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Workshop Summary Report

IC-SEA Report No. 4
GCTE Working Document No. 23

Modelling Complex Agroecosystems under Global Change

June, 1997

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Southeast Asian Impacts Centre (IC-SEA)

IC-SEA was established by the Global Change and Terrestrial Ecosystems (GCTE) Core Project of the International Geosphere-Biosphere Programme (IGBP) in October 1995. It is hosted by SEAMEO BIOTROP the Southeast Asian Regional Centre for Tropical Biology. The objective of IC-SEA is two-folds:

- to assist developing countries in the Southeast Asian region to build their own capacity to analyse, interpret and predict global change impacts on terrestrial ecosystems, including agriculture, production forestry and nature reserve systems; and
- to promote planning for sustainable development and biodiversity conservation in rapidly changing global environment through the policy-makers and resource managers.

To achieve IC-SEA 's objectives the activities planned for the Impacts Centre include:

- Offering technical training workshops on modelling the impacts of global change
- Supporting research fellowship and equipment grant programmes
- Undertaking collaborative impacts analyses with appropriate groups in the region
- Providing expert advice (personal briefings, summaries, impact assessments) for policy-makers and resource managers about the potential impacts of global change in the region

These activities are summarised in the following table.

1995-96

Activity	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Fellowship Proposals		Call	Call	Call	Aw							
Equipment Grant Proposals		Call	Call	Call	Aw							
I. Forest Management								PV	TC			
II. Rice & Crops												
III. Mixed Agriculture												
IV. Forest II/Biodiversity												

1996-97

Activity	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Fellowship Proposals		Call	Call	Call	Aw						Call	Call
Equipment Grant Proposals		Call	Call	Call	Aw						Call	Call
I. Forest Management	PD											
II. Rice & Crops		PV	TC			PD						
III. Mixed Agriculture							PV	TC				
IV. Forest II/Biodiversity												PV

1997-98

Activity	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Fellowship Proposals	Call	Aw										
Equipment Grant Proposals	Call	Aw										
I. Forest Management	PE											
II. Rice & Crops						PE						
III. Mixed Agriculture		PD										
IV. Forest II/Biodiversity	TC				PD							

Call= Call for Proposals; Aw= Awarding of proposals; PD= Project Development Meeting; PE=Project Evaluation Meeting; TC= Training Course; PV= Pre-workshop Visit.

IC-SEA also serves as venue of various science-policy forums on global change-related workshops. An informal seminar series is also organised regularly in the TaJUR Club.

Modelling Complex Agroecosystems under Global Change

Daniel Murdiyarso
Meine van Noordwijk

Acknowledgement

We are very grateful for the tremendous support we have received from colleagues at ICRAF and other CGIAR centres. Our thanks are particularly due to Dr Meine van Noordwijk who helped with the planning of this workshop and interacted closely with the participants during the entire course of the workshop that was held at IC-SEA on 8-21 April 1997.

We also would like to express our sincere thanks to the other main resource persons, Mrs Mirjam Njoroge from ICRAF Head Quarters in Nairobi, Kenya, and Dr Garry O' Leary from ICRISAT Patancheru, India. Both took out time from very tight schedules to participate.

Open discussions on social and human dimension issues led by Dr Thomas Tomich from ICRAF and Dr Jerry Vanclay from CIFOR were greatly appreciated by the participants. Their contributions to the workshop are gratefully acknowledged. Thanks are also due to Dr Gregoire Vincent from ORSTOM/ICRAF for his demonstration of the development of an individual-based modelling tool.

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Dr Daniel Murdiyarso
IC-SEA Programme Head

Dr Louis Lebel
Impacts Centres Overall Coordinator

Summary

Complex Agroecosystems in Southeast Asia are generally practised at relatively small, individual farm, scales. They form a mosaic of food crops, tree crops, and pasture. In favourable environments, they have high productivity, and are profitable and sustainable. In less favourable conditions, however, they often fail, implying the need for further research.

Sustainable management of complex agroecosystem has to deal with the problem that the entire landscape is changing, often rapidly, due to external factors driven by a market economy. The challenge is to develop systems that are feasible alternatives to current agricultural practices in the context of this dynamic environment.

This Training Workshop explored problems in the management of complex agroecosystem. Through lectures and open discussions, the participants developed a better understanding of complex agroecosystems and the application of modelling tools to specific management problems. Case studies demonstrated the processes and interactions in the systems. Models helped participants better understand some of the complex processes and interactions in agroecosystems. A balance of lectures and hands-on computer exercises allowed participants to appreciate the complexity of the problems, but still develop some practical skills and confidence for approaching future analyses.

Through the development of the research proposals more specific problems were identified for possible future investigations. There was also a chance to discuss how future research activities would benefit from networking of researchers and data. In the future, IC-SEA expects to collaborate with other organisations to facilitate future research by this group of scientists on complex agroecosystems.

Contents

Section

1

Introduction

1.1. Rationale of the Workshop

The majority of agro-ecosystems in Southeast Asia are still complex - in the sense that they do not (yet) consist of large areas of monoculture. Complex agro-ecosystems may include food crops, trees, aquaculture ponds and animals with different land uses integrated to varying extents. Smallholder farmers have accumulated knowledge over the ages on how to manage and develop such systems. In highly favorable environments diverse and complex systems offer sustainable land use options of high productivity. In less favorable conditions of soil, climate, markets and/or policies, productivity is less and negative effects on environments 'downstream' may be apparent. Simplified agro-ecosystems have replaced more complex ones all over the world. This is in part because research to overcome environmental constraints and increase productivity is easier for 'simple' monocultures than complex agroecosystems.

In Southeast Asia, growing populations and rapidly expanding economies have driven land-use decisions transforming the agricultural landscape at an unprecedented rate. The consequences of these changes in land use practices, already apparent as losses of biodiversity and, in some areas, soil degradation, may be amplified when coupled with variability and change in climatic conditions. These changes in the terrestrial ecosystem, in turn, impact upon the global atmosphere and marine ecosystems.

The 'complex agro-ecosystems' of the tropics are of interest to global change analyses because they represent an alternative pathway by which agriculture could develop. A route that may not have as large an impact on biodiversity as the conversion to monocultures. Is the trend to simplified systems inevitable or even desirable? The answers to these questions may differ with the perspective of the analysis - farmers, large-scale private sector operators, governments and global environment lobby groups may differ in their evaluation. To inform debate among these stakeholder groups, we need a better understanding of the processes of change and their effects on other parts of the global ecosystems.

A research methodology to understand complex agroecosystems, such as that employed in agroforestry research has gradually evolved from a descriptive stage to the critical and scientific evaluation of biophysical and socio-economic processes (Sanchez, 1995). Incorporation of modelling tools and a system perspective of global change will undoubtedly enhance the predictive capability and facilitate extrapolation.

One of the key issues in complex agroecosystems is interaction between the elements of the systems and trade-offs between multiple objectives. Optimising the interactions to promote complementarity and reduce competition should be the goal. This is especially important for a globally changing environment, where major limiting factors are likely to change.

Further understanding at landscape level should be promoted, since complex agroecosystem are usually differentiated within a landscape. Economic development which involves large government projects like road construction (see *e.g.* Chomitz and Gray, 1996), logging operations, and large scale mono-species plantation can have a major impact. When pressures are increased and resources are degraded smallholders might abandon their multi-species agricultural systems and the landscape might turns into mono-species systems. A fundamental question raised by GCTE Activity 3.4. is whether such specialisation carries additional risks compared with agricultural systems with greater diversity and complexity. The risks should be viewed in terms of the farmers' profit and environmental benefits.

How can modelling help? Modelling has become a common tool and need in many fields of study. This is particularly true when one has to deal with long-term studies in a complex system. Models are indispensable, especially in capturing issues like spatial variability, data inadequacy etc. Modelling is in a sense simplifying the complex processes but at the same time also helping to integrate numerous experimental data with mechanistic understanding of processes in the systems. As a result, models often perform as the best tools to extrapolate fine-scale knowledge to large-scale problems at which measurements are difficult and where understanding is poor. Extrapolation, however, should not just be based on extending current trends, but should include our understanding of driving forces, their interactions and feedback loops.

1.2. Objective

The objectives of the training workshop are:

- to better understand the basic biophysical and socio-economic processes in complex agroecosystems,
- to understand the structure and development of models for further evaluation and validation when applied in future impacts assessment studies,
- to develop methods for assessing the impacts of global change on complex agroecosystems.

This training workshop is part of a series of activities at IC-SEA as shown in Figure 1.1. It was expected that the methods learnt during the workshop would be applicable for future impacts assessment studies.

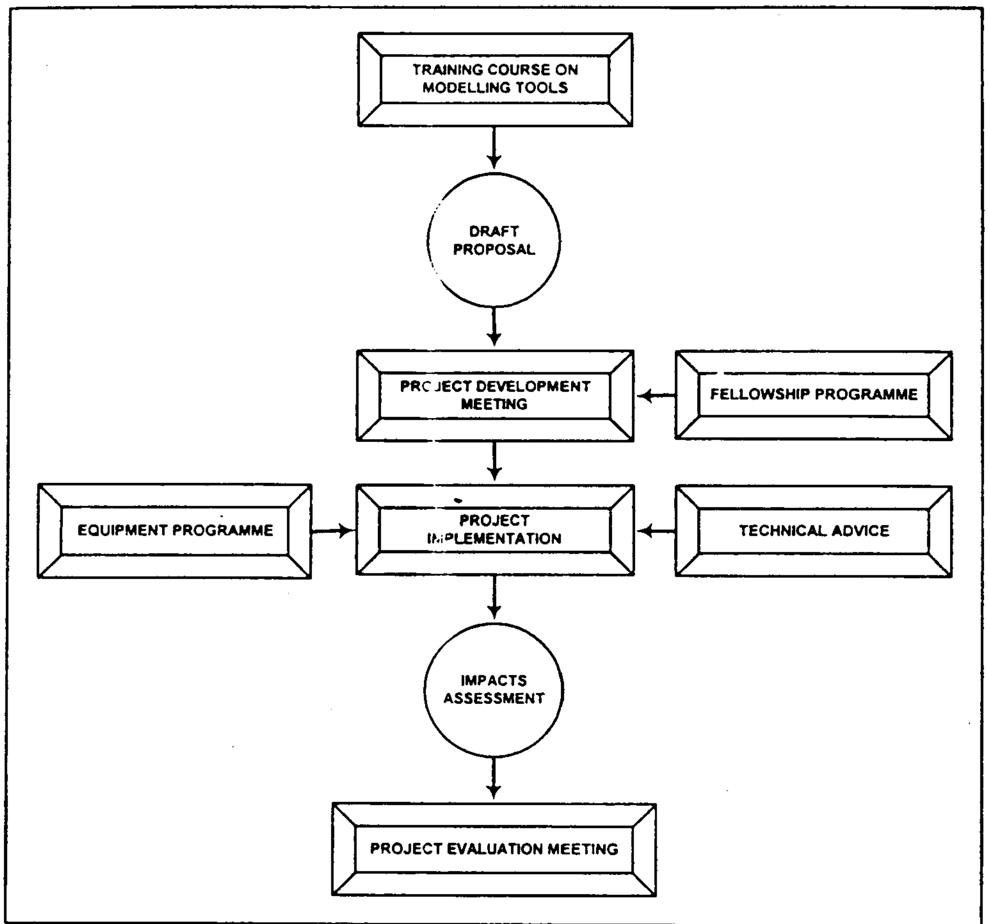

Figure 1.1. The Training Workshop is part of a series of integrated activities at IC-SEA. The final product will be state-of-the-science impacts analyses.

1.3. Timetable and Map of Activities

The timetable of activities is shown in Table 1.1. The opening Keynote Speech by Dr Dennis Garrity, Coordinator of ICRAF Southeast Asia Programme, highlighted the importance of Complex agroecosystems in Southeast Asia. This was followed by an overview of various types of complex agroecosystems practices and the possible impacts of global change. Emphasis was placed on land-use intensity and the common types of interactions found in complex agroecosystems.

The complexity of mixed agroecosystems is indicated by various patterns of mixture between annual and perennial crops, and sometimes animals or fish are also introduced. The practise greatly varies from place to place depending on the knowledge inherited locally. These were assessed and presented by the participants in their Country Reports.

In order to appreciate one of the many kinds of complex agroecosystems the participants were given the opportunity to visit homegardens in a village near Bogor. Although the gardens are no longer part of the main income of the dwellers, the structure, function, and problems associated with their sustainability can be observed.

Table 1.1. The timetable of the workshop.

