmers from adopting high-input technologies. To mitigate against such constraint, low-input technology development through research in the fields of soil/crop management, soil and water conservation and the maintenance or improvement of soil fertility should be enhanced. Some efforts have been made in these areas of research and development.

### Soil and water conservation practices

The government has engineered and promoted some soil and water conservation systems to sustain agricultural production in the upland mainly in the North. Terracing and contour bunding with graded channels are efficient mechanical methods for preventing soil erosion. The soil and water conservation measures recommended by the Land Development Department are both agronomic and engineering. They consist of contour cultivation, strip cropping, cover cropping, soil mulching, terracing, grass waterways, hillside ditch and farm ponds. Agronomic measures are more acceptable to farmers than engineering ones. Farmers cannot envisage the usefulness of expensive engineering measures. In addition to high initial capital inputs, regular maintenance of the system is essential. However, engineering measures, like terracing, have been adopted by farmers to some extent, especially in rubber plantations of the Southern part.

### Soil/Crop management research

Some research has been conducted in the field of soil/crop management which has sought measures to sustain productivity and prevent soil and water loss on uplands.

*Minimum tillage.* The long term no-tillage system research for maize in clay-loam soil indicated that maize grown under the no-tillage system usually produces a yield equal or higher than that with conventional tillage (Na Nagara et al. 1986). The high infitration rate and favourable soil structure due to the killed sod mulch in no-tillage can minimise run-off and erosion (Kubota et al. 1979). The results also indicate that during short term drought periods, the no-tillage system is superior to the conventional system in lessening crop damages. If drought persists for longer periods, however, there is no significant advantage. The no-till system for soybean, peanut and cassava have also been investigated and similar results have been observed.

*Mulching.* There has been quite extensive work in crop residue mulching during the past decade (Kubota et al. 1979, Inoue et al. 1984, Uehara et al. 1985, and Nakaya et al. 1986). It can be concluded that mulching materials behave like killed sod mulch in no-tillage systems for soil and water conservation, but that they are less effective for erosion control. Petchawee (1984) found that plant residue mulch with fertilizer application had a remarkable effect in maintaining high yields of maize throughout eight growing seasons. Under no-mulch practice, the maize yield fluctuated greatly.

*Living mulch.* The results of long term experiments on the effect of leguminous intercropping on the yield of the main crop, have shown that such a practice is effective in conserving soil moisture and maintaining soil fertility. Verapattananirund (1988) reported that *Stylosanthes hamata* (cv. Verano) as living mulch, intercropped with cassava, can increase both root and shoot yield from 16.6 to 23.2 and 14.2 to 26.2 t/ha respectively. Petchawee et al. (1984) also indicated that the use of rice bean and mimosa as living mulch in maize showed high potential for maintaining maize yields at a high level.

*Cropping systems.* Research and development on cropping systems under rainfed condition is being conducted by various agencies and projects supported by international organisations. Such research indicates that there are promising cropping systems which provide a more sustainable and stable generation of income, but most of the systems are rice-based cropping systems in the upper paddy areas (Ratanawaraha, 1989). However, attempts to search for better cropping systems for upland areas is underway.

Boonchee et al. (1988) indicated that strip cropping of rice-peanut or rice-sorghum resulted in less erosion than monocropping in the Northern parts. He also reported that strip cropping of peanut-rice using 10 m wide strips on 3–5% slopes can replace contour banks. Upland rice followed by mungbean combined with grass strips can effectively control soil loss. Aneckeamphant et al. (1990) reported the results of a management of slope lands study in Northern Thailand. The use of alley cropping, grass strip cropping together with hill-side ditches reduced soil loss and run-off by more than 50% when compared to the farmers' practices.

Limpinuntana (1985), reported that in the undulating topography of the upland Northeast, the most promising pattern for intercropping of cassava with short duration crops were cassava with peanut and cassava with cowpea, as these patterns produced higher income than cassava monocropping. He also pointed out that double cropping by using short-duration field crops after the main crops is already practiced by farmers in some areas of the Northeast. The only problems remaining to be tackled are the decreased yield of the maincrops caused by early harvest and the unstable yield of the second crop due to insufficient soil moisture.

## Future Concerns and Issues

### Policies and strategies

Government policy in the ongoing Sixth Plan (1987–1991) has placed more emphasis on agricultural production diversification to overcome the farmers' risks. These risks can be due to declining prices and to crop failures due to the unpredictable agroclimatic conditions. The development of backward areas is an extension of the achievement from the Fifth Plan, with more emphasis on income distribution among agricultural and nonagricultural sectors. Emphasis has also been placed on the reclamation of lost sustainability and stability of farmers' incomes, as well as the improvement or arrest of the deteriorating environment. Agricultural production schemes are emphasised which include both income stabilisation and natural resources improvement at the farm level. Strategies suggested are:

—Increase land-use intensity through appropriate cropping systems.

—Promotion of integrated and/or mixed farming systems in order to make full use of farm resources as well as to bring more balanced diets and income to farm families.

—Rehabilitation of the deteriorated natural environment by encouraging farmers to grow more fruit trees, trees and fast-growing trees for fuel and wood.

—Provision of appropriate low-cost technologies with emphasis on using more available local, natural resource inputs.

—Encourage private sector endeavour to introduce small-scale agro-industries and other manufacturing ventures into the area to encourage even use of labour and to generate more income from non-farm activities.

### Technology generation

Since land degradation, farmers' economic problems and insufficient supporting programs are the major constraints to the development of upland agriculture, the provision of appropriate sustainable low-cost technologies is therefore an essential solution for the farmers' future well-being.

The solution is not likely to be based on any individual discipline. A concerted effort among biological, physical and social sciences is needed to attack the problems.

Multidisciplinary research effort seeking better sustainable production and conservation technologies through crop, soil and farming system management has to be carried on. Farmer participation in technology development must be encouraged through farm trial and demonstration.

In order to strengthen linkages between research and extension, technology development should be a collaborative effort between farmers, researchers and extension agents. Technologies generated by experiment stations must be tested in real farm conditions. The active participation of extension workers is essential for a better understanding and dissemination of the new technology. On-farm testing and feed-back from a systems perspective is essential for more effective technology development and delivery process.

### Future work and research needs

Technically it is apparent that the sustenance of the productivity of upland areas in Thailand will depend on two major inputs: (1) better soil and water conservation practices and (2) improvement of lasting soil fertility. However, to mitigate the socio-economic and environmental problems, more efforts should be placed on:

—Expanding land use planning programs with emphasis on farm conservation planning to cover more upland and highland areas.

—Accelerating land reform and land titling programs in order to alleviate land ownership problems.

—Enhancing the restriction of cultivation in steep slope areas with slope gradients greater than 15% and introduce more woodlot development for fuel wood into such restricted areas.

—Rehabilitation of degraded, abandoned barren lands by using fast-growing leguminous trees must be encouraged.

—Strengthening of technology transfer through training programs for both extension workers and farmers.

Future research work should place emphasis on:

—Soil conservation practices with emphasis on agronomy. Crop management and soil erodability factors for soil loss prediction should also be focused.

—Soil fertility regeneration and maintenance through integrated plant nutrition systems.

—Soil management practices with minimum or no disturbance of soil surface together with mulching and recycling of crop residues.

—Improvement of crop cultivars to assure tolerance to stress including drought, insects, diseases and soil toxicities.

—Existing cropping/farming system research be focused more on upland areas.

—Agroforestry research to better understand how woody and food crops species can be effectively combined in sustainable systems.

—Research and development on the production and use of multipurpose tree species.

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# Technology Generation and Transfer for Sustainable Upland Agriculture: Problems and Challenges in Southeast Asia

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*Abstract*

Sustainable agricultural development of marginal uplands poses a set of complex issues arising from the rapidly changing economic and demographic conditions of Southeast Asian countries, the long-term nature of required investments and the great diversity of socio-economic, bio-physical and politico-institutional environments. Technology design, testing and evaluation are considerably more difficult due to the longer time horizons involved. Low adoption rates of new technologies can be traced to information problems as well as perceived low private returns from such adoption; adequate private incentives for adoption are essential as regulations are difficult to implement. It is emphasised that solutions to sustainability issues in marginal uplands cannot be found solely within those areas; they require favourable developments in the broader economy. Productivity improvements in lowland food crop agriculture have played and will continue to play a crucial role in alleviating pressure on uplands. Research strategy must recognise this interdependence between upland and lowland agriculture.

TECHNOLOGY generation for sustainable agricultural development poses a set of complex conceptual and technical problems. In the case of marginal upland areas, these problems are made more acute by the large off-site effects of resource use patterns and the wide diversity of biophysical and agroeconomic environments found within the seemingly homogeneous conditions implied by the term 'marginal uplands'. They are further aggravated by the results of the relative neglect of these regions in the past; thus there is a paucity of information and a smaller set of appropriate component technologies available for developing more productive technology packages. Until quite recently, the focus of agricultural development efforts in Southeast Asia has been on raising productivity in the rice sector and in some of the key plantation crops (rubber and oilpalm, in particular). With the exception of some areas where high valued temperate crops were grown to serve the urban population centres, the marginal upland areas have been bypassed by the agricultural transformations associated with the Green Revolution. They are, therefore, poorly endowed with infrastructure facilities and are home to some of the poorest of the poor.

## Research Goals and Sustainability

Any discussion of the challenges and opportunities for technology generation for sustainable agricultural development of these areas requires a clarification of the objectives of such research. This raises the issue of exactly what is meant by sustainable agricultural development. The concept of sustainability is one surrounded by intense passion, controversy and debate. Definitions of sustainability are numerous and are increasing almost daily but any consensus on its meaning appears distant. A conference held in Australia in July 1989 (Dovers 1989) which started off by attempting to address the issue of 'what precisely, or if necessary imprecisely, is sustainability?' ended up by concluding that 'the sole point upon which there was overall consensus was that there is a problem (i.e. that present societies are in many ways unsustainable), and that it is a problem of considerable magnitude'. Unfortunately, this is quite representative of the general absence of agreement and clarity on what constitutes sustainability. The World Commission on Environment and Development's report Our Common Future (1987) has been criticised for internal inconsistency in its definitions of sustainability and, in any case, offers no clear guidelines for policy formulation; the Blue Print for a Green Economy (Pearce, Markandya and Barbier 1989), overcomes some of the

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conceptual problems present in Our Common Future, but is itself subject to many of the same conceptual problems (Clarke 1990).

A fundamental issue in this context involves the attitude adopted towards existing environmental 'capital'. A concept of sustainability which envisages **complete** preservation of such existing environmental capital excludes possibilities of conversion of a part of such capital into other forms of (man-made) capital to be used for satisfaction of material human needs; the majority of available or potential agricultural technologies (which modify or alter the levels of environmental capital) will have no place if such a definition of sustainability is adopted. Most economists, certainly, will disagree with such a definition, arguing that there can be some trade-off between preservation of environmental capital and its transformation, through agricultural and other economic activities, to other forms of capital. The optimal trade-off will need to take into consideration the entire range of social objectives, the value placed on the existing natural environment for its own sake, and possible irreversibilities which would suggest a more cautious approach to activities leading to environmental changes, given that our state of knowledge and information is imperfect.

The framework suggested recently by Lynam and Herdt (1989) for incorporating sustainability considerations into agricultural research appears to be consistent with the broader concept of sustainability suggested by the above considerations. They define sustainability as 'the capacity of a system to maintain output at a level approximately equal to or greater than its historical average, with the approximation determined by its historical level of variability. Hence, a sustainable system is one with a non-negative trend in measured output; a technology adds to system sustainability if it increases the slope of this trend line'. This definition is consistent with, but not identical to, the widely quoted definition of Conway (1985) that sustainability is the ability of a system to maintain productivity in spite of a major disturbance; the latter concept has been criticised as being merely the definition of resilience (Dover and Talbot 1987). They go on to suggest that the appropriate measure of output to be used to determine sustainability is total factor productivity of the crop, cropping system or farming system. Their analysis of the issue leads to a series of important conclusions in terms of the attributes that agricultural technologies and the research process should possess to ensure sustainability of particular agricultural systems. In particular, they conclude that '...to be successful the biological research agenda will have to complement the continued use of inputs in the intensification of farming systems in the tropics'. Further, they argue that increased market dependence can, in fact, enhance the sustainability of broadly defined agricultural systems enabling an easing of pressure on the more fragile ecosystems and point out that 'the sustainability of a system is not necessarily dependent on the sustainability of its sub-systems'.

The important implication is that the national food system, for example, may be sustainable even if a particular sub-system, such as a regional agricultural system, proves to be unsustainable.

## The National Context

If we were to adopt the broad framework proposed by Lynam and Herdt to examine the specific issues involved in generating technologies for sustainable agriculture in marginal upland areas, it is important to bear in mind that the agricultural systems in such areas in each country have to be viewed as a sub-system of the broader **national** agricultural system, which is, itself, a subsystem of the national economy. The upland research agenda must be firmly placed within the national context; it must be based on the dynamic interactions between the upland systems and the rest of the economy and, in each country, should be seen as an integral part of the broader strategy for sustainable agricultural and general economic development.

Some key statistics for the four Southeast Asian countries are presented in Table 1. As can be seen, while they are all considered to be developing tropical countries, there are quite striking differences as well as similarities between them. Philippines is by far the most densely populated country, while Malaysia is the most sparsely populated. However, note that the figure for Indonesia masks the huge concentration of its population in Java which has 7% of the land area and over 60% of the total population. The population is everywhere becoming increasingly urbanised; in Malaysia and the Philippines, over 40% of the population is already `urban'. Rapid structural changes of the economics are reflected in the changing composition of gross domestic product (GDP). Agriculture has been declining in relative terms quite rapidly. This is nowhere more strikingly evident than in Indonesia where its share in GDP fell from 54% in 1965 to 24% in 1988. Even in Thailand, until recently considered an agricultural economy, agriculture contributes only about one sixth of total GDP. Food production, in per capita terms, has been growing quite slowly during the 1980s; in fact, the Philippines recorded a 10% decline during the decade. A diminishing share of land is devoted to forestry; the rapid increase in deforestation is an issue of serious concern throughout the region (see Byron and Waugh 1988, for a survey of the evidence).

The inter-country differences are most striking when per capita income levels are considered. Malaysia's per capita income is more than four times that of Indonesia and three times that of Philippines. GDP growth rates, too, show significant differences and Philippines has been the poorest performer in the region which has generally recorded rapid growth. (In fact, over a longer period, the differences are even more striking; in 1960, Thailand's per capita income was only half that of Philippines; in 1990, it had risen to one and a half times that of the Philippine figure).

These broader economic circumstances impact on the patterns of development that condition the nature of appropriate technologies for any particular agricultural sub-system. Even if the basic agro-ecological conditions prevailing in certain locations within this region may be quite similar, broad generalisations regarding appropriate technologies should be avoided to ensure that the differences in the key socioeconomic variables— both at the local and national levels—are fully incorporated into any analysis.

The importance of national level differences can be illustrated by examining the different attitudes to development technologies for sustainable upland systems in Peninsular Malaysia and Java. As Aminuddin, Chow and Ng (these proceedings) point out, 'In Peninsular Malaysia, low emphasis is given to research on the cultivation of annual crops and subsistence farming on steep lands'; rather, the emphasis is on commercial tree crops, including sub-tropical fruit trees. High labour costs, reflecting Malaysia's high income levels and remunerative non-farm employment opportunities, make subsistence food crop farming unprofitable and unattractive. On the other hand, the low income farmers in Java continue to depend on their land for a major part of subsistence food requirements and are more likely to adopt labour intensive new technologies involving annual food crops (see, for example, Roche 1988; Barbier 1989). Obviously, such differences are inevitable across, as well as within, countries given the wide diversity of conditions prevailing at different locations. This, however, does not imply that there are no common issues in the R & D area. In the following sections, some such issues are identified and discussed.

## The Role of Technology

At the start of the research process it is important to demarcate clearly those parameters in the environment which have to be assumed as given by the agricultural researchers whose focus is on the generation and transfer of new technology. In this context, note that many problems of non-sustainable land use arise from problems related to property rights, which are particularly important

**Table 1.** Selected Statistical Data: Indonesia, Malaysia, Thailand and the Philippines (Sources: *Asian Development Bank Outlook 1990;* World Bank, *World Development Report 1990).*

| | Indonesia | Malaysia | Philippines | Thailand |
|---|---|---|---|---|
| Total land area ('000 sq km) | 1905 | 330 | 300 | 513 |
| Arable land area (as percentage of total) | 8.5 | 3.1 | 26.5 | 34.6 |
| Population —1988 (millions) | 174.8 | 16.9 | 59.9 | 54.5 |
| Av. annual growth rate of population (1981-89) | 2.3 | 2.8 | 2.8 | 2.5 |
| Population density/sq km | 92 | 51 | 200 | 106.2 |
| Share of urban population (%) | | | | |
| —1965 | 16 | 26 | 32 | 13 |
| —1988 | 27 | 41 | 41 | 21 |
| Forest and woodland (as percentage of total land area) | 67.1 | 59.6 | 36.7 | 28.2 |
| Average index of food production—1986-88 (1979-81 = 100) | 117 | 106 | 90 | 101 |
| Cereal imports ('000 t) | 1702 | 2387 | 1322 | 303 |
| GNP per capita —1988 (US dollars) | 440 | 1940 | 630 | 1000 |
| Share of agriculture in GDP | | | | |
| —1965 | 56 | 28 | 26 | 32 |
| —1988 | 24 | 21 | 23 | 17 |
| Share of industry in GDP | | | | |
| —1965 | 13(8) | 25(9) | 28(20) | 23(14) |
| —1988 | 36(19) | 40(n.a.) | 34(25) | 35(24) |
| (Share of manufacturing given in parenthesis) | | | | |
| Share of manufacturers in total exports (%) | | | | |
| —1965 | 4 | 6 | 6 | 4 |
| —1988 | 29 | 45 | 62 | 52 |

when there are significant off-site effects ('externalities') which do not affect the land owner (or operator). For example, lack of title to land or the prospect of future eviction from land would generate patterns of land use that would be socially undesirable even if all the 'appropriate' technology was available. Similarly, if farmers can ignore the adverse off-site consequences of their farming practices, they will have no incentive to adopt available technologies which minimise such effects. These issues are well known to social scientists, though implementation of appropriate corrective action is much harder than the identification of the problems. Research for technology generation in a given situation has to be based on assumptions about the particular socioeconomic environment, such as the land tenure system, that is likely to prevail in the future. Thus, the expected future pattern of land tenure can dictate the suitability or otherwise of a particular technology. In general it is important to stress that new technologies and institutional and policy reforms are required to achieve sustainable development. New improved technologies may be a necessary condition for such sustainable development; but they are by no means a sufficient condition.

## The Time Factor

The time involved in the research process and in the implementation of technologies raises a key problem confronting researchers working on upland development. Typically, most technologies which target sustainability as an objective involve relatively long-term investments such as building of terraces, cultivation of long-lived tree crops and raising of livestock. Even when the research process involves only annual crops grown in relatively stable and predictable agro-climatic conditions, the design, testing, adaptation and transfer is a process typically involving a minimum of 4–5 years; the necessary projections on costs and returns required to assess the economic viability of a particular technology even within such a relatively short time period are difficult. A much more difficult task faces researchers who are forced to make projections of expected costs and returns over a much longer period of time in the context of rapidly changing economic circumstances even assuming away the difficult problems of measuring the impact of the relevant environment–related factors required to evaluate sustainability. The complications introduced by the time factor go further. Firstly, when the costs and/or returns are staggered over a long period of time, the weight attached to current and future costs/revenues has to be included in an economic assessment of the technology. While relatively simple rules can be used for such an exercise when an efficient capital market (e.g. a banking system) permits lending and borrowings at a specified interest rate, in developing economies where most small farmers (particularly, in the upland areas) do not have ready access to such a capital market, this poses daunting problems.

Secondly, the technology generation and evaluation process itself takes much longer if the performance of the new technology is to be properly assessed; for example, the performance of a tree crop, such as rubber, under a new cropping system can only be properly evaluated over a period of 20 years or more. While some short cuts in the assessment process are necessary and can be made, the R & D process is intrinsically more complex and lengthy. (These conceptual issues in technology evaluation are addressed in more detail at this workshop.) From a practical point of view, there is an additional problem arising from the fact that funding for such long-term projects is more difficult to obtain as most funding agencies are reluctant or, due to financial regulations, unable to provide such long-term funds. There is also tremendous pressure on researchers to provide quick answers, given the urgency of the problems.

To the extent that a range of technologies is already available, the immediate issue is one of evaluating their appropriateness for the diverse range of conditions prevailing in the marginal uplands. Planning of future research, however, requires greater attention to circumstances likely to prevail in the medium to long run.

What is encouraging about developments in the region is that, despite the difficulties, considerable research into sustainable upland agriculture has been done and more is in progress. Researchers have innovatively tapped research findings available for various component technologies (e.g. tree crops in a monoculture situation) and, with imagination and ingenuity, have undertaken the difficult task of developing new technology recommendations.

## Performance of New Technologies in Uplands

During the 1980s many attempts were made in several parts of the region to establish more sustainable upland agricultural systems based on new technologies. The new technologies typically involved some forms of terracing of the land and the cultivation of a combination of annual and perennial crops, including grasses, leguminous shrubs and tree crops. In the relatively remote areas where deforestation was seen as a major cause of land degradation, the new systems had a reafforestation component; when practiced on a community basis, these new agro-forestry systems were expected to lead to sustainable social forestry systems.

Unfortunately, despite some isolated 'successes', the extent of adoption of the new systems has been generally rather disappointing. The basic problem appears to be the obvious one; farmers are often unconvinced that expected benefits from such projects outweigh the costs. The point made by Hosier (1989) in relation to agro-forestry systems is more generally relevant: 'Agroforestry has gained popularity because of its appeal as an ecologically sustainable approach to agricultural development. However, it is production from agroforestry that makes it an attractive land use system for farmers, not its environmental benignancy'. Fujisaka and Sajise (1986), reviewing the Philippine experience with upland development projects, concluded that 'introduced technologies have so far offered potential adopters limited long-term or societal benefits and substantial costs. As such, in-place or indigenous practices have necessarily been preferred by most uplanders: and adoption of new technologies and project participation have been limited'. In an analysis of upland projects in Java, Barbier (1989) pointed out that when the new technologies involve cultivation of tree crops with gestation lags of three or more years, adoption 'may be extremely difficult for poorer farmers who are dependent on very small landholdings for food production and who have no alternative cropland or employment opportunities' . In such circumstances, new agricultural systems which are socially desirable may not be adopted as they are privately unprofitable from the farmer's point of view.

