A MODELING APPROACH TO COLLABORATIVE FOREST MANAGEMENT

By

HERRY PURNOMO

POSTGRADUATE PROGRAM
BOGOR AGRICULTURAL UNIVERSITY
2003

ABSTRACT

HERRY PURNOMO. A Modeling Approach to Collaborative Forest Management. Under the direction of Rudy C. Tarumingkeng, Endang Suhendang, Dudung Darusman, Mohammad Syamsun and Upik Rosalina.

A successful sustainable development strategy requires that forest management be carried out in a participatory way. This includes the involvement of local communities. The importance of communities' participation has been written into Indonesian Law No. 41 on Forestry (1999). However, how this law can be implemented in areas already allocated to a concession holder is still unclear. The state-owned company, Inhutani II Sub Unit Malinau, has managed a forest area in Malinau District, East Kalimantan for over 10 years. Forest-dependent communities located in the managed area were Long Seturan, Long Loreh and Langap villages. The company managed the area based on plans approved by the local and central] governments. They established permanent sample plots for measuring the stand growth and yield data in their area, and were asked to improve the well-being of local communities. However, the schemes did not give the company sufficient space to manage the area creatively, or provide a systematic way to involve the communities in the management of the forest.

This research was aimed at seeking scenarios of sustainable forest management (SFM) that addressed the above limitations. To reach this aim, two research hypotheses were proposed:

1. Local forest stakeholders can define their own SFM Criteria and Indicators (C&I) for specific sites where they live, or that concern them;
2. Collaborative management of forests by all relevant stakeholders will achieve better forest management outcomes.

An artificial society of primary forest actors was built using a multi-agent system approach, used for developing scenarios to increase the sustainability of forest management. Indicators of forest cover and standing stock, communities' incomes, company revenue and taxes paid to local and central governments measured the sustainability.

The research results showed that local communities that lived in the area of Inhutani II were able to define C&I of SFM. The local C&I are not different from the generic or scientific C&I of SFM. However, these C&I are formulated with different structures and argumentations. The developed knowledge-based system found a way to harmonize this knowledge. Collaboration between concessionaires and the communities appeared to be the most suitable alternative for SFM - particularly for improving communities' incomes without decreasing the quality of the forest. An appropriate decentralization policy is a condition for implementing collaborative forest management.

LETTER OF STATEMENT

I herewith declare that the dissertation entitled "A Modeling Approach to Collaborative Forest Management" is purely my work with the supervision of the advisory committee. This dissertation has never been submitted to other universities to get a similar degree. All data and information sources have been stated clearly in the document and their correctness can be checked.

Bogor, 6 May 2003

Herry Purnomo

A MODELING APPROACH TO COLLABORATIVE FOREST MANAGEMENT

By

HERRY PURNOMO

A Dissertation
In partial fulfillment of the requirements for
the degree of Doctor of Forestry Science

POSTGRADUATE PROGRAM
BOGOR AGRICULTURAL UNIVERSITY
2003

Dissertation Title	:	A Modeling Approach to Collaborative Forest Management
Name	:	Herry Purnomo
Student Registration Number	:	975068
Study Program	:	Forestry Science

Approved by,

1. The Advisory Committee

Prof. Dr. Ir. Rudy C. Tarumingkeng, MSc
Chairperson

Prof. Dr. Ir. Endang Suhendang, MS
Member

Prof. Dr. Ir. Dudung Darusman, MA
Member

Dr. Ir. Mohammad Syamsun, MSc
Member

Dr. Ir. Upik Rosalina, DEA
Member

2. Head of Forestry Science Study Program

Prof. Dr. Ir. Cecep Kusmana, MS

3. Director of Postgraduate Program

Prof. Dr. Ir. Syafrida Manuwoto, MSc

Doctor degree was awarded on 9 July 2002

BIOGRAPHY

The researcher was born in Lumajang, East Java, on 21 April 1964 as the third child of Abdul Rasyid and the late Siti Masamah. His undergraduate program was carried out as a Study Program at the Agricultural Meteorology, Faculty of Science and Mathematics, Bogor Agricultural University, completed in 1987. In 1990, the researcher studied Computer Science at a Sandwich Program in a cooperative program between the University of Indonesia and University of Maryland USA for a Master of Science degree, completed in 1990. In 1997, the researcher joined the Forestry Science Study Program, a Postgraduate Program at Bogor Agricultural University, to do a Doctoral degree.

The researcher is a lecturer at the Faculty of Forestry, Bogor Agricultural University. He primarily teaches Systems Analysis. He is also a researcher at the Center for International Forestry Research (CIFOR) in Bogor.

During the doctoral study, he participated in training on Programming in Logic (PROLOG) for Natural Resource and Environmental Management, University of Edinburgh, United Kingdom (1998), and Artificial Society with CORMAS (Common Pool Resources and Multi-agent Systems), Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), Montpellier, France (2000). In 2002, he presented a paper titled "Development of Multi-stakeholder Scenarios of Secondary Forest Management: A Multi-agent System Simulation Approach" in an international seminar on Dipterocarp Reforestation to Restore Environment through Carbon Sequestration, organized by Gadjah Mada University and KANSAI and KANSO Japan in Yogyakarta. In February 2002, he presented another paper entitled "Developing a Collaborative Model for the Management of the Areas Surrounding Lumut Mountain: A Qualitative Systems Analysis Approach" in the Symposium on Forest Margin Interactions, organized by CIFOR Regional Office, Harare, Zimbabwe. He also visited Beijing, China for presenting criteria and indicators for sustainable forest management and related tools in June 2002

In the year 2002, as a senior author, he submitted five different scientific papers to international journals. Two papers entitled “Multi-agent Simulation of Alternative Scenarios of Collaborative Forest Management” and “Collaborative Modelling to Support Forest Management: Qualitative Systems Analysis at Lumut Mountain, Indonesia” will be published in the Journal of Forest Small Scale Economics, Management and Policy, in the year 2003. The other three papers are in the reviewing processes.

ACKNOWLEDGMENTS

My sincere gratitude and appreciation go to my supervisors Prof. Dr. Rudy C. Tarumingkeng, Prof. Dr. Endang Suhendang, Prof. Dr. Dudung Darusman, Dr. Mohammad Syamsun and Dr. Upik Rosalina for their precious help, continuous encouragement, and wise guidance during my graduate work. Without their contributions, I would never have reached the goal of my doctoral program.

This study would not have been possible without the funding I received. I would like to thank the Ministry of National Education, which provided me financial support for this program. My thanks also to the Center for International Forestry Research (CIFOR) that provided data and information essential to this study. Special appreciation goes to Dr. Ravi Prabhu, Dr. Carol Colfer, Dr. Mandy Haggith and Dr. Doris Capistrano, for their support and help during the completion of this program. I would also thank Catherine Snow for her kind English edit and polish.

Acknowledgment must also be extended to my late mother, my father, my mother-in-law and family members who never forgot to support and pray for the successful completion of my study. I also would like to express my thanks to those involved in the CIFOR Adaptive Collaborative Management Project, CIFOR Bulungan Research Forest and Inhutani II, for sharing data and knowledge during the study. My thanks also to my colleagues at the Forest Management Department, Faculty of Forestry, Bogor Agricultural University, for their encouragement and support.

To my wife, Nina Yudisiana, and to my children, Ryan Maulana Herwindo and Arina Salsabila, please accept my very special thanks. Their love,

compassion and understanding have always been in my deepest heart. I could never have successfully completed this task without their sacrifices.

Above all, praise is to Allah, the Almighty God, who created and sustains us. He is The Ultimate One who has made the accomplishment of my mission of study possible. May Allah, the most gracious and the Most Merciful, bless us and give us every guidance in facing our future.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

I. INTRODUCTION

1.1. Background

Any research on sustainable forest management requires an understanding of what these terms constitute, both on a local and generic level. A forest is an ecosystem characterized by more or less dense and extensive tree cover, often consisting of stands that vary in species composition, structure, age, class, and associated processes. It commonly includes meadows, streams, fish and wildlife (Helms 1998). Helms formulated forest management as the practical application of biological, physical, quantitative, managerial, economic, social, and policy principles to the regeneration, management, utilization, and conservation of forests in order to meet specific goals and objectives while maintaining the productivity of forests. In other words, forest management means managing forest ecosystems to meet specific goals and objectives.

Indonesian forests are complex ecosystems, requiring efficient forestry management. This involves consideration of forest management issues including the richness of living organisms in forests, the uniqueness of forest-dependent people, multiple products produced from the forests and property rights problems. Good forest management takes into account all these aspects.

The Government of the Republic of Indonesia, through the Ministry of Forestry, stated that all forest production should be managed sustainably. It is obvious that sustainability involves satisfying present needs without compromising future options. But what does this mean in terms of forest management? In order to understand whether a particular forest is managed sustainably or not, a set of criteria and indicators for assessment is required.

Research by Osmaton (1968) revealed that in good forest management, there should be an ideal state of perfection that satisfies the purpose of management to the full. Without such an ideal, the organization of ways and means becomes disoriented and there is no standard by which to measure the efficiency of forest management. This ideal state of perfection is called a 'normal forest'. To satisfy the chosen target of management, the 'normal forest' must possess certain general attributes, namely:

a. The specific composition, structure or form of the forest must be in harmony with the local environment. The choice of species grown and methods of silviculture adopted have to suit the particular site. Only then can complete growth be secured.
b. The growing stock of trees must be constituted to provide the greatest possible quantity of desired forest products (with intangible benefits).

In 1992, the International Tropical Timber Organization (ITTO) published criteria for the measurement of sustainable tropical forest management at national and forest management unit (FMU) levels. Webster's New World Dictionary (Neufeldt and Guralnik 1988) defined *criterion* as *a standard, rule, or test by which something can be judged.* The Society of American Foresters (Helms 1998) defined *criterion as a category, condition, or process by which sustainable forest management may be assessed.* The ITTO (1998) defined *criterion* as *an aspect that is considered important by which sustainable forest management may be assessed. A criterion is accompanied by a set of related indicators.* The ITTO's criteria for sustainable forest management at FMU level of the year 1992, are: resource security; continuity of timber production; conservation of flora and fauna; acceptable level of environmental impact; economic benefits; planning and adjustment to experience.

In 1998, the ITTO updated their criteria and indicators (C&I) based on the experience they gained from tropical countries and an improved understanding of the components of sustainable forest management. This 1998 criteria covered: enabling conditions for sustainable forest management; forest resource security; forest ecosystem health ; the flow of forest produce; biological diversity; soil and water; and economic, social and cultural aspects.

There are still a lot of questions to address in relation to the C&I, including how to measure it in the field, how to reason and how to justify the sustainability of forest management practices. The concept of C&I has been broadly adopted in the forestry sector as a common approach to conceptualizing and evaluating SFM. C&I is used to assess the quality of management and the ecosystem.

Other key programs and situations in which C&I have been created, adopted or reformulated for the purposes of sustainable forest management are the Smartwood Program (1993), Amazon Cooperation Treaty A.C. (1995), The Montreal Process (1995), Scientific Certification Systems (1995), and the African Timber Organization (1996), Forest Stewardship Council A.C. (1996), Center for International Forestry Research (CIFOR, 1996), and Lembaga Ekolabel Indonesia (LEI, 1997).

Criteria and indicators developed by ITTO can be categorized as generic C&I. It is not scientifically accepted that a single set of C&I can be implemented everywhere without adaptation. Any set of C&I needs to be adapted to the local situation by taking into account local physical, biological, economic and social conditions. For this purpose, it is necessary to develop a tool for modifying and adapting the generic C&I. In addition, an inference tool by which a conclusion of assessment is made is required – a matter still untouched in the ITTO guidelines. This tool would reflect the capability of reasoning through C&I.

Approaching sustainability and C&I as a system is necessary to understand their components and links. A systems approach to sustainability entails consideration of the various agents interacting in the world as a system.

Such an approach involves establishing general principles with which to draw inferences about likely and actual interactions between the systems under consideration. These principles can also be used to analyze and observe patterns of interaction between systems (Clayton and Radcliffe 1996). The linkage of C&I forms a network instead of a hierarchy. A C&I network is similar to the concept of a semantic network, which is a way to represent knowledge for a particular domain. Thus, a sustainable forest management assessment needs a tool which would enable reasoning through a network of knowledge.

Application of a knowledge-base systems approach to sustainable forest management assessment is quite new. There is no detailed research that has been done in this area. However, the application of a knowledge base systems approach in forestry has been introduced. Walker (1994) developed a knowledge base systems approach to agro-forestry research and extension. Walker developed a methodology for the acquisition, synthesis and storage of knowledge. This was achieved by using the application of a knowledge base systems technique, an AKT2 (Agroforestry Knowledge Kit) - a software toolkit developed in PROLOG, an artificial intelligence programming language. It provides the user with an environment for the creation, storage and exploration of a large knowledge base, containing knowledge on specific topics drawn from a range of resources.

1.2. Research Questions

Criteria and indicators for forest sustainability in Indonesia have been formulated. The process was likely to have been similar to formulating TPTI (*Tebang Pilih Tanam Indonesia* or Indonesian Selective Cutting and Planting). One of the widely detected failures of the TPTI was its incompatibility to all Indonesian forests. A forest is a complex ecosystem, which is unique from site to site. Any general formula on how to manage all forests will never be adequate. Furthermore, the sustainability of forests is not only assessed by biophysical indicators, but also by socio-economic indicators which take into account local stakeholders, including forest-dependent people.

Considering forests are complex ecosystems, any formula to manage them should be adapted to suit the specific site and local cultures. Room for modification and adaptation should always be provided. Criteria & indicators of forest sustainability as a tool for managing forests should also be adaptive.