Date	Morning	Afternoon	Evening	Responsible
Mon, 7 Apr	O Arrival	O Arrival	• Arrival • Welcome Dinner	IC-SEA Staff
Tue, 8 Apr	O Opening Session O Introduction O Workshop Overview O Global Change and Complex Agroecosystems	O TaJUR Club Seminar O Country Report Presentation	• Introduction to Computer Lab	DM, MM
Wed, 9 Apr	O Field trip to homegardens O Complexity, Productivity, and Sustainability of Multi-species Agroecosystems	O Introduction to Modelling	• Use of ModelMaker • Use of Stella	DM MVN
Thu, 10 Apr	O Crop-Fallow Rotation	O Crop-Fallow Rotation	• Computer Exercise	MVN, BL
Fri, 11 Apr	O Up-scaling issue	O Spatial Dynamic Model	• Computer Exercise	MN
Sat, 12 Apr	O Spatial Dynamic Model	O Proposal Development-1	• Organised Dinner	MN
Sun, 13 Apr	ORGANISED TRIP			
Mon, 14 Apr	O SCUAF	O SCUAF	• Computer Exercise	SM
Tue, 15 Apr	O SCUAF	O People-Forest Interaction :FLORES	• Free Evening	SM JV
Wed, 16 Apr	O People-Forest Interaction : Policy Research	O Individual-based Tree Model	• Computer Exercise	TT, GV
Thu, 17 Apr	O WaNuLCAS-1	O WaNuLCAS-2	• Computer Exercise	MVN, BL
Fri, 18 Apr	DAY OFF			
Sat, 19 Apr	O DSSAT	O DSSAT	• Free evening	GO
Sun.,20 Apr	O DSSAT	O DSSAT	• Computer Exercise	GO
Mon. 21 Apr	O Preparation for Proposal	O Presentation of Research Proposal Draft	• Farewell Dinner	IC-SEA Staff
Tue, 22 Apr	O Departure	O Departure	• Departure	IC-SEA Staff

BL : Betha Lusiana, ICRAF Bogor
DM : Daniel Murdiyarso, IC-SEA Bogor
MM : Mario Manzano, IC-SEA Bogor
SM : Stanley Malab, MMSU, Philippines
MN : Mirjam Njoroge, ICRAF Nairobi
MVN : Meine van Noordwijk, ICRAF Bogor
GO : Garry O'Leary, ICRISAT Hyederabad
TT : Tom Tomich, ICRAF Bogor
GV : Gregoire Vincent, ORSTOM/ICRAF Bogor
JV : Jerry Vanclay, CIFOR Bogor

The course ran for approximately two weeks with a variety of activities and daily structures (Table 1.1). The entire course was structured in such a way that the understanding of complexity was built up from the simple models at plot level to much more complex situations at the landscape level. The overall structure of the activities in the training workshop is summarised in the following chart (Figure 1.2).

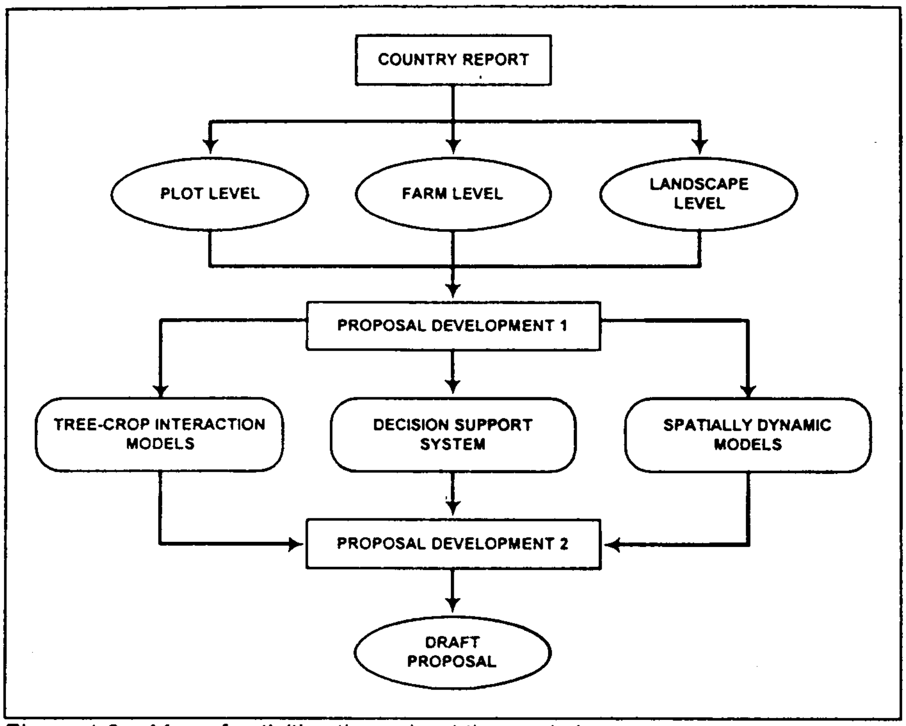

Figure 1.2. Map of activities throughout the workshop.

Section
2

Identifying Complex Agroecosystems and Their Problems

2.1. The Rise and Fall of Complexity

The complexity of agro-ecosystems is largely based on farmer decisions. These decisions can be grouped as choices on the 'planned diversity', on the management of 'associated diversity' and on the harvest of farm components (which may include elements of the 'associated diversity' category). Whereas the harvested components are directly linked to the way agro-ecosystem productivity is measured and evaluated by the farmer in the short run, the non-harvested components play a key role in the functioning of the agroecosystem, its sustainability and long term productivity, and its function to other parts of 'society' at large (Figure 2.1). For example, the maintenance of soil organic matter and a viable soil resource generally depends on sufficient organic inputs to the soil, which means non-harvested parts of total biomass production.

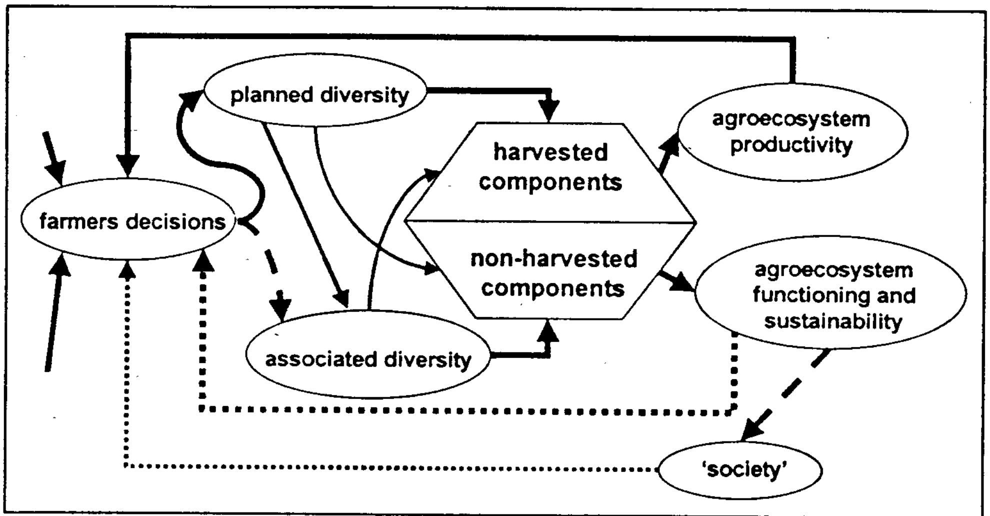

Figure 2.1. A conceptual scheme of relations in agro-ecosystem complexity and function (GCTE Activity 3.4)

Agro-ecosystem complexity and diversity can be based on one or a variety of reasons operating at different scales. At plot/field level these include:

- purposeful mixing of plant species (mixed cropping, intercropping, mixed pastures, agroforestry technologies, mixed tree planting) and/or plants and animals,
- 'negligent' mixing at plot level (maintaining volunteer plants which are not 'weedy' enough to be worth taking them out, allowing insects and other animals to stay on below a 'pest threshold'),

- farmer experimentation and attempts to include new components; some of the components present may be remnants of the past, some current income-earners and others part of a 'trial and error' attempt to cater for the future.

At farm level, additional complexity arises from the multiple objectives and plant functions for a farm household. These multiples objectives can be met in an integrated approach by complexity at plot/field level, in a segregated approach by maintaining between-field diversity on farm, or by participation in a market economy and specialisation in sectors of comparative advantage (segregation at a higher scale). See Figure 2.2 for graphical presentation.

At village/ community/ watershed scale, the presence of multiple actors, all with their own objectives, constraints and ideas (related to gender, age, family size, resource endowment) adds to overall diversity and complexity.

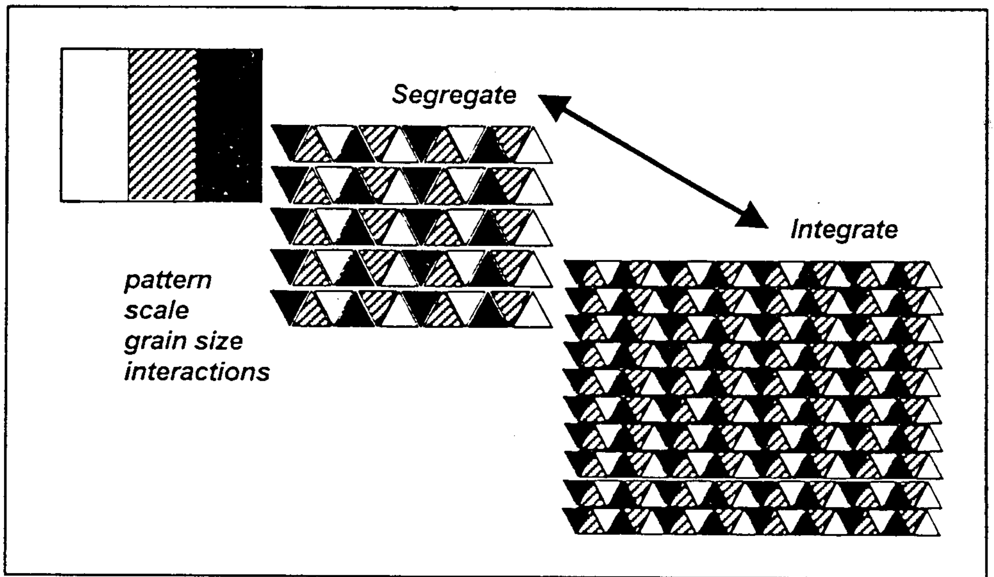

Figure 2.2. Segregated or integrated solutions to multiple objective problems may include the same components and total diversity, but differ significantly in interactions and local diversity.

Agro-ecosystem complexity tends to be reduced by the following driving forces:

- mechanisation, which restricts the opportunities for planned mixed cropping, especially at the transition from manual field operations to draught-animal traction, with further reductions at the transition from animal to tractor-based systems,
- intensification of land use, aiming for higher economic outputs per hectare, reducing the thresholds for 'weediness',
- further market integration of the farm household, inducing specialisation and its ensuing segregation,
- extension services and 'projects' which tend to reduce between-actor variation, especially in combination with 'planning' and 'models' in the sense of 'blue-prints'; such models are usually enforced by credit schemes leaving few options, if not by social pressure.

Agro-ecosystem complexity can be enhanced by one or-more of the following factors:

- recognition and selection of plant-plant combinations which exhibit true complementarily in resource use and may thus have real agronomic advantages,
- 'appropriate technology' developments in mechanisation which allow higher labour use efficiencies without a strong drive for simplifying field plant combinations,

- reduced intensity of land use, as occurs in later stages of economic transformations of (formerly) agricultural economies, when returns to labour are higher in other sectors of the economy,
- the continuous introduction of new germplasm, maintaining or enhancing the 'transient diversity' aspect of the farms (as new germplasm is generally only locally 'new', this type of activity may reduce diversity at global scale),
- effective rewards from society at large by effective policies for maintaining complexity in as far as it is valuable to interest groups beyond the farm,
- development of models which allow more location-specificity in development options, adjusting credit schemes to the real qualities of the site and real objectives of the farmer instead of 'blue prints'.

2.2. Complex Agroecosystem in Southeast Asia

Complex agroecosystems are not widely practised in Cambodia. Forest conversion in areas where the environment is favourable, such as riparian zones, can lead to the formation of complex agroecosystems. These areas are often of conservation importance so research should be directed at improving the sustainability of these systems, while at the same time reducing incentives for further encroachment into forested areas.

A similar situation was described in Lao PDR where forest encroachment through shifting cultivation led to the practice of complex agroecosystems. Since land management is almost absent and infrastructure very limited, the practice has caused considerable depletion of soil fertility, and hence, crop productivity. In both countries, improved management and more appropriate technology is sorely needed.

The issue of population pressure was raised in the reviews from the Philippines and Indonesia. Agricultural activity on sloping lands is common in the Philippines due to lack of access to the more arable lowlands. In Indonesian the complexity of homegarden systems is very much reduced due to the fact that they are no longer the main source of income. While pursuing off-farm activities, the dwellers tend to segregate the production system of the homegardens. At the household level diversity is also less than it used to be. Integration may be seen at farm or even landscape level. The sustainability of the systems is very much driven by external factors, such as land price and government policy in spatial planning.

Industrialisation issues affect complex agroecosystems in Malaysia and Thailand. Due to rapid economic growth, many areas with complex agroecosystems are likely to be converted. Agro-ecological zoning could be a good tool in land-use planning that would help conserve and enhancing the productivity of the system.

Integration of other components like fish and animals was identified to be a potential area of improvement in the complex agroecosystem practices in Vietnam. This was thought particularly beneficial for areas prone to natural disasters, where farmers can then rely on different parts of the production system.

The identified types of complex agroecosystems and their issues are summarised in Table 2.1.