The divergence between social and private profitability (assuming that the new technologies are indeed more socially profitable) has to be addressed by raising the private benefits of adoption or by raising the private costs of non-adoption. When significant off-site social costs are incurred due to non-adoption of the new technology (as when soil erosion results in downstream siltation and flooding problems), in principle farmers can be penalised for socially harmful behaviour. Even if the difficult problems associated with measurement of soil erosion and their harmful effects can be overcome, given the realities of social and political life in developing countries, it appears most unlikely that governments would attempt to tax upland farmers who belong to the poorest segments of the population to impose on them the costs of such externalities, and the costs of tax collection, in any case, are likely to be very high. Regulations designed to reduce socially harmful agricultural practices are even harder to implement and police in developing countries compared to developed countries; economic incentives are a clearly superior tool to regulation in terms of achieving the socially desirable systems of land use. The solution, therefore, has to lie with increasing the relative attractiveness of adoption.

To the extent that farmers' non-adoption is due to lack of adequate understanding of the private costs of non-adoption (e.g. the effects of erosion at current levels on land productivity) or the benefits of adoption (e.g. lack of appreciation of the future returns from tree crops) the problem is one of information dissemination, i.e. effective extension work. Information problems cannot be underestimated. Even in developed economies where farmers have far greater access to information, perceptions of the effects of, say, soil degradation are widely inaccurate (Rickson et al. 1987). It must be stressed that lack of information about the long-term effects of agricultural technologies is not necessarily confined to introduced new technologies. In many parts of Southeast Asia, upland agricultural systems are now the home to recent migrants from the lowlands who have little appreciation of the effects of their current practices (based on lowland agricultural conditions) on upland ecosystems. Further, even when the farmers have been long-term residents in upland areas, rising population pressures, greater commercialisation and other exogenous developments have altered the farming systems so that the impact of traditional technologies in the new farming conditions on land productivity can be poorly understood. If such information gaps are the primary factor causing non-adoption, effective extension activities are the obvious answer. Extension services in the uplands are usually poorly developed; further, providing effective extension services to convey information on a system-based, complex technology package is far more difficult than extension focused on a single crop or crop technology. If the information requirements for the adoption of a new technology are very high, the technology should probably be considered 'inappropriate'.

While the information problems should not be underestimated, researchers are often too easily tempted to attribute non-adoption to farmers' lack of understanding when the problems may be rooted in the nature of the technology itself. Intensive extension efforts, combined with direct and indirect subsidies, are typical of major development projects which focus on a target group of farmers. Under such conditions adoption levels are generally superior. However, even if some subsidy payments may be justified on the basis of capital market imperfections and the existence of important externalities, the intensity of resource mobilisation focused on a small target group that is achieved in a special project cannot be generally practiced on a larger scale due to budgetary constraints; hence, the particular 'success' may not be replicable and little adoption outside the project areas may occur. In certain conditions, when the target farming population is small and the government's financial resources are high, it cannot be ruled out that such resource-intensive projects may provide the answer; this may, for example, be relevant in parts of Malaysia. In general, however, the ecologically sound new technologies would need to offer farmers sufficiently large private incentives to induce adoption.

Developing technologies which offer the benefits of sustainability as well as high present profits is obviously no easy task even if the target location is homogeneous and well defined. It is even harder to develop technologies which will perform in a robust manner across diverse biophysical and socio-economic environments. Appropriate technology development will necessarily involve careful attention to site-specific factors drawing both on available scientific information as well as on farmers' own insights obtained through experience. The broad methodological approach presented by Zandstra et al. (1981) for developing new technologies for cropping systems offers useful directions, but the issues posed in upland systems are made far more complex by the greater diversity of ecosystems in the uplands, the greater sensitivity of technology performance to biophysical as well as socioeconomic parameters, the lack of information and component technologies (e.g. suitable seeds, tree cultivars, etc.) and the complications introduced by the longer time factor. Methods for improving the research process in upland situations include greater use of farmers' knowledge and participation (Fujisaka 1989). While farmers have much to contribute to the research process at all stages, in the context of rapidly changing circumstances the value of farmers' past experiences are necessarily limited; an interactive partnership between farmers and researchers is necessary for optimal results. However, while continuing efforts to develop more productive and sustainable upland systems have to be pursued, miracles cannot be expected. Broad national strategies should involve policies aimed directly at better technology generation for uplands as well as policies which would tend to reduce the intensity of those factors which are putting continual pressure on these fragile ecosystems.

In this context, it is useful to distinguish between two types of upland agricultural systems. Firstly, there are the very highly productive upland systems, located in relative proximity to the population centres, which produce high valued, often temperate climate, horticultural crops (e.g. Cameron Highlands in Malaysia; Ngadas, East Java; Baguio, Philippines). Secondly, there are those upland areas where, either due to distance or physical characteristics, farmers practice low input, subsistence oriented farming systems. In areas in the first category, farmers practise high input farming systems with heavy use of chemical fertilizers and pesticides, and attempt to maintain productivity through ever greater applications of such inputs; for example, in Ngadas, East Java, it has been reported that 1000 kg /ha of chemical fertilizers are used to produce two 10 t potato crops (Barbier 1990). The extent of productivity decline in such upland systems varies from location to location depending on factors such as initial topsoil depth but, in general, topsoil losses on steep slopes and chemical residues which pollute waterways are steadily worsening problems. The extent to which farmers can maintain current farming practices is influenced by government policies in relation to agricultural chemical input subsidies (which are substantial in Malaysia and Indonesia, in particular). However, such farmers who are strongly commercialised and relatively well-off have shown that they are receptive to technologies which can help contain soil erosion problems. Carson (1987) reports that farmers in Ngadas (Java) started to engage in soil conservation measures and increased their use of organic fertilizers when they realised that better soil conservation measures were more profitable than resorting to continually higher application of chemical fertilizers. Being better-off commercial farmers, they have better access to capital markets; hence, they are more willing and able to undertake long-term investments for land improvements. Increasing consumer resistance to heavily chemically contaminated horticultural crops, too, has helped to move them away towards more sustainable forms of agriculture involving lower use of pesticides.

In the upland areas belonging to the second category, farmers are unable to afford to replenish the land with sufficient chemical fertilizers to even partially arrest declining land productivity. Lack of access to capital markets effectively constrains them from undertaking cash-intensive long-term investments to sustain land productivity; in any case, the cost of waiting for such investments to bear fruit is often too high. Such farmers are trapped in situations of declining land productivity and rising poverty; their agricultural practices also confer significant adverse effects on the rest of society through negative off-site effects.

## Sustainable Development of Marginal Uplands and the Wider Economy

In conclusion, it must be strongly emphasised that the solutions to the problems of sustainable development of marginal uplands cannot be found solely within the uplands themselves. A holistic approach which sees the inter-linkages of the upland systems and the wider economy or, in economics terminology, a general equilibrium approach, points to the importance of developments elsewhere in the economy.

Successful large-scale shifting to more sustainable systems, which are more likely to involve perennial crops rather than annuals, would require some important changes in the wider economic environment. Firstly, rapid economic growth with an expansion of employment in labour-intensive industry and service sectors, coupled with slower population growth rates, would reduce the incentives for migration from lowlands to uplands and, at some point, would begin to reduce upland population pressures both relatively and absolutely. Greater off-farm employment would also lower incentives for intensification of upland land use. Secondly, improvements in the capital markets (and/or the provision of cheaper credit) would facilitate the long-term investments necessary for arresting land degradation. Thirdly, rapid technological change in lowland food crop agriculture would lower food prices as domestic food supplies significantly affect domestic prices and make it more attractive for upland farmers to shift to commercial tree crop cultivation and purchase their food from the market. Such a loss of 'food self-sufficiency' and increased market dependency would raise their welfare as well as that of society in general. Nor is there any reason to fear that such a change would necessarily lower their food security. As has been demonstrated in the analysis of famines throughout the world, famines are more likely in situations where market linkages are poorly developed; famines hardly ever happen in urban areas! Fourthly, economic growth resulting in higher income levels makes it possible for countries to afford the necessary investments in ecosystem preservation.

Finally, it should be noted that there is a direct and important interdependency between lowland and upland agricultural research. The faster the rate of growth of lowland food crop agriculture and consequent declines in relative food prices, the greater will be the potential for establishing sustainable upland systems, provided researchers have developed attractive alternatives to subsistence food crop production. There can be little doubt that the massive increases in food production achieved in the past two decades through the Green Revolution in lowland agriculture have contributed enormously to the alleviation of pressures on the ecologically fragile upland regions. In this context, the doubts raised about the potential long-run viability of the current lowland rice technology (Pingali et al. 1990) have disturbingly direct relevance for the region's capacity to establish sustainable upland agriculture. The essential complementarity between productivity and sustainability in the lowland and upland agricultural systems must be the basis for an integrated approach to sustainable agricultural development.

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# The Role and Impact of Socioeconomic and Policy Research in Effecting Technology Adoption

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## *Abstract*

Deforestation, population growth, and soil loss have led to reduced sustainability of the marginal uplands of Southeast Asia. Farmer-appropriate technologies to address problems of soil degradation being developed by researchers are largely agroforestry based. Adoption of such technologies have been limited in the target areas. Socioeconomic and policy research on adoption have been concerned with: a) issues directly tied to particular technologies such as near-term costs and benefits or land tenure, and b) broader issues of agricultural intensification, near vs long term benefits, 'incompatible use goods' or 'public choice' problems, and learning costs. Socioeconomic and policy issues relevant to the adoption of sustainability enhancing technologies are examined and implications of some of the broader issues are touched upon.

ONE definition of sustainability is a 'non-negative trend over time in terms of particular systems attributes' (Lynam and Herdt 1988). As such, the declining productivity or stagnant productivity at increased input rates is indicative of reduced sustainability of many upland agroecosystems in Southeast Asia (i.e. Burma, Thailand, Laos, Cambodia, Malaysia, Indonesia, and the Philippines). Three causes include continued conversion of tropical forests, increasing population pressure, and soil loss and soil nutrient depletion (although not the same) in areas now used for agriculture.

The Food and Agriculture Organization (FAO) drew a bleak picture of the forest: more than 50% of the global tropical forests have disappeared since 1900; more than 11 million ha are deforested per year; more than 50% of the developing world's people live in the 56 most affected countries; and 1.5 billion people depend upon wood for cooking and heating in developing countries (FAO 1983).

Southeast Asia is characterised by a high annual population growth rate (2.05, 70% higher than that of E. Asia's 1.22: United Nations 1986) and low per capita arable land. Population growth has led to increasing demands for upland agricultural land and fuelwood. In the Philippines, an estimated 30% (18 million) of the country's population live in areas of 18% slope or greater (Cruz 1986); and 79% of all households rely on fuelwood for cooking (Cabrido 1984). Similar trends are evident in Thailand and Vietnam. Settlement of Indonesia's infertile outer islands is substantial and in part actively encouraged by the government.

Upland sub-ecosystems in the region include gently sloping, moderately fertile drylands of less than 18% slope where productive agricultural systems are feasible and also those with strongly acidic, infertile hilly lands (Garrity and Sajise 1990). Unfortunately, most upland agricultural systems in Southeast Asia are located on the approximately 180 million ha of erodable acid Ultisols. In recent decades, these areas have been subject to extensive deforestation, massive human settlement, and environmental degradation in the form of soil erosion and loss. In general, soil losses have increased as upland agriculture intensified from traditional shifting cultivation featuring short cropping periods (1–2 seasons) and long fallows (10–15 years) to longer cropping periods and shorter fallows and, in many cases, to permanent plough agriculture of annual crops and even greater intensification (e.g., to more than one crop per year). Indicating the magnitude of the problem, the major rivers in Southeast Asia carry ten times more sediment out to sea than any of the river systems of other parts of the globe. Measurements of soil losses indicate that open field sloping agricultural systems in Southeast Asia typically lose 2 to 4 cm of soil per year or the equivalent of 200 to 400 t/ha/year.

Many technologies developed by researchers to enhance sustainability of upland agricultural systems are agroforestry based. These include alley cropping, home gardens, taungya systems, and various mixes of trees,

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pasture, crops, and livestock (Huxley 1983, Kang et al. 1984, Young 1986, Steppler and Nair 1987, Young et al. 1987, Cuc 1988, Capistrano et al. 1990, Gordon and Bently 1990). Work with farmers has shown that: a) different types of contour hedgerow systems (Huxley 1986, Samson 1986, Fujisaka 1989a, Garrity and Sajise 1990, Watson and Tacio 1990) and minimum tillage (Sajise 1982) are appropriate ways to control soil erosion in permanent plough agriculture; b) legume and perennial based improved or enriched fallows are appropriate ways to improve shifting cultivation systems (Ahn 1979, Mongi and Huxley 1979); and c) engineering or mechanical structures for soil erosion control (Jasmin and Martin 1984, Saplaco 1983, PCARRD 1984) are not feasible for adoption by Southeast Asian upland farmers. In spite of these findings, there has been little adoption of even agroforestry technologies considered 'farmer appropriate'.

## Policies for the Adoption of Sustainability Technologies

A review of ongoing work reveals that policies regarding access to forest resources, land tenure, credit (and subsidies), price, markets, and costs-benefits (near-term) have been considered to be relevant to upland farmers' adoption of innovations leading to more sustainable systems.

### Deforestation and its effects

The conversion of tropical forests initially reflected national forest policies of the 1950s when it was assumed that wealth created by industrialisation would trickle down to benefit all. Commercial forestry provided quick infusions of needed foreign exchange to support such development in Southeast Asia (as is still the case in Laos and Cambodia); and governments saw forest revenues as a legitimate right. Research has shown, however, that benefits have not accrued to rural people (Dargavel et al. 1985, Shepard 1986); and the need to change forest policy to benefit the poor is now being felt in some countries (Westoby 1983, Evans 1986). Timber cutting remains a major cause of forest conversion and needs to be considered on a regional basis: cutting of Indonesian, Malaysian, and Philippine forests in the 1970s to supply wood to Japan which was then able to protect its forests (Fujisaka 1985, Westoby unpublished) may now be occurring with the cutting of Lao and Burmese forests to supply Thailand and protect Thai forests.

In the 1970s and 1980s, policymakers favouring forest protection in Southeast Asia largely accepted that cutting forests reduces rainfall, dries up water supplies, causes floods, and leads to accelerated reservoir sedimentation (Vohra pers. comm.). These effects of converting tropical forests to other uses, however, have not been scientifically established (Hamilton 1983); and more research on the effects of forest conversion is needed.

Overall, research is needed to determine the effects of forest conversion to other uses, the amount of forest lands 'needed' as forest per country and by the region, and the wisdom of banning forest land use by small farmers. As discussed in the following section, governments have given considerable attention to this last point.

### Land Tenure

The need to earn foreign exchange and protect forests led to policies to exclude settlers and agriculture from forest lands. The Thai government tried to preserve 50% of its lands as forest (Pragtong 1987); Indonesia is 75% forest, with 50% classified as production and 24% as reserved forest (Tjodronegoro 1987); in the Philippines, 62% of the area is public and 32% is forest land (Cornista 1987). On these areas, farmer settlers have commonly been classified as 'squatters'. State control of the uplands is even more complete in mainland Southeast Asia.

Attempts to exclude people from forest lands have been unsuccessful; and environmental degradation accompanied the expansion of upland agriculture. Researchers contend that long-term land tenure security leads to adoption of better management practices by poor upland farmers in Southeast Asia (Soermarwoto and Soermarwoto 1984, Sajise 1987, Roche 1988, Pingali and Vo 1989). As a result, national governments realised a need for new policies regarding land tenure and community access to forest resources.

Approaches that grant land use rights (but rarely ownership) are being tried. The Philippine social forestry program grants use rights (25 year renewable leases) to individuals, communities (usually tribal minorities), and associations in return for more sustainable management. In Thailand where 23% of national land was cleared for agriculture in the last 20 years, the Royal Forest Department encouraged tree plantations in public areas settled by small farmers, with farmers receiving wages for labour and limited rights to cultivate annual crops. Limited success of the plantations led to a Land Certificate Program in which farmers' land tenure systems are respected (land and tree tenure belonging to farmers, can be transferred via inheritance, but cannot be sold) and the Department assists farmers in tree planting (Pragtong 1987). Although it started a social forestry program (Fox et al. 1990, Sunderlin et al. 1990) and although researchers pointed out a need for tenure rights for farmers (Soetrisno 1987, Tjondronegoro 1987, Suwardi Machfud 1990), the Indonesian government has generally tried to maintain control over forests and teak production.

More research is needed, however, on the implementation of policies and the danger that beneficiaries may easily turn out to be the 'richest of the rich' rather than the 'poorest of the poor' (Fujisaka and Capistrano 1985, Dove 1987, Barber 1989, Fox et al. 1990). Research is also needed on customary or traditional tenure vs legal tenure so that the former can be incorporated where it continues to exist (Lynch 1986), and in order that 'traditional' forms are not created where they have ceased (Shepard 1986).

### Credit and subsidies

The role of credit in the adoption by upland farmers of soil-conserving technologies is not well understood; and more research on the subject is needed. Although governments have often taken a view that credit or subsidies are necessary for farmer adoption of soil conservation technologies, research has generally shown that credit and subsidies hinder, or at least do not contribute to, sustainable adoption (Kirwan 1986, Austria and Bantilan, unpublished, Huzar and Cochrane 1990).

### Markets and price policy

Perennial cash crops can be soil conserving (Greenland and Lal 1977); plantation cropping has been found to be more stable than annual cropping on upland acid soils (Craswell and Pushparajah 1989); and in Philippine 'farm forestry' projects farmers were encouraged to grow trees via loans and guaranteed markets (Foley and Barnard 1985). In spite of the above, commercial incentives for farmers to shift from annual to perennial cropping have been weak. An exception on Java where small farmers adopted perennial crops was due to there being fertile volcanic soils, strong world prices for the major export crops of coffee, coconut, and cloves, and import barriers protecting fruit production (Roche 1988).

### Near-term costs and benefits of agroforestry technologies

In spite of the importance of evaluating costs and benefits over the near and long-term to adoption of sustainability enhancing technologies (Kummer 1984, Harrington 1988), little has been accomplished even in terms of near-term impacts (Austria and Bantilan, unpublished, Mindajo 1978, Tapawan 1981, and Segura, de Los Angeles 1986 supplied examples from the Philippines). As a result, it remains difficult to evaluate statements such as, '...a technology promoted by a project should...offer a high financial rate of return, i.e. of 50–100% or more. A possible increase of 10 or 20% will not stimulate rapid uptake' (Hudson 1990).

## Broader Issues

Broader issues can also be considered in examining lack of widespread adoption by farmers of technologies intended to enhance the sustainability of the acid uplands of Southeast Asia. Issues include the process of agricultural intensification in general, as well as concerns for near vs long term benefits, incompatible use goods and public interests, farmers' learning costs, and various policy issues (Harrington 1988).

### Agricultural intensification

Fortunately, present day social and agricultural scientists agree with the well documented notions that farmers are fully rational, that agricultural intensification has taken place in many areas of the world as populations grew (Boserup 1965), and that farmers have adopted soil conserving technologies where rates of return to land investments were sufficiently high (Pingali et al. 1987 and Roche 1988). At the same time, less adoption has occurred on more marginal areas, as in the acid uplands of Southeast Asia, where farmers may migrate to other areas, engage in off-farm enterprises, or reach a low-yield/low-input equilibrium in which soils are mined for nutrients and soil conservation measures are not adopted (Pingali and Binswanger 1987, Pingali 1989) inspite of their awareness of and concern about the problem.

### Near vs long term benefits

To the degree that subsistence level farmers are forced to prefer present over future consumption (Davis and Schirmer 1987), technologies directed towards improving sustainability must be considered over time. Farmers may be forced to reject technologies if near-term benefits are low; and may continue unsustainable practices if near-term benefits of such practices are substantial. Unfortunately, many projects trying to understand and address sustainability problems ignore the phenomena (and the underlying 'time value of money' concept). A recommendation is to apply the tools used by economists to compare costs and benefits earned at different times (Gittinger 1982). In order to do so, appropriate time horizons have to be chosen and benefits and costs corresponding to present and future time frames need to be estimated (Harrington 1988).

### 'Incompatible use goods' and 'public choice'

Different groups can have conflicting and interacting goals; and 'rational' individual actions viewed at the group level can lead to system degradation (Schmidt 1978). Upland annual cropping without soil conservation technologies may cause soil erosion and downstream irrigation system siltation and degradation. Quantitative evidence, however, supporting this commonplace idea is inconclusive (Hamilton 1983, Johnson 1988). In this case, upland and lowland farmers are at odds (i.e. there are 'incompatible use goods') and the issue becomes what is in the public interest and how can it be served, i.e. analysis of 'public choice' is needed (Olsen 1965, Buchanan, 1968).

### Learning costs

Technologies for long-term enhanced sustainability can be difficult to learn. Practices associated with such technology sets as integrated pest management, reduced tillage, and contour hedgerows require learning investments. That the 'learning costs' can be so high as to discourage adoption has been proposed (Byerlee and Hesse de Polanco 1982).

Implications are simple but crucial: upland farmers often cannot adopt technologies that force a choice between near term survival and both long-term personal as well as public benefits. Technologies that are difficult to master will have additional problems in adoption.