A forest is not only characterized by its complex ecosystem, but also by the complex social system around it. Different stakeholders with legitimate interests in using the forest are located in the same area. An arrangement for those stakeholders to share the benefits and costs of managing the forest is required. However, the impacts of any policy option on collaborative forest management between stakeholders always takes many years to measure - often beyond the time allocated for research on the subject. How can we ensure that collaborative arrangements are leading to better results for both stakeholders and the long-term sustainability of forests? A simulation model is an appropriate approach to use when the system is large and complex, and requires the ability to observe potential impacts of different options on forest management. “Simulation” means making a simplified representation of the reality.

Concerning those problems, the research tried to find the possible answers for the following questions,

a. Could indigenous knowledge of forest-dependent people be incorporated into current/generic knowledge to assess the sustainability of forests?
b. Could an artificial society of forest actors be built and simulated in order to learn the impact of their activities on forest sustainability?

1.3. Research Objectives

The objectives of the research were:

a. To harmonize the relationship between local people and modern actors in the framework of a multi-stakeholder forest management aimed at achieving sustainable forest management;

b. To develop tools to facilitate collaborative management of the forest.

1.4. Research Hypotheses

The research hypotheses were formulated as follows:

a. Local communities of forest-dependent people can define their own sustainable forest management criteria and indicators suitable to the specific site in which they live or depend on;

b. Involving local communities of forest-dependent people in the forest management scheme can lead to better sustainability outcomes.

The research involved finding out what sustainability constitutes from different angles and ways to go about achieving it. The first angle was modern knowledge. This modern knowledge ideally becomes the basis on which governments and forest managers develop sound forest management approaches. Another angle was the knowledge of forest-dependent people who live in the same area as the forest. The first hypothesis assumed the conformity of the modern and local knowledge. It rose due to the fact that some people were in doubt about the capacity of local people to understand and manage forest sustainability.

The second question was how to achieve sustainability given each stakeholder has a different interest in the forest. If there was a shared ideal concept of forest management among stakeholders, then collaboration would be possible. Otherwise, co-existence was a possible scenario as an alternative to collaboration.

II. LITERATURE REVIEW

2.1. Sustainable Development Conceptual Framework

According to Webster's New World Dictionary (1988), the etymological root of sustainability is derived from the Latin verb *sustenere* (= to hold). This etymology is also reflected in the debate among Spanish-speaking scientists about whether *sostenibilidad* (from *sostener*) or *sustentabilidad* (from *sustentar*) is the more accurate translation. The first term is closer to "being upheld" while the latter term is closer to "to uphold" (Becker 1997). The latter terminology indicates a strong normative component in the concept of sustainable development.

Sustainable development has an essentially normative character, which makes it difficult to put into practice. It implies a close relationship between environmental considerations and economic growth. Within sustainable development, economic and social objectives must be balanced against natural constraints. A spirit of solidarity with future generations is included in the concept. Sustainable development is based on the common principles of self-reliance, fulfillment of basic needs and quality of life (Schtivelman and Russel 1989). Bruntland's Commission defined sustainable development as a process in which the exploitation of resources, direction of investments, orientation of technology development and institutional changes are all in harmony, enhancing both current and future abilities to meet human needs and aspirations (WCED 1987 in Haeruman 1995). Sustainable development must involve an interdisciplinary approach. To present the interdisciplinary nature of sustainability assessment, a conceptual framework or basic structure for sustainability assessment (Figure 2.1) was proposed (Becker 1997).

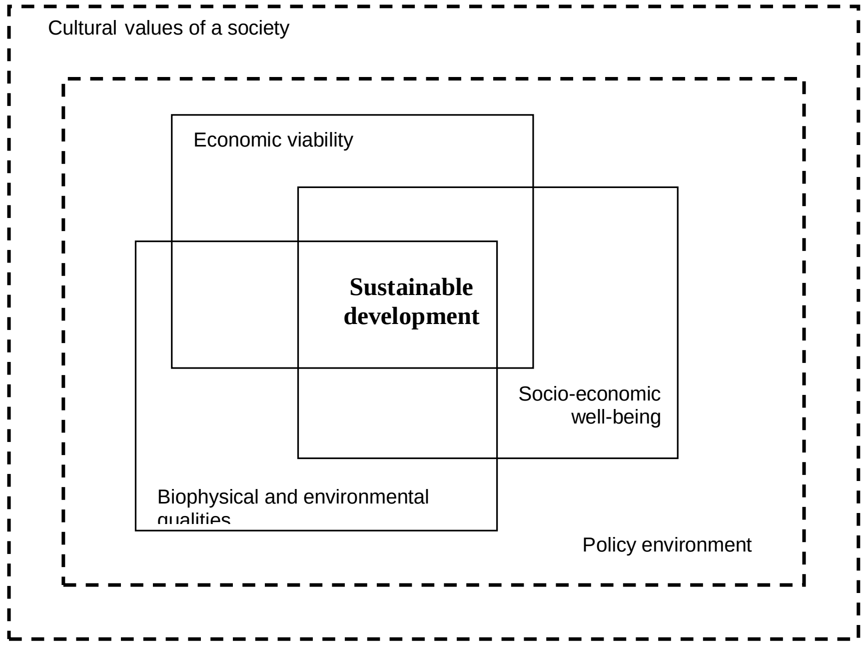


Figure 2.1. Conceptual framework for sustainability assessment
(Modified from Becker 1997)

The framework shows very clearly that an assessment of sustainable development must involve consideration of society's ethical or cultural values. Thus, any discussion about sustainable development in Indonesia should involve an understanding of local values.

In addition, the policy environment has an impact on sustainability assessment. Neglecting policy considerations in an assessment is likely to lead to an incorrect assessment result. Figure 2.1 shows that development is sustainable if it is economically viable, environmentally sound, socially accepted, culturally appropriate and based on a holistic scientific approach.

As previously mentioned, sustainable development has normative and scientific aspects - these are depicted in Figure 2.2. The normative approach sees sustainable development as leading to the wise use of natural resources and environmentally sound activities. It deals with nature and environmental values, intergenerational and intra-generational equity. To be scientifically sound, a new paradigm should be implemented that takes into account all relevant factors.

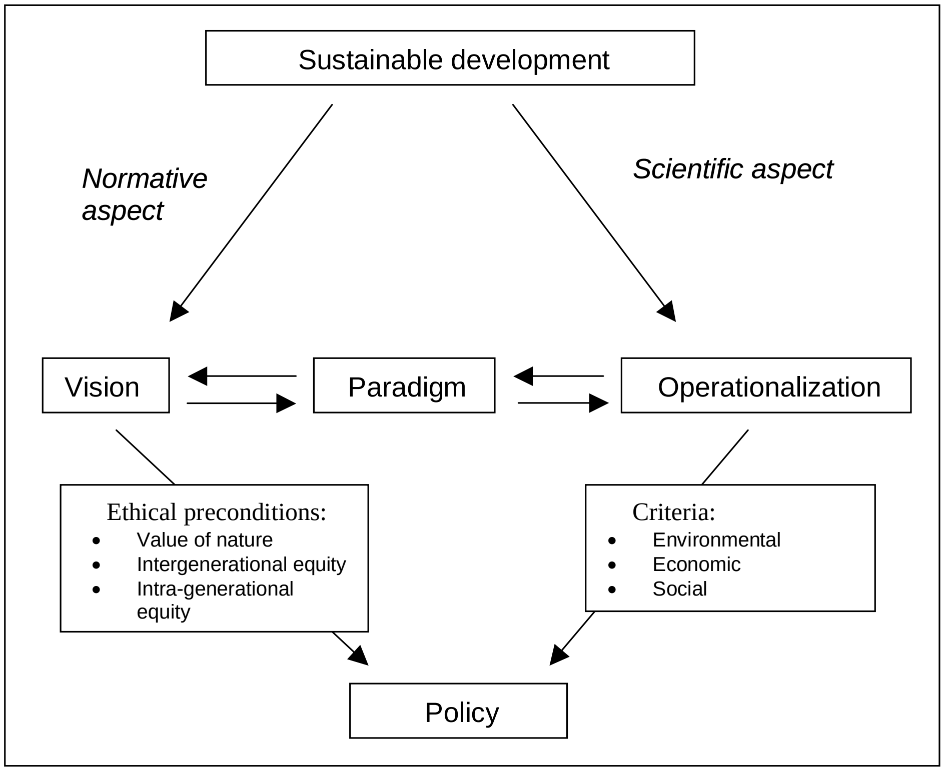


Figure 2.2. Normative and scientific aspects of sustainability (modified from Becker 1997)

Webster's New World Dictionary (1988) defines *paradigm* as an overall concept accepted by intellectuals as a science, because of its effectiveness in explaining a complex process, idea, or set of data. The vision of sustainable development must be placed into a new development paradigm which allows for the actual implementation of sustainable development. In the implementation, environmental, economic and social disciplines should be taken into account when assessing sustainability.

2.2. Local Knowledge and Perspectives

Wavey (1993) stated that recently, academics, scientists and researchers have "discovered" that the knowledge which indigenous people hold about the earth, its ecosystems, wildlife, fisheries, forests and other integrated living systems is both extensive and extremely accurate. On the eve of the 500^{th} anniversary of Christopher Columbus having stumbled upon North America, it is appropriate to provide comments from an indigenous North American person on how they perceive the concept of "discovery'.

Johannes (1993) suggested that research on indigenous people, their traditional ecological knowledge and management systems should focus on four essential perspectives and frames of reference:involving taxonomic, spatial, temporal and social factors. Kearney *et al.* (1999) studied stakeholders' perspectives on appropriate forest management in the Pacific Northwest of North America by using a conceptual content cognitive map (3CM) and semi-structured interviews. The study found how stakeholders conceptualised "good forest management", as shown in Figure 2.3. Three stakeholders were identified in the study - environmentalist, industrialist and government (United State Forest Service) stakeholders. Each explained their perspective on "good forest management" which was then categorized. It was found that different stakeholders might have different perspectives on "good forest management".

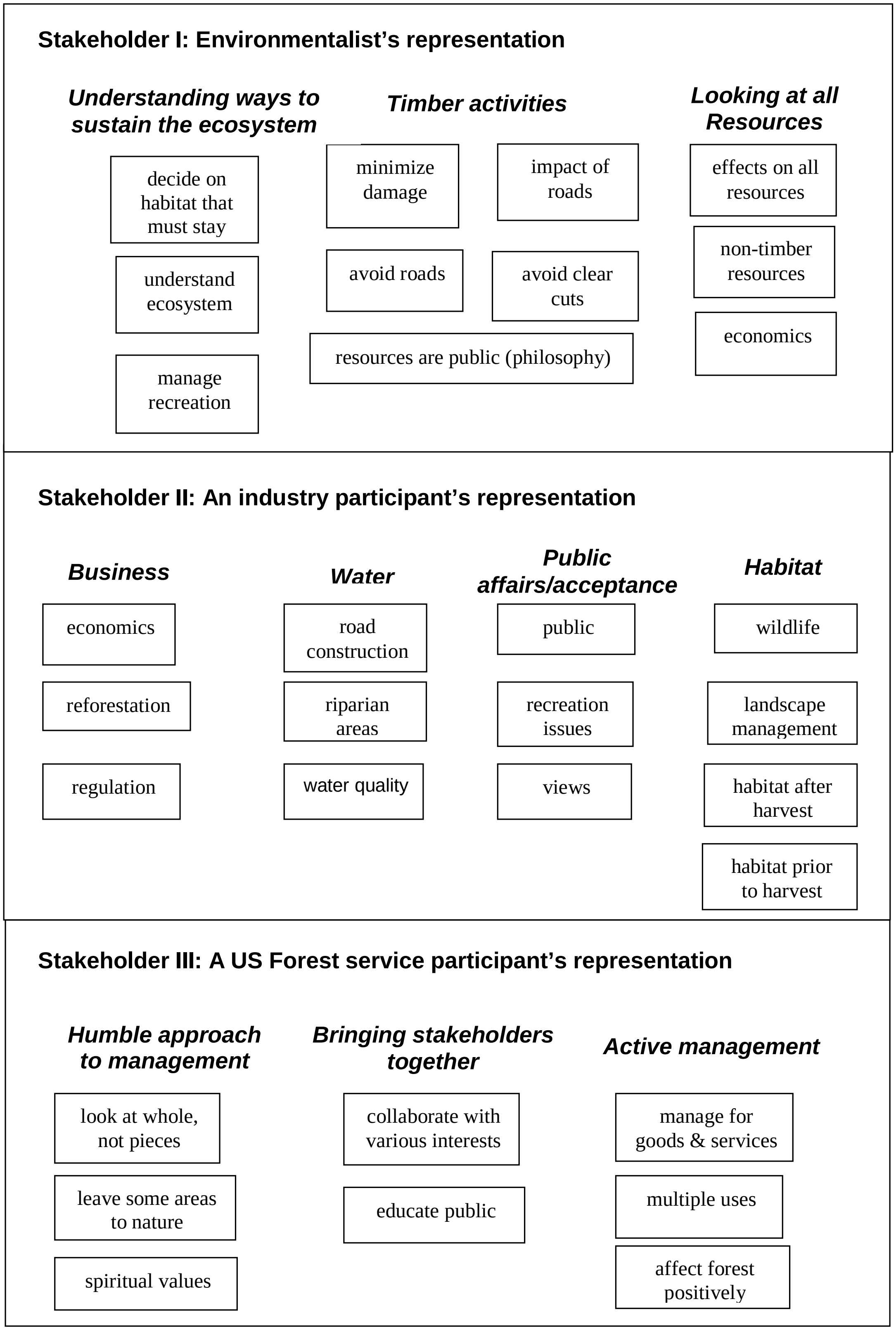


Figure 2.3. The stakeholders conceptualized components (in box) and their perceived categories (in italic) of "good forest management" (Kearney *et al.* 1999)

2.3. Knowledge Base System Development

A knowledge base system (KBS) is a combination of a knowledge base (an articulated and defined set of knowledge) and an inference engine. Inference engine is a logic-based algorithm that draws inferences and conclusions from the broad knowledge base. A knowledge base system is 'domain specific', meaning it is developed for a particular knowledge. The knowledge has to be clearly declared, to ensure the inference engine can accurately 'reason' with that knowledge. Figure 2.4. describes the general architecture of a knowledge base system. The knowledge base is comprised of any type of relevant knowledge including local and scientific knowledge.