Table 2.1. Complex agroecosystem in Southeast Asia

Country	Type of Complex Agroecosystem	Dominant Issues
Cambodia	Wetland/riparian areas	• Forest encroachment
Indonesia	Homegardens	• External pressure • Integration/segregation
Lao PDR	Shifting cultivation	• Increasing productivity of secondary crops • Lack of infrastructure
Malaysia	Sustainability of complex agroecosystems	• Industrialisation • Economic growth
Philippines	Sloping areas	• Technological packages
Thailand	Sustainability of land resource	• Agro-ecological zoning
Vietnam	Integration of animal, and fish in the system	• Natural disasters

Section 3

Models and Their Roles in Understanding Complex Agroecosystems

3.1. Scaling Issues

Scaling maps and the real world. The word scale occurs in almost every other sentence of current texts on landscape sciences. The scale of a map is expressed as a ratio. e.g. 1:10 or 1:100 000. The larger this ratio, the smaller the area depicted on a unit map area. Small scale maps can thus be more precise than large scale ones. Conventional map making sees this as merely a problem of representation - the real world does not change with the maps we make of it. Simple arithmetic can be used to scale up or scale down and to calculate the size at which features will be represented on the map (be is paper or screen). Our perception of the world and decisions based on those perceptions are, however, influenced by maps, and their tendency to represent the world as a mosaic of internally homogeneous units. What is internally homogeneous at a certain scale, however, may be rich in variation when we look more closely. Decisions which are based on the average of a map unit may be grossly inadequate in the real world. When national level policies are based on small scale maps, they may be very crude approximations of reality from the perspective of a local farmer ; the policies, however, will tend to make the real world more homogeneous and are to a certain extent self-fulfilling prophecies.

Scaling issues in 'empirical' research methods. Research methods are normally based on the fiction that there are internally homogeneous units in the landscape and that studying a few representatives of these units is a sound basis for 'scaling up' to the landscape scale. Internal homogeneity of experimental units may reduce the experimental error term when treatment effects are quantified, but often the implicit assumption is made that treatment effects would not be modified by internal heterogeneity. This assumption may have lead to substantial underestimates of the 'environment' - 'production' conflict in agricultural fertilizer use, as both the yield response curve and the nitrate pollution response curve depend on field level heterogeneity in factors determining N supply and demand to the crop.

Extrapolation from small measurement units to landscape scale can thus not be based on the average values assigned to 'units', but should incorporate internal heterogeneity. Rooting patterns are important in exploiting as well as creating spatial heterogeneity of the soil.

Three stages can be recognized in field experimentation with agroforestry systems:

1. a period of blissful ignorance of lateral interactions when the difference between crop yields in agroforestry and nearby 'control' plots was interpreted as yield effect of the agroforestry system;
2. following recognition of the lateral extension of tree root systems, a period with strong emphasis on the need for trenches and barriers between experimental plots, assuming that the 'true' yield effect of agroforestry estimated in this way is independent of the scale at which the system is to be applied;

3. recognition of lateral resource flows and resource capture as an essential element of agroforestry systems on real world farms, making the overall yield effects dependent on the scale of application.

We are at the verge of the third period and just discovering the tools which are needed to scale up from 'small plot' (0.001 ha) or 'big plot' (0.01 ha) experiments to small, medium or large scale fields (0.1, 1, 10 ha fields) on real farms. Lateral resource capture by horizontally oriented tree roots forms a 'unifying' element in landscape mosaics.

Scale system boundaries. Economies of scale normally indicate that activities become more profitable when done at a certain scale, because the costs and benefits per unit product do not change in the same way. For economists it may be an exception rather than a rule that 'value' is independent of scale.

In ecological modelling it, similarly, is a common observation that the parameters and values depend on the scale. The definition of a 'system' implies a boundary between 'inside' and 'outside' - otherwise there are no 'inputs' not 'outputs'. When we change the boundary of the system under consideration, the sum of all inputs is probably less than the sum for all components, because some 'inputs' are now based on 'outputs' from other parts. In this sense the adagium 'the whole is more than the sum of the parts' has to be revised: both total output and total input are less than the sums of component inputs and outputs. A term such as 'efficiency', which essentially refers to an output/ input ratio is thus likely to be scale dependent. Yet the way in which its value will change with scale is predictable from the 'model' diagram we have, by looking at the importance of the various types of arrows.

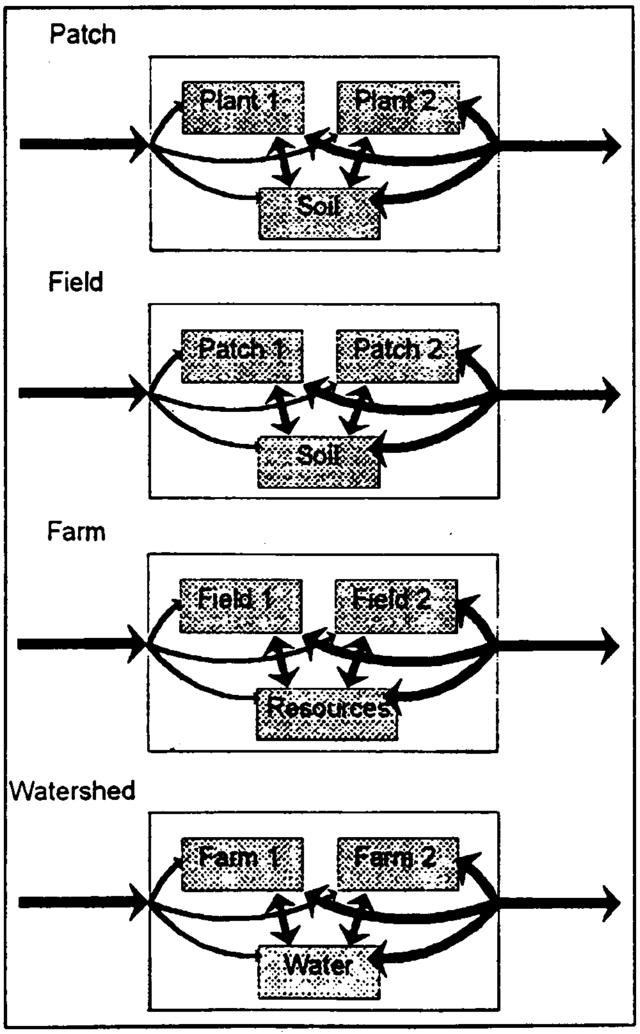

Figure 3.1. A hierarchy of models: plant-plant interactions define a 'patch', patch-patch interactions define a 'field', field-field interactions define a landscape; at each higher scale part of the inputs and outputs change from 'external' to 'internal'.

A patch-level model can thus not be directly used to predict effects at a higher level in the hierarchy, because we need additional information on the links between patches. A classical example in this respect is erosion. Many national level estimates of erosion are still based on multiplication of the land area with the rate of erosion per unit area. This amount of sediment, however, does not leave the terrestrial ecosystem at the mouth of the rivers. A large share of the sediment, depending on the landscape, stays somewhere along the way and becomes an input to 'sedimentation zones'. Many previous assessments of changes in soil carbon have included 'erosion' as a loss factor - from the perspective of a global C balance, however, this is not necessarily correct. Under certain circumstances erosion may be a 'C sequestration' activity.

Considering 'scaling' can thus lead to some unexpected conclusions. There is no single 'correct' scale for studying any given problem - rather we have to study and model it at a hierarchy of scales and identify the changes occurring at scale transitions.

3.2. Choice of Modelling Tools

'Models' appear both under the complexity-reducing and complexity-enhancing factors of Section 2.1, and it may be clear that they can be used in different ways. Although it is not necessarily so that more complex models do more justice to real-world complexity than simple models, models which simplify the world too much in the assumption stage tend to become self-fulfilling prophecies, as they will be used to simplify the real world accordingly. Complexity of the real world needs to be appreciated and evaluated on its functionality by models which are transparent and simple enough to help in our understanding, but are based on critical evaluation of (aspects of) the real world's complexity.

To a large degree, the simplification and specialisation of agro-ecosystems under the pressures of economic development is an inevitable process, but it also involves balancing short-term private gains versus long-term public costs, and this can easily lead to situations where the feedback loop from 'society' via policy development is too slow and inappropriate (especially where policy making is linked to the private gains). Modelling, when done in a sensible way, can help in assessing the real costs and benefits of agro-ecosystem complexity and the way it changes over time. Simplification of agro-ecosystems may also be due to misperceptions on the superiority of more homogeneous, simpler systems and to a lack of well-articulated more complex alternatives. This is a major challenge to the research community.

Three major existing classes of models are described in Table 3.1, with their main strengths, weaknesses and opportunities in dealing with complex agro-ecosystems. In this course we will demonstrate and discuss examples of all three classes. The future clearly lies in marrying the best of all approaches and new developments in spatio-temporal modelling as well as non-linear multiple goal evaluation analysis are promising. Models used during the workshop should find a balance between spatial and temporal aspects of complexity, and should explore the diagonal of the model complexity space in Figure 3.2.

In the end, the complexity of agro-ecosystems will still largely be based on farmer decisions. We may hope to counter-balance the current driving forces for reducing complexity in as far as these factors are non-rational and based on incomplete understanding of true costs and benefits.

Table 3.1. Three classes of models which are used in evaluating complex agro-ecosystems

Model type	Strength	Weakness	New Opportunities
Compartment-flow (box and arrow models, e.g. CSMP, Stella, ModelMaker or equivalent in Basic, FORTRAN, Pascal, or C, object-oriented link	Dynamically interacting processes	Lack of spatial explicitness in dynamic interactions	Modelling interaction processes among local neighbourhoods, scale dependency
Spatial pattern (GIS, image analysis)	Stratification and spatially explicit transitions	Lack of dynamic interaction among local neighbourhoods	Dynamic GIS system, integrating fractal rather than area-based scaling
Multiple goal evaluation	Choices among different options, treated as muatually independent (multiple goal linear programming)	Lack of trade-offs in 'segregate-integrate' type of analysis, non-linearity	Non-linear, scale dependent evaluations, game theory of multiple actor conflicts of interest

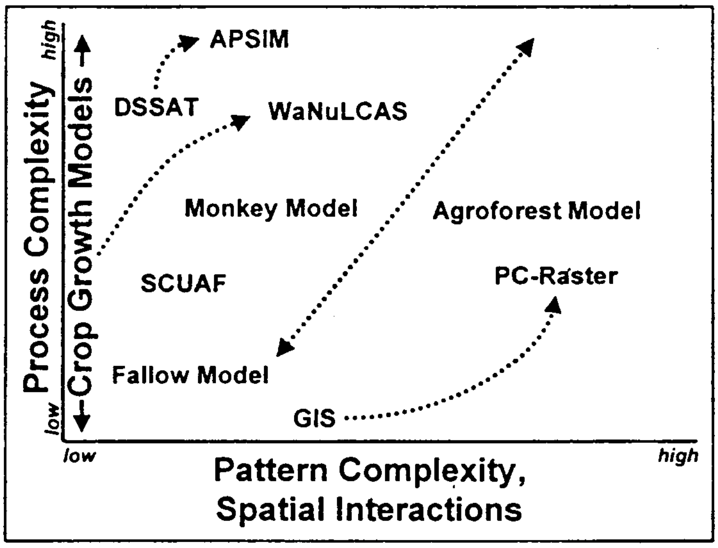

Figure 3.2. Balancing pattern and process complexity in models of agro-ecosystems; models discussed in the training course are placed along the diagonal line.

3.3. Some Examples

Fallow Rotation Model. In order to get started smoothly, the participants were introduced to development of simple models on the restoration of soil fertility during fallow periods and depletion during cropping periods, using ModelMaker and Stella. The conceptual framework of the model is adapted from Trenbath (1984).

According to Trenbath (1984), soil fertility is a complex of effective nutrient supply and biological factors (diseases, weeds) affecting crop yield. Crop yield is assumed to be directly proportional to soil fertility (see Figure 3.3). Conversion efficiency of soil fertility to crop yield depends on crop genotype and crop management.