## Implications and Conclusions

Technologies will not be adopted if near and long term rates of return are low. The acid uplands, unlike the volcanic hills of Java, feature conditions that may continue to result in a low-yield/low-input equilibrium and continued system degradation. Action is needed, however, because other possibilities, e.g. the idea that lowland and urban economic development would result in migration from and eventual environmental recovery in the uplands (Mellor pers. comm.), are not taking place at a sufficient pace or are not taking place at all. Consensus as to what can be done, albeit without any guarantees of success, is emerging along the following lines:

1. Institutional change may be as important as technical change. Granting upland farmers land tenure rights is a step in this direction. Land tenure security may also form a part of farmers' near-term benefits to the adoption of technologies that otherwise pay off only in the long term.
2. Although credit and input subsidy schemes do not work, awareness that near term goals of upland farmers may not coincide with the broader public goal of environmental protection argues for increased, but careful and selective, public investment in sustainability enhancing technologies (Blaikie and Brookfield 1987, Bojo 1988, Fones-Sundell 1989). The global community may be realising this in its recent debt-for-conservation swaps.
3. In order to develop sustainability-enhancing upland technologies that make sense to potential adopters, awareness of the need to build upon farmer knowledge (Richards 1985, Raintree 1987, Fujisaka 1989a, ODI Social Forestry Network Papers, and many others), to meaningfully involve farmers in the development, testing, adaptation, and extension of such technologies (Chambers et al. 1989, Fujisaka 1989b, ODI Agricultural Administration [Research and Exension] Network Papers, and many others), and to carefully consider gender-based issues (Fortmann and Rocheleau 1985, Shepard 1986, Borlagdan et al. 1990) has continued to increase in recent years.

Innovations intended to ensure system sustainability must not only function technically as intended, but must provide potential adopters with alternatives whose returns are attractive even when discounted over the long term. The questions as to what such benefits are, what they might be worth, and who would pay for them remain to be answered.

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# Integrated Research and Development Projects in the Uplands

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## Abstract

Upland farmers have been cultivating hillsides for thousands of years. Farming systems were sustainable as long as opportunities to migrate existed. This is no longer true. Increasing population pressure has caused extensive pressure on the land which has led to non-sustainable farming sytems. Hill-land farmers have not adapted to new environmental, social and economic conditions.

The farmer must adopt farming practices to meet new challenges. A basic approach involving six steps which projects can use to bring about this adoption and implementation of technologies on a sustainable basis is described. Three supporting mechanisms which will enhance implementation of the basic approach are listed.

Three Philippine upland resource management projects which have used the six basic steps and support mechanisms are briefly described. Important basic lessons gained from project implementation are enumerated while indicators of project sustainability are listed.

## Upland Farming Systems

THE upland environment has become, during the past 20 years, a focal point for developmental efforts. Public agencies and private organisations both have contributed efforts to assist local residents stabilise and protect their natural resources base while obtaining an adequate income from their labours. All groups basically attempt to obtain the same goal: a sustainable, ecologically sound production system.

This farming system can take many forms but generally includes permanent as well as annual crops, an integrated animal component, appropriate technologies and proper land use. One or more of these components can be combined to formulate systems which, over time, can prove to be sustainable and provide ecological, financial, and social stability.

If we look at the systems which exist in the uplands today, we frequently find they closely resemble those systems developed many years ago. In some cases the systems are hundreds of years old. The slash and burn (swidden) systems used by the original settlers are examples. A farmer clears the land, plants crops for a few years, and moves on when the soil is depleted. Sometimes, the farmer returns several years later when the land has recovered and is again productive. The system has been proven sustainable over a long time frame. These farmers can be looked upon as reasonably good natural resource managers.

The system worked when there were few farmers. Population growth makes this less possible today. The ability to move to new areas has been reduced or completely eliminated. However, the burning and vegetation removal part of the system remains. Forest areas in the Philippines have been reduced from 17 million ha to 6 million ha, about 57% and 21% of land area respectively. Out of this, only 1.04 million ha of old growth Dipterocarp, seasonal Molave and broad-leafed forests remain (USAID 1989). The production systems which have replaced these forests are generally not sustainable and provide a substandard living for the implementer. These systems must be improved.

In spite of the changing ecological and social situation, and the fact that the systems are ecologically unsound, many upland farmers have not changed their production systems. More appropriate farming methods have been developed through research efforts, but they are not applied by the upland resource manager.

Therein lies the problem. The environmental, social, as well as economic conditions have changed but the local resource managers have not. They continue to farm in the same way as their forefathers. Consequently, their systems have become non-sustainable and frequently destructive.

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A sustainable upland farming/resource management system requires that the farmer must first know how to adopt and modify his farming system to meet changing conditions, second, he must be comfortable with the idea of change, i.e., he must not be afraid of change, and third, he must trust the technology he uses.

One method to find out what works and what does not is to conduct 'research' on a specific technology and methods. Universities, private companies, government agencies and individuals are constantly engaged in this activity. New technologies, plant and animal varieties, storage methods and marketing strategies appear daily. However, the application of these ideas, products, strategies under field conditions in the mountains is generally far removed from the conditions under which the formal research has taken place. The upland farmer operates under much harsher conditions than his 'lowland' counterparts. Frequently the necessities for complicated or long term research are missing. This however does not stop the farmer from carrying out his own 'research'. The effects, though, are limited as is his exposure to new ideas.

## How Does an Upland Farmer Change His System?

If they are extremely poor, or the 'poorest of the poor', chances are they will not make many changes or attempt to 'experiment with a new crop'. Why? If they fail, their families may go hungry. If the farmer is financially better off, he may more readily initiate change. The increments of change, however come in small doses. The farmer will certainly not risk substituting one crop for another or using a new technology simply because some project or government extension agent tells him he will obtain much better yields. He must prove to himself that the new crop/technology is better and then work out the fine points of growing the new crop or using the technology so he feels comfortable with it.

If the results of the experiment are positive, there is a good chance the farmer will adopt and increase the planting area or the use of the technology on his farm.

## Stimulating Research and Its Application

There are various methods which upland management projects may use to generate the enthusiasm required to stimulate farmers to conduct research, experiment with new ideas and then apply these ideas to the local situation. These activities, in turn, can generate the sustainable farming systems required to stabilise the farmer's natural resources while providing a decent living for the family.

### The Basic Approach

Successful upland management projects work with technologies which have a good chance of success and with farmers who are willing to implement them. Technologies should be tested on site. If not on site then in places where similar ecological conditions exist as those found at the farming site. It should be noted that each farmer usually has a system and no two systems are exactly the same. The plants and animals selected, technologies used, and allocation of farm areas vary from farmer to farmer, site to site. Projects can teach technologies, recommend varieties, teach skills but the farmer is the person who makes the final decision as to what happens on the farm. The farmer is the one who will determine if a given resource is used properly, conserved or squandered for a short term return on investment rather than long term sustainability.

There are six basic steps (See Bunch 1985) which have been used in several projects here in the Philippines to teach farmers to be better resource managers and develop their own sustainable farming systems. To do this, we implement small-scale experimentation and then facilitate the spread of experimental results. The basic steps in the process are:

1. *Start with the farmers' technology.* This is critical to any sustained development. There are many technologies existing today which are very appropriate for the given situation. In some cases, the existing technology may need slight modification or changes to make it more sustainable but still retaining its ecological soundness.

2. *Discover limiting factors (constraints to sustainable production).* Frequently development projects start without thoroughly investigating why people are not adopting better farming methods. A clear understanding of local constraints is necessary to determine where interventions should take place.

3. *Select the appropriate technology to remove the constraint.* Generally the simplest technology is the most effective. It may be that a small modification in an existing technology is all that is required. Other technologies introduced may be more complicated but should not be totally unfamiliar to the local residents. The technology selection is a critical step which can determine future project success. The technology may come from outside the site but should, if possible, have already been examined and tried by other farmers.

4. *Test the technology on a small scale.* The testing should be done on a farmer's field, under his given management conditions. This means that he is not 'paid' for the work or the area used is his entire farm. The research is generally simple. One variable experiments with plot sizes ranging from a few square metres to 0.25 ha are adequate. The plot size is determined by how much land a farmer is willing to risk for the experiment.

5. *Monitor/evaluate.* Both the farmer and the technician are responsible for this activity. Items to be monitored should be listed before the experiment begins. A simple data form may be devised for data gathering purposes. A final evaluation should be made after the experiment is completed. In most cases, this will be after harvesting. The evaluation is better accomplished and more significant if neigbouring farmers are brought in to witness the event and help determine the usefulness/appropriateness of what has been tested.

6. *Teach farmers to teach the technology.* Once satisfactory results have been obtained and initial farmers feel competent with the innovation, some or all should be used to teach the technology to neighbouring farmers. This mechanism ensures that the technology is passed from one farmer to another and does not require extensive 'extension' programs.

## Supporting Mechanisms to Help Ensure Success

There are different supporting mechanisms which can assist implementation of the above six steps.

A. *Cross-visit.* This is the popular term given to the process of one or more farmers visiting other farmers who have successfully implemented and maintained technologies on their own fields. It may also mean educational trips to appropriate schools, experiment stations, research farms. This activity is perhaps the fastest way to generate interest if the conditions that exist at one site are similar to those at the other site.

B. *Starter packages.* If farmers are to make innovations, they frequently require some inputs. Examples would be seeds or other planting materials if a new variety or species is to be tested. Tools or other equipment may be necessary. If inputs are needed, they should not be free. A mechanism must be designed so the farmers can obtain ownership of equipment/hand tools or can give back the amount of seeds if the trials are successful. If the trials fail for reasons other than negligence, the loss is absorbed by the project.

C. *Continuous follow-up by technician/farmers.* Going on a cross-visit, returning home and not implementing at least some of the knowledge gained from the trip, negates the purpose of the trip. To assist farmers and maintain the interest the project technicians must visit the cross-visit participants on a regular schedule. These visits will reinforce the farmers' implementation activities and show the project is interested in the results.

All farmers who participate in the cross-visit should also exchange farm visits. Periodic meetings may also be held to ascertain the status of the technology implementation.

## Three Philippine Project Examples

### A. The World Neighbors Assisted Soil and Water Conservation Project, Cebu, Philippines (Granert et al., 1985, 1988).

This project was started in 1981 at two sites in Cebu. It has expanded to three sites in Cebu and, as a joint effort with the International Institute of Rural Reconstruction, a fourth site in the Bicol region. Originally, there were five farmers in the Guba, Cebu City site and four in Argao, Cebu. From this humble beginning, the Guba site grew from five farmers in one sitio (division of a barangay/village) to 450 farmers in six barangays in 1988. The other site grew from 4 to 125 farmers in Argao. From the very start, farmers were encouraged to test different innovations on a small scale. Frequently, new innovations were developed by farmers without assistance from the formal project staff. Table 1 gives a summary of some of the new crops and technologies which have been implemented and/or developed at the project sites.

### B. The Rainfed Resources Development Project (RRDP) — Jose Panganiban Agroforestry Project (RRDP 1987).

This is the most successful of the 15 agroforestry projects under the RRDP. The USAID-funded project was implemented through the Department of Environment and Natural Resources. Originally the project was implemented by administration. The last 2.5 years have been the responsibility of the private foundation formed by the staff and project participants. All of the extension work carried out in the project expansion areas has been done by specially trained farmer instructors. The farmers have carried out a number of field trials to test sustainability of new crops, methods of hillside stabilisation and livestock integration. (See Table 1).

### C. Manjuyod and Mananga River Watershed Development Projects (Soil and Water Conservation Foundation 1990).

These two relatively new (1.5 years old) projects are carried out with the assistance of the Soil and Water Conservation Foundation, Inc.

The Manjuyod River is located in Manjuyod, Negros Oriental while the Mananga River is located in Cebu City and Talisay, Cebu. Both projects have started with a number of technicians dispersed in several barangays. The technicians work with interested farmers, solving immediate farming problems while teaching natural resource management and sustainable agriculture. Small-scale experimentation on farmers' fields has been used in the project to test new technologies, try new crops, and as a means to assist in selecting potential farmer instructors. Major project crop and technology interventions are shown in Table 1.

**Table 1.** Examples of technologies/tested/developed/adopted by three field projects using small-scale, on-farm experimentation

| **Technologies/New crops** | WN(1) | RRDP–JPAP(2) | SWCFI(3) |
|---|---|---|---|
| A-Frame transit construction and use | x | x | x |
| Basic animal medicine application | x | – | x |
| Napier grass production | x | – | x |
| Cacao production | x | x | – |
| Cacao varietal trials | x | | |
| Goat production — upgrading, breeding | x | – | – |
| Swine production | – | – | x |
| Hedgerow species trials | x | – | x |
| Fodder production for zero tillage systems | x | x | x |
| Corn varietal trials | x | – | x |
| Rotation cropping | x | x | –[1] |
| Organic fertilizer trials | x | x | x |
| Fish pond development | – | x | – |
| Fish breeding (Tilapia) | – | x | – |
| Corn inoculant trials* | – | – | x |
| Plant propagation | | | |
| — marcottage | x | x | x |
| — budding | x | x | – |
| Citrus production | x | x | – |
| Vegetable species trials | | | |
| Tomato | x | – | x |
| Cabbage | x | – | – |
| Garlic | x | – | – |
| Wax peppers | x | x | x |
| Chayote | x | – | – |
| Beans | x | x | x |
| Squash | x | x | x |
| Flowers | x | – | x |
| Sweet potatoes (6 varieties) | x | x | x |
| Pineapple | x | x | – |
| Farm planning | x | x | x |
| Biomass studies of covercrop | x | – | – |
| Nursery management technologies | x | x | x |
| Small-scale contract reforestation | x | x | x |
| Soil and water conservation technologies | x | x | x |
| In-row tillage | x | – | – |
| **Generated Technologies** | | | |
| Ubi planting behind contour canal mound | x | – | – |
| Mixing techniques for commercial and organic fertilisers | x | – | – |
| Pruning techniques for eggplant/pepper | x | – | x |
| Local adaptations of SWC structures (check dam, soil trap, drainage systems) | x | x | x |
| **Social Technologies** | | | |
| Tried on small scale to start | x | x | x |
| Use of work groups for implementation | x | x | x |
| Use of small revolving funds for credit | x | x | x |
| Regular farmer participant meetings | x | x | x |
| Cross visits to other farms/sites | x | x | x |
| Self and peer evaluation | x | x | x |

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* In progress of establishing practice

[1] WN = World Neighbors Assisted Soil and Water Conversation Project

[2] RRDP–JPAP = Rainfed Resources Development Project-Jose Panganiban Agroforestry Project

[3] SWCFI = Soil and Water Conservation Foundation, Inc.

The project has made special use of cross-visits to the Baptist Rural Life Center in Bansalan, Davao del Sur. Here the farmers have observed first hand technologies which may work in the same or modified forms on their own land. Ten-year old examples can be shown to farmers who have implemented the technologies on their own farms during the past 6–12 months. The encouragement and broadening of experiences that these farmer-participants gain also reinforce ideas originally introduced in the project sites.

## Are the Projects Sustainable?

This question is frequently asked. In the case of the RRDP and World Neighbors projects, the answer is' yes'. The Soil and Water Conservation Foundation implemented watershed projects are still very young. They are, however,following the general pathways of their predecessors.

In all cases, farmers have already been, or are, in the process of discovering they are: a) very capable of improving their own farming systems; b) diversifying their cropping pattern; c) planting more permanent crops; and d) able to carry out their own research with proper monitoring, evaluation and then to decide if they wish to continue with the technology. In two projects, the World Neighbors and RRDP, the projects have already formed local foundations which are composed of some staff members and local farmers. These foundations now receive funding from sources other than the original funding agency.

## Lessons Learned From These Upland Projects

There have been many lessons learned from these projects (Sabueto 1989, RRDP 1990, Granert 1990) which may be helpful to other projects. These lessons mentioned below come from the field projects and are specifically directed towards the technologies and ways of implementing them at the project sites.

—Some inputs are required for a project. These may include an agreed amount of hand tools, seeds, seedlings and fertilizers (organic/inorganic) which should not be given free. Cash should not be given.

—Proper orientation to a technology is critical. A farmer must understand the technology and why it works.

—A project should try to mobilise traditional work groups as a way to implement selected project activities. Field testing of technologies, new plant varieties and species, livestock adaptation, soil and water conservation technologies are good tasks for such groups.

—Soil and water conservation systems should be tied to increased food production or other short term returns on investment or the systems will not be adequately maintained.

—Soil fertility in land between soil conservation structures must not be overlooked. This is a good area for trials of different fertilizers, legume rotation, multiple and relay cropping studies, use of legume inoculants.

—Animals are extremely important from the standpoint of both income generation and manure production. Feeds should be grown on the farm.

—A farmer-based extension system should certainly be a goal if the project is to phase out and leave behind a trained group of local persons who can better manage their natural resources. The system allows capacity building at the local level.

—The technologies introduced should initially resemble the technologies which are already present on the site.

## Some Indicators of Project Sustainability

There are several indicators that projects exhibit which will indicate there is a move towards stability. The World Neighbors project and several RRDP projects have these indicators. The Soil and Water Conservation Foundation Inc. projects are beginning to show these indicators on a smaller scale.

**Social indicators**

—Replication of the technology without regular staff involvement

—Increasing number of adopters

—Lessening demand for project assistance from the community

—Decision making shifts to the local participants

—Plans for the project are made by and implemented by the community

—Increase in formal and informal organisations in the community

—Increase in number of full-time farmers

—Increase in number of children who regularly attend school classes

—Decrease in number of people who engage in destructive natural resource management practices (such as illegal logging, kaingin making, fish poisoning) as well as destructive social practices (excessive drinking, smoking, fighting)

—Increasing willingness to protect the natural resources of the community

—Enhanced ability of farmers to use their own farm trials and make innovations

**Bio-physical indicators**

—more permanent crops planted

—better and more regular maintenance of on-farm and community structures

—Increased or maintained water flow from springs during dry months

## Conclusion

The methods suggested in this paper to develop satisfactory upland research and development projects whose end goals are sustainable resource management systems are not difficult to follow. There are numerous opportunities and ways to carry out each of the six steps depending on a person's orientation. The most critical points to remember are: first, begin where the farmers are, at their technology level and proceed from there, and second, trust the farmers. There is a tremendous amount of knowledge which can be generated if the local farmers are treated as partners in research and development. Third, to plan and implement with them from the very beginning of the project. Based on the experiences of RRDP, World Neighbors and the Soil and Water Conservation Foundation, Inc. good progress is being made towards sustainable uplands. The six steps do work!

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# Technologies for Sustainable Agriculture on Marginal Uplands in South East Asia: an AIDAB Perspective*

*Summary*

AIDAB has given high priority to agricultural development projects as a means of achieving its broad objective of promoting the economic and social advancement of the peoples of developing countries. As a result, AIDAB has built up considerable experience in projects aimed at adapting and developing technologies for sustainable agriculture on marginal uplands in South East Asia. This paper aims to to summarise this experience in terms of a number of common broad lessons, some specific agronomic lessons and a suggested strategy for developing future sustainable agricultural technologies. AIDAB wishes to maintain the high priority given to agricultural assistance and believes that it can continue to make a valuable contribution to the development of sustainable agricultural technologies for developing countries, including the marginal uplands of South East Asia.

## AIDAB's Role and Functions

THE Australian International Development Assistance Bureau (AIDAB) is an autonomous Bureau within Australia's Department of Foreign Affairs and Trade, charged with delivery of Australia's official development cooperation program. The broad objective of the program is to promote the economic and social advancement of the peoples of developing countries in response to Australia's humanitarian concerns, as well as Australia's foreign policy and commercial interests. Australia provides about US$950 million ($A1.00 = US$0.79) each year for development cooperation, some 0.33% of GDP. AIDAB aims to ensure that its programs are properly planned, subjected to detailed appraisal, and reviewed regularly. The Bureau is managed on a program basis, with responsibility resting with individual program managers. Country programs are the core of the bilateral cooperation program, requiring the formulation of strategies which establish the most appropriate Australian response to each individual country's development needs. Country programs receive about 70% of annual allocations. Global programs (about 25% of allocations) include Australia's contributions to international organisations such as FAO, and international financing agencies such as the World Bank and the Asian Development Bank. Australia's global programs also contribute significantly to the international agricultural research centres and to emergency and refugee programs. In addition, the Bureau provides direct assistance to international agricultural research, valued at some US$43 million over the last ten years, through the projects and programs of the Australian Centre for International Agricultural Research (ACIAR).

## AIDAB's Agricultural Operations

Agricultural cooperation (about US$260 million per year) forms about a third of the total Australian development cooperation program, and agricultural projects receive about a third of such agricultural assistance. Over the past ten years (1978–79 to 1987–88), AIDAB has provided about US$650 million for some 1150 projects in agriculture, forestry, fisheries and livestock. Over that period, forestry received about 7% of agricultural project funding, fisheries 5%, and livestock 6%. Agriculture per se thus forms the largest share of agricultural services (extension, research, quarantine etc); approximately a third for both agricultural education and training, and the balance for a wide range of agricultural production schemes.

Most agricultural cooperation is with countries in the tropics, with about 85% targeted at South East and North Asia, Papua New Guinea, the Pacific and Africa. AIDAB's interest in sustainable agriculture on marginal uplands in South East Asia is demonstrated through the funding of specific land capability surveys; the improvement of institutions providing services in land use and agricultural planning; promoting reforestation; and adapting and developing appropriate agricultural technologies for all land development and crop improvement projects supported by Australia's development cooperation program.

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## AIDAB and Sustainable Agricultural Development

In common with nearly all donors, AIDAB reacted in the 1970s to the problems of severe food scarcity and chronic rural poverty by focusing mostly on projects to increase food production and accelerate rural development. While there have been important successes in these areas in some countries, in other countries famine and poverty persist. Some of our projects have been a little over-ambitious and, because of that, not too successful. However, our success rate parallels that of other donors. Other concerns have become more urgent in recent years, particularly the importance of achieving sustainable agricultural output, given the evident depletion of soils, forests and fisheries.

## Developing Sustainable Agricultural Technologies on Marginal Uplands

### Common problems of uplands or hill people

If one of the principal objectives of Australia's aid program is to promote the economic and social development of the people of developing countries, then it seems appropriate that aid projects should address the socioeconomic problems that these people have to confront. A number of poverty-related problems seem to be common to many of these uplands people:

—food scarcity is prevalent due to increasing population pressure and decreasing land productivity resulting from increasing soil erosion and decreasing soil fertility;

—poor health and sanitation, due to poor water supplies (in both quality and quantity terms), endemic diseases and inadequate health services, are commonplace;

—poor education services result in many people being illiterate;

—physical access is often so poor that many may only be contactable by walking tracks;

—the isolated environment in which these people live generally means that they have a different language (or dialect) and culture from the bulk of the population, which may result in communication problems;

—insecurity of land tenure is particularly acute for those people who are actually marginalised lowlanders.