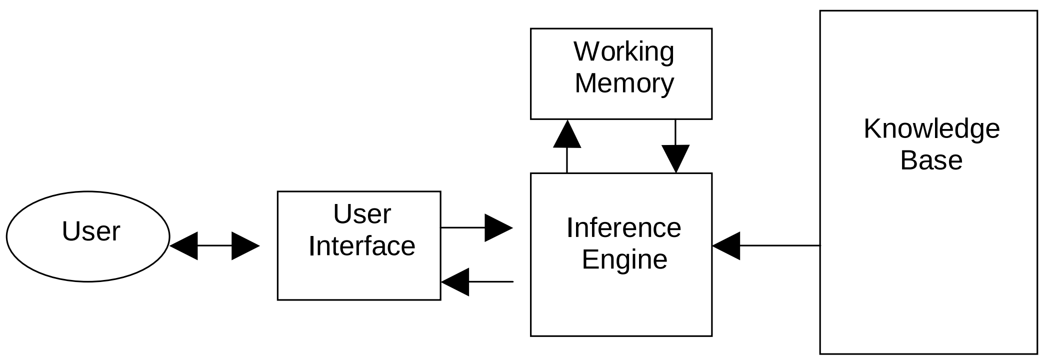


Figure 2.4. The general architecture of a knowledge base system

The body of knowledge is obtained from experts in a particular domain of knowledge. The outcome of this process can be expressed in languages such as English and Bahasa Indonesia instead of computer languages. It is important to make the outcomes understandable to all stakeholders who are involved in the knowledge base system development. These stakeholders should be able to testify to the outcomes drawing on their own knowledge or by reviewing relevant literature. The domain experts consist of scientists and traditional experts. In forest sustainability assessment, the local people, who have extensive experience in managing forests, can act as local experts. Structuring and incorporating these two types of knowledge is challenging, because the methodology used to form indigenous or traditional knowledge is often different to the methodology used in scientific knowledge. These differences are shown in Table 2.1.

Table 2.1. The differences between scientific and indigenous or traditional knowledge (Walker 1994)

Characteristics	**Scientific Knowledge**	**Indigenous Knowledge**
Scale	Universal	Local
Supernatural	Absent	Present
Transmission	Formal	Informal
Leaders	Professional	Informal leaders
Methodology	Hypothesis and experiment	Live experiences
Original Lifestyle	Western world	Eastern world
Viewing natural resources	Exploiting natural resources	Harmony with nature

Forests, from a scientific knowledge perspective, are regarded as sources of biodiversity. Traditional knowledge practitioners use the forest as a source of traditional medicine. Many of these traditional practitioners live a subsistent lifestyle. To assess whether forest management practices maintain forest biodiversity, scientific knowledge needs to use certain assessment parameters - for instance, a Simpson Index or Shannon-Wiener Index, during the forest utilization period. Sometimes, this is impractical, because it is difficult to show changes in biodiversity during the utilization period. Traditional experts may assess forest biodiversity based on the forest’s provision of medicinal sources.

This is not always the case, but generally it offers a possible way to complement modern knowledge in measuring biodiversity.

Knowledge synthesizing between different sources is critical to sustainable forest management. One rule of thumb is using scientific knowledge for universal ideas or concepts and traditional or indigenous knowledge for local applications. It complies with a well-known environmental principle: “think globally act locally". Scientific knowledge is not adequate to understand the complexity of all forest eco- and social systems. Indigenous knowledge is not optional, but a necessary condition to gain a greater understanding of forests. Furthermore, the term ‘sustainability’ is influenced, if not dominated, by cultural values.

Sukadri (1997), at the XI World Forestry Congress in Antalya, Turkey, revealed there are many different ways to analyze and assess policy reform for sustaining forests, one of them, through ‘expert system’ application. Guangxing Wang (1998) developed an expert system to improve forest inventory and monitoring. This involves incorporating multi-source knowledge into the knowledge base, with three paradigms of rule-based, object-oriented, and procedural programming.

Panigrahi (1998) urged the utilisation of fuzzy logic in biology and agriculture KBS decision-making techniques in response to its lack of quantitative knowledge in some parts. The fuzzy system model is depicted in Figure 2.5. Guerinn (1991) used qualitative reasoning for ecological process modelling in hydro-ecology. The architecture of his model is shown in Figure 2.6. Both the fuzzy system and qualitative reasoning help us tackle uncertainties when we are determining the values and parameters of sustainability.

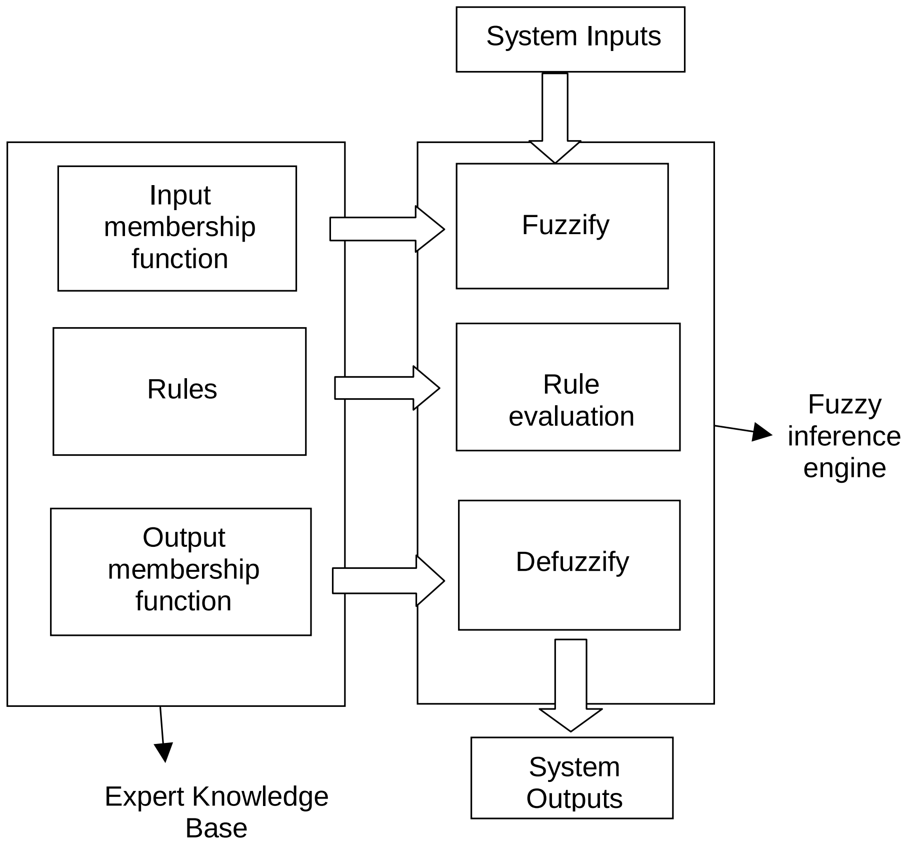


Figure 2.5. Model of a fuzzy system (Panigrahi 1998)

2.4. Multi-agent Systems

Using a simulation model is an appropriate approach when the system is large, complex and requiring a study of different potential impacts of various options. Simulation means making a simplified representation of a reality. Just as a model aircraft captures many important physical features of a real aircraft, a simulation model captures important operational features of a real system (CACI n.d.).

One well-known computer-based simulation dealing with this matter is a systems dynamics approach. This provides an understanding of how things have changed through time (Forrester 1999). System dynamics software such as STELLA, POWERSIM, SIMILE and VENSIM helps to formulate a model using stock and flow components according to difference equations. Systems dynamics has its roots in the systems of difference and differential equations (Forrester 1980). The difference equation is usually used on biophysical problems where the future state depends on the current state and other factors. Another system is the multi-agent system (MAS), which focuses more on stakeholders' interactions.

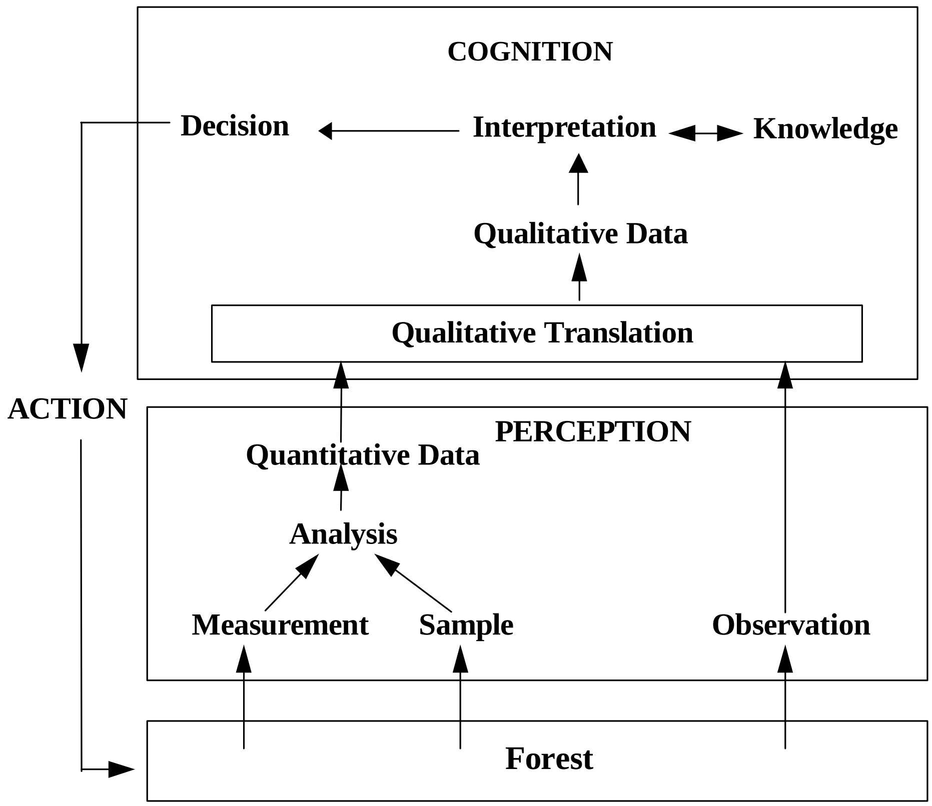


Figure 2.6. Qualitative and quantitative reasoning (Guerinn 1991)

MAS is an emerging sub-field of artificial intelligence that aims to provide both principles for the construction of complex systems involving multiple agents, and mechanisms for the coordination of independent agents' behaviors. While there is no generally accepted definition of "agent" in artificial intelligence, an agent is generally considered as an entity with goals, actions, and domain knowledge, situated in an environment. The way an agent acts is called its “behavior" (Stone and Veloso 1997). The use of modelling based on MAS for tackling natural resources and environment management issues is growing steadily (Bousquet 1999). The study of MAS focuses on systems in which many intelligent agents interact with each other. The agents are considered to be autonomous entities, such as software programs or robots. Their interactions can be either cooperative or egocentric – in other words, the agents can share a common goal or they can pursue their own interests. (Sycara 2000).

Flores-Mendez (1999) said that agents are entities within an environment, and that they can sense and act. This means that agents are not isolated, and that they can communicate and collaborate with other entities. Once agents are ready for collaboration, they need to find other appropriate agents with whom to collaborate.

In this case, a MAS technique was chosen instead of a stock and flow systems dynamic because the focus of this modeling is on forest stakeholders or agents. The research was aimed at answering questions related to a future scenario, aimed at improving the well-being of stakeholders and improving forest sustainability. The hypothesis of the research was formulated to result in better outcomes in forest co-management by all relevant stakeholders.

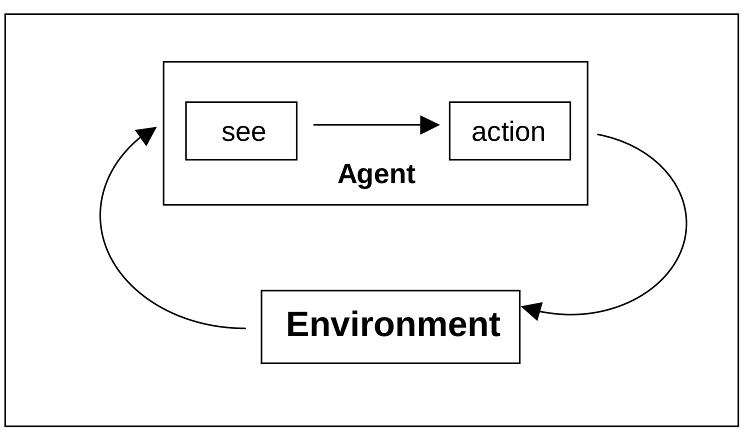


Figure 2.7. Perception and action subsystems (Weiss 1999)

In order to simulate stakeholders' activities and interactions, we need a tool that can represent stakeholders' individual knowledge, beliefs and behaviours. This modelling assumes that each stakeholder or agent acts autonomously, depending on their own perceptions of the environment, as shown in Figure 2.7.

If the agent wants to take into account previous perceptions, then the agent needs to integrate what they perceive and what is already in their mind, as illustrated in Figure 2.8. Figure 2.9 shows a more comprehensive architecture namely *Belief-Desire-Intention* (BDI). These architectures have their roots in the philosophical tradition of understanding *practical reasoning* – the process of deciding, moment-by-moment, which action to perform in order to achieve a goal.