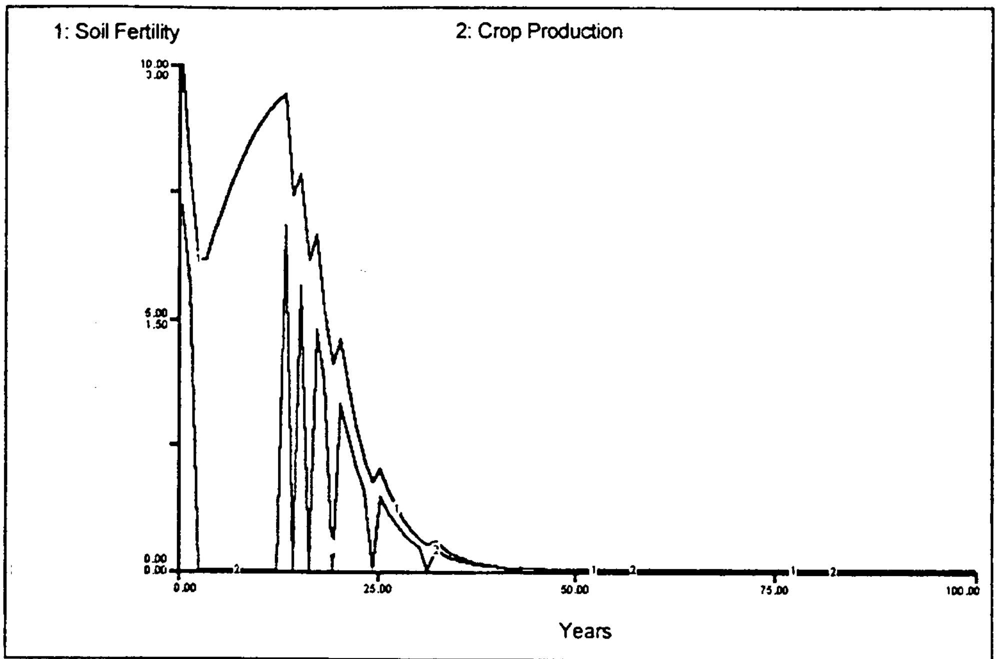

Figure 3.3. Proportional correlation between soil fertility and crop production during cropping years in a version of the Trenbath Model with dramatic shortening of fallow periods.

During cropping periods, soil fertility will decline with a fraction D per crop. D is a reduction factor that depends on the cropping practice (e.g. soil tillage may increase D and thus increase crop yield, but speed up soil depletion).

During a fallow period, soil fertility can be rebuilt with an asymptotic approach to a maximum value. Thus, restoration rate depends on maximum fertility, which is reached after an infinitely long fallow period, as well as fallow vegetation type and climatic conditions, which are represented by 'half-recovery time' factor, K_f.

As the exercise goes on, the model was elaborated by putting human factors influencing the system. As human population increases the need for food will increase. Reducing the length of fallow periods will decrease yields per unit area of cropped land, but still with higher yields per unit crop + fallow land. It means that the human carrying capacity of the system is increased. At a certain point, however, the system will crash when shorter fallows that lead to lower yields per unit total land area are practised, unless additional inputs are introduced. Figure 3.4 shows correlation between human population density, human carrying capacity, and cumulated crop production.

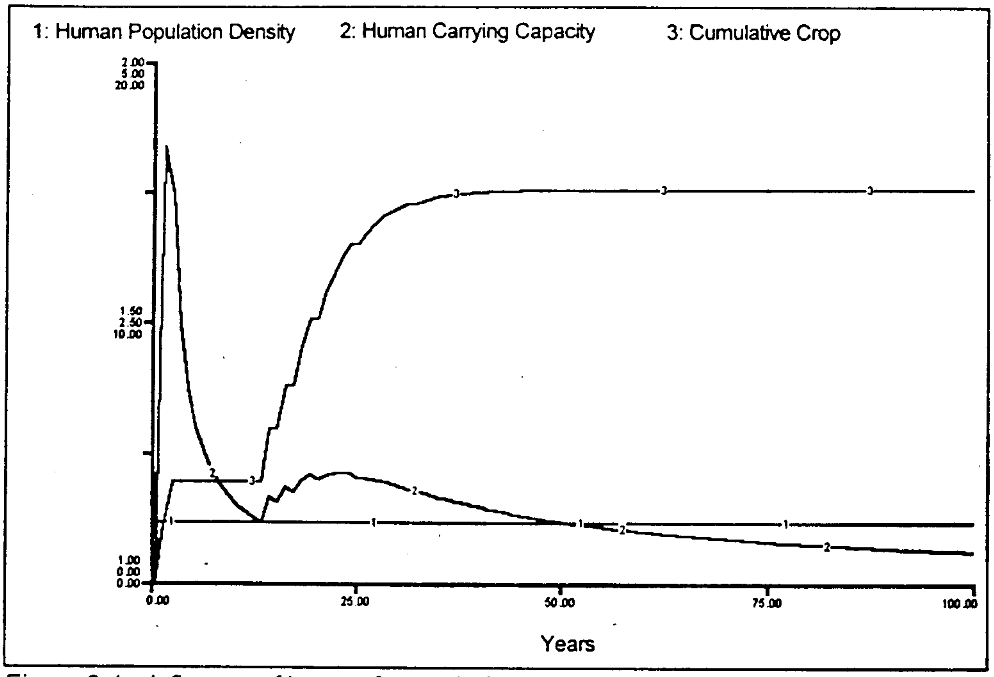

Figure 3.4. Influence of human factors in fallow rotation.

SCUAF. The Soil Changes under Agroforestry (SCUAF) Model is primarily intended for analysis of agrosylvicultural systems, with a focus on soil changes.

The major components of agroforestry systems treated in SCUAF are trees, crops and soils. The main processes modelled are soil erosion and the plant-soil cycles of carbon and nitrogen. These processes operate within a specified physical environment. The economic and social functions of agroforestry systems are not included, but can be linked with SCUAF through its specification of inputs (*e.g.* fertiliser) and outputs or harvest. Specifically, data derived from SCUAF can be entered into the MULBUD computer model, which is directed primarily at cost-benefit analysis (Etherington and Matthews, 1984).

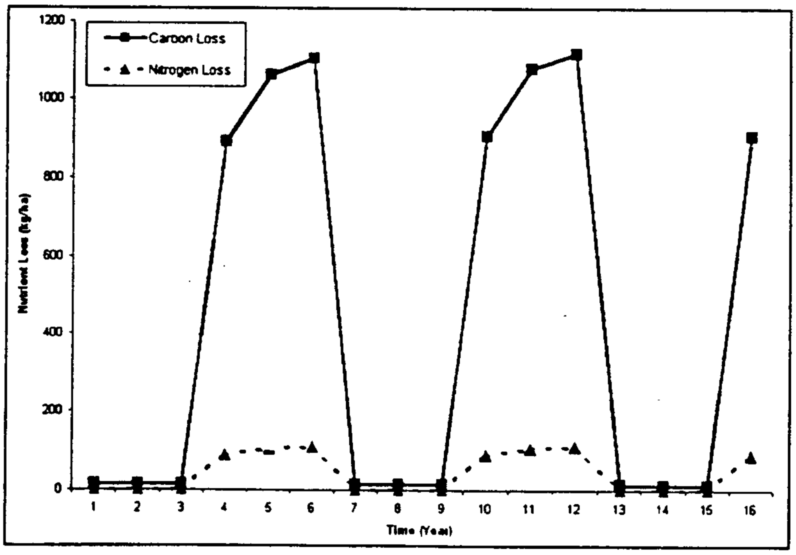

Figure 3.5. Simulation of changes in soil carbon and nitrogen content under hedgegrow intercropping in the highland sub-humid zone using SCUAF. The hedgegrow is pigeon pea and the crop is maize.

Disturbances. A Stella-based disturbance model was developed. It was taken from a case in rubber agroforests on Sumatera's forest margin, that is damaged by simpai (*Presbytis melalophos nobilis*), an endemic monkey species of central Sumatera. The initial model is to summarise the existing bits and pieces of information within the group and explore likely interactions. The analysis reflected by the model can be used to consider the problems solving.

In the model, the probability that a rubber tree will be damaged on a given day is described as a function of monkey population, food intake per monkey per day, rubber intake as fraction of total food intake, number of rubber trees damaged per unit rubber intake, rubber population, and length of time that rubber trees are sensitive to damage. Trees, which have been damaged once, may survive, but the length of their growth period is increased with an elongation factor.

Option of solutions suggested by the model include:

- reducing monkey population (by reducing access to the plot, guarding, etc),
- reducing rubber intake (by providing alternative food sources during the sensitive period)
- increasing rubber population (by opening large field at a time (joining neighbouring farmers, etc.),
- reducing length of time that rubber trees are sensitive to damage (by speeding up growth of the young rubber trees).

In the exercise the number of rubber trees which have been damaged once, twice or more often, and have not been damaged by monkeys is shown in Figure 3.6. It was assumed that the guarding fraction is 0.5, accessibility factor is 0.3, attractiveness factor of food elsewhere is 0.4, monkey population is 15, rubber field area is 3 ha, and initial rubber population is 600 trees per ha.

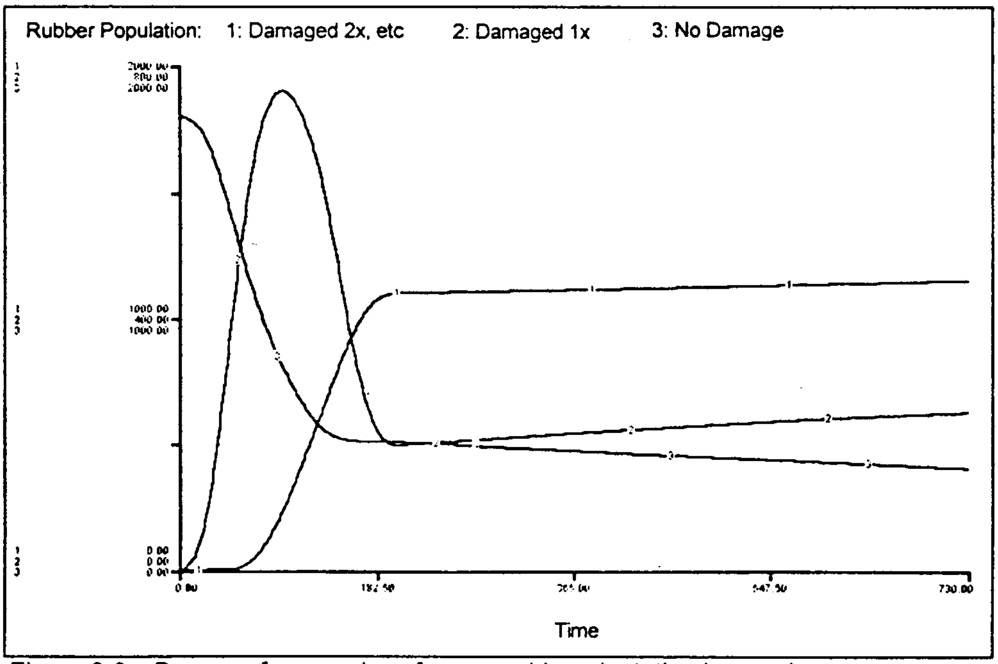

Figure 3.6. Damage frequencies of young rubber plantation by monkey.

WaNuLCAS. The model of water, nutrient and light capture in agroforestry systems (WaNuLCAS) was demonstrated to explore a number of options. The model is formulated in the STELLA Research modelling environment and thus remains open to modification. Emphasis was given to below-ground interactions, where competition for water and nutrients (nitrogen) depends on the effective root length densities of both plant components and current demands by tree and crop.

The key feature of the model is the description of uptake of water and nutrients (at this stage only N) on the basis of root length densities of both trees and crops, plant demand factors and the effective supply by diffusion at a given soil water content. The model was developed to emphasize the common principles underlying a wide range of tree-crop agroforestry systems in order to maximize the cross-fertilization between research into these various systems and explore a wide range of management options. The model can be used for agroforestry systems ranging from hedgerow intercropping (alley cropping) on flat or sloping land (contour hedgerow intercropping), via (relay-planted) fallows to isolated trees in parkland systems.

The model represents a four-layer soil profile, with four spatial zones, a water and nitrogen balance and uptake by a crop and a tree. The model can be used both for simultaneous and sequential agroforestry systems and may help to understand the continuum of options ranging from 'improved fallow' via relay planting of tree fallows to rotational and simultaneous forms of 'hedgerow intercropping'. The model explicitly incorporates management options such as tree spacing, pruning regime and choice of species or provenance. The model includes various tree characteristics, such as root distribution, canopy shape, litter quality, maximum growth rate and speed of recovery after pruning.

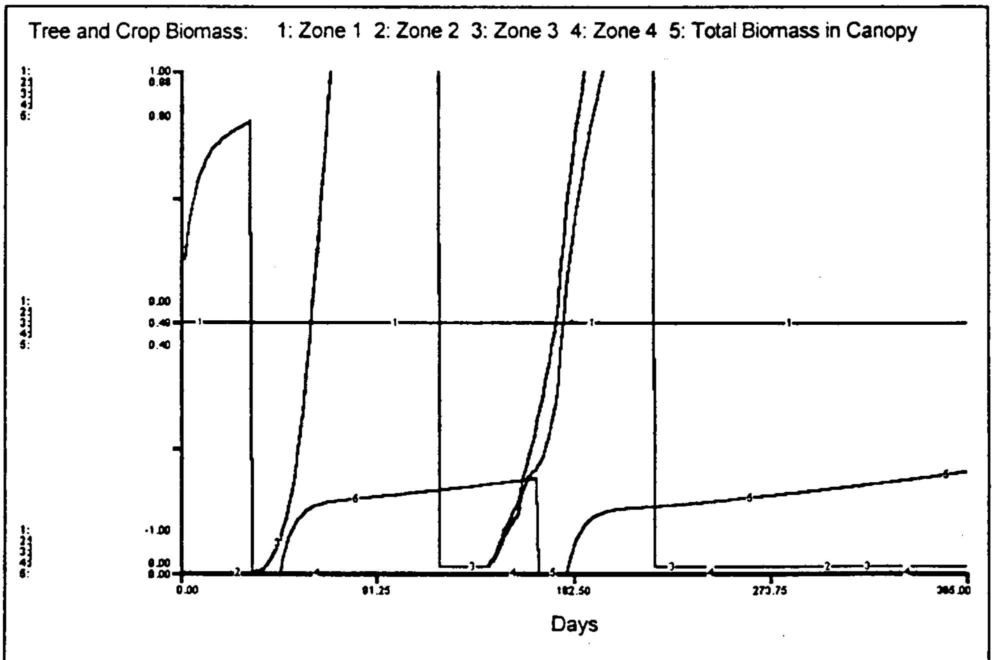

Figure 3.7. Simulated tree and crop biomass of each zone using WaNuLCAS.