### Common broad lessons

A number of broad lessons can be synthesised from AIDAB's experience with projects aimed at developing and encouraging the adoption of sustainable agricultural technologies for these marginal uplands. Owing to the complex nature of the technology development and adoption process, it is not appropriate to confine these lessons to the technical dimension only. The following are some of the more important lessons:

—Institutional development of key line department(s) is needed to support and implement technological change. Particular areas of emphasis included: planning and administration procedures; identification of program priorities and the reallocation of resources accordingly; definition of roles and lines of authority and responsibility; postgraduate training and the need for bridging programs; middle level management courses and the training of extension officers in technical and extension skills; and the nurturing of cooperation between key institutions and levels of government.

—Emphasis upon the training of line department staff and farmers is generally regarded as a key factor in ensuring the sustainability of project innovations.

—Land tenure security is basic to farmers adopting a responsible attitude to long term strategies such as conservation farming practices.

—The bottom-up planning process using the problem-census/problem-solving method has assisted with the process of participatory development and hence project effectiveness. For social and cultural reasons it is likely that the communities in upland areas will have a high priority for non-economic objectives. This suggests that community development components will have a high priority and may be a prerequisite for significant and sustainable agricultural development.

—These upland areas have historically received relatively low priority in the allocation of government developmental funds. While this explains the poor levels of health care, education and other government services, it also has implications for the recipient government's commitment to ongoing funding of the new initiatives and hence their long term sustainability.

—Projects implemented by special project management offices established outside of the regular programs of key line agencies have doubtful sustainability. In fact, the effectiveness of advisory teams has often been enhanced by locating them within the appropriate line agencies.

—NGOs often have a valuable role to play in supporting technological change, particularly at the community level.

—Detailed land capability and use plans need to be determined and agreed with the villagers concerned before implementation starts, to reduce the scope for conflict between villagers and resource conservationists.

—The adoption of single-species introduced agricultural production packages in a high risk environment are vulnerable to failure (e.g., the devastating insect damage to the *Leucaena* forage crop in West Timor).

—It would be fair to say that until the mid 1980s the valuable role of women in development was underestimated.

—The introduction of multiple cropping programs, based on improved technologies which require nontraditional purchased inputs into largely subsistence, resource-poor, rainfed farms, have not proven sustainable once project subsidies have been withdrawn.

—Even when an appropriate agricultural technology existed, its widespread adoption was often constrained by difficulties experienced in obtaining credit or problems associated with marketing of the product.

### Some specific agronomic lessons

Considerable differences in the climatic, social and economic settings between the various AIDAB projects in marginal uplands make it difficult, and arguably inadvisable, to generalise about the agronomic lessons learned from specific projects. Hence, the following lessons need to be interpreted with these limitations in mind and considered as a sample, rather than an exhaustive list of these lessons:

—Evaluation trials in northern Thailand have shown that one to three metre grass strips on the contour can reduce the annual soil loss from over 50 t/ha to less than 2 t/ha. These grass strips are as efficient as bench terraces, do not cause the yield reduction associated with the construction of terraces and can be installed by farmers for a fraction of the cost of terrace construction. However, to date, the rate of adoption of this livestock and contour strip technology package has been slower than expected, due partly to a problem with land tenure security and partly to the longer time-frame associated with the benefits.

—The successful adoption of coffee as a cash crop on the medium slopes (36-55%) in northern Thailand, has significantly raised farmers' incomes and released land which could be returned to native forests.

—The adoption of legume-based crop rotations in northern Thailand has been slower because the lower food yields are counter to the farmer's first priority of meeting short term food deficits.

—In northern Thailand, the alternation of dryland rice and peanuts in 10 m strips on the contour has resulted in reduced soil loss.

—From a technical point of view, the key to successful and stable dryland cropping of upland soils in northern Thailand centres on the maintenance of organic matter, prevention of compaction, surface protection, crop rotation and adoption of contour earth works, contour planting, and strip-cropping procedures.

—The following set of guidelines for watershed development has been adopted in northern Thailand:

0–5% slope: paddy
6–35% slope: field crops and contour grass strips
36–55% slope: tree crops
>56% slope: forest

—The introduction of improved pasture legumes into natural grasslands and contour planting of tree legumes on the steeper slopes has improved livestock production, produced sustainable fuel-wood supplies, and reduced erosion in West Timor.

—In the dry upland of West Timor, intercropping offers potential for at least stabilising food production and possibly even increasing food production and farm income. The main intercropping system involves crops which do not compete against maize, the principal upland crop. Crops that mature after harvesting the maize crop and grow on residual soil moisture are preferred, e.g., cassava, sorghum and pigeon peas. Crops that have a similar growing period to maize, e.g., peanuts, are not well accepted because they compete for available resources. Intercropping is most popular with farmers who have sufficient land to ensure that the amount of maize produced is maintained.

—Relay cropping with short-term duration crops, while a reasonably common practice for increasing food production in West Timor, has potential for further development. The planting of early maturing peanuts (80 days), mungbeans, sweet potato and cowpeas warrants further consideration. The relay crop should be planted as the maize crop matures and the canopy of the maize crop opens.

—Intercropping perennial crops with annual crops has the potential to reduce the variability of food crop yields, but will tend to reduce the annual crop yields. Alley cropping with tree legumes is one promising method of incorporating a leguminous perennial crop with annual food crops. Alley cropping complements the annual crop by supplying nitrogen, reducing soil erosion and reducing the amount of labour required for weeding and for initial land preparation. In addition, the tree legume also provides firewood, fodder for livestock, and fencing materials. Management of the tree legume is limited to pruning of the tree to reduce competition with the annual crop. Intercropping with coconuts, cashews, candlenut and lontar is reasonably common throughout West Timor. The increased usage of fruit trees is another form of low input intercropping which has potential for diversifying food supply and producing a possible financial benefit.

### A possible strategy for developing sustainable agricultural technologies

Without wishing to be interpreted as suggesting a 'cookbook recipe' for success, the following are a few comments on a possible strategy for developing and encouraging the adoption of sustainable agricultural technologies in marginal uplands:

—Project planning should bear in mind that the primary goal of development is the raising of the people's living standards and welfare. To achieve this, the agricultural component must consider and complement other community/social, institutional and environmental concerns and programs.

—Initially, it is necessary to give consideration to socioeconomic and land use capability surveys to provide an appropriate level of baseline data, key indicators for measuring project progress, and an understanding of existing traditional farming systems, villager needs and institutional issues.

—Having identified the real problems constraining agricultural development, undertake a program of testing possible technologies for long term solutions. It should be stressed that these new technologies need to be not only technically feasible but also environmentally sound, economically attractive, socially acceptable and educationally or managerially attainable.

—Once an appropriate technology has been developed, the next step is to develop a suitable extension program and train field staff thoroughly in how to transfer the message. The adoption process starts with farmers being made aware of new technologies, generally through demonstration plots which may be funded and managed by the project. The more progressive farmers are then encouraged to try the new technology on a small scale, possibly using project supplied inputs. Where the farmer is convinced of the new technology's suitability, adoption on a larger scale may then need to be assisted with inputs supplied from a revolving fund. It must be appreciated that the process of developing appropriate technologies and encouraging their adoption can take over a decade, which is often beyond the time horizon of development assistance agencies. This may mean that this process needs to be funded through successive discreet projects.

—To allow for this gradual diffusion process, and to incorporate concerns about the recipient country's absorptive capacity and its long term financial commitment to these new initiatives, it has been suggested that these projects should have both a phased build up and a lower maximum funding contribution (percentage-wise) from the donor country.

## Future AIDAB Assistance for Sustainable Agricultural Development

AIDAB would like to concentrate its future agricultural assistance on three areas:

—First, we wish to continue developing skilled manpower and facilities to enable our partners to address local constraints to agricultural development, including appropriate policy formulation. It follows that agricultural education and training will continue to be an important development assistance function, though possibly more focused and often through research collaboration.

—Next, technology adaptation and development will become more important. We need to take stock of Australia's experience in sustaining growth in agricultural output, that is, in making agriculture more efficient. We want to apply and adapt this knowledge to serve the needs of developing countries. Our program should facilitate the promotion of new advances, for instance in biotechnology, or in biological control techniques for lowering pesticide use or reducing pest damage. It is our aim that the actual process of developing and encouraging the adoption of sustainable agricultural technologies, for the people of the marginal uplands of South East Asia, will better reflect the suggested strategy outlined above.

—Finally, Australia will give more attention to questions of sustainable agricultural growth and proper husbandry of soil, plant, forest and fisheries resources. We aim to do more through our development assistance to resolve the conflicting demands for use of scarce land, genetic and water resources, and the need to conserve them. Sustainable natural resource management will be the underlying theme.

We expect to focus on these issues in formulating individual country programs and establishing how best we can help. The agricultural projects we support, for instance, must contribute to seeking sustainable agricultural output. In addition, all projects supported by AIDAB are required to be supportive of ecologically sustainable development.

The development of appropriate technologies for sustainable agriculture on marginal uplands in South East Asia is considered to be an important element in the process of promoting the economic and social development of the people who live in these areas. Clearly, from AIDAB's experience we believe that Australia can continue to make a valuable contribution to the development of these technologies through the funding of appropriate research and development projects and programs. AIDAB will be looking to this workshop for further ideas and suggestions as to how the Australian development cooperation program can better contribute towards the development of technologies for sustainable agriculture throughout the developing world.

## Acknowledgment

AIDAB wishes to acknowledge the pre-eminent role played by the numerous personnel involved in these projects; including both consultants and the staff of the recipient governments.

# Soil Management and Crop Technologies for Sustainable Agriculture in Marginal Upland Areas of Southeast Asia

E.T. Craswell* and E. Pushparajah**

## *Abstract*

Improvements in agricultural technology, and hence in crop productivity, in Southeast Asia have been restricted largely to the high potential cereal production areas to the neglect of the marginal uplands. The upland areas are however under increased pressure because of the reduced land:person ratios as population continues to grow. The major soil problems in the upland areas are soil acidity and steep slopes which are widespread and make the land subject to degradation through soil erosion unless appropriate measures are taken.

Recent collaborative research projects in the region have produced new soil management and crop technologies which are designed to enhance the sustainability of agriculture in upland areas. Examples of soil management technologies include the use of dolomitic limestone to increase the yields of groundnut and corn crops grown as intercrops in newly planted rubber plantations. This technology, which is particularly suited to smallholders, not only provides the farmer with cash income before the rubber can be tapped, but also advances the tapping of the rubber trees. Other soil management technologies are designed to reduce soil erosion losses in the steeply sloping areas in the region which increasingly are being cultivated by resource-poor farmers. Hedgerows of *Desmanthus virgatus* planted on the contour, and used to produce mulch to fertilize corn, and protect the soil in the inter-row space, reduced soil loss from 127 to 3 t/ha. Other biological approaches to soil conservation are being tested in research which IBSRAM is coordinating in the region.

Crop management and fertilizer technologies are also discussed. One technology involves a balance sheet approach to assessing the need for sulfur and phosphorus fertilizer inputs. The need for balanced fertilization and especially to take account of micronutrient deficiencies has been indicated in research in Thailand where boron deficiency has proven to be a widespread constraint to food legume growth. Technologies have also been developed for enhancing biological nitrogen fixation, which is a key component of sustainable production systems in upland areas.

Population growth in the Asia region has placed tremendous strains on the natural resource base for agriculture. During the 24-year period from 1961 to 1985, the population grew from 1647 million (50% of the world's population) to 2703 million or 56% of the total. As a result the land:person ratios changed from 0.34 ha/caput for the region as a whole in 1961 to 0.27 ha/caput in 1985. In the developing countries of southeast Asia, the population is projected to increase from 361 million in 1985 to 463 million in 2000 when the area of cropland per person is projected to decline to 0.20 ha/caput (Craswell and Karjalainen 1990). Based on his analysis of FAO's data base on population, land resources and soil constraints, Dent (1989) concluded that the majority of countries in the region have little land left for prudent agricultural use and that some countries have already 'passed the safe arable land frontier'.

In the past two decades Asian agriculture has responded quite spectacularly to the needs of the burgeoning population. For example, over the period from 1973 to 1977, cereal production in Asia as a whole increased at an annual rate of 3.5%, almost entirely due to increases in yield per hectare (Byerlee, 1989). In Southeast Asia total production of rice increased from 59 million t in 1974–76 to 89 million t in 1985. However, much of the expansion in production of rice and other cereals came from high potential, irrigated areas where the so-called green revolution packages of technology were adopted on a wide scale. In contrast, marginal upland areas — with the exception of the plantation crop sector — have been the neglected clients for agricultural research (Remenyi, 1986). These areas are important not only because of the large population they support but also because inappropriate cultivation of the steeply sloping

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upland areas is having major off-site impacts on high potential areas downstream. The World Bank has estimated that 65% of the Asian region's rural population of 1.6 billion live and earn their livelihood in areas which can be classified as rainfed, watersheds (Magrath and Doolette, 1990). The sustainability of agriculture in these areas is the central theme of this workshop and the paper by Jayasuria (these proceedings) presents an analysis of the research and development problems in a regional context.

The success of the green revolution packages of technology in the high potential areas may prove difficult to repeat in the marginal areas for a number of reasons. The green revolution packages consisted largely of semi-dwarf cereal varieties, fertilizers and pesticides and were readily adopted in the high potential areas because farmers grasped the opportunity to increase their profits substantially with relatively little risk. Roling (1990) has suggested that technologies such as these be classified as hardware (seeds and agrochemicals) whereas information- or skills-based technologies can be classified as software. The hardware of the green revolution technologies was relatively easy to disseminate provided farmers had access to credit, which was provided by government schemes in many areas. The large areas of rainfed uplands in Southeast Asia will require a combination of hardware and software, with the emphasis on the latter since the dominating influence of risk in marginal environments on farmers' (and bankers') decision-making is likely to inhibit the adoption of purchased inputs (hardware). To be successful, technologies for sustainable agriculture in the uplands must be based on what the Office of Technology Assessment of the US Congress has termed 'low resource agriculture' (OTA 1988) i.e. the cropping systems should maintain or improve soil fertility with a minimum of purchased inputs, relying on biological nitrogen fixation and efficient nutrient recycling, combined with practices such as mulching to arrest soil erosion.

This paper focuses on soil management and crop technologies required for sustainable agriculture in marginal uplands of Southeast Asia. The technologies discussed are largely those which have emerged from research projects supported by ACIAR. This discussion is preceded by a general description of the soils and cropping systems in the region.

## Soils and Landscape

In Southeast Asia sloping lands account for over 70% of the arable land; 35% of the total area has slopes greater than 30%. Additionally over 40% of the arable land consists of acid upland soils classified as Ultisols and Oxisols. The climate is mostly warm humid tropical although some areas are seasonally dry. The native vegetation is generally tropical rain forest. When initially cleared the soils can sustain productive agriculture for a number of years with little or minimal external input of fertilizer and other agrochemicals. Shifting cultivators recognised the need to put the land under bush fallow for a period sufficient to restore soil fertility through recycling of nutrients from deep in the soil profile and through natural biological nitrogen fixation. However with pressure for more land the fallow period has been reduced or even eliminated. Furthermore, land settlement schemes in some countries have led to the clearing of large areas of forest for continuous cultivation. Unfortunately, continuous cultivation of crops without appropriate soil management practices has led to soil erosion, declining soil productivity and often to the abandonment of land to pernicious weeds such as *Imperata cylindrica*.

The two factors of acid soils and steep slopes are major constraints to sustainability if not managed well. Acid soils have a pH less than 5.5, and are generally low in cation exchange capacity, exchangeable bases, phosphorus and nitrogen. An added factor is the toxic levels of aluminium and sometimes manganese. In these soils the fertility is often governed by the level of organic matter which acts as a store of nutrients, provides additional cation exchange capacity, binds toxic elements such as aluminium, and stabilises the soil aggregates in the surface layers. Clearing the land for agriculture removes the vegetation and, with inappropriate soil management, leads to a rapid decline in organic matter and hence soil fertility. Such deterioration is accelerated by erosive loss of the fertile topsoil in areas with steep slopes and high intensity rainfall.

A further feature of the Ultisols in the region is the often unfavourable texture of the surface soil. Where the soil texture is sandy to sandy clay, cultivation over time leads to the formation of plough pans at 20–25 cm depth. Formation of a plough pan is exacerbated by the use of heavy tractors (as occurs in a number of countries). Plough pans restrict the rooting depth and hence the volume of soil exploited by crop plants. This not only limits the size of the nutrient pool upon which the plants can draw but also reduces the amount of soil water available to the plant. Pushparajah (1990) has shown that in some parts of Malaysia periods of water deficit extending to over 30 days can occur occasionally during the wet season even in areas which on average experience not more than 30 days of moisture deficit in a year. Such adverse weather conditions can be an especially serious limitation if the rooting zone of crop plants is restricted by a plough pan or by sub-surface acidity.

## Technologies for Sustainable Agriculture

In this, the main section of the paper, some examples of component technologies for sustainable agriculture in upland areas are presented and discussed, in line with the theme and purpose of this workshop. Many of the examples given are concerned with technologies which have been the subject of recent research supported by ACIAR and other agencies, so no attempt is made to provide a comprehensive review of the subject. It should also be pointed out that since some of the research results discussed derive from studies narrowly focused on a specific component technology, the most appropriate next step would be a series of on-farm trials with full farmer participation in a multidisciplinary mode i.e. a farming systems approach.

## Soil management technologies

### *Acid soil management in rubber intercrops*

The plantation crop sector has developed sustainable production systems based on the use of legume cover crops to stabilise the soil and provide nitrogen inputs to the establishing tree crops. In the case of rubber, the big disadvantage of this system to smallholders is that it provides no cash income during the first 3–4 years before tapping can begin. Smallholders now cultivate just under 75% of Malaysia's rubber area, large parts of which are in need of replanting (Pushparajah, 1985). If food crops could be grown as intercrops before the canopy of the young rubber trees closed, farmers would be able to supplement their incomes during the re-establishment period. ACIAR project 8375 — The Management of Soil Acidity for Sustained Crop Production — was therefore begun in 1986 as a research partnerhip between the Rubber Research Institute of Malaysia, Universiti Pertanian Malaysia and the University of Queensland with the objective of evaluating the response to dolomitic limestone of groundnut and corn grown as intercrops with young rubber. The project also involved evaluation of liming in continuous cropping but in this discussion the intercrop systems are the main focus.

Experiments over a three year period involving 5–7 crop seasons at both an Ultisol and an Oxisol site showed that an initial application of 2 t/ha of dolomitic limestone increased yields of crops of groundnut and both sweet and grain corn (a basal application of NPK fertilizer was made to each crop). An economic analysis showed that the only profitable crop was groundnut although sweet corn was profitable in some years (Edwards et al. 1990). The yield of the first crop of groundnut at one site increased from 1.24 to 2.72 t/ha when 2 t/ha of lime was applied, which more than paid for the costs of lime application in the first year. One serendipitous outcome of the research was the finding that the production of food crops in the inter-row space advanced the tapping of the rubber by 7–8 months, thus making the technology more attractive to smallholders. This finding means that liming and fertilization associated with the food crop production not only results in an earlier return from tapping but also leads to faster growth and production of wood which is becoming an important product from rubber plantations.

This technology for producing food as inter-crops in plantations on acid soils would find application in many parts of the Southeast Asian region. A number of aspects of the sustainability of these systems warrant special mention. Firstly, the food production gained by the adoption of the technologies will reduce the need to clear more land for food production and hence help to conserve tropical forests. In areas where rubber trees have become old and unproductive, the wood production from felling the rubber trees themselves reduces pressure on the rainforests. Secondly, the growth of the crops will help to stabilise the soil in the inter-tree space at a time early in the plantation development and thus reduce erosion; in this regard, there would appear to be greater incentive to small farmers to vegetate and protect the land with food crops rather than cover crops, although pasture and animal production under the trees would also be a viable alternative. Thirdly, the plantation crop systems which are established are ecologically sensible, and therefore durable, because they are based on trees which are the dominant plant type in the native ecosystem i.e. the tropical rainforest; some authors have called this principle 'ecological mimicry'. Trees not only help stabilise the soil, but also recycle nutrients which have been leached into the subsoil. Sustainability depends on such mechanisms in high rainfall areas so it is not surprising that agroforestry is being advocated widely as the most effective approach to managing upland areas in the humid tropics. In some parts of the Asian region such as Java, traditional agroforestry systems have been in use for many generations and have proven to be diverse, productive and sustainable even in steeply sloping areas. Research to adapt and improve systems such as those in Java and to develop new agroforestry systems should be given high priority.

The ACIAR project identified a number of aspects of the acid soil management systems which require more research. These include the problem of induced magnesium deficiency, the need for better characterisation of aluminium in the soil solution so that the problem of acidity in different soils can be more precisely defined, and the improvement of the management of organic matter. Nevertheless, while this research continues, wider scale testing and economic evaluation of technologies for acid soil management in both inter-crop and continuous cropping systems are warranted. For this purpose, IBSRAM has recently initiated the ASIALAND network on the Sustained Management of Acid Soils which is discussed in more detail below.

### *Soil erosion management for crops on steeplands*

Although common sense would dictate that steeply sloping lands should not be cropped without substantial investments in terracing, land with slopes greater than 30% are cultivated without terracing in many parts of the Asian region. The consequent cost of soil erosion includes both the reduction in on-site productivity of the soil and the negative off-site impacts such as reduced life of water storages, increased incidence of flooding and damage to fisheries etc. A wide variety of mechanical structures have been used for soil conservation but inevitably these require considerable investments beyond the reach of most farmers in the upland areas. Alternative methods of reducing soil loss without large investments of capital and labour have recently become more widely known. These include the use of grass strips (including *Vetiver* grass) and a number of different types of agroforestry, such as establishing hedgerows of shrub legumes planted on the contour. Although these biological means of erosion control are being advocated widely, few experimental data are available on which to base recommendations to farmers. Fundamental information is lacking about the extent of erosion control and the productivity of the various systems in relation to the characteristics of different sites.