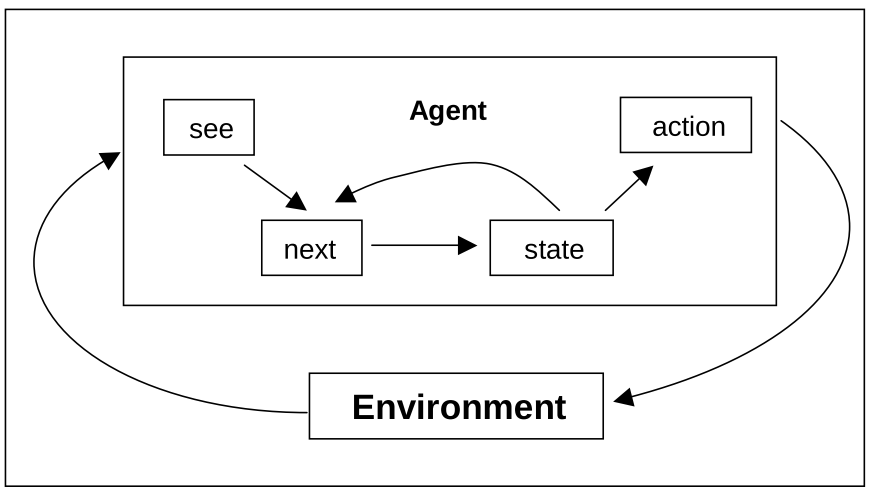


Figure 2.8. Agents that maintain state (Weiss, 1999)

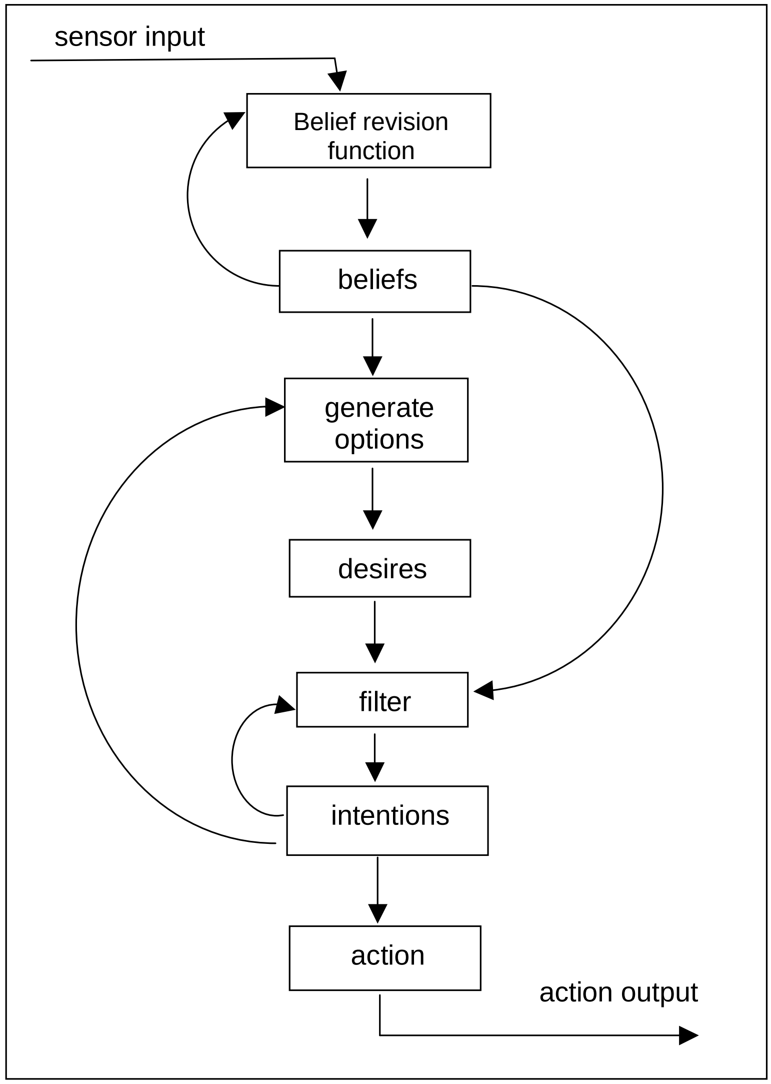


Figure 2.9. Schematic diagram of a generic belief-desire-intention architecture (Weiss 1999)

The process of practical reasoning in a BDI agent was illustrated by Weiss 1999 as involving: a set of current *beliefs*, representing information the agent possesses about the current environment; a *belief revision function (brf)* which takes into account a perceptual input and the agent's current belief - and on the basis of these, determines a new set of beliefs; an *option generating function, (options),* which determines the options available to the agent (its desires), on the basis of its current beliefs about its environment and its *current intentions;* a set of *current* options, representing possible courses of actions available to the agent; a *filter* function *(filter),* which represents the agent's deliberation process, and which determines the agent's intentions on the basis of its current beliefs, desires, and intentions; a set of current *intentions*, representing the agent's current focus – those states of affairs that it has committed to trying to bring about; and an *action selection function (execute),* which determines an action to perform based on current intentions.

Agents always operate and exist within an environment. The environment might be open or closed, and it might or might not contain other agents. If it contains other agents, it can be seen as a society of agents or MAS. Ossowski (1999) illustrated the coordination among agents as shown in Figure 2.10.

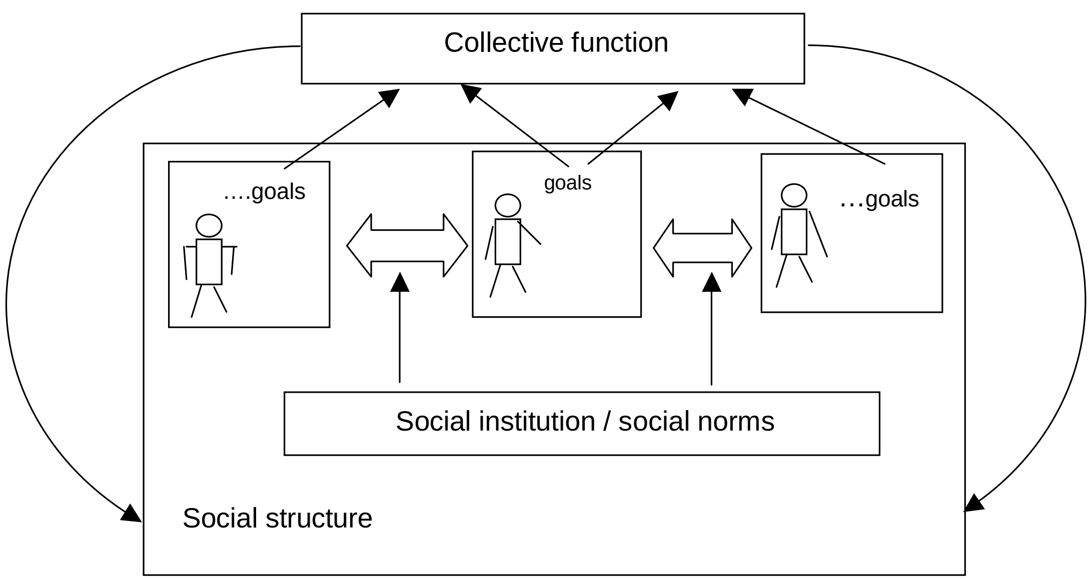


Figure 2.10. Coordination among agents (Ossowski 1999)

The communication protocols enable agents to exchange and understand messages. A communication protocol might specify that the following messages can be exchanged between two agents (Weiss 1999): Propose a course of action; Accept a course of action; Reject a course of action; Retract a course of action; Disagree with a proposed course of action; Counter-propose a course of action.

Although a simulation is a useful approach to a complex system, a precise definition of a "complex system" is neither possible nor necessary. However, it is possible to relate types of systems to formal methods of problem solving in a very general way. The most useful method of dealing with a given problem at a particular time depends on our conceptualization of the problem and the current state of knowledge about the problem within a conceptual framework - which places us in one of the regions in Figure 2.11. Definitely, a simulation method is useful to apply when we have little data but a high level of understanding. Otherwise, statistics or physics would be more appropriate.

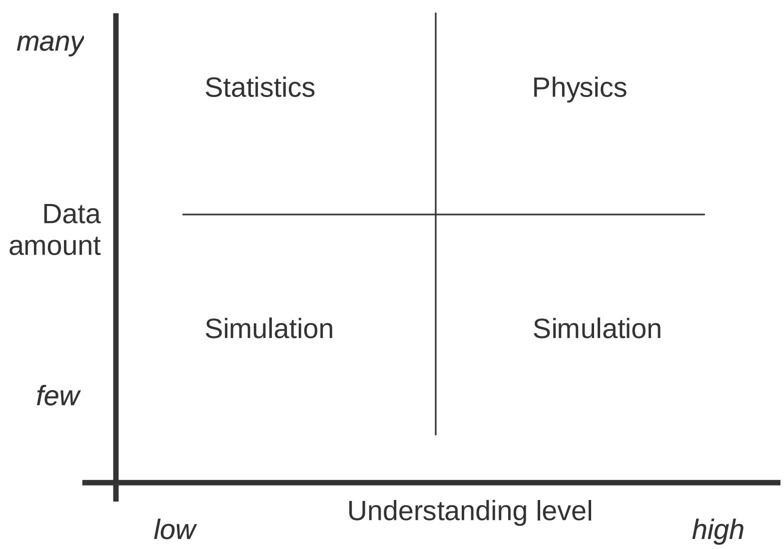


Figure 2.11. Comparison in methods of problem solving (modified from Holling 1978, and Starfield and Bleloch 1988 in Grant *et al.*, 1997)

Here, it is useful to distinguish models for understanding and models for prediction (Bunnell 1989 in Vanclay 1994). Models for understanding are useful for comprehending and linking previously isolated bits of knowledge, and may help to identify gaps where more work is needed. The benefits come from insights gained while developing and exploring the model (Vanclay 1994).

2.5. Forest Stand Dynamic

In Indonesia, forest management and harvesting operations are regulated under TPTI (Armitage and Kuswanda 1989). This system allows for all commercial trees to have 50-60 cm dbh (the minimum harvest diameter depends on the type of production forest), removed within a felling cycle of 35 years. However, in previous times, not all trees above these diameter classes were cut because some of them were not harvestable e.g. non-commercial trees, protected trees (such as *Dyera Costulata, Koompassia Excelsa, Eusideroxylon Zwagery,* and *Shorea Pinanga*), hollow trees, trees at steep slope, flute trees and trees that are considered as seed bearers.

Diameter class projection methods (DCPM) represent the oldest class of mathematical models developed for growth projection in tropical forests. The basic concept of DCPM is that the forest is represented as stand table of tree numbers classified by diameter classes. The change in the stand table is calculated over an interval of perhaps 5-10 years using periodic increment data. The revised table is then used as a starting point from which to repeat the calculations. In this way, increment, mortality and in-growth observations made from permanent sample plots over relatively short periods may be used to estimate growth over a complete felling cycle or rotation (Alder 1995).

Vanclay (1994) categorized forest stand growth models into three categories: whole stand models; size class models; and single tree models. He stated that size class models provide information on the structure of the stand. This approach is a compromise between whole stand models and single tree models. Stand growth models, logging and logging damage constitute stand dynamic.

The form and extent of logging damage on forests is varied. The method and intensity of logging will influence the degree and type of damage (Alder and Synnott 1992). Sist *et al.* (in prep.) noted that logging in Inhutani II was done under such high felling intensity (more than 9 trees per ha or about 80%), it led to high damage to residual stands. Dead trees due for felling within residual stands for dbh class one to five are 50% (20-30 cm), 40% (30-40 cm), 30% (40-50 cm), 20% (50-60 cm) and 10% (above 60 cm).

III. RESEARCH METHODS

3.1. Research Framework

Sustainability in relation to forest ecosystems incorporates biophysical, economic and social aspects. The well-being of forest-dependent people cannot be neglected if sustainability is a primary goal of forest management. However, forest policymakers frequently think that local people do not have sufficient knowledge on sustainability. Forest managers use this situation as a formal reason to exclude forest-dependent people from their forest management schemes. Many forest managers believe that they will maximize their own benefits by not sharing forest management with others. On the other hand, many non-government organizations (NGOs) and people's organizations are struggling to represent the interests of local people. This struggle, however, is often based on idealism and romanticism.

The first hypothesis of this work - that *local communities of forest-dependent people can define sustainable forest management criteria and indicators* - indicates local community knowledge of sustainability. A comparison of scientific and local sustainability indicators tested the first hypothesis. If this hypothesis is accepted then rational policymakers have no reason not to include local people in current forest management schemes. Furthermore, because local people have been there for hundreds of years they should be made a priority in any new forest management scheme. Even if this hypothesis is rejected, forest policymakers still have to improve local people's well-being and benefits they obtain from the forest, even without automatically including them in forest management.

The next question to ask is how to actively involve local people in forest management if the first hypothesis is accepted? We also need to ask how to share forest benefits if the first hypothesis is rejected? Most production forests in Indonesia have been allocated to forest concession companies. Right now about 375 forest concession companies are operating. The operators have legitimate rights to manage forests. However, most of these forest managers think that the involvement of local people in their management will decrease their profit.

The second hypothesis*, involving local communities of forest-dependent people in the current forest management scheme would achieve better sustainability outcomes,* was tested through developing a simulation model of forest actors. Scenarios of collaboration were proposed if the first hypothesis was accepted. Alternative scenarios of providing forest benefits to local people were proposed. A simulation model was used because assessing the real impact of policy options on natural forest management can take many years. Simple indicators of sustainability agreed to by forest actors were used in the simulation model to measure the impact of different scenarios.

Through testing these two hypotheses, it is possible to propose a way to manage forests more sustainably. The research also proposes a way to integrate modern C&I knowledge and local people's C&I knowledge, and to formulate agreed sustainability indicators among different forest actors.