If applied to hedgerow intercropping, the model allows for the evaluation of different pruning regimes, hedgerow tree spacings and fertilizer application rates. When applied to rotational fallow systems, the 'edge' effects between currently cropped parts of a field and the areas where a tree fallow is growing can be simulated. For isolated trees in parkland systems, equidistant zones around individual trees can be 'pooled'.

DSSAT. A software package called Decision Support System for Agrotechnology Transfer (DSSAT) version 3.0 was explored to show the integration between Data Base Management System (DBMS) of a minimum data set required to validate, list, and use the crop models for solving problems; a set of validated crop models for simulating processes and outcomes of genotype by environment interactions; and an applications program for analysing and displaying outcomes of long-term simulated agronomic experiments.

Crop models used in DSSAT version 3.0 are cereal crop models, which include maize, wheat, sorghum, millet, and barley models referred to as the generic CERES model and a rice model based on CERES-Rice; grain legume models (SOYGRO, PNUTGRO, and BEANGRO), which operate using a generic grain legume model structure, called CROPGRO; cassava model as one of root-crop models, which uses the CROPSIM model structure. Figure 3.8 shows some simulation results of the soybean model.

For computing potential evapotranspiration in the models, DSSAT version 3.0 supports the Priestly-Taylor method and the Penman method using the FAO definitions of the wind term. The models also have the capability to simulate the effects of CO_2 on photosynthesis and water use and built-in capabilities for simulating weather using either SIMMETEO (Geng, 1986) or WGEN (Richardson, 1985).

Regarding climate change studies, the models are supported by facilities to modify daily weather data that are read from the weather file. Each weather variable can be modified, by multiplying and/or adding a constant to it. Users can specify the date when the modification was started, and have more than one entry if the experiment included environment switching of any types.

There is a useful feature in the model that allows users to select whether to reinitialise soil variables after each run or to end the run, from which the output of one run will be treated as input to the next run. This allows crop rotation studies with carry over effects in the soil factors (soil N, carbon, and water) with depth. A sequential model option is available to run the different crops in sequence, including a fallow period between crops. Any number of years of a crop rotation can be simulated in multiple replications, as specified by the users.

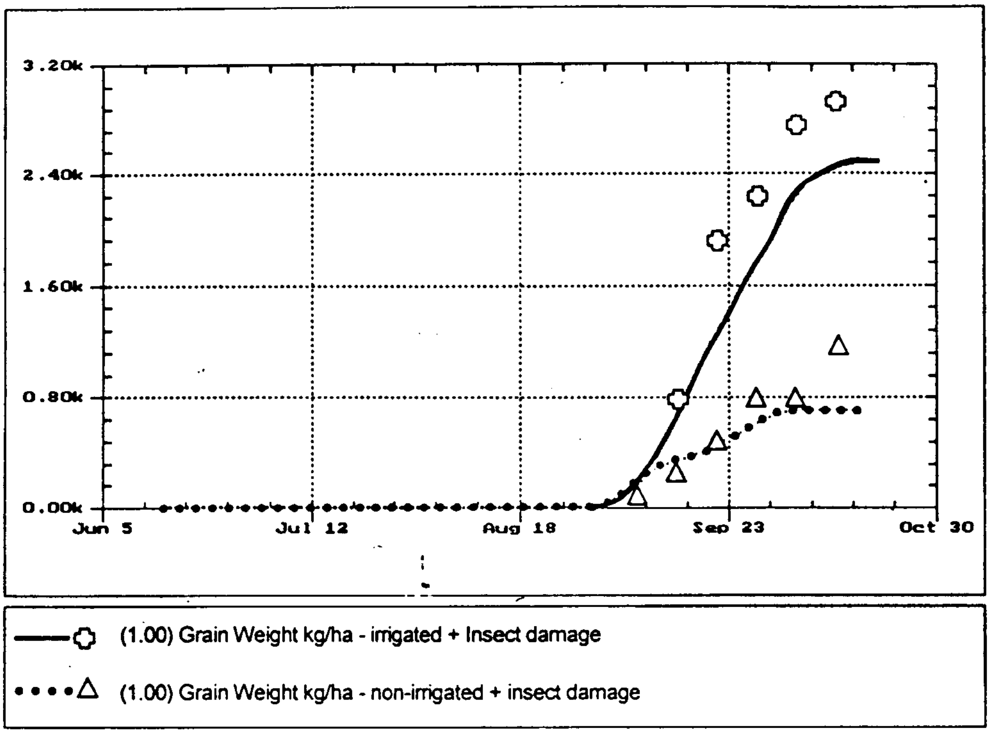

Figure 3.8. Simulated grain weight of soybean model with insect damage in irrigated and non-irrigated farm, using DSSAT.

Spatially Dynamic Model. Exercise in spatially dynamic modelling in complex systems using PCRaster were carried out, with extensive examples on soil erosion. PCRaster is a GIS based modelling tool, which allows the development of a two-dimensional model from basic to complex processes, and from plot to catchment scales. PCRaster is flexible and can be applied to a spatially dynamic system.

In developing a model using PCRaster, a raster map input is required. The model itself is written as a script, that contains binding, area map, timer, initial, and dynamic commands.

Spatially dynamic modelling is very important since researchers sometimes obtain different results when comparing different scales. Sources of upscaling errors can be the number of samples, direction of processes, and other scale-dependent processes.

During the workshop, participants did some exercises on spatially dynamic models, *i.e.* a simple seed dispersion model, which was then elaborated to show differences between segregation and integration, and run-off model based on Manning's equation.

Section

4

Proposed Impacts Assessment Studies in Southeast Asia

4.1. Cambodia

Upland areas were chosen by the Cambodian team for further studies on complex agroecosystems.

The objectives of the proposed study were to find the most feasible type of complex agroecosystem, and to find strategies for improving the yield of traditional complex agroecosystems. It is expected that forest encroachment problems could be reduced if the systems were effectively applied.

There are three traditional complex agroecosystems, that are known by Cambodian farmers: agroforestry, alley cropping, and intercropping. By improving those three systems with some adaptations to upland area conditions, the Cambodian team hypothesised that yield from all systems can be increased.

The study will begin with a survey to refine the research questions. Then, the survey results will be compiled and analysed to develop a complex agroecosystem model in order to find the most feasible complex agroecosystem that can be applied to the farmers. After finding the best result from model simulations, the team plans to conduct a training workshop with people whom will be involved with implementation of the improved system. The activities will involve related government agencies and non-governmental organisations.

The study will be conducted in two type of land-tenure systems: private land and state land. Private land is managed by farmers and state land is managed by community. The conceptual framework of the study is shown in Figure 4.1.

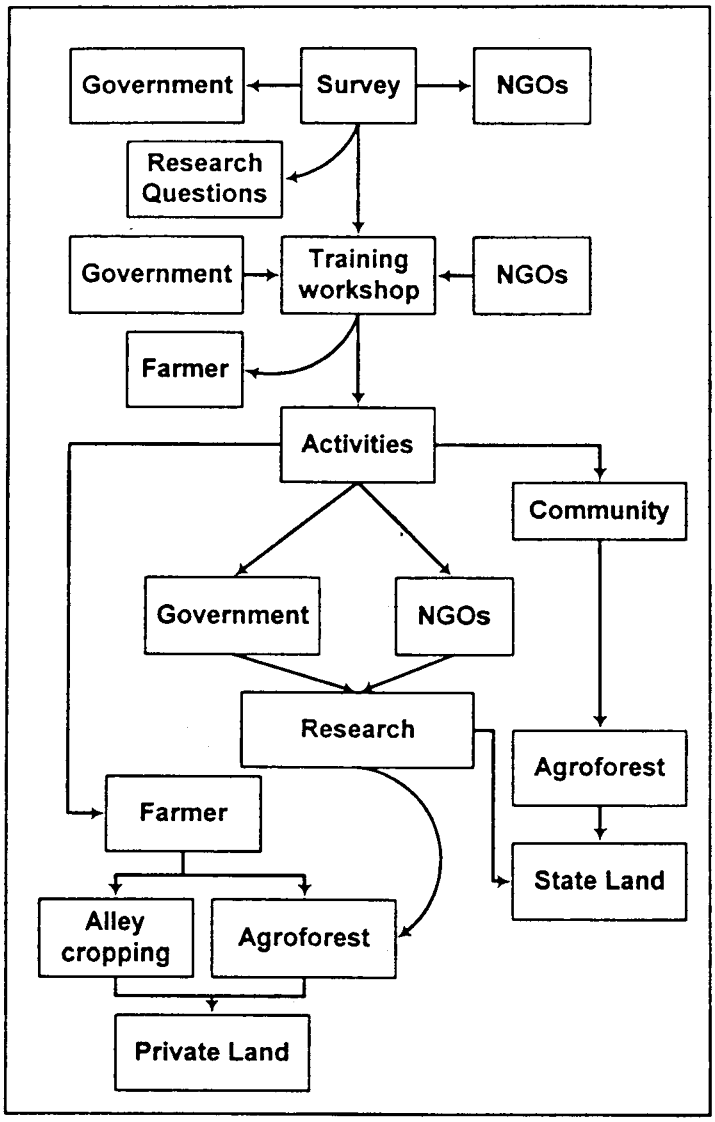

Figure 4.1. Conceptual framework of Cambodian team, which attempts to integrate the role of government and non-governmental organisations in solving the problems.

4.2. Indonesia

The Indonesian team viewed the sustainability of homegardens as an important issue within the context of global change (see Figure 4.2). Traditionally, homegardens or man-made forests have made a substantial contribution to rural communities. The continued existence of homegardens, however, is threatened particularly in those near urban areas. The question is how such systems could withstand external pressure to convert , and whether the pressure would dictate the integration or segregation of the systems.

The objectives of the study are to determine the importance of homegardens within the context of global change, to study the integration or segregation of the systems and to explore policy alternatives which would promote the continued maintenance of homegarden systems.

It is hypothesised that homegardens are relatively stable systems under global change, and that thee integration system will be better than segregation system as indicated by the role of the system in moderating water and nutrient cycles as well as in their productivity.

The study will consist of biophysical measurements regarding mass and heat transfer within the systems. This will lead to the quantification of processes at micro level (soil-plant-atmosphere-continuum). The use of spatially dynamic model will be employed to evaluate the processes at larger scale where external factors such as land-use change can be incorporated.

Some study outputs which are expected by the team are sets of recommendation to policy makers about the strategy to maintain the existence of homegardens, sets of recommendation to farmers how to improve the profitability of homegardens.

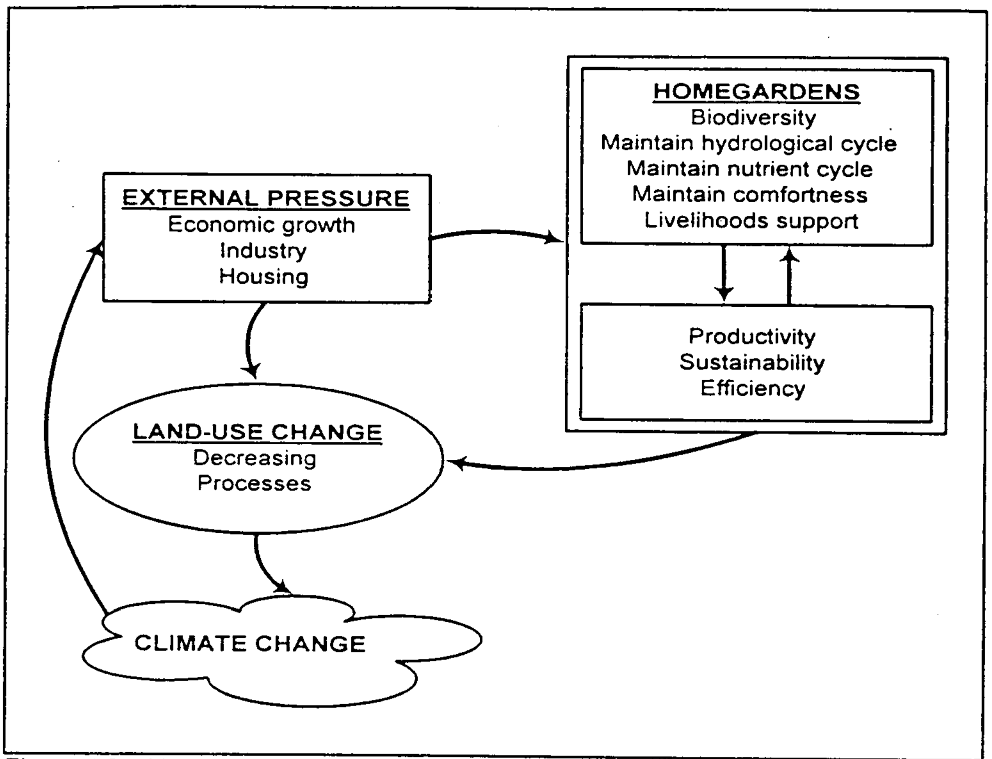

Figure 4.2. Homegardens potentially provide multiple functions and ecosystem services that could help adapt to and mitigate global change.