Research on soil erosion management has been the focus of an ACIAR project involving scientists from Malaysia, Thailand, the Philippines and Australia. The objectives of the project were to gain an understanding of the process of soil erosion in steep, high rainfall areas and to evaluate cropping systems and conservation practices for erosion control. An illustration of the effect of soil management technologies on soil loss is given in the Table 1 below. The measurements of erosion were made at a site in Los Baños where the soil is a Typic Tropudalf and the slopes 14% to 19%. The farmer practice mimicked the traditional upland farmer practice of clean cultivation up and down the slope. The alley cropping technology consisted of 1 m wide strips of *Desmanthus virgatus* planted on the contour at 5 m intervals to form the alleys in which the corn was planted. Hedgerows were trimmed every 45 to 60 days and trimmings managed as indicated in the Table. In the alley cropping systems, tillage operations were performed along the contour except in the zero till treatment. The results show clearly that alley cropping is an effective means of reducing soil erosion but that mulching of the trimmings of *Desmanthus* was necessary to protect the soil surface in the alleys and thus reduce the rate of soil erosion to a tolerable level. A significant added advantage from zero tillage was not indicated in this experiment. Yield did not vary significantly amongst treatments but greater effects of the mulch on corn yield might be expected after the experiment had been running longer.

**Table 1.** Effects of alley cropping, mulching and tillage practices on soil loss and corn yield (fresh cob weight) during a 3 month period during which 1424 mm rain fell. Site Los Baños (Paningbatan 1990).

| Treatment | Shrub trimmings kg/sq m | Soil loss t/ha | Corn yield t/ha |
|---|---|---|---|
| Farmer practice | 0 | 127 | 1.47 |
| Alley cropping no mulch + tillage | 0 | 41 | 1.47 |
| Alley cropping + mulch + tillage | 0.33 | 3 | 1.47 |
| Alley cropping + mulch no tillage | 0.32 | 0 | 1.49 |

The ASIALAND network coordinated by IBSRAM on the Management of Sloping Lands has since 1988 been engaged in evaluating technologies for sustainable agriculture on sloping lands in Indonesia, Malaysia, Nepal, Philippines and Thailand. Early results of field trials in Chiang Mai and Chiang Rai on an Ultisol and an Alfisol at steeply sloping sites provide valuable data on the effects of different conservation systems on crop yields and soil erosion (Aneeksamphant et al. 1990).

The main approaches taken in the trials include:

—compensating for loss of crop area (due to use of hedgerows, ditches, grass strips) by increasing the planting rate of the crop in the alleys.

—introducing pigeon pea, a multipurpose fast growing shrub legume, to complement the slow growing leucaena in the hedgerows.

—introducing cash tree crops such as coffee and Chinese plum grown on grass strips to overcome farmer resistance to unutilised areas.

Results of the work in northern Thailand show that the traditional farmer practice of cultivating and planting up and down the slope can lead to soil losses as high as 120 t/ha. Alley cropping and grass strips incorporating cash tree crops significantly reduced soil erosion and appear to be quite promising in terms of yield. Though it is too early for conclusive results it is possible to project that these approaches would be useful and amenable to farmer acceptance.

The use of agroforestry systems to stabilise hillsides in southeast Asia would seem to have wide application. The technologies have been available for many years and have been given a strong push by some development agencies, especially NGOs which are attracted by the fact that technologies such as alley cropping can be targeted at the many resource-poor farmers who currently eke out a living in the marginal upland areas. However, more on-farm research is needed to evaluate these technologies and identify key factors determining the rates of farmer adoption, which have been disappointingly slow in many areas. At the same time strategic research — on aspects such as the effects of the technologies on erosion processes and nutrient cycling — is needed to provide a better basis for improving the productivity and sustainability of the systems. The research results will also provide the basis for improved recommendations on land use practices for areas with different soil types, slopes and rainfall intensities. The current basis for such recommendations is derived from research in temperate agricultural areas where very different conditions prevail.

### Crop management/fertilizer technologies

Although nitrogen can be supplied to low resource systems from legumes, phosphorus and sulfur must normally be supplied from purchased inputs. In order to ensure that these inputs are used efficiently, ways must be developed for predicting where an economic response to the fertilizer is likely. Information is also needed on the most efficient sources of the nutrients required and on the best agronomic practices for recycling the nutrients. An especially difficult problem is that of unbalanced fertilization, which reduces the response and profit from fertilizer use. For example, modern high-analysis fertilizers commonly do not contain sulfur. Therefore in areas where the soil is naturally low in sulfur and sulfur accessions in rainfall are low, sulfur deficiency can be induced by the use of fertilizers such as triple superphosphate. Deficiencies of micronutrients can also be induced and constrain responses to applications of major nutrients. This has the even more insidious effect of destroying farmer confidence in the use of fertilizers. Although the term sustainability is associated with 'low input' agriculture in some developed countries where excessive use of agro-chemicals is causing serious environmental problems, it is patently obvious that some use of purchased inputs in marginal upland areas is essential to ensure that the soil is not mined of nutrients, then abandoned to degrade further through erosion. Restricting the access of farmers to fertilizers not only leads to further land degradation but also perpetuates their poverty. As discussed above, the key to sustainable agriculture in the marginal uplands is to combine biological nitrogen fixation and the balanced and efficient use of fertilizers, with nutrient recycling from organic sources.

#### *Phosphorus and sulfur management*

Phosphorus deficiency is a major problem in large areas of Southeast Asia because the highly weathered, acid soils have a high capacity to fix phosphorus (von Uexkull and Bosshart, 1989). As a major nutrient for plant growth, phosphorus is absorbed in relatively large quantities and therefore is removed in large quantities in harvested products e.g. in an unfertilized corn/mungbean sequence at a rainfed upland site in Thailand researchers in an ACIAR project measured an annual removal in grain and crop residues of 20 kg P/ha. Repeated cropping without fertilizer application mines the soil nutrient reserves and eventually yields decline to a point where land is abandoned. In the case of sulfur, a secondary nutrient for plant growth, the removal is less — 7 kg S/ha at the Thai site mentioned above — but the problem of depletion of soil reserves can be exacerbated by the application of sulfur-free N and P fertilizers. In the case of sulfur, some accessions can occur in rainfall; the annual amounts measured in Malaysia by the researchers in the Universiti Pertanian Malaysia ranged from 2 to 30 kg S/ha (Lefroy and Hussin 1990). However sulfur is also susceptible to leaching losses, especially in sandy soils.

Over the past five years the ACIAR project which involves scientists from Indonesia, Malaysia and Thailand and is coordinated by the University of New England, has conducted experiments on the response of upland crops to sulfur and on the interactions between sulfur and phosphorus. In addition crop uptake (and offtake) of these nutrients, the inputs from the rain and fertilizers and the movement of sulfur in the soil profile have been measured. The crop responses to fertilizer can largely be explained by the nutrient status of the soils, the balance between the nutrient input and offtake and, in the case of sulfur, the leaching of sulfate in the soil profile. The use of this balance sheet approach, together with data on the soil sulfur status, allows different cropping systems to be evaluated for their sulfur fertilizer requirements. The research has now shifted to focus on evaluating cost-effective fertilizer sources of sulfur and phosphorus. This is important work for marginal upland areas because low resource systems based on the use of legume trees and crops for inputs of nitrogen will in many instances require external inputs of phosphorus and sulfur to maintain even low to moderate levels of productivity.

In terms of the Roling's classification of technologies mentioned above, fertilizer technologies involve both hardware and software. Much research is aimed at developing or improving the software i.e. the management aspects such as which fertilizer nutrients are needed, and in what combination; when, how and where the fertilizer should be applied; and how crop residues and other organic sources of nutrients can be utilised with fertilizers in an integrated and efficient way. The ACIAR project has provided valuable information about the need for sulfur fertilizer inputs in different upland (and lowland) areas and the extent to which this knowledge is used will depend on how effectively the government agencies in the region can pass the information on to farmers. Progress in this regard has been made in Indonesia where Government policy on sulfur fertilizers for lowland and upland cropping systems was recently reviewed and revised (ACIAR 1990). The decisions taken in Indonesia were based to a large extent on information that emerged from the ACIAR project. However, as with much technology in the software category, it is difficult to assess the economic impact of information gained in such projects or to pinpoint the impact of particular research results.

#### *Micronutrients for food legumes*

Much of the above discussion about the need for sulfur and the impact of new technologies also applies to micronutrients. Micronutrients can be a particular problem for legumes which require molybdenum and iron to ensure effective symbiotic nitrogen fixation. Observations of symptoms of boron deficiency in mungbean, and other crops such as sunflower, in the Chiang Mai valley led to a cooperative research project between Chiang Mai University, Khon Kaen University, the Thai Department of Agriculture and Murdoch University in Western Australia to determine the extent of micronutrient deficiencies of food legumes in Thailand.

Nearly 30% of some 4000 farmers' peanut crops sampled in 50 provinces in Thailand were boron deficient based on the symptom of hollow heart disorder(Bell et al. 1990). This disorder appears as a hollowing and browning of the inside of the peanut kernel. The deficiency was widespread in Thailand but most common in the north and northeast. Most of the samples were from crops in upland areas but boron deficiency was also common in peanut crops grown after rice in lowland areas. The research showed that there were large differences in the susceptibility to boron deficiency of different varieties of soybean, peanut, black gram and green gram. For hollow heart disorder, rates of boron fertilizer as low as 0.6–1.2 kg B/ha corrected the problem. Low levels of boron in the seed of the legumes caused poor germination and loss of viability in storage, contributing to poor seed quality which is a serious problem constraining the yield of legumes such as soybean. Boron fertilizer rates as low as 2 kg B/ha were sufficient for three successive crops after application even on a sandy Ultisol. Other deficiencies discovered include molybdenum, iron and copper, although copper deficiency assayed by foliar analysis was identified in only 1% of 636 farmers' peanut crops sampled.

Current emphasis on blanket recommendations and NPK fertilizers appears to be misplaced. On sites with a single deficiency, the use of compound fertilizers is wasteful and, on sites with micronutrient deficiencies, is ineffective. In northeast Thailand superphosphate enriched with boron and molybdenum would be better for general use than the NPK compound fertilizers currently available. The Soil Science Division of the Royal Thai Department of Agriculture has issued reports and brochures in the Thai language to publicise the new information about micronutrients. The extent to which this technology has been adopted or will be adopted in the future is difficult to guage. One spillover effect of the research is that awareness created about boron deficiency has been taken up by the horticultural sector which can make profitable use of applied boron fertilizer because of the high value of the products.

### *Inoculation of food legumes*

Technologies designed for low resource agriculture are commonly based on the use of legumes and other nitrogen-fixing systems to provide free nitrogen from the atmosphere to the farming system. By substituting a renewable resource or process for nitrogen fertilizer, the production of which is based on fossil fuels which are non-renewable resources, this approach satisfies one of the central tenets of sustainability (Daly, 1990). However, because it is based on a sensitive symbiosis, nitrogen fixation by legumes should not, as is so often the case, be taken for granted. In developed countries most farmers have access to cheap inoculum which supplies effective strains of *Rhizobium* for whichever legume crop they choose to plant. Unfortunately this technology is not available to many farmers in developing countries. Research is needed to determine which crops need inoculation and to select, multiply and distribute effective inoculum for those crops that need them. An alternative approach is to develop or select crop and tree legume cultivars which nodulate effectively with the *Rhizobium* strains already in the soil. This latter approach is particularly appropriate for farmers in marginal upland areas.

Unfortunately research on the ecology of root nodule bacteria is very painstaking and often does not yield clearcut answers. Nevertheless, one example of a fortuitous result from an ACIAR project involving Chiang Mai University and the New South Wales Department of Agriculture is worthy of mention. The project scientists planted a wide range of local and introduced cultivars of soybean at a large number of sites in northern Thailand. The important finding was that the native root nodule bacteria in the soils were very effective in nodulating all of the cultivars, including the introduced soybean varieties, and that inoculation was unnecessary. The sites of the field trials included upland areas recently cleared for cultivation. It appears that northern Thailand is near the centre of origin of the soybean which co-evolved with the root nodule bacteria of the region. The result is fortuitous for the farmers in the area who do not need to inoculate their soybeans and also illustrates the importance of assessing the need to inoculate experimentally before commitment to developing the inoculation technology.

### *Corn–ricebean intercropping*

For upland farmers the cultivation of two or more crops simultaneously — i.e. multiple cropping — has a number of attractions. In addition to providing insurance against the loss of one crop through disease or pest attack, multiple cropping provides variety to the diet and diversity which is a buffer against fluctuations in market prices. When a legume is intercropped with a cereal crop, not only is the extra protein an important dietary supplement, but also the nitrogen fixed by the legume can contribute to the fertility of the soil and thus reduce dependence on purchased inputs. Finding a good combination of cereal and legume species, and developing crop management technologies to maximise the production of both crops, is an important goal for research. In upland areas of northern Thailand, the intercropping of corn and ricebean is being recommended to hill-tribe farmers because it is thought that this cropping system can sustain productivity in the absence of fertilizers (Rerkasem and Rerkasem 1988). Research at Chiang Mai University showed that the relative yield totals of the intercrops were always greater than the yields of the corn and ricebean grown as a monoculture using their respective share of the plant population as the reference point.

One of the important Chiang Mai findings in relation to sustainability came from collaborative research to measure biological nitrogen fixation in the intercropped systems. Some of the research involved CSIRO Division of Plant Industry and was supported by ACIAR. The results showed that ricebean fixed just as much nitrogen when planted in a ratio of 1:3 in a ricebean–corn intercrop as it fixed in a monocrop (Rerkasem et al. 1988). This result occurred because the corn competed with the ricebean for the available nitrogen in the soil, making the ricebean symbiosis fix more of its nitrogen from the atmosphere. Over the long term, intercropping will contribute to the fertility of the soil while at the same time enhancing the overall productivity of the farming system. Intercropping is as old a technology as farming itself. The Chiang Mai work provides knowledge which can be used in the refinement of cereal-legume intercrop systems which have many attractions in relation to sustainability, especially so far as upland farmers in marginal areas are concerned.

## Conclusions

The main clients for the technologies described in this paper are resource poor farmers cultivating the upland areas in southeast Asia which have steep slopes and soils which are acid and are inherently infertile. These areas are being cultivated because the farmers have nowhere else to go. Providing these farmers with improved technologies for sustainable food crop production will improve their livelihood and stabilise the hillsides which they farm. Important indirect impacts of these improvements will be reduced migration to the overcrowded cities, reduced need to clear new forests for cultivation and less off-site damage to high potential areas from soil and sediment originating in the upland areas.

The component soil management and crop technologies described in the paper should now be evaluated in on-farm trials involving a multi-disciplinary systems approach. Obviously, the key factor determining adoption of the technologies will be the extent to which they fit the needs and the socio-economic situation of the farmers.

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# Contributions or Potential Contributions of Technology to Development Problems Within a Sustainable Framework in Crop/Livestock Systems

**Graeme Blair*, Denis Hoffmann**, Tajuddin Ismail*****

## *Abstract*

The integration of animals into marginal upland areas can have both positive and negative consequences which are primarily determined by their density. Proper integration of animals can reduce the risks in upland agriculture through diversification.

A number of technologies have been developed, or are under development, which assist in better integration of livestock and crops. Six such technologies are discussed in the paper. These are:

1. The introduction of appropriate tree and shrub legumes. Whether these contribute to increased sustainability depends on their effect on nutrient cycling rates which is influenced by residue and animal waste management.
2. Soil moisture and plant growth computer models to characterise environments to allow better selection of germplasm.
3. Incorporation of quality forages into upland rubber and coconut plantations.
4. Utilisation of risers of bench terraces by planting appropriate grasses and legumes which can reduce erosion and provide animal feed.
5. Oral vaccination of chickens against Newcastle disease which will reduce the risk associated with integration of chickens into upland cropping systems.
6. Improving feed utilisation by ruminants through the provision of urea–molasses–multinutrient blocks. This technology increases the efficiency of utilisation of crop residues.

The impact of these technologies on system sustainability is discussed.

NUMEROUS links between crops and livestock have long existed in the tropics. These linkages include:

- — Food linkage: almost all livestock-keepers consume cereals and many farmers consume some meat and milk products;
- — Investment linkage: income from crops is used to buy livestock and animals are sold to finance cropping inputs;
- — Manure linkage: animal manure is used to fertilize cultivated fields and home gardens;
- — Forage linkage: crop residues and fallow fields are used as fodder and pasture;
- — Draught linkage: animal traction is used for cultivation and transportation, also of cropping inputs and outputs;
- — Employment linkage: pastoralists sometimes keep animals for farmers, or members of farm families may be employed by pastoralists for herding or cultivation.

There is a diversity of views on the impact of animals in marginal upland systems. Generally there is agreement that chickens and ducks cause little environmental impact when incorporated into upland cropping systems at reasonable densities. Pigs, on the other hand, may

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compete with humans for valuable grain and root crop resources or cause potential environmental damage through the gathering of forage materials from marginal areas. Similarly, small and large ruminants may cause environmental degradation through the impact of overgrazing, soil compaction and intensive cutting of forage and tree material.

On the other hand the introduction of animals may be viewed as a means of income diversity and risk reduction. In many upland situations a viable livestock sector within the cropping system means that farmers have the opportunity to cash in their surplus animals in times of crop failure. There is little doubt that such diversity of income is a favourable aspect of the incorporation of animals into such systems; however, for the system to be sustainable, special attention must be paid to generating fodder resources for these animals. There are a number of technologies which have been developed or are under study which will contribute to a more sustainable integration of livestock into upland cropping systems.

## Shrub and Tree Legumes

The incorporation of nitrogen fixing shrub and/or tree legumes into steepland systems has a number of potential advantages. The trees or shrubs may contribute directly to soil stability, enhance nutrient cycling and provide firewood for households, which can relieve pressure on adjacent forest areas.

The most common form of incorporation of tree and shrub legumes into cropping systems has been that of hedgerow or alley planting of such material. These may be on previously terraced land, where the tree or shrub is planted at the outer edge of the cropping terrace, or on non-terraced land, where close planting on the contour allows the accumulation of soil and debris on the upper side of the contour and hence the formation of natural terraces.

In the past, most attention has been paid to the tree legume *Leucaena leucephala*. This tree has made a considerable impact on upland farming systems on areas such as Timor and Flores, Indonesia and in the Philippines. The success of such systems met with great enthusiasm, such that this single species was planted in a wide range of environments. Many of these were clearly unsuitable to *Leucaena*, such as those with acid soils. In addition, the reliance on a single species meant that the system was potentially unstable because of the risk of insect or disease attack. The arrival of the psyllid insect in Southeast Asia meant that large areas of this valuable tree material were decimated and the sustainability of the technology placed in doubt.

A current ACIAR project titled 'Production and utilisation of shrub legumes in the tropics' (PN8836) is investigating the adaptation of a number of trees and shrubs in upland areas of Indonesia. These studies complement earlier trials conducted in an AIDAB-sponsored Forage Research Project in Indonesia. Both these projects have shown the value of alternative tree and shrub materials. The tree legumes *Calliandra callothyrsus* and *Gliricidia sepium* have shown wide adaptation in both upland and lowland areas of Indonesia. In addition, the short-lived perennials or annuals such as *Desmodium* (formerly *Codariocalyx gyroides*), *Desmodium rensonii* and *Cajanus cajans* have shown particular promise in some locations. The incorporation of these rapidly growing annuals or short-lived perennials into upland cropping systems potentially provides fodder in the short term and thereby allows the longer lived perennial trees to become properly established before cutting commences. The project has identified sufficiently diverse genetic material such that mixed plantings should reduce the risk of insect and disease attack that occurred with *Leucaena*.

There are two alternative systems of utilisation of the leaf material from these trees. The first is to use the leaf litter directly as a soil mulch. This is the most common practice in upland areas in the alley cropping system. In such a system, atmospheric nitrogen fixed by the trees results in a net gain in nitrogen to the cropping system. Whether or not the trees enhance the content of other plant nutrients is not clear. Some argue that the deep-rooted nature of the trees means that nutrients deeper in the profile are taken up and recycled to the cropping system via the leaf litter. If this is the case, then such a redistribution of nutrients may be viewed as a mining operation and non-sustainable. Where nutrients are removed from deeper layers and deposited on the surface in leaf litter, such nutrients are either subjected to surface erosional losses or removal in crop products both of which mean that there is a net outflow of nutrients from the system. In soils where deep leaching of nutrients is a loss pathway, the nutrient balance may be less negative, as the deep-rooted trees may capture sufficient leaching nutrients to counter the other loss pathways. The impact on individual nutrients will vary according to their mobility in soils.

Tree or shrub legume leaf material placed on the surface is subject to a slower breakdown rate and hence a slower release of nutrients from the leaf material. Potential trade-offs from surface application of litter include improved moisture retention from the impact of the litter on weed growth in crops. A system developed at the Visaya State College of Agriculture, Philippines has attempted to incorporate the desirable effects of nutrient recycling and weed control into an alley cropping system. In the uplands areas of Laete, a double hedgerow system which includes *Gliricidia sepium* and *Flamingia congesta* has been developed. The concept is that the rapid breakdown rate of the *Gliricidia* leaf adds nitrogen to the upland rice cropping system, whereas the slower rate of breakdown of the *Flamingia* leaf maintains ground cover which smothers weed growth. Such mulches are applied several times throughout the rice-growing season to maintain a continuity of supply of nitrogen to the system and maintain weed control. Clearly the impact of this system on nutrient dynamics requires further study.

An alternative to use of the mulch is to use the leaf material as an animal feed and to recycle nutrients and organic matter via the animal dung and urine and unutilised leaf material. With many nutrients, such as nitrogen, phosphorus, potassium and sulfur, as much as 80% of the nutrient ingested by the animal is returned in either dung or urine. In addition, a considerable proportion (upwards of 50%) of the ingested fibre material is returned in dung.

In most systems little effort is made to collect urine for recycling so the losses of nutrients such as nitrogen and sulfur can be high in these systems. Recent studies in the AIDAB Indonesian Forage Research Project have indicated that the release of N from urine was more rapid than from dung and tree legume leaf and the incorporation of urine, faeces and leaf material into the soil resulted in increased nitrogen cycling in the system (Fig. 1). This indicates that, with proper management of the urine, an enhanced recycling rate of nitrogen can be obtained. For such a system to be efficient attention needs to be paid to the entrapment of ammonia from the dung and urine material. Such a system is practiced in China, where the daily collection of dung and urine soiled straw bedding material is placed in piles and covered with a thin layer of soil. Such a soil layer acts as an ammonia absorption trap and retains this nutrient within the system. Clearly, for the residue material to retain its nutrient value until required in the cropping system, such material must be stored under cover where leaching by rain cannot occur.