3.2. Site

The field study was carried out at FMU level of Inhutani II in Malinau District, East Kalimantan. The research took place in the year 2000 and 2001. The site was chosen because the area has many different stakeholders with a willingness to accept researchers and to collaborate. The availability of biophysical and socio-economic data also supported the site selection.

The FMU is located at 116^{o}28' East Longitude and 3^{o}14' North Latitude. The area was legally allotted to Inhutani II by the Government of Indonesia on 30

January 1991 through Minister of Forestry decree no. 64/KPTS-II/91. Before 1991, the area was allocated to Inhutani I and co-managed with Inhutani II.

According to the Long-term Temporary Forest Utilization Work Plan (*Rencana Karya Pengusahaan Hutan Sementara*) 1996, the total area is about 48,300 ha, of which 14,180 ha is comprised of limited production forest which is pristine forest, and 34,120 ha of production forest including 23,890 ha of pristine forest, 7,280 ha of logged-over forest, 2,920 shrubs and fallow (*ladang*), and 30 ha of settlements.

According to the Plan, Inhutani II will continue logging an area amounting to 1,106 ha per year or approximately 11 blocks of 100 ha. The silviculture system implemented is TPTI. Because Inhutani II has no industry close to the area, the timber is sold as logs. Commercial species that dominate the area are *Shorea* spp. (Meranti), *Dryobalanops* spp. (Kapur*), Dipterocarpus* spp. (Keruing), *Shorea laevis* (Bangkirai), *Palaquium* spp. (Nyatoh), *Gonistylus* spp. (Ramin) and *Agathis* spp. (Agathis).

3.3. Methods

The research was carried out using a combination of deductive and inductive methods. The deductive parts took place in the process of formulating hypotheses, formulating generic C&I and developing computer-based tools. Inductive methods took place in formulating local communities' C&I and testing the hypotheses. The research was conducted in the following steps:

a. Identifying and formulating a set of generic and scientifically based C&I for sustainable forest management based on the ideal function of forests and existing C&I from different sources;
b. Formulating a local C&I set through field observation and related literature;

c. Testing the first hypothesis;

d. Developing a knowledge base system (KBS) for adapting generic criteria and indicators for sustainable forest management to meet local conditions;

e. Developing and simulating forest stakeholders' activities and interactions in order to know their influence on the sustainability of the forest;

f. Testing the second hypothesis.

Figure 3.1. illustrates the steps involved and the links between each step. The literature review and field study initiated these steps. The steps conclude with a discussion of policy links related to the research.

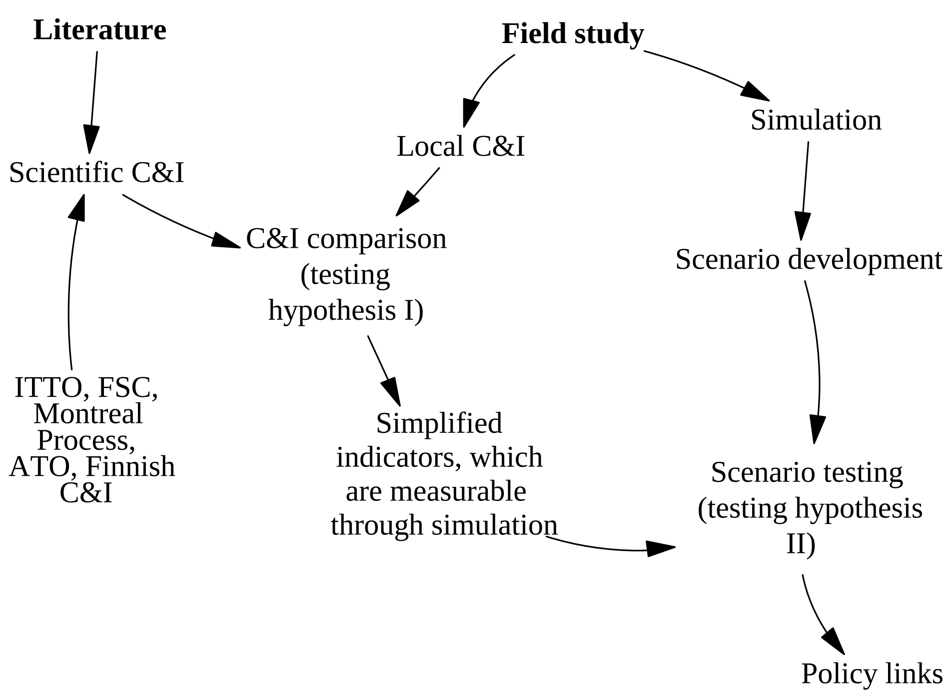


Figure 3.1. The research sequence

3.3.1. Identifying Scientific C&I Knowledge

The relevant knowledge for SFM was derived from the ideal function of forests in Indonesia and existing C&I from different sources including the ITTO, FSC (Forest Stewardship Council) and ATO (African Timber Organization). Forests, in general, possess ecological, economic and social functions. In order to assess sustainability of forests, these functions were taken into account and were elaborated on in a particular way so that the assessment process could be carried out. The end of the elaboration process resulted in a set of SFM criteria and indicators. This knowledge acted as a benchmark on which to compare local knowledge. The knowledge, which was scientifically sound, was able to represent future stakeholders in their absence.

Consideration of the ecological, economic and social functions of forests was used to derive principles, criteria and indicators (P, C and I) for sustainable forest management. *A principle is a fundamental truth or law as the basis of reasoning* (Concise Oxford Dictionary 1995). A principle refers to a function of a forest ecosystem or to a relevant aspect of the social system(s) that interact with the ecosystem. This means that all forest functions, and relevant aspects of the social system(s) that interact with it, are covered. A principle could be described as an objective or attitude in relation to these functions and aspects. However, measures and prerequisites for the realization of the goal or attitude should not be formulated as principles - for instance, issues concerning legislation and institutions (Bueren and Blom 1997).

Criterion is *a standard, rule or test by which something can be judged* (Concise Oxford Dictionary 1995). The function of the criteria is to show the level of compliance with principles related to the forest ecosystem or its related social system. Compliance with the principles is translated into descriptions of resulting specific and concrete states or dynamics of the forest ecosystem, or the resulting states of the interacting social system. These descriptions will reveal the practical results of complying with each principle, and also provide more concrete principles which are easier to assess than the abstract non-measurable principles. As the function of criteria is to show the level of compliance with a principle for the forest ecosystem or related social systems, criteria should be formulated in terms of outcome. This means that a criterion describes which state is most desired in the forest or social system. Formulations of criteria must not express that a desired state should be achieved nor how this state is to be achieved. Formulations in the form of prescriptions do not comply with the requirements for criteria in the hierarchical framework. Prescriptions should be reserved for the formulation of guidelines and actions. The formulation of a criterion must allow a verdict to be given on the degree of compliance within an actual situation. (Bueren and Blom 1997).

An indicator was defined by the ITTO (1998) as a quantitative, qualitative or descriptive attribute that, when periodically measured or monitored, indicates the direction of change. To “indicate” is defined in the Concise Oxford Dictionary (1995) as *point out, make shown, show*, or *be a sign or symptom of, express the presence of.* FSC defined indicators as *any variable, which can be measured in relation to specific criteria*. An indicator is an assessable parameter describing features of the ecosystem or social system (outcome parameters), or policy and management conditions and processes (input or process indicators). An indicator as an outcome parameter often describes the actual condition of an element in the forest ecosystem or related social system in quantitative or relative terms. Indicators may also refer to a human process or intervention which is to be executed - or to an input (e.g. the existence or characteristics of a management plan; or a law). These types of indicators are respectively known as process and input indicators. They are in fact indirect indicators that reflect elements of the management and policy system (Bueren and Blom 1997).

LEI Standard 5000-1 about a System for Sustainable Natural Production Forest Management classifies indicators into three categories: necessary conditions; core activities; and sufficiency requirements. Necessary conditions are all those processes or factors that have to be fulfilled before the next process or factor can be implemented. Core activities are all those processes or factors that should be implemented in a management procedure. Sufficiency requirements are possible supportive processes or factors required to achieve management objectives.

Indicators may be identified at any point in the causal chain from human intervention to biodiversity (Boyle *et al.* 1998)**.** Brown et al. (1997) in Boyle *et al.* (1998) mentioned that pressure indicators are easier to develop than state or response indicators, but provide much less valuable information. Response indicators, potentially the most valuable indicators, are also the hardest to develop and apply.

The P, C and I concept forms a hierarchy (Bueren and Blom 1997) as shown in Figure 3.2. A hierarchical framework describes hierarchical levels (P, C, & I) to facilitate the formulation of a set of parameters in a consistent and coherent way. It describes the function of each level as well as the common characteristics of the parameters appearing on a particular level. The potential value of a hierarchical framework is that it: increases the chances of complete coverage of all the important aspects to be monitored or assessed; avoids redundancy; limits the set of P, C & I to a minimum without superfluous indicators; shows a clear relationship between indicators measured, and compliance with the principles.

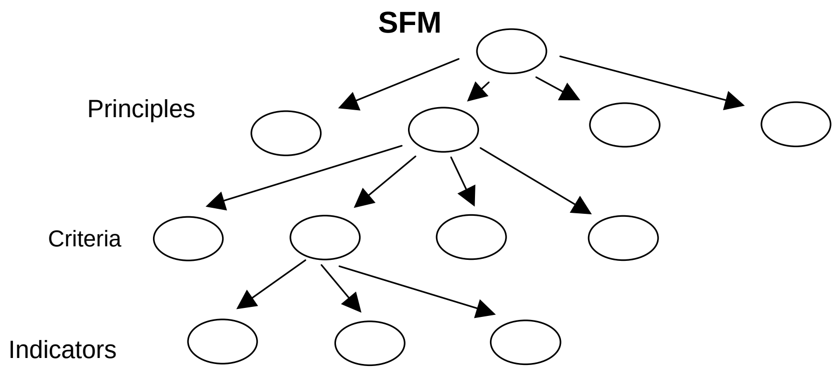


Figure 3.2. P, C & I concept for sustainable forest management assessment

A fourth hierarchical level, below the level of these indicators, may be needed to describe the way the indicators are measured in the field. The parameters at this level are called verifiers. Verifiers are not shown in the hierarchy because they are optional. They refer to the source of information for the indicator and relate to the measurable element of the indicator. The verification procedure clarifies the way the indicator is measured in the field and the way reference values are established. Choosing a reference value is always difficult when formulating target values or thresholds because it is often an arbitrary procedure (Bueren and Blom 1997). Since this research was not aimed at describing the operational use of developed C&I, verifiers were not investigated.

However, according to the established knowledge a network form of C&I is more useful than the hierarchy system. An indicator, for instance, of water quality, could not only help indicate the quality of forest harvesting, but also the quality of human well-being, as is schematically expressed in Figure 3.3.

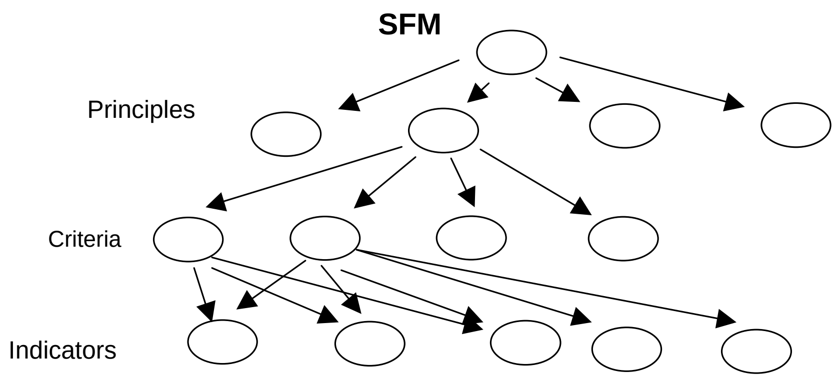


Figure 3.3. A network of C&I for sustainable forest management assessment

In general, sustainability indicators mean “things that point out or show sustainability”. Conditions of sustainability are things to make those indicators happen. Condition is defined in Webster’s’ New World Dictionary (1988) as *anything required before the performance of or completion of something else, or anything essential to the existence or occurrence of something else*. So if we talk about sustainability, it means the conditions required before sustainability, or anything essential to the existence or occurrence of sustainability.

Conditions are divided into two categories: necessary conditions and sufficient conditions. Swartz (1997) defined necessary condition as follows:

> A condition **A** is said to be necessary for a condition **B**, if (and only if) the falsification (non-existence/non-occurrence) of **A** guarantees (or brings about) the falsification (nonexistence/non-occurrence) of **B**.

Curtis (2001) defined it as:

> A condition that must be true if the proposition that it is a condition for is to be true. In other words, "**p** is a necessary condition for **q**" means "if **q** then **p**".

These definitions actually have the same meaning as $\sim A \rightarrow \sim B$ is equal to $B \rightarrow A$. The other category, sufficient condition, is defined by Swartz (1997) as follows:

> A condition **A** is said to be sufficient for a condition **B**, if (and only if) the truth (existence/occurrence) of **A** guarantees (or bring about) the falsify truth (existence/occurrence) of **B**.

Meanwhile Curtis (2001) defined it as:

> A condition which, if true, ensures that the proposition that it is a condition for is true. In other words, "**p** is a sufficient condition for **q**" means "if **p** then **q**".

Both definitions are the same.

Frequently the terminology "individually necessary" and "jointly sufficient" is used. One might say, for example, "each of the members of the foregoing set is individually necessary and, taken all together, they are a jointly sufficient condition. However, we must not generalize. Sometimes it is much easier to specify (some or many of the) necessary conditions even though we are unable to specify a set that is jointly sufficient. Other times, the converse is true: in some cases it is easier to specify sufficient conditions even though we are unable to specify individually necessary ones (Swartz 1997). Figure 3.4 illustrates the relationship between conditions and indicators of sustainability.