4.3. Lao PDR

Extensive shifting cultivation has been identified by the Lao PDR team as serious problem in the country. Total area of Lao PDR is about 236,800 km^2. Almost 75% of the total area is hilly to mountainous. Slash-and-burn practised in shifting cultivation has led to soil fertility loss and soil degradation, and hence, declining crop production. In order to solve those problems, the Lao government has implemented a policy that emphasises land-use planning in agriculture development. The policy stresses the importance of improving yields and reducing slash-and-burn by using new systems such as regreening and agroforestry.

The proposed study will try to help identify the best complex agroecosystem from among a series of options, and make recommendations to government on appropriate land use systems. Figure 4.3 shows the framework of replacing shifting cultivation using complex agroecosystem to be introduced to the community.

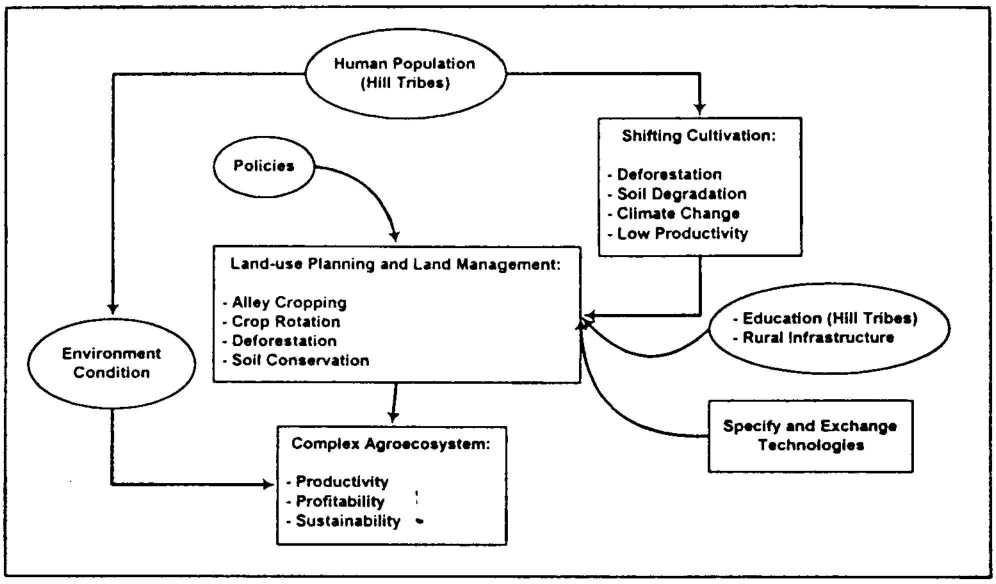

Figure 4.3. Complex agroecosystems alternatives to shifting cultivation practices in Lao.

The objectives of the study is therefore to identify appropriate complex agroecosystem type capable of reducing slash-and-burn and deforestation, and at the same time increasing farmers' income.

The study is designed to answer some questions about type of appropriate technologies for sustainable land management that are consistent with increased food and agriculture production, and the means to transform land management technologies for profitable and sustainable agriculture, especially for the hill tribes.

The Laotian team offered the hypotheses that alley cropping and fruit tree agroforests will be one of the most appropriate systems for profitable and sustainable agriculture on sloping land. Moreover, they suggested developing rural infrastructure will further increase crop and fruit yields of those systems.

Demonstration plots are proposed by the team to show the effectiveness of alley cropping and fruit tree system in slopping area. The team expects to be able to measure the impacts on the increase of upland productivity and profitability through development of sustainable multiple cropping systems; to improve capacity of Lao researchers in order to help the hill tribes to solve their own problems; and the transfer of land management technologies for profitable and sustainable agriculture to hill tribe communities.

4.4. Malaysia

The Malaysian team proposed a study, which would examine the impacts of land-use changes on the complex agroecosystem in the rapidly developing Klang Valley.

There are both human and biophysical factors that affect land-use and land cover change. These can tentatively be grouped into: demographic and socio-economic factors (population growth and distribution, income per capita and consumers demand, and access to capital), policy and institutional factors (national policies, and choice of technology), and biophysical factors (soil fertility and land suitability, and accessibility).

The major land-use change in Malaysia has resulted in the conversion of forest to other land-uses, especially during the years 1966-1990. The causes of forest depletion in Malaysia have been due mainly to the opening of new land schemes, logging activities and shifting agriculture practices.

Malaysian has a vision toward the year 2020 to become an industrial country and the centre of excellence *i.e.* Multimedia Super Corridor which is situated within the area of 15 km wide and 50 km length around the Klang Valley. This vision has promoted rapid development in this area. The existing land-use such as homestead garden, rubber plantation, oil palm plantation, forest plantation and natural forest are changing into industrial, commercial, recreational and urban areas. These changes cause serious environmental problems such as accelerated soil erosion, land slide, loss of wildlife, degradation of watershed through increased surface runoff, flash flood due to siltation of water ways and air pollution.

The study has objectives: to analyse the patterns of changes in land-use and its relationship to the climate pattern over the long-term period; to evaluate and predict the potential impact of land-use changes on agroecosystem and climate pattern; and to determine the methods and/or strategies to reduce the impacts on agroecosystem in Klang Valley and the surrounding areas.

The study will begin with a preliminary workshop and briefing with policy makers based on a literature review of previous local and overseas studies on the status and effect of land-use change. The workshop will be conducted with the assistance from various agencies, universities, departments and NGO's.

The main purpose of the workshop will be to increase the awareness of policy makers, planners, and individuals about the rapid change of land-use in the study area and Malaysia and its effect on the agroecosystem and environment. Thereafter, the team will commence the primary research activities. Research activities can be divided into two categories *i.e.* historical evaluation and 'on-farm' monitoring and/or experiment. Long-term evaluation by using secondary data such as climate and land-use data will be conducted to determine the relationship between land-use change and climate system and the trend of the changes. Historical data of climate and land-use can be obtained from Malaysia Meteorological Services, Department of Agriculture and Malaysia Remote Sensing Centre.

Meanwhile, 'on-farm' monitoring will measure the occurrence of flash flood, soil erosion, and variability of climate factor due to the change in land-use and to compare the situation with the 'undisturbed areas'. The results from long-term and 'on-farm' monitoring will be applied to several model that will be implemented using modelling software such as Stella and PCRaster to predict the change and its impact for certain period of time. Research finding will be documented and presented to policy makers, planners and stakeholders.

It is expected that the preliminary study will provide evidence of rapid and poorly managed land-use changes, which could potentially produce flash floods, soil degradation and altered local climate system. By providing results from preliminary studies and research activities to the policy maker and planner, the proper planning and management strategies for change of land-use can be implemented to sustain the agroenvironmental condition for these study area. Figure 4.4 shows the conceptual framework of the study proposed by Malaysian team.

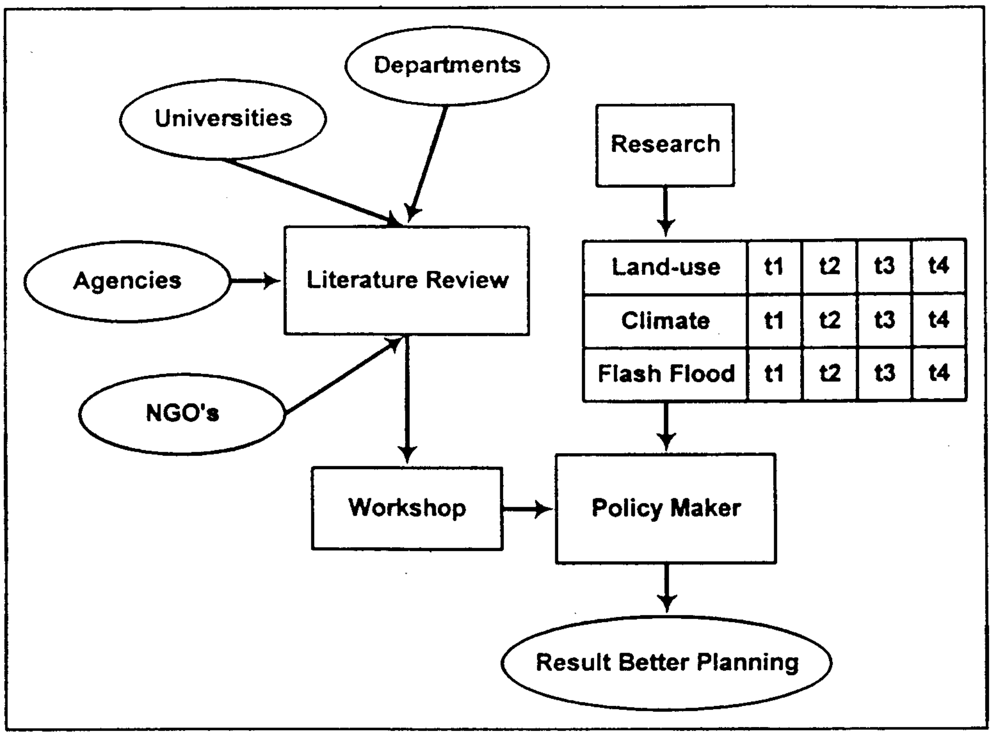

Figure 4.4. Conceptual framework of the 4-years study proposed by Malaysian team to demonstrate the impacts of land-use changes.

4.5. Philippines

The team proposed a study on the Management of Agroforestry in Sloping Upland Catchments under Global Change. Philippines is a country with more than 50% of its 30 million hectares of land is considered as forest land based on slope. While in the early 1960's there were more than 10 million hectares of standing old growth forest, recent data show that there are now less than a million hectares of standing forest. The deforested areas are now converted into either farm land, pasture land, plantation farm and others, with a significant portion has been converted into unproductive grassland or barren lands as a result of intensified farming with poor management and conservation practices.

The continuing exploitation of the forest is mainly due to population pressure and also to socio-economic developments in the lowland areas, *i.e.* rapid economic development, conversion of prime pre-urban agricultural lands into non-agricultural purposes and other related activities. As a consequence, the resource-poor sector of the society is continually forced either to migrate and cultivate the forests and marginal uplands or settle in the congested urban centres. Regardless of where they settled, some form of environmental degradation occurs, but at varying intensities.

The objectives of the study are to simulate and predict the productivity and sustainability of catchments under different agroforestry scenarios; and to validate the appropriate agroforestry models generated from modelling and simulation.

The team hypothesises that farm productivity, profitability, and sustainability in a complex agroecosystem in Philippine uplands are influenced not only by the biophysical and socio-economic conditions of the farm but also by the farm to farm interactions and other external factors that include policies, local and global economy and environmental concerns.

Appropriate modelling tools could now be easily accessed and used to enhance analyses, integration and assessment of the spatial and temporal distributions of the components of the agroenvironment and farming activities at landscape or catchment scale.

For spatial and temporal distribution of the components of the catchment, the PCRaster and Stella-based WaNuLCAS will be used. For the selection and assessment of appropriate soil conservation technologies, SCUAF, and WaNuLCAS will be utilised. For crop suitability and cropping pattern, including economic analysis will be tested using DSSAT. The role of the animal component within the catchment in terms of utilisation of the non-harvestable component of the crop sub-system and in nutrient recycling will be simulated using STELLA software.

It was proposed that the study will involve different agroforestry systems in sloping upland. Two catchment areas will be selected in the province of Laguna and Bukidnon. Priority will be given to catchments that were previously used as study sites to take advantage of availability of data and on-farm and/or plot size research results. The conceptual framework of the study is shown in Figure 4.5.