An alternative to the hedgerow system on less critical land, is the provision of fodder banks on land unsuitable for cropping. Such fodder banks can provide a cut-and-carry feed resource for use in upland crop/livestock systems. Recent research (Catchpoole and Blair 1990a) has shown that, in a cut-and-carry system with tree legumes and understorey grass, there is little or no transfer of nitrogen from the tree legume to the associated grass. This means that there is a net removal of nutrients from such fodder bank areas to other parts of the cropping system. It is unrealistic to expect that, without return of either animal residues or fertilizers to such fodder bank areas, they will remain productive. A balance needs to be struck between the recycling of animal wastes and/or fertilizers to the fodder bank areas to maintain their productivity and to the cropping areas to enhance the fertility of these systems.

Clearly, the incorporation of shrub and/or tree legumes into uplands cropping systems is an attractive proposition to enhance the sustainability of the system. However, it must be remembered that such a system may lead to a long-term depletion of nutrients through increased crop removal or removal of nutrients from deeper in the soil profile to the surface where they are subject to erosional losses.

## Soil Moisture and Plant Growth Computer Models

In many marginal upland areas, seasonal droughts are a major limitation to agricultural development. Such events are often exacerbated by the low water-holding capacity of the soil, which results from the low organic matter content and/or shallow soil depth following erosion.

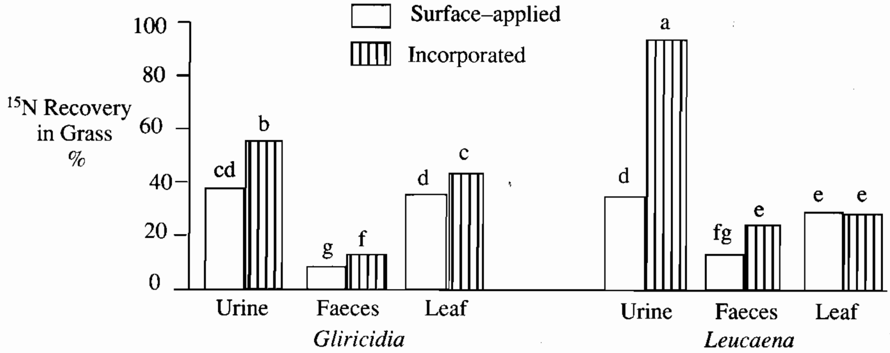

**Fig. 1.** Percentage of applied nitrogen recovered in grass after 10 weeks growth on an N deficient soil. N applied as urine or faeces, derived from goats fed *Gliricidia* or *Leucaena* leaf, or directly as leaf. Treatments showing the same letters are not significantly different ($P < 0.05$ according to Duncan's Multiple Range Test, Catchpoole and Blair 1990b).

Computer models, such as WATBAL, have been developed, which compute soil moisture and quantify its impact on plant growth. Such computer programs rely on rainfall and evaporation data from meteorological stations and estimates of the available soil/water-holding capacity and water infiltration rate. These models can be linked to growth prediction models such as the simple Growth Index (GI) model of Fitzpatrick and Nix (1970). In this model, light (LI), temperature (TI) and soil moisture (SMI) are converted to indices which range from 0 = complete restriction to 1 = no restriction on growth. The GI is computed by multiplication as follows:

$GI = LI \times TI \times SMI$

Such a model has made a significant contribution to the selection of forage germplasm to rehabilitate eroded red soil areas in S. Central China (ACIAR Project 8925). In an area of Hunan Province previously classified as sub-tropical, use of the model has indicated that the environment most closely matches that of the Mediterranean region and that soil moisture constraints during summer means that perennial forage species must possess drought escape mechanisms (deep roots, or high temperature or post-flowering dormancy) or must be annuals which set seed before the rapid onset of the dry season. This has allowed the selection of seeds from germplasm banks not previously thought to be appropriate to the region. Some species such as *Phalaris aquatica, Dactylis glomerata, Cassia rotundifolia* and *Macroptylium lathyroides* have shown promise. The model has also assisted in the selection of late maturing Triticale varieties for the region.

Such models are readily available and require simple computing skills. They provide a technology which allows an analysis of longer term climatic conditions and a prediction of the effects on plant production and erosion risks. They should be used more widely.

## Incorporation of Quality Forages into Upland Rubber and Coconut Plantations

As in the systems mentioned above, the incorporation of animals into upland rubber and coconut plantations offers a potential diversification of income. In addition, in rubber plantations the grazing of sheep, which cause little or no damage to the rubber trees and collection cups means that a reduction in herbicide use can be effected. This has both a direct economic benefit and a benefit to the environment as a whole.

Ground cover legumes such as *Centrosema pubescens, C. caeruleum* and *Pueraria phaseoloides* have been widely planted under rubber plantations in Malaysia. These legumes provide rapid soil cover that reduces soil erosion and suppresses weeds; however, *Calopogonium caeruleum* is not well accepted by sheep.

Despite the large areas planted to forages under plantation crops, there has been no systematic evaluation of shade tolerant forages for these environments. A current ACIAR Project entitled 'Improvement of forage productivity in plantation crops' PN8560, has searched germplasm banks for material originating in shaded environments. These are undergoing evaluation under rubber in Malaysia and under coconuts in Indonesia. In these evaluations, criteria such as provision of ground cover and feed acceptable to animals are the major selection criteria. The project has identified several promising species for incorporation into cropping systems. In Malaysia, species such as *Panicum maximum* Riversdale, *Brachiaria brizantha* and *Stenoteaphrum secundatum*, and legumes such as *Stylosanthes scabra* cv. Seca, *S. guianensis* CIAT 184 and *Arachis pintoi* have shown potential for increased animal productivity under immature rubber. In Indonesia, the legume *Arachis pintoi* and the grasses *Stenotaphrum secundatum, Paspasum wettsteinii* and *Paspalum notatum* have also shown considerable promise. In these evaluations, plant characteristics which are likely to enhance persistence under grazing mismanagement conditions are a major part of the selection criteria. In a species such as *Arachis pintoi* the stoloniferous habit and seed burial attributes are two characters which favour persistence under close grazing conditions. Incorporation of livestock into these plantation systems would be expected to enhance the rate of nutrient cycling and reduce the need for weed control, both of which would produce the major direct benefits to the plantation crop. In addition, the production of livestock means that smallholders have an alternative source of income and such diversity is expected to reduce the risks associated with utilisation of these marginal upland areas.

## Utilisation of Risers of Bench Terraces

In many areas of steepland agriculture, high capital or labour inputs into the construction of bench terraces has taken place. This has been a major thrust of development in the watershed areas of Central and West Java, Indonesia. In one such watershed basin on the Citanduay River, Siregar (1988) it has been shown that these risers are a major source of soil loss into the river system. By planting forages on these rises, it is possible not only to produce a valuable fodder resource for livestock, but also to reduce soil erosion losses. Siregar found that an annual production of 3519 g DM/m$^2$ of *Brachiaria decumbens* could be obtained from these risers and that when planted to grass the soil loss was reduced from 1110 g/m$^2$ to 143 g/m$^2$ of riser over a 6-week period. In an area such as the Citanduay Basin, which is famous for the Garut fighting sheep, the forage grown on the riser of the terrace provides a valuable alternative source of income for the marginal upland farmers. As in the case of tree legumes, this system is not sustainable in the long-term unless there is a return of nutrients from the animals to the forage system. If this residue material is based returned to the bench of the terrace, then the nutrients are potentially available not only to the crop, but to the grass growing on the riser. In the studies mentioned above, the selection of a legume for these high manganese-containing acidic soils has not met with great success. Clearly there is a need to incorporate a legume into the system in the longer term to enhance the overall nitrogen status of the system. This aspect of the technology requires more research.

## Oral Vaccination of Chickens Against Newcastle Disease

Scavenger poultry has received increasing recognition as an important resource for the developing world. Chickens are a multi-purpose asset, capable of generating protein in convenient quantities for home consumption or local sale. Despite a strong growth of broiler and layer industries in many Southeast Asian countries, the village chicken retains an integral role among the households of village and even city dwellers.

Other benefits associated with village birds can be found in the almost symbiotic relationship they have with human communities. No garbage collection services exist in the developing rural world, so the free service provided by poultry has undoubted benefits such as increases in local cleanliness and hygiene. They also benefit the human communities because of insect control, weed reduction, and they provide their 'owners' with a form of savings account which can help out in times of need or be exploited when seasonal peaks in poultry demand occur such as at religious festivals or celebrations.

Improving the efficiency of indigenous poultry production in the rural environment should be seen as a distinctly different development from the growth of commercial livestock production industries based on purchased inputs. The inputs of village production are largely non-purchased. Apart from some supplementary feeds, they have little or no opportunity cost.

Newcastle disease, a virus desease of poultry, appears able to cause average losses of up to 12%/month in unprotected flocks, which amounts to a wasting away equivalent of 72% of the standing flock numbers over one year. The rates in epidemics are much higher. Superimposed on mortalities from other causes, and with the very low reproductive rates common in village poultry, the deaths from Newcastle disease are often sufficient to bring flock sizes down below the carrying capacity of the habitat for considerable periods (Johnston 1990).

Vaccines are available for Newcastle disease control; however, indigenous birds found around many households in the developing world are difficult to vaccinate by normal methods.

Spradbrow et al. (1987) conducted protection assessment trials in Malaysia which found and confirmed that the Australian V4 strain of ND virus gave substantial protection against challenge with virulent ND virus.

The trials in Malaysia led to speculation that live vaccines based on the Australian V4 Strain of Newcastle Disease could be added onto poultry feeds and fed out periodically to village birds. This would provide protection against the mortalities induced by Newcastle disease virus. A further refinement was to select a heat-stable variant as the vaccine virus which could be used in the field where minimal refrigeration facilities existed.

In 1983, ACIAR and subsequently AIDAB co-financed additional research which was initially done in Australia and Malaysia. These two years of laboratory research were followed by efficacy and challenge trials and associated village trial vaccination in Malaysia, Thailand, Sri Lanka, the Philippines and Indonesia.

Data to date suggests that oral vaccination can result in a two- to fourfold increase in survival rate and productivity. These estimates must be tempered by considerations of the foraging environment. It may be that the occasional episode of Newcastle disease or other flock-reducing influence gives the habitat surrounding the village household a chance to recuperate from the foraging birds. Insects and green plant life could regenerate, to the benefit of subsequent generations of birds. Consequently, spectacular claims of possible threefold increases in production should not be made at this stage, unless the capacity of the foraging environment is fully understood (Johnston 1990).

This low cost vaccination technique will allow village people to run a more stable poultry population and hence maintain protein supplies to the residents.

## Improving feed utilisation by ruminants

In many areas of the developing world, particularly in low income areas of marginal uplands, animal productivity and survival is low because of a combination of insufficient forage and forage of poor quality. In upland areas, crop residues provide a major component of ruminant feeds. The quality of these forage resources is often insufficient to meet the maintenance requirements of the animals and this leads to weight losses, susceptibility to disease and poor reproductive performance.

Low efficiency of rumen digestion leads to the production of methane, a gas which contributes to the problem of global warming. It has been estimated that ruminant animals contribute between 15 and 25% of global methane, with cattle providing most of this output.

Strategic supplementation of animals with urea and molasses and nutrients has been shown to increase the efficiency of utilisation of low quality roughages. A technology to provide these ingredients in a village-made block has been developed in a joint Indian-Australian ACIAR project. In these studies milking buffaloes were fed a mixture of rice straw, compounded cattle feed and the animals given access to a urea/molasses/multi-nutrient block (UMB).

Village trials in India have shown that the provision of UMB resulted in a 10–46% increase in milk production and that milk fat content was also increased.

The increased efficiency of rumen digestion resulting from UMB supplementation offers an opportunity for upland and lowland farmers to increase the efficiency of animal production. This will result in an enhancement of draught power and a more assured alternative income source from both better ground preparation for crops and a greater opportunity to sell livestock. It is likely that increased efficiency of feed utilisation will lead to lower rather than higher grazing pressures as producers can maintain fewer animals to obtain the same productivity.

It is unlikely that animal raisers on marginal lands will adjust feeding regimes to reduce methane production per se. This aspect of production may be viewed as one to which society as a whole could contribute. This could possibly be achieved by an international input, through aid agencies, in establishing block production facilities and in the provision of ingredients for block production.

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# Tree Technologies with Potential to Contribute to Sustainability in Marginal Uplands of Southeast Asia

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## *Abstract*

The main economic benefits from integrating trees and agriculture in the less-productive marginal uplands in the tropics will be gained through raising or maintaining land productivity on a sustained basis. However, resource-poor farmers will need to see clear evidence of economic gain because conservation without discernible benefits will be difficult to promote.

Current agroforestry systems have evolved from traditional farming practices and are already applied effectively in some parts of Southeast Asia. Research to improve agroforestry technologies is relatively recent and must address a range of complex issues. The selection of appropriate woody germplasm and its management has begun and a range of potentially useful species of *Acacia*, *Casuarina* and *Sesbania* have been identified. The improvement of tree nutrition at low cost through inoculation with selected strains of VA- and ecto-mycorrhizas, *Frankia*, and *Rhizobium* is making significant progress and technologies are being field-tested.

POPULATION growth has led to increasing needs for agricultural land and fuelwood in tropical uplands. To meet these needs there has been accelerated forest degradation, deforestation and dependence on non-sustainable land use practices (Gregersen et al. 1989). Since the mid-1970s, massive deforestation and fuelwood shortages have been given wide publicity and there is now a recognition of the inter-relationship of people, trees and agriculture.

Until recently there has been a polarisation of foresters and agriculturalists. Foresters have been concerned largely to manage natural forests and extensive plantations for industrial wood production, whereas agriculturalists have largely regarded trees as impediments to clearing land for crops. Neither group saw a connection between trees and agricultural production, and both failed to recognise that many farmers had traditionally incorporated trees into their farming systems. These farmers regarded trees as just one class of plants that could be included in their production systems to provide basic needs of food, shelter, fuel and fodder (Raintree 1982).

In the 1970s terms like 'social forestry' used interchangeably with 'farm and community forestry' and 'forestry for community development' came into use. Agroforestry was recognised by some as a distinct discipline and the International Council for Research in Agroforestry (ICRAF) was established in Nairobi. Agroforestry is a collective name for all the land use systems and practices in which woody perennials are deliberately grown on the same land management unit as crops and/or animals. This can be in some form of spatial arrangement, e.g. boundary plantings, or in a time sequence where trees and/or shrubs are rotated with crops. Strictly, agroforestry must permit significant economic and ecological interactions between the woody and non-woody components of the system (Lundgren 1987). Agroforestry is a major tool in social forestry programs involving farmers as it is a practical, low-cost alternative for food production as well as environmental protection (Swaminathan 1987).

In considering the role of tree technologies in upland sustainability it is helpful to visualise tree/crop systems as positions along a continuum between the extremes of monoculture of annual field crops and single purpose industrial forestry plantations (Barker 1990). Cropping systems are most productive on level or gently sloping land with deep soil of high fertility and adequate soil moisture. In these situations the economic returns from annual crop plants generally far exceed those of tree crops which take several years to mature and trees usually only find a role in the farming system as windbreaks. The main benefits from integrating trees and agriculture appear to be in the less-productive marginal uplands where

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ecological benefits are eventually translated into economic advantages, i.e. higher productivity on a sustained basis (Vergara and MacDicken 1990). The perceived ecological benefits are: (1) nutrient and soil conservation in fragile and hilly lands and (2) restoration of productive capacity of degraded lands, through soil biological processes controlling the decomposition of plant residues (Young 1986).

The application of social forestry to increasing agricultural productivity, to soil conservation and to the provision of wood products has two elements, i.e. local participation and the sustainable increase of productivity on a fixed area of land. Local participation will occur only if farmers have the ability to take up new technologies and a range of incentives to stimulate them. Government commitment to promoting new technologies through legislation, technical support, market development and financial support will be a key factor.

Integrating trees with agriculture where land is scarce is a major challenge. Increases in productivity can result from trees or shrubs that provide several products and services. These so-called 'multipurpose tree species' (MPTS) can be planted to provide shelter from wind, as living fences on boundaries to contain livestock, to add nutrients and organic matter to the soil, and provide cover. They can also produce fuelwood, timber, food and animal fodder. Of course judgement must be exercised in introducing trees into farming systems, as trees may also compete with crops and so reduce food production. Overall there must be economic gain as conservation without discernible economic benefits is difficult to promote.

The following sections give a brief account of agroforestry systems in upland areas and describe some of the component technologies being developed to improve their effectiveness.

## Agroforestry Systems

Upland areas of Southeast Asia fall mainly into the climatic zone designated the 'humid tropics'. The climatic conditions vary somewhat depending on altitude but overall are conducive to rapid plant growth. The potential for high levels of dry matter production is frequently constrained by soils with low nutrient reserve, aluminium toxicity, high phosphorus retention and soil acidity (Sanchez 1987). High intensity rainfall can lead to soil erosion, nutrient depletion and heavy weed growth. However, these conditions do provide opportunities for the development of a variety of agroforestry systems.

Agroforestry in the tropical uplands does not differ in principle from agroforestry in other environments. In practice, soil conservation assumes a greater profile because farms are frequently characterised by erosion-prone, steep slopes. Traditional agroforestry systems often reflect this concern.

Current agroforestry systems in the highland tropics have evolved from traditional shifting cultivation practices and are a response to local ecological and cultural conditions. The introduction of fast-growing nitrogen-fixing trees into the fallow period of shifting cultivation has been practiced in some areas for centuries. The planting of *Casuarina oligodon* in the highlands of New Guinea is an example (Thiagalingam 1983, Askin et al. 1990). The more recent use of nitrogen-fixing trees in agroforestry systems is well documented in the Philippines and Indonesia. A rotational system using *Leucaena leucocephala* followed by maize and tobacco started in Cebu in the early 1900s (MacDicken 1990). In northern Luzon the Ikalahans use vegetative terrace strips of sweet potato vines in their fields to slow run-off. A more recent innovation to this system has been the introduction of nitrogen-fixing trees, *Alnus* sp. and *Casuarina* sp., to form contour hedges (Barker 1990). This is a form of 'alley cropping', a system in which food crops are grown between hedges of trees or shrubs which are pruned periodically to prevent them shading adjacent crops. Kang and Wilson (1987) claim the following advantages for alley cropping over the bush fallow system:

- combined cropping and fallow phases;
- increased land use intensity and longer cropping period;
- effective soil fertility regeneration;
- reduced need for external inputs;
- applicable to both small and large farms.

Variations on the alley cropping system include the sloping agricultural land technology (SALT) model developed in the 1970s on hilly land in Mindanao, Philippines. This system combines *Leucaena leucocephala* and perennial crops such as bananas, coffee and fruit trees planted on the contour with annual crops planted in intervening strips (Watson and Laquihua 1986). *Leucaena leucocephala* is a common component of agroforestry systems being both nitrogen-fixing and amenable to repeated coppicing. A well-known example of its use in contour plantings to control soil erosion is on hilly land on Flores Island in Indonesia where 20 000 ha were terraced and planted from 1967 to 1982 (Piggin and Parera 1985). The arrival of the leucaena psyllid has slowed the use of leucaena in Southeast Asia and stimulated research to identify alternative species and resistant leucaena germplasm.

## Agroforestry Research

There are many technical, managerial and socioeconomic problems which are candidates for research in agroforestry. In an attempt to rationalise research efforts conceptual frameworks have been produced by ICRAF scientists (eg, Von Carlowitz 1989, Huxley 1983, 1990).

In the technical area, much effort has been directed to researching the complexities of alley cropping, possibly at the expense of other agroforestry technologies such as boundary plantings or multistoried home gardens. There has also been concentration on empirical research based on the approach of 'try it and see if it works' in order to produce technologies that can be quickly put into practice. Aid agencies seeking to demonstrate benefits to the farmer in development projects drive some of this type of research (Young 1986). A strong case can be made for research to gain an understanding of the processes involved in agroforestry. This is particularly important in determining the extent to which trees will improve sustainability through maintaining soil fertility and reducing erosion.

Agroforestry experiments must address issues relating to both the woody and non-woody plant components in any technology. Most crop plants may fulfill expected outputs as there is usually considerable experience in their management as monocultures, but the same cannot be said of the woody components. Many agroforestry programs must start with a series of experiments to learn more about a tree species response to a range of environments, its adaptability, and its responsiveness to simple management procedures, such as pruning or lopping, before considering the more complex, and often relatively site specific, questions of tree-crop mixtures.

In developing a small portfolio of research projects with relevance to social forestry, ACIAR has focused its support on two main areas: (1) identification and testing the adaptability and productivity of multipurpose trees and (2) improving tree nutrition, and hence productivity, through low-cost technologies. The following sections describe some research in progress to develop low-cost technologies of relevance to the use of trees in upland areas of the humid tropics of Southeast Asia.

## Selecting appropriate germplasm

According to Nair et al. (1984), the most decisive factor for the success of agroforestry technologies is the choice of suitable tree species. Many tree species have been identified for industrial wood production and their domestication through selection and breeding is well-advanced. There has been little comparable research for tree planting on farms or for land rehabilitation, and even species selection is at a very early stage.

The ideal tree for industrial forestry is usually fast-growing with a single long straight bole and light, self-pruning branches. This ideotype, typical of many eucalypts, suits the transport methods and needs of a highly mechanised industry using wood for sawn timber or chipped and reconstituted for boards, paper or rayon. Trees on farms on the other hand have a multiplicity of end uses including round timber for building, fuelwood, animal forage, fruit and medicines. The trees may also be required for shade and shelter, bee forage or other services. Clearly the ideotype will frequently differ substantially from that of the industrial species. It may include trees or shrubs with a low branching habit, multiple stems, high coppicing ability and the capacity to yield edible fruits or leaves.