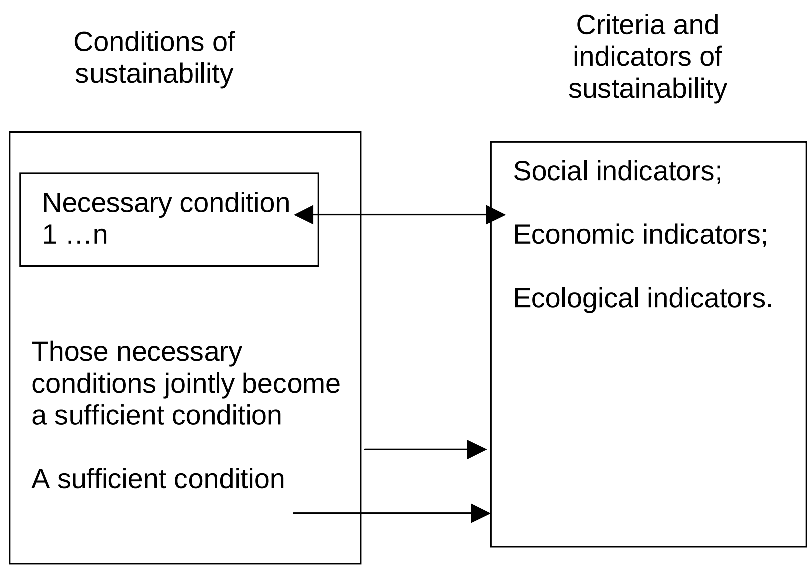


Figure 3.4. Relationship of conditions and indicators of sustainability

3.3.2. Formulating Local C&I Knowledge

The stakeholders involved in C&I formulation were identified using the criteria of their proximity to the forest, pre-existing rights, dependency, poverty, local knowledge, forest/culture integration and power deficits (Colfer *et al*. 1999). Schmoldt (1998) suggested a linguistic-based knowledge analysis to formulate knowledge. This analysis approaches knowledge acquisition (a process whereby selected stakeholders are encouraged to articulate their knowledge), by categorising knowledge into three major types: lexical knowledge; syntactic knowledge; and semantic knowledge. *Lexical knowledge analysis* creates the lexicons that make up the domain language, from which it becomes possible to discuss knowledge structure (syntax) and tactical and strategic knowledge (semantics). *Syntactic knowledge analysis* involves identifying, labelling, and describing the relationships among factors identified in lexical analysis. *Semantic knowledge analysis* focuses on a specific combination of factors (lexicons) and relationships (syntax) to indicate plausible avenues to search towards a problem's solution.

Bernard (1994) stated that unstructured interviewing is the most widely used method in cultural anthropology. There is a continuum of interview situations based on the amount of control we try to exercise over the responses of informants (Dohrenhead & Richardson 1965; Gorden 1975; Spradley 1979 in Bernard 1994). Bernard divided the continuum into four large chunks: informal interviewing; unstructured interviewing; semi-structured interviewing; and structured interviewing. Semi-structured interviewing has much of the free-wheeling quality of unstructured interviewing and is based on the use of an interview guide - which is a written list of questions and topics that need to be covered in a particular order.

To gather local knowledge, focus group discussions were conducted with village people located inside or adjacent to the FMU boundary. These discussions centred on indicators or signs of good forest management. . These discussions were categorized into semi-structured interviewing. The guideline for this semi-structured interviewing is given in Appendix 1. At the end of the focus group discussions, a list of SFM criteria and indicators from local communities was obtained. The list represents the communities' perception of what constitutes good forest management.

The Central Bureau of Statistics (1993) in a diagnostic study of HPH *Bina Desa Hutan* (1993) reported the villages' status, as listed in Table 3.1. However, this report was not very true. The first three villages were located outside the boundary, and Langap Village was very close to the boundary. The three selected "villages" were Long Loreh Long Seturan and Langap. However, Long Loreh and Long Seturan are not villages but groups of very small villages.

Table 3.1. Villages inside Inhutani II boundary

No	Village name	Status
1	Tanjung Lapang	Not poor[1]
2	Batu Kajang	Poor
3	Gong Solok	Poor
4	Long Loreh	Not poor
5	Langap	Poor
6	Paya Seturan	Poor

Source: Diagnostic Study of Inhutani II Community Development (1993)[2]

3.3.3. Testing Method of the First Hypothesis

Comparing scientific knowledge and local knowledge, (the communities' perception of good forest management), involved examining a hypothesis of homogeneity between scientific knowledge and local knowledge. The procedure began by identifying the level of compliance between communities' perceptions of sustainability with scientific perceptions of sustainability. Since the communities identified they could express their perceptions in terms of indicators, a comparison was made at the indicator level.

Data gathered from the field was formed into a table filled with "presence" or "absence" indicators for each knowledge type - as shown in Table 3.2. Character zero related to absence of that knowledge and one related to presence.

[1] "Not poor" refers to the status of the village above the poverty level assigned by the government. "Poor", according to the government is defined as person who consumes less than 2,100 calories per person per day (Ravallion in Pradhan, 2000)
[2] A diagnostic study or *studi diagnostik* is a study conducted by external consultants to provide information to timber companies on the social aspects of an FMU.

Table 3.2. Presence or absence indicator of each knowledge type

	Indicators for SFM								
Knowledge type	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	…
Generic/Scientific knowledge (X_1)	0	1	…						
Local knowledge (X_2)	…								

Table 3.2. shows X_1 and X_2 as generic indicators and local indicators. A value Y is defined as

$$Y = 1 \quad \text{if } X_1 = 1 \cap X_2 = 1$$

$$Y = 0 \quad \text{if } X_1 = 1 \cap X_2 = 0 \text{ or if } X_1 = 0 \cap X_2 = 1$$

Local indicators have to meet scientific indicators in order to say that the local C&I set conformed to the scientific C&I set which is the acceptance of the first hypothesis.

3.3.4. Developing a C&I Knowledge Base System

Developing a Knowledge Base System (KBS) involved knowledge elicitation, intermediate representation, formal representation and keyword specification (Walker *et al.*, 1994) - as explained below and shown in Figure 3.5. Knowledge elicitation is the process whereby selected informants are encouraged to articulate their knowledge. Knowledge can also be abstracted from written material. Intermediate representation is the process of recording simple natural-language statements abstracted from text or interview material. This form is more restricted than natural dialogue, and provides an intermediate stage between articulation and formal representation. Formal representation is the process of coding knowledge using a restricted syntax as defined by a formal grammar. Formal representation results are statements with which you can reason automatically on computer. Keyword specification is the process of identifying key components of the knowledge represented. Keywords may be objects (e.g. 'soil'), processes (e.g. 'erosion'), attributes (e.g. 'rate of erosion', or 'pest population size') or actions (e.g. 'pruning').

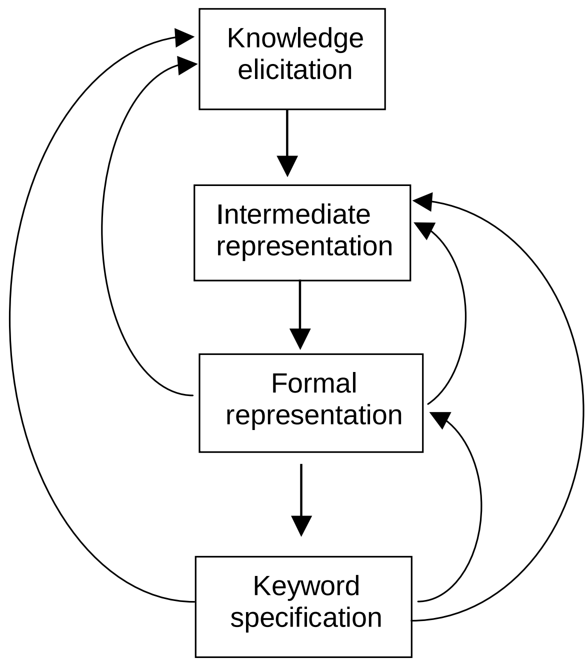


Figure 3.5. The four principle activities in the creation of knowledge base (Walker *et al.* 1994)

The KBS creation activities occur in sequence (straight arrows), but evaluation during the creation of the knowledge base and consequent return to previous activities (arc arrows) means that the process is in fact a series of cycles.

A network of C&I was used for representing knowledge of sustainable forest management as depicted in Figure 3.3. The inference engine is the heart of the knowledge base system, embodying the main control structures and algorithm. The basic process of the inference engine is illustrated in Figure 3.6. The indicators are classified to form criteria, and by applying multi-criteria analysis - such as Analytic Hierarchy Process (Saaty 1994; Saaty 1996), ranking or rating - a decision on sustainability is derived. The decision-making process needs to be scientifically sound, locally accepted and transparent to all stakeholders. The involvement of all stakeholders, who have different educational backgrounds, in the decision-making process is a necessary condition for co-management. The decision-making process was observed during the field study.

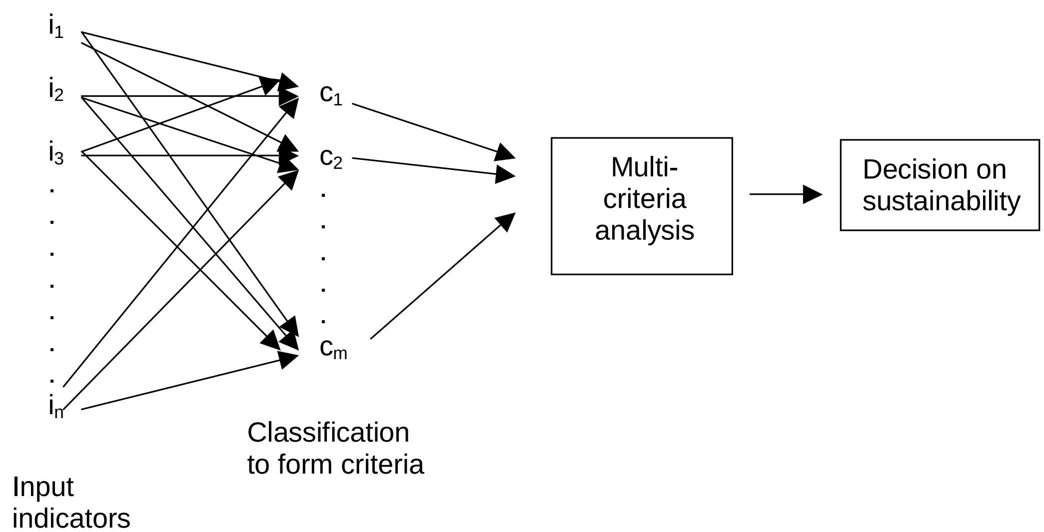


Figure 3.6. KBS inference engine

3.3.5. Building a Simplified Artificial Society of Forest Actors

The purpose of building an artificial society was to observe whether the localized C&I by which local knowledge on sustainable forest management was embedded, could be applied in real life. It is almost impossible to see the full effects of using localized C&I in real life - it would take a long time, beyond the research period. Simulation techniques are well-known methods for addressing this matter. In this research, a Multi-Agent System (MAS) was used to simulate the behavior of each agent and the interaction between agents. The agents are located in a spatial system environment. In Figure 3.7, **for example**, there are four kinds of agents in the simulation: a firm, villagers, non-government organization (NGO) and local government. The firm's forest concession and the villagers are located in a forest. The local government has an obligation to maintain this forest's sustainability by providing rules to the firm and local people. As shown in Figure 3.8, the concession is located in a certain area. They log wood by taking into consideration the distance between the logging site and available wood. The NGO advocates on behalf of villagers to help them realize their rights. The villagers move to the best site for collecting NTFP (Non-Timber Forest Products).