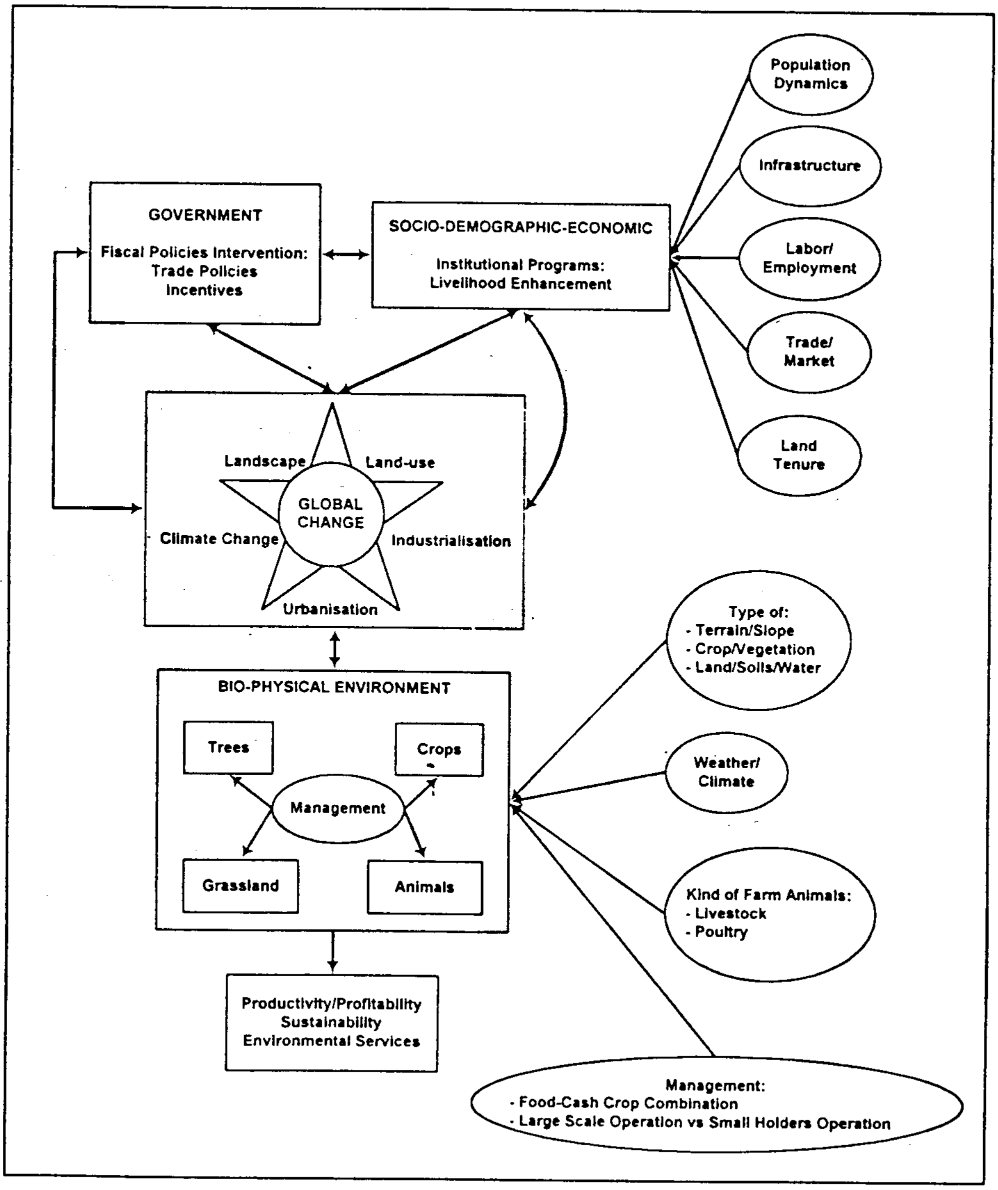

Figure 4.5. Agroecosystem and externalities: components and interactions. Philippines setting and experience.

4.6. Thailand

Watershed has been chosen by the Thai team as unit of ecosystem to be studied. The team concerns with the role of complex agroecosystems in moderating crop and water yields. The importance of complex agroecosystems is underlined by the fact that they would be the first system used after deforestation occurs in many parts of the country.

The objective of the study is to evaluate the impacts of converting tropical forests into complex agroecosystems on crop and water yields.

Measurements in the selected location consist of characterisation of soil and water components of the system, plant growth and biomass, climatic condition and the river system.

The experimental site for the study will include natural forest, secondary forest and degraded grassland, in western part of Thailand. The study site is focused at Maeklong Watershed, Tong Pha Phum, Kachanaburi Province, Western Thailand (Latitude 14° 30'-14° 45' N and Longitude 98° 45'-99° E). For long-term observation, the experimental permanent plots were set up at Maeklong Watershed Research Station, as follow:

- plot no. 1 is representative of natural forest, and the size of this experiment plot is 200 m x 200 m on the steep slope 23-28 degree. Covered vegetation is from several natural trees with bamboo more than 20 years;
- plot no. 2 is representative of secondary forest, and the size of this experiment plot is 200 m x 200 m on the steep slope 20-22 degree. Covered vegetation is from several trees with bamboo and banana more than 15 years;
- plot no. 3 is representative of grassland, and the size of this experiment plot is 200 m x 200 m on the slope 11 degree. Covered vegetation is from *Sesbania* sp., *Ya Kaa* and *Ya Pong* and several grasses more than 10 years.

From the research, the team expect to get the pattern of sustainable agroecosystem in different tropical forest types (especially in grassland), and the suitable modelling for simulation of tree-crop system in this watershed area.

4.7. Vietnam

The Vietnam team propose the research on the Evaluation of the RVAC (R - forest planting and protection, V - home garden, A - fish pond, C - domestic animal husbandry) ecosystems in midland areas of Vietnam under global change. Vietnam covers an area of 33 million hectares in total of which three quarters consists of hilly and mountainous landscape with varying slopes. In recent decades, the forest disappearance process is recorded at rather high rate (more than 200,000 ha/year). In 1996, the forest coverage dropped to 26.5% in comparison to 43.7% in 1943. The area of degraded land is increasing year by year. In 1993, the number reached 13.4 million hectares and most of them are recorded in the midland areas.

In recent decades, the land-use in midland areas has been strongly affected by external pressures such as immigration of population from dense plain areas to the midlands, high population growth (2.5 % annually), rapid economic development of the country (>8% GDP annually), change of policy in land-use, etc. Deforestation, and slash and burn agriculture are the main reasons for enlarging areas of degraded lands and the accelerated soil erosion and runoff in these areas. It also impacts on the ecosystem function decreasing green house gas absorption sink, decreasing productivity, profitability and threatens sustainability of the agroecosystems.

Therefore, there is an urgent need for creation of plantations, and the development of complex agroforestry systems or RVAC (R-forest planting and protection, V-home garden, A-fish pond, C-domestic animal husbandry) in the midland areas of Vietnam.

The long-term objectives of the study are to green up the barren lands in the midland areas; to develop the productive, effective and sustainable agroecosystems in the midland areas; to raise the living standard of ethnic minorities; to protect environment; and to improve the landscapes of the midland areas. The immediate short-term objective is to evaluate productivity, sustainability and profitability of RVAC-ecosystems in midland areas under global change.

The study consists of four phases: characterisation, application of modelling tools to simulate the processes within the system, validation, and result dissemination. The conceptual framework of the study is shown in Figure 4.6.

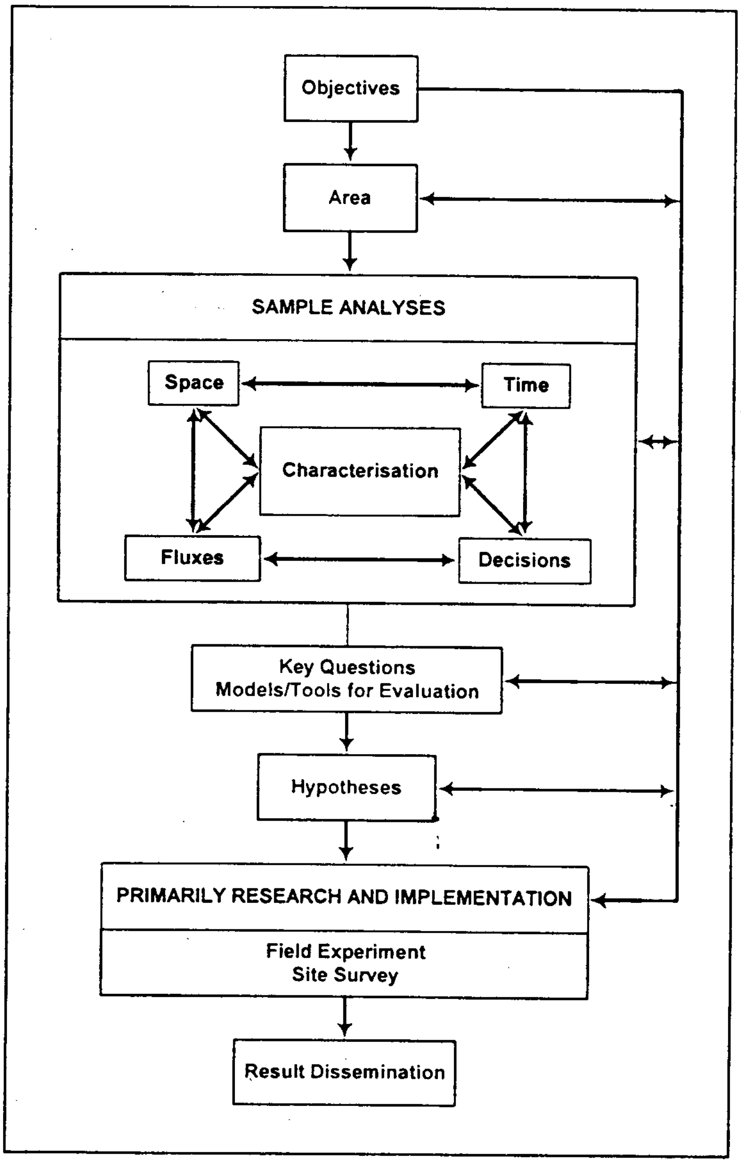

Figure 4.6. Vietnam conceptual framework.

The study proposals map of all countries is shown in Figure 4.7 below.

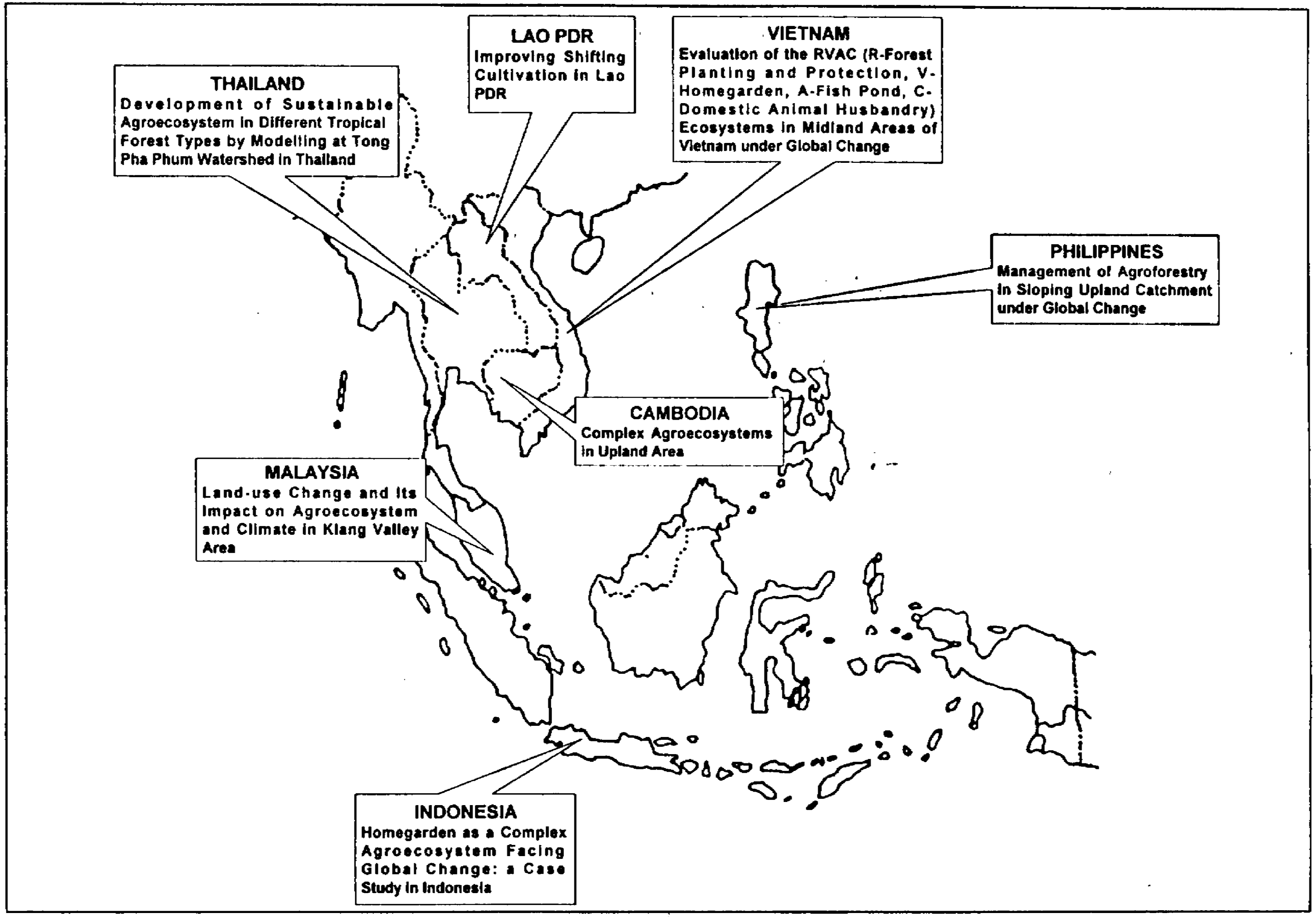

Figure 4.7. Country proposals drafted during the workshop

Section

5

Concluding Remarks

5.1. The Setting

Complex agroecosystem are practised in different ways and scales across Southeast Asia. The specific problems that are faced by complex agroecosystems differ from country to country, but there is a common issue of sustainability. On the one hand, land-use changes at rapid rates are threatening the existence of the system. On the other hand, the technology and supporting infrastructure have not been optimised to maintain its productivity, profitability and sustainability.