In an attempt to define MPTS ideotypes, US AID's Forestry/Fuelwood Research and Development (F/FRED) project surveyed farmers in South Asia and Southeast Asia (MacDicken and Mehl 1990). Fruit trees were found to be important sources of food and income for rural households but over 75% of species were also used for fuelwood and over 50% for timber when fruit yields declined. Such trees need to regrow vigorously after pruning or lopping for fodder and/or fuel, and have a single straight stem to provide a merchantable log. For other uses, multiple stems were not a constraint and in general, farmers wanted trees with deep roots to improve wind resistance, absence of thorns, rapid growth and resistance to pests and diseases.

In 1983 ACIAR recognised that many little-known Australian trees and shrubs had the potential to be useful in social forestry, for fuelwood and integration with agriculture. It approached the problem by calling together a group of foresters, botanists, ecologists and land managers with a knowledge of the Australian flora to identify species with potential for community use in the tropics. In selecting candidate species the group gave preference to:

- plants capable of providing products and services in addition to fuelwood;
- adaptable plants that are easily established and maintained;
- plants capable of growing in extreme environments including arid and humid tropical zones, infertile soils, heavy clays, saline, highly alkaline or waterlogged sites or exposed coastal situations;
- species with ability to fix atmospheric nitrogen, capacity for rapid growth, ability to coppice, and good burning properties.

Some 170 species were nominated, information on one hundred of them was collated and published (Turnbull 1986), seed collections were made, and field trials to evaluate them were established at selected sites in Australia, China, Indonesia, Kenya, Pakistan, Thailand and Zimbabwe. The early results of the trials have been presented at workshops, e.g. Turnbull (1987), CAF (1988) El-Lakany et al. (1990) or published in scientific journals. A major compilation of the early results was prepared by Boland (1989).

Many of the more promising species are nitrogen-fixing acacias. Small tropical acacias such as *A. oraria, A. polystachya* and *A. simsii* have grown fast and exhibit a bushy, often multistemmed, habit which suggests useful application for soil stabilisation, low windbreaks and fuelwood. Some of the larger acacias have exciting potential for farm woodlots. *Acacia aulacocarpa,* *A. crassicarpa*, and straight-stemmed forms of *A. auriculiformis* have grown up to 15 metres tall in three years on acidic soils and have promise for timber production as well as poles, posts and fuel. *Grevillea glauca* and *G. pteridifolia*, relatives of *G. robusta*, a well-known agroforestry species, are tolerant of very harsh acidic and infertile sites and *G. pteridifolia* is already being applied to mining site revegetation.

Most of the trials have been on highly leached acidic soils but a series of trials is on alkaline sites in Indonesia and saline sites in Thailand and Pakistan. Initial results from Indonesia show local species such as *Sesbania grandiflora, Casuarina junghuhniana* and *Acacia oraria* are highly tolerant of alkalinity but new introductions of *A. ampliceps, A. auriculiformis, Sesbania formosa* and some eucalypts are also well-adapted (McKinnell 1990). In saline areas *A. ampliceps* offers possibilities for fodder, fuelwood and shelter.

The need to have MPTS which are not susceptible to pests and diseases has been highlighted by the devastating attacks by psyllids on *Leucaena leucocephala* throughout Asia. Termites are also a major problem in the tropics and the identification of a range of more tolerant tree species could benefit farmers. Several African, Australian and Central American species were significantly more tolerant than the commonly-planted *Eucalyptus camaldulensis* in a trial in Zimbabwe (Mitchell 1989).

Although trees must be well-adapted to the local environment and grow fast, it is the products and services they provide that make them attractive to farmers. ACIAR has supported research to determine fuelwood values, tannin yields, essential oil contents and forage value. Clones of *Eucalyptus camaldulensis* which have high yields of cineole oil have been identified and these could offer substantial benefits to farmers and form the basis of village industries (Doran and Brophy 1990).

*Acacia holosericea* is one species which has proved very adaptable in subhumid/semiarid environments in Asia and Africa. This fast-growing, multistemmed, nitrogen-fixing shrub or small tree is relatively unpalatable to animals but is a useful fuelwood species which can also be used in boundary shelter belts. It produces prodigious amounts of seed starting about one year after planting and some farmers in West Africa have started to harvest the seeds as a protein-rich food source (Rinaudo pers.comm.). In drought prone areas such a woody perennial could provide a valuable food reserve should main food crops fail.

Information from this extensive network of ACIAR field trials is being incorporated in the ICRAF MPTS Data Base which has as a primary objective the preselection of candidate species for agroforestry research and development projects by site and use/function matching (von Carlowitz 1989).

## Improving tree nutrition

The use of symbiotic micro-organisms to increase tree productivity on infertile soils is an attractive proposition if low-cost technologies can be developed. Progress towards this objective has been made in Asia recently.

### *Mineral uptake : mycorrhizal technologies*

Mycorrhizas are symbiotic associations between plant roots and soil fungi which provide a means of improving nutrient absorption from the soil. Most mycorrhizal studies have pointed to the crucial role of mycorrhizas in phosphate uptake but they also appear to improve the availability of poorly mobile ions such as zinc, copper and molybdenum.

There are two major types of mycorrhiza : the vesicular arbuscular (VA) mycorrhizas (endomycorrhizas), which have a low degree of specificity, and the highly specific ectomycorrhizas. Large differences occur between strains of VA and ectomycorrhizas in the extent of their stimulation of plant growth on particular soils. There is considerable scope for selection and matching efficient fungal strains with hosts (Bowen 1981).

Scientists at the College of Forestry, University of the Philippines and CSIRO Forestry and Forest Products in Australia have been developing mycorrhizal technologies. The Philippines research group is pursuing four research directions (de la Cruz 1989) : (1) mass inocula production of 'effective' mycorrhizal fungi for wide scale field planting, (2) generation of effective inoculation technologies, (3) increased survival and growth of inoculated plants in marginal sites, and (4) replacement of inorganic fertilizers by mycorrhiza particularly in the field.

The first step was to screen fungi for effectiveness in improving growth in selected host trees on representative soil types. In one study, *Acacia auriculiformis, A.mangium* and *Albizia falcataria* were inoculated with four VA mycorrhizas and tested on an acidic grassland soil low in phosphorus and high in aluminium. *Glomus fasciculatum* and *G. margarita* improved growth of *A. mangium* and *A. falcataria,* while *Scutellospora persica* and *G. fasciculatum* were most effective on *A. auriculifosmis* (de la Cruz et al. 1988).

Although endomycorrhizas show a low degree of specificity and can infect many host species it is not easy to produce the inoculant. Laboratory culture has failed and the current method is to grow the fungi on the roots of 'trap' plants. After 4-5 months the mycorrhizal soil and infected root fragments serve as effective inoculants. They are converted into granules and, more recently, into tablets for ease of handling.

The use of ectomycorrhizal fungi on a large scale will require technology to produce bulk inoculum of reliably uniform viability, together with a simple rapid delivery system. In the Philippines a number of inoculation methods have been developed for ectomycorrhizas but two methods, mycorrhizal tablets and alginate beads, appear superior. The tablets are produced by compressing mixtures of basidiospores and soil. Seedlings are inoculated in the nursery with one tablet per seedling. For bead inoculants, the fungus is grown in liquid fermenters and the mycelial fragments are embedded in the alginate beads. Commercial production of tablets effective for *Pinus* and *Eucalyptus* has begun in the Philippines.

Australian research has concentrated on ectomycorrhizas for eucalypts but a start has been made on *Acacia* and *Casuarina* species. In one experiment, pot-grown eucalypt seedlings inoculated with selected fungi were 20 times larger than seedlings without fungi within a period of three months (Bougher et al. 1990).

Many exotic plantations of *Casuarina* and *Eucalyptus* are devoid of mycorrhizal associations since compatible fungi are not usually present in the soil. Poor growth rates in such plantations may be partially explained by lack of suitable mycorrhizas. A research project, funded by the ACIAR, is examining the potential of mycorrhizal fungi from Australia as a viable management option in growing *Casuarina* and *Eucalyptus* in China. These trees are used widely in industrial plantations, in protection forests and in agroforestry situations. The project aims to: (1) select mycorrhizal fungi effective in enhancing *Eucalyptus* and *Casuarina* growth on different soil types, (2) develop appropriate methods for producing mycorrhizal seedlings in forest nurseries, (3) demonstrate field responses of *Eucalyptus* and *Casuarina* to ectomycorrhizal inoculation.

During the initial part of this project, a wide diversity of fungi were collected from forests in Australia. Previous estimates of the diversity of ectomycorrhizal fungi associated with Australian trees in the tropics have been vastly surpassed by this project, as many of the fungi represent undescribed taxa. In this project, less than 50% of fungi for which cultures were attempted produced pure isolates (Malajczuk pers. comm.). During this project, several means of inoculating seedlings were used. Mycelium encapsulated inside alginate in the form of Mycobeads is one alternative prospect for producing bulk inoculum which has the potential for large scale application. The beads have a high capability of delivering the mycorrhiza to seedlings in a nursery and to micropropagated plantlets under aseptic conditions. They have the advantage of a long storage life.

Although the ectomycorrhizas show great promise in nursery and glasshouse trials the effects of mycorrhizas in field trials established in China during this project are as yet inconclusive. In field trials with pines and eucalypts in the Philippines it has been shown that savings of 60-85% in fertilizer use are possible on marginal sites (de la Cruz 1989). Given the adverse site conditions, the marginal fertility status of the uplands and the beneficial effects of mycorrhizas it appears they may have implications for upland development and sustainability. The main effects of inoculating trees are increased survival and growth with the potential to partly replace fertilizer requirements.

It is emphasised that although the inoculation of trees with VA and ectomycorrhizas offers good prospects for increasing tree productivity on nutrient deficient sites it may not be the panacea for all problem sites. Considerable validation is still required of the technologies that have been developed and their applicability to a wide range of species and sites remains to be demonstrated conclusively.

### *Nitrogen fixation*

Nitrogen (N) is a major limiting factor in soils of the tropics. In Australia leguminous plants, such as *Acacia*, *Albizia*, and *Sesbania* spp, and some non-legumes, especially in the family Casuarinaceae, overcome the problem of limited nitrogen availability by forming symbiotic nitrogen-fixing associations with bacteria. The bacterial symbionts are *Rhizobium* and *Bradyrhizobium* for legumes and filamentous soil actinomycete, *Frankia*, for the casuarinas. It is this ability to fix atmospheric nitrogen which has made acacias and casuarinas so attractive for planting in marginal lands such as highly leached lateritic soils, beach sands and mining wastes. In agroforestry, nitrogen-fixing trees grown in association with crops have the potential to improve soil nitrogen status and enhance the productivity of the crops.

The actual rate of nitrogen fixation is a matter for considerable debate due mainly to the difficulties of measurement, especially under field conditions. A dense stand of *A. mearnsii* in South Africa was reputed to have fixed 180 kg N/ha annually (Orchard and Derby 1956) but studies of small native acacias in Australia have indicated rates from 3–16 kg/ha per annum (Langkamp et al. 1979). Field studies of *Casuarina equisetifolia* suggest annual levels of nitrogen fixation in the range 12–80 kg/ha depending on the extent of environmental constraints, such as water availability (Dommergues et al. 1990).

Although acacias and casuarinas have been used widely, it is open to question whether the local *Rhizobium* and *Frankia* in the soil always form effective symbiotic associations with the tree host. There are varying degrees of specificity in the tree species — *Rhizobium* strain interactions in nodulation (Roughley 1987), and there are even differences between provenances in their susceptibility to nodulation by *Rhizobium* (Dart 1988). Soils usually contain several types of *Rhizobium* and some soils may have too small a population of strains appropriate for a particular legume so that nodulation is limited. It is in these situations where a response to inoculation of the plant with *Rhizobium* might be expected. In the Philippines, *A. mangium* seedlings inoculated with *Rhizobium* in the nursery were twice as large as uninoculated plants and this difference continued in the first year after outplanting (Dart 1988). The same study found that 14 species of Acacia responded to inoculation in an acidic soil.

In 1984, ACIAR commissioned CSIRO Division of Soils to investigate the management of nitrogen fixation by casuarina for fuelwood and agroforestry. Research aimed at increasing the productivity of plantations by enhancing symbiotic nitrogen-fixation and has concentrated on : (1) selecting strains of *Frankia* effective in promoting growth of *Casuarina*; (2) developing a simple but effective inoculation technology suitable for forest nurseries; and (3) identifying soil factors that influence tree responsiveness to inoculation. Field trials have demonstrated substantial benefits of inoculation of nursery stock of *Casuarina* with *Frankia*, wood production increases in excess of 200% being recorded in some situations. Factors affecting tree response to inoculation include tree provenance, strain of *Frankia* and phosphorus status of the planting site. Nursery studies have shown inoculum placement can be critical for rapid nodulation and fast seedling growth, while glasshouse studies have identified isolates of *Frankia* effective in promoting seedling growth (Reddell et al. 1989).

Although the isolation and culture of *Frankia* has made comercial production of inoculants feasible, major limitations to its implementation still exist. These include the slow growth rate of *Frankia* in pure culture, suitable carriers for *Frankia* and inoculant quality control techniques. Progress made in France preparing an inoculant of air-dried alginate beads entrapping *Frankia* is encouraging. Storage of the beads for two years prior to use has not reduced the infectivity and effectiveness of the inoculant (Diem et al. 1988). The bead technique offers the opportunity for dual inoculation of seedlings in the nursery with both *Frankia* and mycorrhizal fungi.

## Conclusions

Multipurpose trees incorporated into farming systems have high potential to improve the productivity and sustainability of marginal upland areas in Southeast Asia. Agroforestry technologies are being developed which, if adopted, will enable resource-poor, small farmers to achieve self-sufficiency in basic commodities such as food, fuel and shelter. They may even provide opportunities for cash income through sales of poles, sawn timber or fruits.

A number of component technologies for agroforestry systems are being developed and these will need to be fine-tuned for particular environments. The choice of tree species is still a major question and screening of candidate species must be on-going. Attention to the selection of effective symbiotic micro-organisms to improve productivity at low cost and the development of appropriate inoculation technologies is warranted.

Scientists have only recently begun to identify existing agroforestry technologies, conduct detailed research on the tree components of such systems and test new agroforestry systems. The preliminary results from the work of ICRAF and other national and international organisations are promising but there is still a long way to go before appropriate tree technology packages will be available for upland farmers in a wide range of environments. There is little doubt that technologies will be developed, whether the institutional, sociocultural and economic factors which constrain their adoption can be overcome remains to be seen.

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# Moving Technologies from Research Laboratories to Commercial Application

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## *Abstract*

There are two main pathways by which research-developed agricultural technologies are transferred from laboratories to field practice: direct transfer to farmers and indirect transfer through manufacturing. The primary constraint that limits the speed of this transfer process is the difference in criteria for excellence between the researchers who are the developers of the new technology and the manufacturers and farmers who are the technology users.

To the researcher, the usual criteria for excellence are high productivity under ideal conditions and technical feasibility. To the end users, however, what is important is profitability in a less than ideal environment, and marketability of the end product. It is suggested that the criteria of both groups be combined and used as basis for evaluating potential for commercial application of proposed research products as well as finished products of completed research. In addition, criteria for sustainability may have to be added to ensure that the new technology contributes to the conservation of natural resources.

Two recent experiences in the areas of on-farm trials for technology verification and evaluation for commercial utilisation of research results are presented as potential tools for hastening the transfer of research results from laboratories to end users.

THERE are essentially two pathways by which new technologies are transferred from laboratories to field practice. The first is by the direct use of these technologies by the end users. A typical example of this type of transfer is farmer adoption of newly developed technologies such as new varieties, new fertilizer management, or a new pest control method. In most cases, adoption by the final end users, the farmers, is catalysed by extension workers assigned by and paid for by government.

A second pathway for commercial use of technologies is through the manufacturing process. A new and more efficient technology may be adopted by a firm in the manufacture of a new product which is sold to the final end users for a profit.

In this paper the problems and solutions in promoting the commercial application of new technologies are described and finally recommendations are made as to the steps that could be taken by both researchers and fund donors in order to facilitate the actual commercial use of new technologies.

## Direct Transfer to Farmer End Users

For most research institutions with a mandate for rural development, much of the effort is directed to the development of technologies that can improve farm productivity. These technologies are either designed to increase output or to minimise cost of production. The new technologies are usually developed and tested first at research stations and the good ones may eventually be tested in actual farmers' fields. The final judges of the goodness of these technologies are the farmers who will either adopt or reject them on their own farms.

### The problem

The primary constraint to the direct adoption by farmers of newly developed technologies is the difference in environment and management practices between farms where the technology is to be applied and the research station where the technology is developed and tested. Research stations are traditionally selected for their ideal environment. In addition, they are usually provided with the best management, i.e. adequate fertilizer, assured irrigation water, good pest management, etc. The farmers' fields, however, are located where land is available and are managed at minimum cost. Consequently, farm yields

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are, in almost all cases, significantly lower than that of the research stations.

Gomez (1977) developed a conceptual model explaining the yield difference between experiment stations and actual farm (Figure 1). This difference in yield, termed as the yield gap, is partitioned into the following components:

*Yield Gap 1:* the difference between experiment station yield and potential farm yield which is due to deficiencies in the farm environment which are beyond the farmers' capacity to modify and therefore signifies that portion of the technology that is not transferable to farmers' fields;

*Yield Gap 2:* the difference between potential farmer's yield and economic farm yield which represents the portion of the potential that is not economical for farmers to adopt;

*Yield Gap 3:* the difference between economic farm yield and actual farmers' fields which represents the additional yield that farmers can derive from the new technology but has not been adopted.

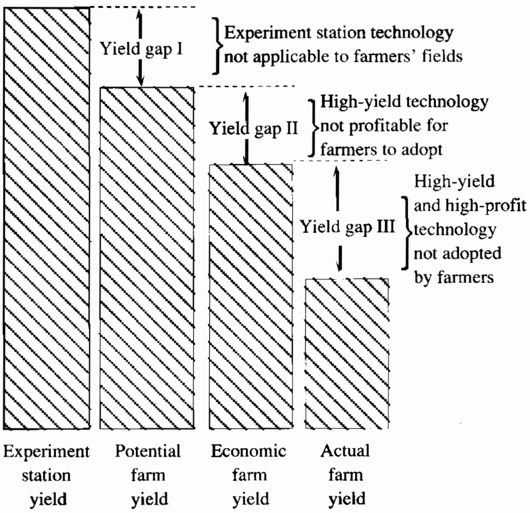

**Fig. 1.** Conceptual model explaining the gap between experiment station yield and actual farm yield (adapted from Gomez 1977).

**Table 1.** Estimated yield difference between existing farmers' practice and new technology for different crops (Gomez and Gomez, 1983)

| Item | Crops | | | | |
|---|---|---|---|---|---|
| | Rice WS | Rice DS | Corn | Rice | Mungbean |
| Number of Trials | 145 | 87 | 52 | 4 | 4 |
| Farm yield (t/ha) | | | | | |
| New Technology | 4.6 | 6.2 | 3.02 | 3.65 | 1.08 |
| Farmers' practice | 3.5 | 4.2 | 1.76 | 3.10 | 0.76 |
| Yield gap (t/ha) due to: | | | | | |
| All test factors | 1.2 | 2.0 | 1.26 | 0.55 | 0.33 |
| Fertilizer | 0.3 | 1.0 | 1.05 | 0.17 | 0.32 |
| Insect Control | 0.5 | 0.6 | 0.57 | –0.11 | 0.09 |
| Weed Control | 0.1 | 0.2 | 0.61 | –0.35 | 0.05 |
| Variety | – | – | 0.77 | – | – |
| Planting Method | – | – | 0.50 | – | – |
| Added Output Value ($/ha) | 144 | 255 | 201 | 73 | 176 |
| Added Input Cost ($/ha) | 137 | 178 | 116 | 237 | 1 |
| Added Return ($/ha) from: | | | | | |
| All test factors | 6.8 | 77 | 85 | –164 | 175 |
| Fertilizer | 10.4 | 97 | 101 | – 47 | 160 |
| Insect Control | –28.7 | –30 | 56 | –104 | 53 |
| Weed Control | 8.0 | 19 | 68 | –121 | 48 |
| Variety | – | – | 99 | – | – |
| Planting Method | – | – | 63 | – | – |

The magnitude of the yield gap has been measured in several experiments involving different crops such as rice (de Datta et al. 1979a, b, c; Gomez, et al. 1979; Herdt 1979) corn (Mercado 1981) and multiple cropping (Santos and Gomez 1981). The results of these experiments (Table 1) indicate that only some components of the technology package are economical for farmers to adopt. In rice, improved fertilization was an economically feasible component but not insect control; in corn, improved fertilization and new varieties were feasible components; while in the rice-mungbean sequence, rice yield was not significantly improved while that for mungbean resulted in significant improvements in farm yield and income.

Other findings from similar on-farm trials have also shown the following:

1. Improvement in productivity due to a new technology as measured in the favourable environments of research stations and research laboratories is usually an over-estimate of the level of improvement that can be obtained in the less favourable environment of the farmers' fields.
2. Farmers will not change their existing practices to a new practice unless the latter will result in a significant improvement over their own. Experience in the Philippines and other Asian countries indicates that a minimum improvement of 30% over the existing practice is necessary to motivate farmers to change their traditional practice.
3. Less than half of the new technologies that are shown to be superior in research stations and laboratories continue to be superior in farmers' fields. This finding tends to indicate that the research stations are more amenable to the new technologies whereas the farmers' fields are more amenable to the existing farmers' practice. Thus, it is necessary that new technologies should be evaluated in actual farmers' fields in order to validate their applicability for wide scale adoption.
4. Many technology innovations, especially those for agricultural production, are usually location specific. The best technology for one environment is not necessarily the same for another environment. Thus, for the best fit between technology and environment, there is a need for extensive on-farm trials of innovations.

### The solution

The previous section clearly shows that technology evaluation in research stations is not enough to evaluate benefits that farmers can derive from a new technology. There is wide variation in technology performance among farmers and between farms and research stations. This is primarily due to major differences in environment between research stations and farmers' fields and even more important the large differences in environment among farms themselves. Thus, there are two main suggestions for increasing the frequency and benefit that farmers can derive from new technologies, namely: (1) conduct of on-farm trials to verify applicability in farmers' fields and (2) improvement of services to improve management in farmers' fields.