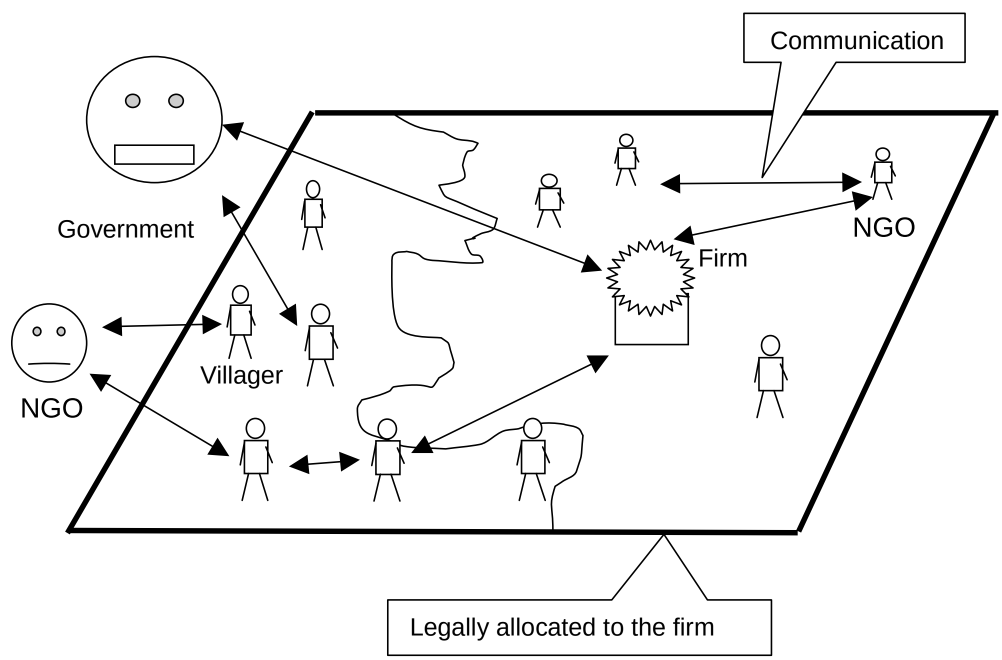


Figure 3.7. An example of model components and their interaction located in the spatial system

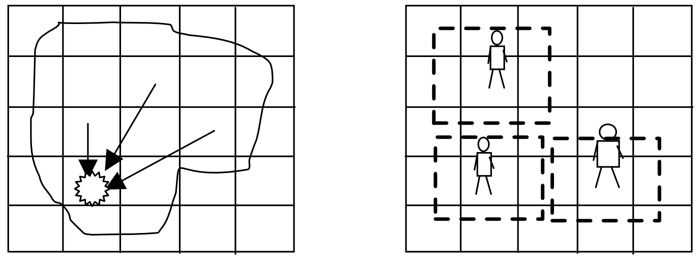


Figure 3.8. Spatial representation of the firm's activities and the movement of villagers

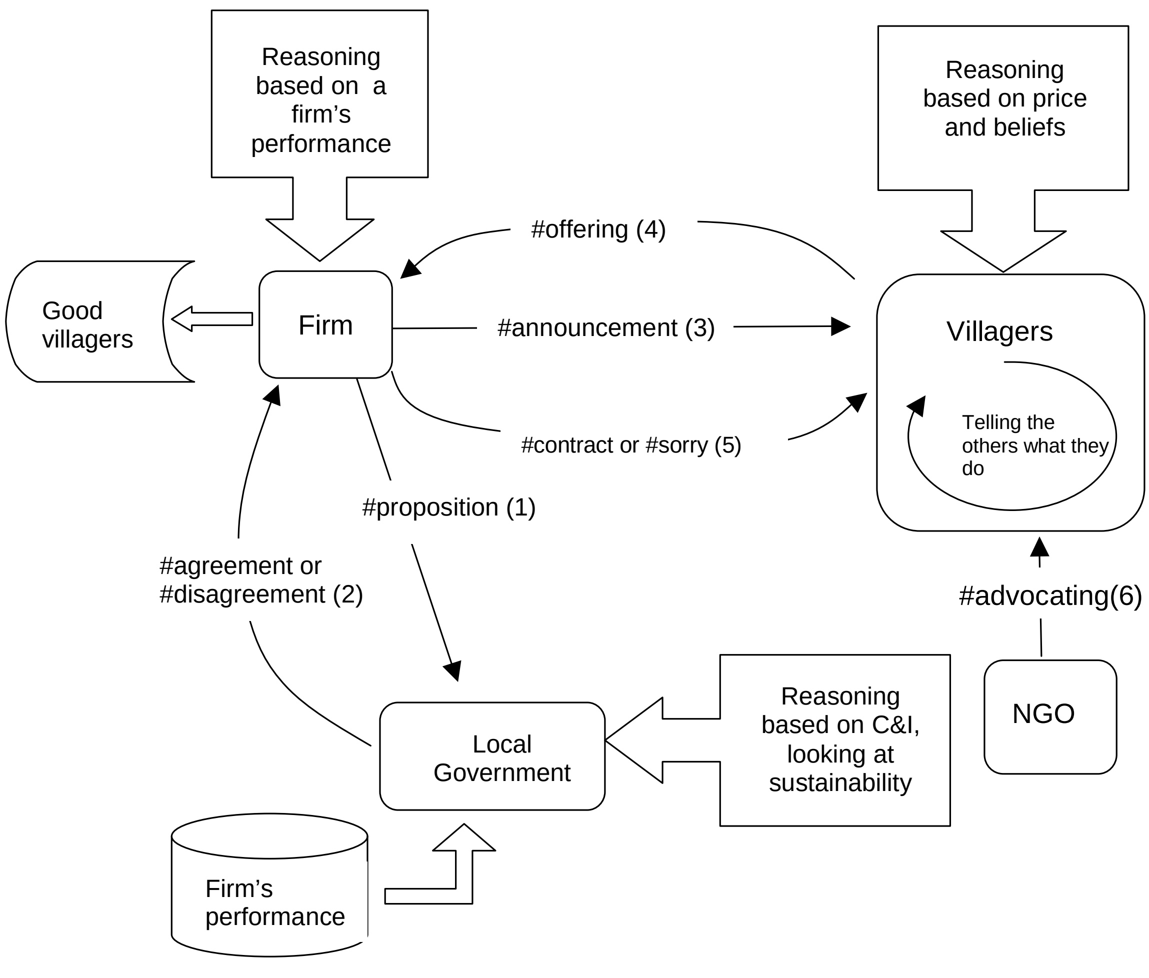


Figure 3.9. Communication among forest stakeholders

A model of the communication process among stakeholders was arranged to meet actual conditions in the field with some simplifications. An example of the communication process is shown in Figure 3.9. The firm send a message (#proposition) to local government that they need wood - more than they get from the current logging area. The government considers this message and then gives either an #agreement or #disagreement message in response. Since the sites are not allocated to the firm but to the villagers, the firm sends a message (#demanding) to the villagers, asking if they want to sell wood to the firm. The villagers consider this message, and then some of them send a message (an #offering) to the firm. The firm finds the best offer and makes contact with them. The villagers who have the contract will not move to collect NTFP, and will tell other villagers and the government they have the contract. The firm will record the performance of each villager for future use.

The artificial society was developed with Smalltalk Computer Language in a CORMAS (Common Pool Resources and Multi-agent Systems) environment. CIRAD Fôret, France, developed CORMAS (Bousquet *et al.* 1998). CORMAS is a simulation platform based on the Visual Works programming environment, which allows for the development of applications in Smalltalk.

CORMAS is a programming environment dedicated to the creation of multi-agent systems, with specificity in the domain of natural-resources management. It provides a framework for developing simulation models of coordination modes between individuals and groups that jointly exploit common resources (CIRAD 2001). There exist more and more programming environments dedicated to the creation of multi-agent systems. Some of them are oriented towards communication between distributed systems, while some others are more oriented towards the building of simulation models such as Ascape, MODULECO, MadKit and Mobydic.

The CORMAS programming environment belongs to this second category. It provides a framework that is structured in the following three modules. The first module allows for defining the entities of the system to be modeled (which are called informatics agents), and their interactions. These interactions are expressed in terms of direct communication processes (transfer of messages) and/or the sharing of the same spatial support. The second module deals with the control of overall dynamics (ordering of different events during a time-step of the model). The third module allows for the defining of observations of the simulation based on different viewpoints. This feature allows for the integration, within the modeling process, of representation modes. CORMAS facilitates the construction of a model by offering predefined elements.

Among these items are the CORMAS entities. These are Smalltalk generic classes from which, by specializing and refining, the user can create entities specific to the needs of his application. The data used in the simulation is gathered from the secondary data and interviews. Key phases in the development of the model (Grant et al. 1997) were:

- *Forming a conceptual model*: stating the objectives, bounding the system of interest, categorizing its components, identifying relationships, and describing the expected patterns of model behavior;
- *Quantifying the model*: identifying the functional forms of model equations, estimating the parameters, representing it in CORMAS and executing baseline simulations;
- *Evaluating the model*: re-assessing the logic underpinning the model, comparing model predictions with expectations and with the real system; and
- *Using the model*: developing scenarios, testing hypotheses and communicating results.

3.3.6. Testing Method of the Second Hypothesis

Barreteau *et al.* (2001) described the use of simulation models as learning and research tools. As a research tool, a simulation model is often used to test a hypothesis (Barreteau *et al.* 2001; Grant *et al.* 1997). Some indicators were observed through the developed model during the simulation period. These indicators were determined by considering the sustainability aspect, stakeholders' interests and what was measurable through simulation.

Testing the second hypothesis involved comparing outcomes of the current forest management system and examining a scenario of collaborative forest management. Firstly, a scenario of collaborative management was developed using the model. Secondly, to compare the simulation outputs of a current and a developed scenario of forest management, the hypothesis was formulated formally as follows:

$$H_0: m_{ci} = m_0$$
$$H_1: m_{ci} \neq m_0$$

The "ci" represents collaborative management indicators and the "0", non-collaborative indicators. A non-parametric statistical test was used to test the hypothesis. While there is only one baseline simulation for deterministic models, the baseline for stochastic models actually consists of a set of replicate simulations. The formula for calculating the number of samples needed to detect a given true difference between sample means (assuming that we have an estimate of variability within samples) is (Sokal and Rolf 1969 in Grant *et al.* 1977):

$$n \geq 2\,(\sigma/\delta)^2\,[t_{\alpha,\gamma} + t_{2(1-P),\gamma}]^2$$

where

n =	Number of samples
α =	True standard deviation, which we estimate as the square root of the estimated variance within samples
δ =	Smallest true difference that we desire to detect
γ =	Degrees of freedom of the sample standard deviation with b group of samples and n samples per group or $\gamma = b(n-1)$
α =	Significance level
P =	Desired probability that a difference will be found to be significant if it is as small as δ
$t_{\alpha,\gamma} + t_{2(1-P),\gamma}$ =	Two-tailed values of students-t.

IV. RESULTS AND DISCUSSIONS

4.1. Generic C&I Knowledge for Sustainable Forest Management

Natural forests are a very important renewable natural resource in Indonesia. They produce tropical timber and provide many other socio-economic, cultural and environmental benefits. In Indonesia, natural forests are divided into three categories: conservation forests; protection forests; and production forests. This research dealt with production forests, which are mainly aimed at producing goods and services and improving the well-being of people.

A literature analysis was conducted to search for the scientific or generic knowledge available for assessing forest sustainability. The first step was to construct generic C&I deductively based on the concepts of forest, forest functions and sustainability. The second step was to compare the developed generic C&I with other C&I produced by internationally recognized organizations and processes, including the International Tropical Timber Organization (ITTO), Forest Stewardship Council (FSC), Montréal Process, African Timber Organization (ATO), and Finnish Process. During the second step, adding, deleting and modifying the developed C&I were performed. This generic knowledge was to be used for a comparison with local knowledge derived from local people's perceptions. A comparison of the generic and local knowledge of sustainable forest management tested the first hypothesis.

4.1.1. Forest Management Unit

Understanding of the term that refers to Forest Management Unit (FMU) or unit of forest management was explored by firstly organizing forest and forest management terms. A primary territorial unit of forest is shown in Figure 4.1. Osmaton (1968 p. 114) defined woods, blocks and enclosures as synonymous terms used to refer to wooded areas bounded by natural features, which have well-known local names. They may have been the result of legal separation by closing off from surrounding land for the purposes of preservation or distinction of ownership. Osmaton also defined ‘compartment’ as the smallest permanent sub-division of a forest. B.C.F.T (1953) in Osmaton (1968 p. 114) defined compartment as a territorial unit of a forest permanently defined for the purposes of administration and records. Being a permanent unit, the compartment should be clearly demarcated on the ground and its boundaries should follow natural features or definite artificial features. A sub-compartment was defined as a unit of treatment.

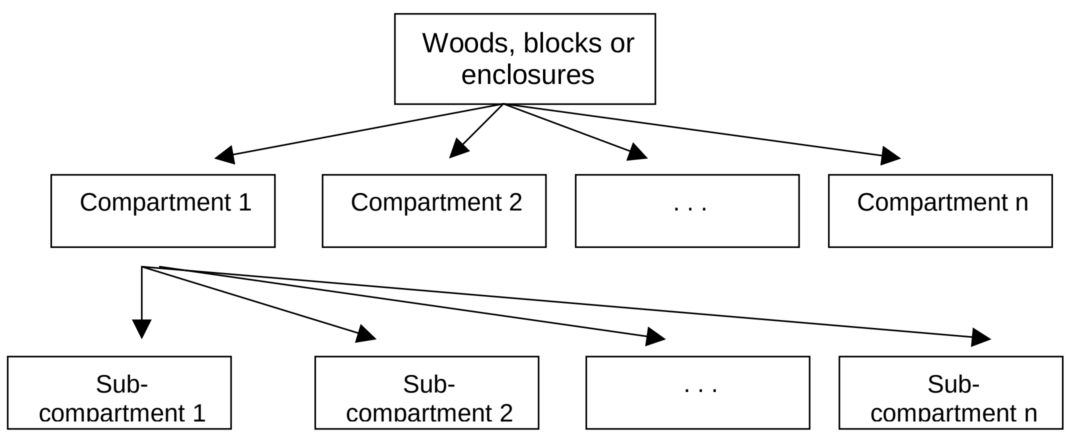


Figure 4.1. Organization of a forest

The ITTO (1998 p. 5) defined an FMU as a clearly defined forest area, managed in accordance with a set of explicit objectives and long-term management plan. Prabhu *et al.* (1996) defined an FMU as a clearly demarcated area of land predominantly covered by forests, managed in accordance with a set of explicit objectives and long-term management plan. Therefore an FMU is more or less similar to: wood, block and enclosure. However, because FMU has a clearer definition than the terms wood, block and enclosure, the term FMU was used in this research.

4.1.2. Forest Functions

Any understanding of forest management requires a look at forest functions. Helms (1998 p. 54) defined a forest as an ecosystem characterized by more or less dense and extensive tree coverage, often consisting of stands that vary in species, composition, structure, age class, and associated processes, and usually including meadows, streams, fish and wildlife. Helms (1998 p. 54) also defined an ecosystem as a spatially explicit, relatively homogenous unit of the Earth that includes all interacting organisms and components of an a-biotic environment within its boundaries.

It is clear that a forest is an ecosystem dominated by trees. If an ecosystem is spatially explicit, then all living organisms, including people who live there, need to be taken into account in the forest management process. Helms (1998 p. 71) defined forest management as the practical application of biological, physical, quantitative, managerial, economic, social and policy principles to the regeneration, management, utilization and conservation of forests aimed at meeting specified goals and objectives while maintaining forest productivity.