Small holder farmers decisions determine the complexity in terms of structure, function, and diversity of the system. However, the decisions are driven by external factors such as market integration, which induces specialisation, land-use intensification, which leads to higher output, and large scheme 'projects' played by external actors. As far as the scale of the ownership is concerned, less complex systems are usually found at farm level. When the integration is viewed at the landscape level, for example, a more complex system is encountered. Multiple objectives at the farm level, however, are being replaced by specialist small holders who also rely on off-farm activities.

5.2. The Future Studies

In order to increase the productivity, profitability, and hence the sustainability of complex agroecosystems, especially those located in less favourable environmental conditions and those facing tremendous external pressures, a lot of improvements have to be made. Research results should give guidance for the management of the system at various level.

To this end, the scaling issues should be raised again. It is generally believed that smaller scale research such as that of farm level (as opposed to the landscape level) will bring about information on the processes better than that occurring in larger scale. Scientists are having serious problems when the outputs have to be extrapolated. Conversely, large scale studies often fail when they have to explain detailed processes while still capturing major and observable phenomena. Thus, it is important to select the observations and modelling tools appropriate for the scale of interest, and to be prepared to use more than one approach when their is need to work at multiple scales.

The future studies should be technically feasible in terms of the availability of the resources. They should also be policy-relevant and incorporate local knowledge of complex agroecosystems.

5.3. The Organisation

In collaboration with organisations like ICRAF, CIFOR, and GCTE Activity 3.4, IC-SEA should support regional impacts studies on complex agroecosystems. It is very logical that such a collaboration would employ the network strengthened through this Training Workshop. The draft of proposals developed during the workshop should be used as a starting point.

The role of the National Team Coordinators is important to mobilise the expertise and resources available. IC-SEA should be able to facilitate the group in implementing the research activities and interaction within and between the groups.

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Appendix

1

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The National Team Coordinators have been helping IC-SEA in selecting the participants. They also act as contact persons for future studies and other events related to IC-SEA activities.

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Appendix

2

Models Used during the Workshop

Models	Developer	Software/Operating System
Fallow-Rotation Model	Dr Meine van Noordwijk ICRAF Southeast Asia Regional Research Programme Jl Gunung Batu no 5, PO Box 161, Bogor 16001 **Indonesia** Ph: 62-251-315 234; Fax: 62-251-315 567 *E-mail: icraf-indonesia@cgnet.com*	Stella® Research 4.0/ Windows
SCUAF	Dr Anthony Young and Dr Peter Muraya ICRAF House, United Nations Avenue, PO Box 30677, Nairobi **Kenya** Ph: (254 2) 521450; Fax 521001.C. ICRAF; Tx: 22048ICRAF *E-mail: ICRAF@cgnet.com*	DOS
Monkey Model	Dr Meine van Noordjwijk ICRAF Southeast Asia Regional Research Programme Jl Gunung Batu no 5, PO Box 161, Bogor 16001 **Indonesia** Ph: 62-251-315 234; Fax: 62-251-315 567 *E-mail: icraf-indonesia@cgnet.com*	Stella® Research 4.0/ Windows
WaNuLCAS	Dr Meine van Noordwijk and Mrs Betha Lusiana ICRAF Southeast Asia Regional Research Programme Jl Gunung Batu no 5, PO Box 161, Bogor 16001 **Indonesia** Ph: 62-251-315 234; Fax: 62-251-315 567 *E-mail: icraf-indonesia@cgnet.com*	Stella® Research 4.0/ Windows

Models	Developer	Software/Operating System
DSSAT version 3.0	IBSNAT Project 2500 Dole Street, Krauss 22, Honolulu, Hawaii 96822 **USA** Ph: (808) 956-8858; Fax: (808) 956-3421 *E-mail: ibsnat@hawaii.edu* *URL: http://everex.ibsnat.hawaii.edu/dssat/info.htm* *Listserver: listserv@uga.cc.uga.edu*	DOS
PCRaster	Dr Peter Burrough Faculty of Geographical Sciences, Utrecht University, PO Box 80115 , 3508 TC Utrecht, **The Netherlands** Ph: (31) 30 2532768 Fax: (31) 30 2540604 *E-mail: pcraster@frw.ruu.nl* *URL: http://www.frw.ruu.nl/pcraster/pcraster.html*	DOS

Appendix

3

Reading Materials

The following reading materials were provided to the participants for their future reference. They are grouped into various headings with regards to the topic and area of this workshop.

Introduction

Bachelet, D., King, G.A. and Chaney, J. 1995 . Climate change scenarios. *Modelling the Impacts of Climate Change on Rice Production in Asia:pp:67-83.*

Bachelet, D. and Kropff, M.J. 1995. The impacts of climatic change on agroclimatic zones is Asia. *Modelling the Impacts of Climate Change on Rice Production in Asia.* pp:*85-94.*

Agroforestry Systems

Gouyon, A., De Foresta, H. and Levang, P. 1993. Does 'Jungle Rubber' deserve its name? An analysis of rubber agroforestry systems in Southeast Sumatra. *Agroforestry System 22:181-206.*

Michon, G. and Mary, F. 1994. Conversion of traditional village gardens and new economic strategies of rural households in the area of Bogor, Indonesia. *Agroforestry System 25:31-58.*

Nair, P.K., 1993. Shifting cultivation and improved fallows. *An Introduction to Agroforestry. pp:55-74.*

Nair, P.K. 1993. Taungya. *An Introduction to Agroforestry. pp:75-83.*

Nair, P.K. 1993. Homegardens . *An Introduction to Agroforestry. pp:83-97.*

Nair, P.K. 1993. Alley cropping. *An Introduction to Agroforestry. pp:97-139.*

Modelling and Systems Approaches

Gardner, G. 1996. Asia is losing ground. *World Watch. pp:19-27.*

Hall, C.A.S., Tian, H., Qi, Y., Pontius, G. and Cornell, J. 1995. Modelling spatial and temporal patterns of tropical land use change. *Journal of Biogeography 22:753-757.*

Loehle, C., and Li, Bai-Lian. 1986. Statistical properties of ecological and geologic fractals. *Ecological Modelling 85:271-284.*

Riebsame, W.E., Parton, W.J., Galvin, K.A., Burke, I.C., Bohren, L.., Young, R. and Knop, E. 1994. Integrated modelling of land use and cover change. *BioScience 44(5):350-356.*

Shepherd , K.D., and Soule, M.J. 1996 (?). System analysis: agroforestry application.

Shepherd , K.D., and Soule, M.J. 1997 (?). Framework for economic and ecological assessment of agroforestry and other soil management option on west Kenyan farms using a dynamic simulation model.

Tuner II, B.L.. 1994. Local faces, global flows: the role of land use and land cover in global environment change. *Land degradation & rehabilitation 5:71-78.*

van Noordwijk, M. And Ong, C. 1996. Lateral resource flow and capture - the key to scaling up agroforestry results. *Agroforestry Forum 7(3):29-31.*

van Noordwijk, M., Tomich, T. P. , De Foresta, H., and Michon, G. 1997. To segregate -or to integrate? *Agroforestry Today, Jan-March 1997 Edition. pp:6-9.*

van Noordwijk, M. 1997 (?). Models as part of agroforestry research design. *Agrivita.*

Veldkamp, A. , and Fresco, L.O. 1996. CLUE: a conceptual model to study the conversion of land use and its effects. *Ecological Modelling 85:253-270.*

Tree-Crop Interaction

van Noordwijk, M., and Lusiana, B. 1997. Models of fallow rotations at different temporal and spatial scales. Manuscript for Fallow Symposium Malawi, March 1997.

van Noordwijk, M., Hairiah, K., Lusiana, B., and Cadisch, G.. 1997. Carbon and nutrient dynamics in natural and agricultural tropical ecosystems. CAB International (*in press*).

van Noordwijk, M., Hairiah, K., Lusiana, B., Cadish, G.. 1997. Tree-soil-crop interactions in sequential and simultaneous agroforestry systems (*in press*).

People-Forest Interaction

Vanclay, J.K. 1996 (?). Modelling land use patterns at the forest edge: feasibility of a static spatial model. *Ecological Economic:79-84.*

Modelling Tools

Anonymous. PCRaster, Dept of Physical Geography, Utrecht University, The Netherlands, 1996. An introduction to cartographic modelling with GIS. *Environmental Modelling in GIS.*

Anonymous. PCRaster, Dept of Physical Geography, Utrecht University, The Netherlands, 1996. An introduction to dynamic modelling with GIS. *Environmental Modelling in GIS.*

Malab, S.C. 1990 (?). Model Simulation of soil carbon and nitrogen changes under *A. auricauliformis* + *M. indica* agroforestry system.

Muraya, P., and Young, A. 1990. SCUAF Soil Changes Under Agroforestry, A Predictive Model Version 2, Computer Program with User's Handbook. International Council for Research in Agroforestry.

van Noordwijk, M. 1997. Monkey damage to young rubber: a conceptual model of management options at the forest margin (*draft manuscript*).

van Roode, M.N. 1997 (?). Application of a simple distributed runoff model in planning conservation farming with trees.

Appendix

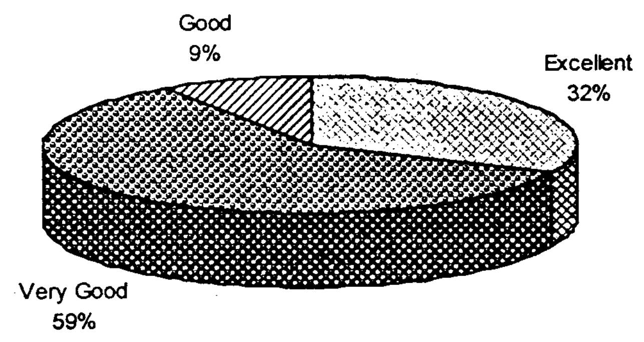
4

Evaluations

Participants

:valuation by participants was conducted weekly on their level of satisfaction on ›orkshop content considering the knowledge gained and the services/facilities ›rovided. The scores given as 1 (poor), 2 (fair), 3 (good), 4 (very good), and 5 excellent). However, individual qualitative comments were also accommodated. 'he results are 32% excellent, 59% very good, 9% good, 0% fair, and 0% poor. The ıraph shown below is summarised participants' evaluation on overall aspects of

Partcipants' Evaluation on Workshop Rate



workshop.

Trainers

The trainers were asked to evaluate the participants on preparedness, motivation, interest, initiative, and understanding. The score for preparedness is 4.00, motivation is 4.75, interest is 4.75, initiative is 4.25, and understanding is 4.00. The scoring system has the scale of one to five.

The Southeast Asian Regional Centre for Tropical Biology (BIOTROP) was established in 1968 and based in Bogor, Indonesia. It is one of the twelve centres under SEAMEO (Southeast Asian Ministers of Education Organisation). The organisation consists of nine member countries of Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Philippines, Singapore, Thailand and Vietnam. BIOTROP is aiming at becoming a leader in some general areas of tropical biology through quality research and training , as well as establishing and coordinating sustainable networks and linkages within the region and beyond. There Programme Thrusts have been identified to address BIOTROP's concerns about environment, natural resources, and sustainable development. These are: Tropical Ecosystems and Environmental Impacts, Biodiversity Conservation and Sustainable Management, and Environmental and Forest Biotechnology.

The Global Change and Terrestrial Ecosystems (GCTE), is one of the five Core Projects of the International Geosphere-Biosphere Programme (IGBP). Its objectives are built around two major themes - *feedforwards (impacts)* and *feedbacks* of global change to the terrestrial ecosystems - and include the entire range of terrestrial ecosystems, from pristine natural systems to intensively managed agricultural systems. Its Core Research Programme consists of 48 contributing projects involving over 700 scientists and technicians from 41 countries. They are organised in scientific frameworks which consists of four Foci and a large number of Activities and Tasks.

START - The Global Change SysTem for Analysis Research and Training - primary objectives is to provide support for regional research related to global change. It is supported by three international global change science programmes: IGBP, World Climate Research Programme (WCRP), and International Human Dimensions of Global Environmental Programme (IHDP). Its quarter head based in Washington D.C., USA is very active in coordinating, and obtaining funds for training courses, workshops, fellowships and visiting lectureships related to global change research and capacity building. The Southeast Asian regional centre known as SARCS is based in Bangkok, Thailand. It was directly involved in the establishment of IC-SEA at BIOTROP, Bogor. SARCS continues to be involved with IC-SEA, providing a supporting network for distributing information about IC-SEA activities, and participating in the project steering committee.

Funds for the initial establishment and first three years of operations of IC-SEA are provided by the Australian Agency for International Development (AusAID) through a grant to CSIRO, Division of Wildlife and Ecology. It is envisaged that the Centre will later become self-supporting through partnerships and grants for global change impacts assessment and sustainable management studies.