*On-farm trials.* On-farm trials should be a regular part of technology evaluation. These trials should be simple and inexpensive, but must be done over a wide range of farms representing various environments (bio-physical and socioeconomic). The primary feature of these trials is to compare the new technology to the existing farmer's practice under the existing farm environment (not the environment of the research station): A significant body of knowledge and experience is now available on how to design these trials, how they are analysed, and how the results are used as the basis for designing location specific rural development programs. It should be emphasised, however, that the present procedure is heavily focused on flat lands where sustainability problems are minimal. Additional work has to be done to incorporate not only economic benefits into the evaluation process, but also environmental sustainability.

*Improved Services.* Productivity as well as sustainability can be greatly enhanced through improved management which in turn can be enhanced by better services. Improved market, better credit, and improved irrigation facilities are often good incentives for improved farm practices. It is therefore suggested that new technologies should be matched by improved services in order to enhance their rapid adoption by farmer end users.

## Commercial Utilisation Through Manufacturers

While the transfer of new technologies directly to the farmer's field is a traditional concern of government, that through manufacturing is relatively recent. Private sector groups, who can afford to capitalise a manufacturing process, are expected to be financially well off and can finance the technology transfer with minimal, if not without, government assistance. In fact, manufacturers often develop their own technologies rather than depend on government laboratories to satisfy their needs. The transfer of technologies, therefore, from research laboratories to manufacturing enterprises, especially in the less developed countries of Southeast Asia, has been rare.

### The problem

The primary problem in commercialisation via manufacturing is the difference in perception between the researcher and the manufacturer as to what constitutes a mature research result. While the manufacturer's primary concern is the profitable marketing of the products of the new technology, the researcher's main preoccupation is technical feasibility. Thus, a research result that is perfect from the academic point of view may be worthless to the manufacturer if the end product cannot be sold at an acceptable profit margin. In addition, Gomez and Abejuela (1988) cited three constraints to commercialisation of innovations. These are: (1) commercialisation is not the primary basis for recognising excellence in academe, (2) the procedure for financial rewards to discoveries that are commercially profitable are unclear, and (3) the criteria for supporting research proposals are not based on its potential for commercial use, and (4) good researchers are usually not the best communicators.

In recognition of the above problems, an IDRC-supported project has been launched at SEARCA to develop a procedure for identifying research results that are ready for commercial manufacturing. The primary criteria used are marketability, 40%; technical feasibility, 30%; and profitability, 30% (Table 2).

*Marketability.* This is the heart of the procedure. The basic issue addressed by this criterion is: 'is there a demand for this technology'. Evaluating all other aspects of the technology such as the technical and profitability aspects, is useless if there is no demand for the technology. What propels a technology to be utilised commercially or otherwise, is that there is a massive need for it. An accurate reading of the market is very important before pushing a product/technology for commercialisation. Under this criterion we determine the technology's substantial demand; its competitive edge over alternative technologies and the technology's potential market share.

*Technical Feasibility.* A research result is said to be technically feasible if its technical performance is acceptable and can be mass produced easily. The technical feasibility evaluation looks into the technical soundness of the technology. This simply means looking into whether the technology or research result does what it is designed to do. The cost and availability of production factors required for mass production are also determined in this evaluation.

**Table 2.** Weighted criteria for evaluating Potential for commercial utilization of newly developed technology.

| Criteria | Weights (%) | |
|---|---|---|
| Market feasibility | 40 | |
| Substantial demand | | 10 |
| Competitive edge over alternative technologies (products) | | 20 |
| Potential market | | 10 |
| Technical feasibility | 30 | |
| Technical soundness | | 20 |
| Availability of production factors | | 10 |
| Profitability | 30 | |
| Financial | | 20 |
| Economic | | 10 |
| Total | 100 | |

*Profitability.* The profitability criterion looks into the financial gains the technology will generate for the end user as well as the economic benefits utilisation activities will give to the community, country or society. The financial evaluation uses the basic financial ratios used traditionally in determining financial profitability. These are the Net Present Value (NPV); the Internal Rate of Return (IRR); the Return on Investment (ROI); and the Payback Period (PP).

This procedure has been used to evaluate six rootcrop-based and two coconut-based technologies. The results (Table 3) show that:

1. The procedure is able to discriminate among technologies with respect to potential for commercialisation. For example, only three out of the eight were considered ready for mass production.
2. Technical feasibility, as expected, is satisfied by almost all technologies. Marketability and profitability, however, are the two criteria where the five technologies that are not ready for mass production failed.
3. The quality of the product already in the market which is to be substituted by the new technology is clearly an important determinant of the commercial potential of a new technology. Excellent competing products make it more difficult for a new technology to be commercialised.

## The solution

It is clear that technical feasibility is not enough to motivate the private sector to mass produce a new product. Such a new product must also show a significant level of improvement over an existing product in the market. Improvement may be in the form of higher quality, better production efficiency or a much higher level of profitability.

Clearly, a new technology to be of commercial value must satisfy not only the traditional feasibility criterion of the researchers but more importantly the profitability that manufacturers universally require.

The evaluation procedure developed by SEARCA is an example of how the manufacturer's criteria can be incorporated in the evaluation process. The results further indicate that indeed it is the manufacturer's concern that is most often deficient in new technologies produced in the research laboratories of the public sector. Clearly, a concerted effort has to be undertaken by academe to remedy this important deficiency.

While the focus of SEARCA's evaluation is on technologies that have already been developed, it should be clear that such an evaluation can be done also for a

**Table 3.** Weighted ratings[1] on potential for commercial utilization of eight technologies based on the evaluation criteria given in Table 2.

| Criteria | Technologies/research results | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Rootcrop-based technology | | | | | | Coconut-based technology | |
| | Delicious sweet potato | Sweet potato catsup | Sweet potato jam | Sweet potato soysauce | Cacharon[2] | Cassava flour | Cooking oil | Laundry soap |
| Market feasibility | | | | | | | | |
| Substantial demand | 0.35 | 0.40 | 0.25 | 0.40 | 0.30 | 0.40 | 0.40 | 0.40 |
| Competitive edge over alternative technologies/products | 1.00 | 0.60 | 0.60 | 0.60 | 0.60 | 0.20 | 1.00 | 1.00 |
| Potential market | 0.35 | 0.40 | 0.30 | 0.35 | 0.40 | 0.10 | 0.35 | 0.35 |
| Technical feasibility | | | | | | | | |
| Technical soundness | 0.80 | 1.00 | 0.80 | 0.80 | 1.00 | 0.60 | 1.00 | 1.00 |
| Sources and cost of production factors | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.30 | 0.30 |
| Profitability | | | | | | | | |
| Financial | 1.00 | 0.40 | 0.20 | 0.20 | 0.20 | 0.20 | 0.90 | 0.90 |
| Economic | 0.50 | 0.30 | 0.30 | 0.30 | 0.30 | 0.01 | 0.30 | 0.50 |
| Total weighted rating | 4.20 | 3.30 | 2.65 | 2.85 | 3.00 | 1.71 | 4.25 | 4.45 |

Note:

[1] Ratings are given on a scale of 1 to 5 with 5 as perfect score and then multiplied by the weights given in table 2.

[2] Puffed casssava flour.

planned research product. The advantage of doing this pre-development evaluation should be obvious. Research proposals whose products are shown to have very little potential for commercialisation must be given lower priorities and should receive lower financial support.

## Recommendations

Applied research that is designed to develop new technologies for improving productivity in the rural areas, as well as in the manufacturing sector, is gaining more and more importance in the developing countries of Asia. For this type of research to have a significant impact, its result must eventually be applied commercially for the benefit of its end users. To hasten the process of applying research results, the following are recommended:

1. Incorporation of on-farm trials as a regular component of evaluating new technologies. The research station, with its more favourable environment, has been and will continue to be the primary testing ground for developing new technologies. While this procedure is effective and must continue, it is clear that results of experiment station trials are not enough to specify the domain of applicability of a new technology. To do this, on-farm trials are needed. Such trials must be a standard feature for technology evaluation in order to identify, in specific terms, the geographic area where new technologies are more superior and are, therefore, suited for farmer adoption.
2. Incorporation of users' preferences in the design of new technologies. The feature of an improved technology, as perceived by the researcher, may not totally reflect the requirements of the target users of such a technology. Technical feasibility, which is the main concern of researchers, does not usually assure profitability which is the main concern of end users. Thus, both concerns must be incorporated in the generation of new technologies if such technologies are to be mass produced for the benefit of the intended users. To do this, research plans for the development of new technologies must be required to:

   a) describe in detail the new technology it plans to develop,

   b) identify the existing product or practice the new technology is designed to improve, and

   c) describe in detail and, if possible, quantify the advantages of the new technology over the one it is designed to replace.
3. Evaluation of research proposals for financial support must incorporate potential for commercial use. Applied research designed to develop new technologies must

clearly specify the three items given in (2) above before it can be considered for financial support. In addition, priority for support must be given to those researches whose proposed innovation has the highest potential for commercial application.

4. Academic recognition and rewards to researchers must include commercial application of research results. Evaluation of outstanding research work must not be based mainly on the more traditional criteria of papers published but, more importantly, must include the extent with which research results have been actually used and adopted by end users.
5. Researchers must be assured of a fair share of the profit from the use of technologies developed. Promising new technologies, even those developed by publicly supported institutions, are often not accessible to the general public because of unclear policy on ownership and benefits derived from the innovation. Such secrecy stifles rapid commercial utilisation. If, however, there is a clear policy on the division of benefit, and if this policy assures a fair share for the research inventor, then the flow of information from researcher to end-users would be greatly enhanced.

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# Report of Working Groups

The aims of the working groups were:

a) To identify constraints to the introduction of new technologies into upland agriculture and ways of alleviating such constraints:

b) To identify new technologies which have been sufficiently developed to warrant inclusion in upland agricultural systems; and

c) To indicate areas of research for technologies that will potentially enhance the sustainability of upland agricultural systems and the organisation of groups who might work together in such projects.

The groups were structured so that each delegate participated in both discipline and system- orientated sessions. The four discipline oriented sessions covered soil and water, trees, socioeconomics and forages and livestock. Each group covered a) to c) above within the discipline and prepared a report for consideration at the later session.

The groups were restructured so that each discipline group was represented in sessions concerned with systems. The report of the discipline oriented groups have not been included in these proceedings as it was felt that the information in them had been captured in the systems based reports.

There was general agreement among the groups that all marginal upland systems should attempt to move from an annual crop base to those with a higher component of perennial trees and eventually to a permanent tree crop system. In all these initiatives technology transfer and developmental research should have poverty alleviation and conservation as primary focuses.

A series of performance indicators should be established so that upland systems can be monitored in terms of conservation and sustainability. Such indicators could include nutrient balance, water relations and pest population. Appropriate techniques need to be developed to provide these indicators for the range of systems found in marginal uplands.

## Crop Based Systems

The group considered the three components discussed at the workshop and these are summarised in Table 1. A total of 12 new technologies were identified that were sufficiently developed to warrant inclusion in upland agricultural systems (column 1). These ranged from alley cropping, crop rotations and adapted crop cultivars to other technologies such as tree cropping, tillage, crop-livestock management and also included nutrient, water and pest control management.

### Constraints to the introduction of technology

The group also identified constraints to the introduction of these new technologies into upland agriculture. These constraints are also summarised in Table 1 (column 2) and included socioeconomic constraints such as lack of labour, land tenure, credit and access to markets. Other identified constraints were the availability of suitable planting materials, inadequate extension systems and personnel in the uplands, loss of cropping area, inappropriatness of technologies, high costs and lack of on-farm adaptive research.

The group also identified intervention measures that could be initiated by government, non-government organisations, and international development agencies. These possible interventions are shown in Table 1 (column 3). Finally, the group identified policy/country relevance of these constraints (Table 1, column 4).

**Table 1.** Technologies, adoption constraints, intervention measures and policy or country relevence for sustainable crop based systems.

| Technology | Adoption constraints | Intervention measures | Policy/ country relevance |
|---|---|---|---|
| Integrated farming system based on soil and water conservation measures | | | |
| 1. Alley cropping (hedgerow & contours) | – lack of labour | | |
| | – lack of tenure | GI | yes |
| | – access to market | GI, NGO | yes |
| 2. Crop Rotation | – lack of credit | GI | |
| | – planting materials | GI, NGO | yes |
| 3. Multi-story cropping system | – availability species | IDA | |
| | – multi-uses | | |
| 4. Adaptive crop varieties | – limited rural infrastructure | GI | yes |
| | – inadequate extension systems/personnel | GI | |
| 5. Tillage | – suitable crop mixes | IDA | – |
| 6. Tree cropping | – farmers perception | GI, NGO | – |
| | – delayed returns | GI | – |
| 7. Crop-livestock | – loss of cropping area | – | – |
| 8. Nutrient management | – appropriateness of technology | IDA, NGO | – |
| 9. Water management | – lack of on-farm adaptive research | GI | – |
| 10. Intercropping | – cost of technology | GI | – |
| 11. Pest management | | | |
| 12. Liming | | | |

NGO – non-government organisations
GI – government intervention
IDA – international development organisations

## Research needs

The group discussed the constraints and identified areas of research for technologies that will enhance the sustainability of upland agricultural systems. These research topics are listed in Table 2. The areas of research are listed under adaptive, applied and basic research. The group considered all three research areas to be important, but recommended that the adaptive research should have the highest priority.

**Table 2.** Research Needs in Crop-Based Systems

| | |
|---|---|
| Adaptive | • On-farm testing of promising technologies in various agroecological environments<br>• Fish-livestock and crop/tree integration |
| Applied | • Suitable crop mixes (space and time) between annual food crops and perennials<br>– between hedgerows and alley crops<br>– between cereals and legumes (to consider problems of loss of cropping area)<br>• Pest management<br>– biological control<br>– integrated pest management<br>– weed management<br>• Soil management<br>– tillage practices<br>– nutrient/fertilizer management<br>– crop residue management for water conservation<br>• Water management<br>– supplemental irrigation<br>• Postharvest and value added |
| Basic research | • Breeding/crop improvement<br>– screening for stress tolerance<br>– germplasm collection, characterisation, conservation and distribution<br>• Biological nitrogen fixing systems<br>• Pest management<br>• Soil management<br>– chemistry (acidity), hydrology, erosion, physics, biology<br>• Nutrient recycling<br>• Soil-crop-weather models |

## General recommendations

1) The sustainable development of the uplands will require the institutionalisation of a systems approach. This development is closely linked to the community based/participatory approach.
2) A major factor leading to effective technology transfer of sustainable crop-based systems involves the co-ordination of implementation agencies. This co-ordination will require collaborative programs among institutions involved in the transfer of technology.
3) For effective transfer of the available appropriate technology, it is essential to strengthen the extension system in the uplands and to promote better co-ordination of all agencies (government and non-government).
4) To obtain a better understanding of uplands crop-based farming systems, a biophysical characterisation must be undertaken to provide base-line information on current farming practices.
5) Technology transfer can also be enhanced by better international arrangements. To facilitate technology transfer in the region, adequate networking must be established for the exchange of information, technology and germplasm.
6) To have an immediate effect on the conservation and sustainable development of the uplands, promising technologies must be tested and verified in various agroecological environments supported by both applied and basic research.
7) In the past, resources have been biased towards agricultural development in the lowlands. It is recommended that there be a re-allocation of resources to enhance the sustainable development of the uplands.
8) Efforts on decision support systems should be intensified to improve the database for better decision making.

# Tree Based Systems

Available evidence suggests that tree-based systems which include single and multiple-purpose tree species and multi-storied systems are sustainable. However, the task of identification of specific systems to suit specific environments remains.

Sustainable upland agriculture should be viewed in the context of interaction between forest and lowland economies. Given this and the long lead time in the conduct and adoption of agricultural research, potentially higher returns may be expected from research on improving upland tree-systems and in improving lowland agricultural (food crops) technology.

The importance of animals in upland systems should be recognised and then should be examined.

## Constraints to the introduction of technology

Achieving the general objective of getting upland farmers to establish more trees on their farms is faced with the following constraints.

a) Biological

i) Knowledge is inadequate with respect to (a) site-species compatibility, (b) species-mix, and (c) current and potential uses. Ethnobotany research needs to be pursued.

ii) Germplasm supply and availability is often inadequate thus there is a need for studies on reproductive biology.

iii) The long term sustainability of tree-based systems needs to be assessed in terms of impacts on nutrient cycling, hydrologic interaction and other parameters.

iv) In order to improve the potential for early cash returns from tree products, studies on utilisation (including processing), tree breeding, and management practices are necessary.

v) Research on low cost technologies for integrated pest management in tree-based systems is important and should also address trees as potential secondary hosts for pests and diseases.

b) Socioeconomic

i) Location specificity in upland farming systems is inherently greater than for the lowlands. This creates a need for a meaningful characterisation and classification of the uplands from the viewpoint of technology design and land use policy.

ii) Uncertainty regarding the property rights for both trees and land creates a severe dis-incentive to the development of tree-based systems.

iii) There are difficulties in enforcing government policies with respect to land use. Government regulations should be complemented by incentives for better land use management.

iv) The market for commodities involved in new upland technologies should be capable of withstanding large-scale production increases without an accompanying fall in price and profitability.

v) Labour is often the only substantial input into agricultural production. Labour is not costless, and is likely to get more expensive in real terms over time. In any evaluation of new technology a careful analysis of labour input is essential including gender analysis.

vi) Sustainable tree-based systems require capital inputs. Resource-poor farmers in the uplands have little or no access to capital, and do not have the cash to sustain them while waiting for the economic pay off from investment in trees. Part of the reason for the lack of capital is the lack of security and property rights to assets.

vii) Inadequate knowledge of existing and new technologies, current farm practices, and markets and market prices. Farmers do not always know best especially where the total farming system has undergone substantial change (as with the shortening of the fallow in upland systems).

**Research Needs**

1. There is a need for classification and characterisation of the uplands to help provide a framework for technology research, extension and land-use policy.
2. There is a need to make an inventory of technologies for the uplands and to review the literature on these technologies.
3. Research is required on government land-use policies for upland areas. This should be addressed, on a watershed basis:

   a) quantification of off-site costs/benefits

   b) desirability of new technology developments for very steep sloping land (which could be counterproductive).
4. Implications for management of forests including access rights.

## Crop/Livestock Systems

In considering livestock in marginal upland crop/livestock systems, the range of animal enterprises is large. These include chickens, ducks, pigs, small and large ruminants, native animals, bees and fish. In introducing these animals into such cropping systems, attention needs to be paid to their complementarity. Given that crop production (either annual food or perennial tree crops) is the primary focus of marginal upland farmers, it is an important criterion for the development of such systems.

**Constraints to the introduction of technology**

a) In the past, animals have not generally been considered in the cropping system. This has led to a lack of expertise in animal management by farmers and of integrated animal research by research institutions.

b) The availability and division of labour in marginal upland farms is often a constraint to the integration of animals. Whilst excess farm labour may be available over the farm as a whole, specialist expertise in the care of animals may be lacking.

c) Social and cultural limits. Some upland communities may have cultural views against animals such as pigs and goats. This can limit their integration into upland systems.

d) Market access and instability is often a problem for upland farmers. Lack of trans-portation facilities and access to viable markets limits the marketability of the product. This may mean that the producer has to sell to a middle man with little or no bargaining power. This can result in a loss in profitability of the enterprise, hence a lack of adoption of available technology.

e) Lack of decision support systems based either on models or data bases. This means that researchers, extension workers and farmers are unable to investigate the likely outcome of integration of alternative enterprises.

f) Limited research, training and extension in both upland area agriculture and integrated livestock systems.

g) Lack of institutional flexibility and cooperation. Many of the existing agricultural institutions have been structured on lowland mono-crop systems and this leads to an inability to integrate activities between institution and the sharing of resources.

h) Lack of capital and credit, especially at the entry point of the enterprise. Farmers may identify the need for animals in the systems but do not initially have the capital to purchase these animals.

i) Lack of appropriate start-up materials such as seeds and animals. Although technologies for hedgerow systems are available, often seeds and planting materials are not. Similarly, animals adapted to the feeding and climatic regimes in a particular area may not be available.

j) Instability of tenure. This is a serious constraint in many locations. Farmers are unwilling to invest capital and resources into integrated systems which require a longer term investment because of the lack of tenure.

### New technologies

A number of new technologies are in the pipeline which could greatly assist crop/livestock farmers in marginal uplands. Care must be taken in adapting lowland technologies to the uplands as the inputs and mangement required are often inappropriate. Variations in climate and topography are often so great in uplands that it is difficult to generalise from one location to another. Specific technologies which are in the pipeline which could greatly assist upland crop/livestock are:

a) the use of strategic mineral and feed supplements, and,

b) the use of urea-molasses mineral blocks to enhance the utilisation of low quality crop residues.

Market information is available in many countries but is not easily accessible by upland farmers. In addition, information on postharvest handling of crops and on-farm processing is available for the major crops, but again not readily available to upland farmers. Research and development on specific crop, livestock combinations needs to be collected. Such systems as rubber/sheep, coconut/cattle and poultry/agriculture are under investigation in Southeast Asia and are developing appropriate input and management systems for these enterprises.

### Research needs

1. A major need for marginal uplands is adaptive on-farm research. These may be con-sidered as verification trials and should include the farm family as an integral part of the inputs into the system.
2. Classification of upland systems is required. These should include land use, planning, policy and economic components in the classification system.
3. A survey of the formal published and report literature should be undertaken to compile existing information. This should be included in an accessible data base for use by personnel involved in upland research and development.
4. Characterisation of crop/livestock systems, including the soil loss potential, nutrient dynamics, economics, marketing and social issues.
5. Component research on species/genotype selection and plant and animal husbandry components of the system should continue. This should identify material potentially available for marginal upland systems which can be assessed in on-farm trials where the appropriate management systems can be developed. At this phase the local extension personnel should be intimately involved to enhance the transferability of the information.

## General Recommendations

1. There was general consensus that the education and training of research and extension personnel in the areas of forage agronomy was lacking. This is largely because this component of teaching falls between crop agronomy and animal husbandry departments in tertiary institutions. There is a need for locally written text books on integrated farming systems, particularly on aspects of forage, crop and animal husbandry.
2. There needs to be improved co-operation and flexibility between institutions.
3. Establishment of a regional network of researchers and research activities would strengthen the transfer of information between institutions.
4. All country representatives at the meeting endorsed future collaborative research and development between organisations and institutions both within and between countries.

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