A forest can be illustrated by the model in Figure 4.2. Originally, forests were places where all living organisms lived and interacted to form a life system. As sinks of CO_2 and sources of O_2, forests have incredible functions. At the same time, forests provide timber and non-timber for human needs. Most human settlements and housing needs in tropical countries cannot be separated from timber needs. When there is a scarcity of timber, it becomes an economic good. People owning the timber can sell it and obtain money or other returns from trading and exchange. Forests also support the life of the people who live nearby. Forests provide almost everything people need and that makes local people feel secure. In other words, forests can have three important functions: economic, ecological and social.

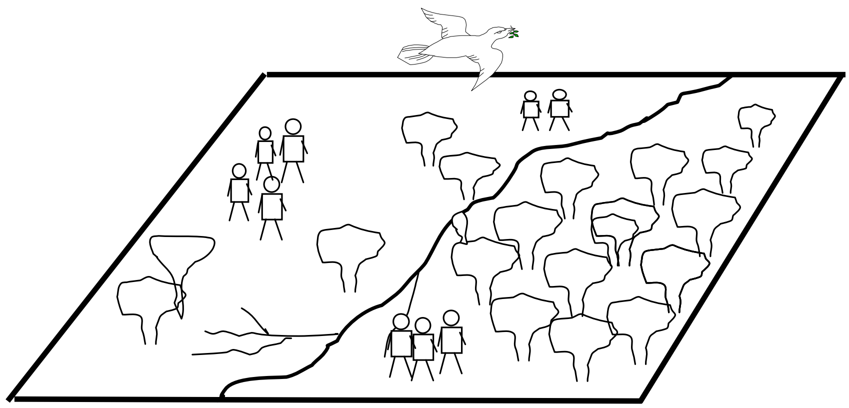


Figure 4.2. A model of a forest

These functions imply that any forest management strategy should always involve consideration of changes in these aspects. Essentially, ecological, economic and social aspects of forests are inherent to the existence of forests. This is a situation well illustrated by Figure 4.3. The new functions of managed forests may be very different from the original. Dash lines illustrate how those functions differ from their original. Each function may enhance or decrease as an impact of forest management processes.

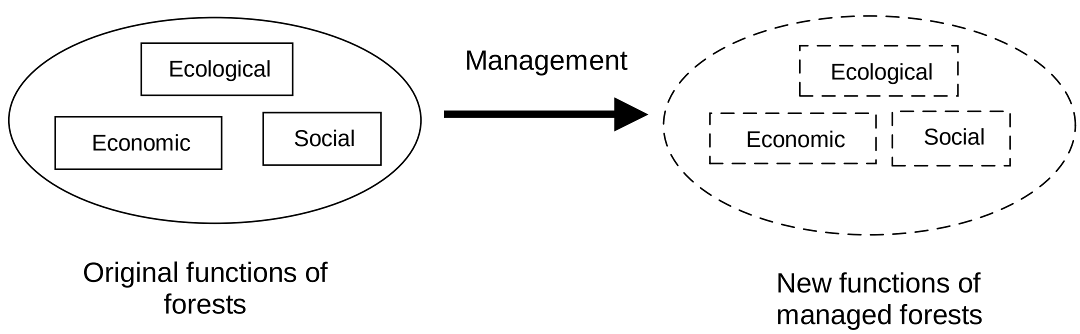


Figure 4.3. Original and new functions of forests due to management

4.1.2.1. Managing Forest Functions

Sustainable forest management requires enhancing or maintaining forest functions to ensure intergenerational equity. Enhancing the functions of forests involves consideration of two concepts. First, the concept of a trade-off among those functions - enhancing one function can decrease other functions. Secondly, the concept of a synergy among those functions - enhancing one function could enhance other functions. The trade-off concept puts forest decision-makers in a situation where they have to decide which functions are enhanced and which functions are sacrificed. In most cases, the trade-off situation happens more frequently than the synergy situation. The trade-off situation is illustrated in Figure 4.4 and the synergy situation in Figure 4.5.

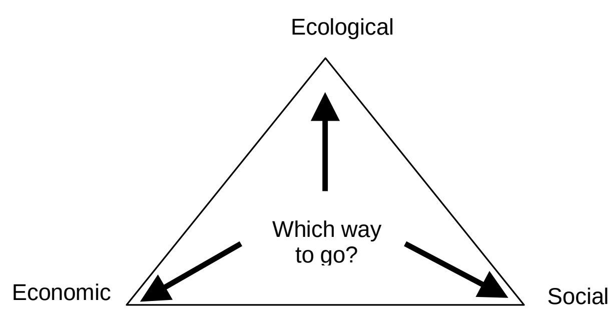


Figure 4.4. Trade-off situation faced by forest managers

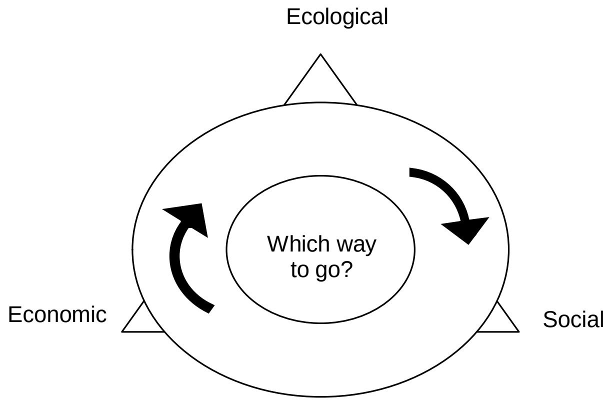


Figure 4.5. The synergy situation faced by forest managers

As illustrated in Figure 4.3, the management of forest production involved performing production functions without sacrificing other functions. To know whether production functions or other functions were treated properly in the process of managing a forest, a set of criteria measuring how these functions performed was developed. This set was then called the criteria of good forest management. This set of criteria derived from the forest functions, could be used to assess the sustainability of forest management.

4.1.2.2. Ecological Criteria

Ecology is defined as the study of interactions between organisms and their environment. Such interactions are understandably varied and complex. To ensure ecological function is maintained, the ecological principle of SFM was determined as *ecosystem integrity is maintained*.

The first criterion was to maintain biodiversity. Biodiversity is defined as the variety and abundance of life forms, processes, functions and structures of plants, animals and other living organisms, including the relative complexity of species, communities, gene pools and ecosystems in spatial landscapes that range from local through to regional and global (Helms 1998, p. 16). Good forest management requires maintaining biodiversity in order to continue supporting life on earth. As indicated, the term biodiversity includes the diversity of ecosystems, communities, species and genetic structures.

Areas which are identified as functionally sensitive to any disturbance must be protected to ensure the continuity of ecosystem functions. These areas also function as reserved forests - any uniqueness should be as representative as possible to the FMU. This became the second criterion. The ecosystem integrity principle includes maintaining hydrological functions to avoid water erosion and floods, soil quality and food chains - and it became the third criterion. Table 4.1 shows the ecological criteria for SFM. All these criteria are outcome parameters derived from the principle: e*cosystem integrity is maintained*. This means these criteria are used to judge the impacts of forest management at FMU level.

Table 4.1. The generic knowledge of ecological criteria for SFM

Category	Text
Principle 1	Ecosystem integrity is maintained
Criterion 1.1	Biodiversity is maintained
Criterion 1.2	Maintenance of ecologically sensitive areas
Criterion 1.3	Ecosystem function is maintained

4.1.2.3. Economic Criteria

A forest management unit is a commercial unit of managed forest aimed at producing products and services from which economic benefits are derived. The principle of economic sustainability of forests was determined by the sustainability of forest products and services. It is close to the concept of sustained yield principle, which is the central term of traditional forest management. This principle is defined as the regular and continuous supply of desired products according to the full capacity of the forest. Under this principle, two criteria were derived. These criteria stated the importance of the concept of a ‘normal’ forest. Helms (1998 p. 125) defined a normal forest as a forest composed of normal stands that have reached a conceptual ideal in stocking and age- and size-class distribution.

The first criterion was the *forest has a normal series of diameter size-gradation, a normal volume and a normal increment*. Each of those diameter size-gradations differs by one diameter class. The normal state of size-gradation, volume and increment can be found through extensive work in the area, guided by knowledge of similar forests used as benchmarks. An inverted J curve for the number of stems and diameter class relationships is usually found in the normal forest, as shown in Figure 4.6.

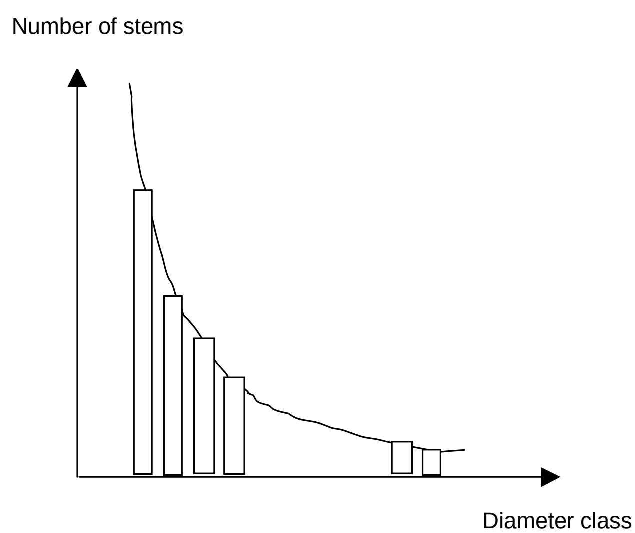


Figure 4.6. Number of stems and diameter class relationship.

The idea of normality should also relate to non-timber forest products (NTFP) and services - in the sense of those products and services being produced by the forest in a sustainable manner and according to the forest’s full capacity. That became the second criterion. Table 4.2 lists the economic criteria for SFM. All these criteria become outcome parameters of the principle: *forest products and services are sustained*.

Table 4.2. The generic knowledge of economical criteria for SFM

Category	Text
Principle 2	Forest products and services are sustained
Criterion 2.1	Forest has a normal series of diameter size-gradation, a normal volume and a normal increment.
Criterion 2.2	Normality in non-timber forest products and services

4.1.2.4. Social Criteria

Forests are natural resources that many parties have interests in. Governments, in most countries, act as regulators, ideally responsible for making the best use of and maintenance of forests. Local communities who live nearby are greatly dependent on forests. Timber companies, in most cases, depend on the ability of forests to produce timber. Non-Government Organizations (NGOs) empower and advocate on behalf of local communities, helping them to claim their rights. Other parties such as universities, research institutes and international communities play a role in declaring their interests in having more sustainable forests.

Since one party does not own a forest exclusively it is important to manage it cooperatively. In other words a forest should be managed in a multi-stakeholder environment. This was chosen as the principle of the social aspect. This principle meets the idea that a forest is a public good, where the external requirements of managing it cannot be avoided.

The rights of relevant stakeholders should be acknowledged. This means relevant stakeholders must be identified, along with their rights to forests - either legally or informally. Informal rights include pre-existing rights that have existed for a long time before legal rights have been declared by the government. Each stakeholder derives a fair benefit from the forest, according to their rights.

A forest is known as a complex ecosystem - therefore there is always an incomplete knowledge available in forest management. Under these circumstances, forest management prescriptions must be treated as working hypotheses. These working hypotheses could be right or wrong. Working hypotheses are subjects which modify and improve situations when they are executed in the real world. The stakeholders' abilities to learn ways of modifying and improving the current system is a criterion of sustainability. This situation is described in Figure 4.7. Table 4.3 shows social criteria for SFM.

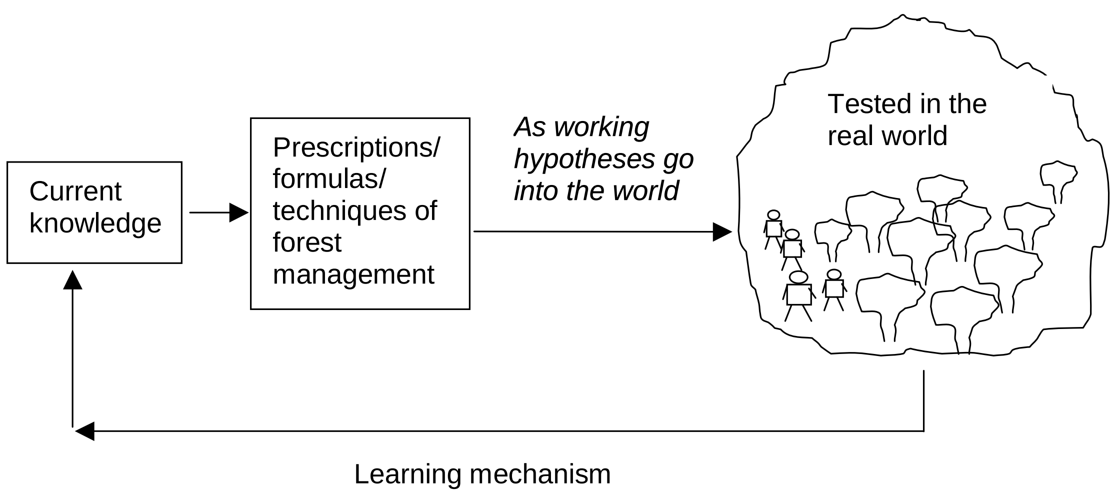


Figure 4.7. Learning mechanisms of stakeholders

Table 4.3. The generic knowledge of social criteria for SFM

Category	Text
Principle 3	Forest is managed in the multi-stakeholder environment
Criterion 3.1	Rights of stakeholders are established fairly and acknowledged
Criterion 3.2	Fair benefit distribution among the stakeholders
Criterion 3.3	All relevant stakeholders have a learning capacity in relation to the complexity of forest ecosystem management

4.1.2.5. The Complete C&I Set

The complete scientific knowledge of SFM as described previously, and its indicators are shown in Table 4.4. Each criterion followed by indicators was to be used as a quantitative or qualitative attribute of that criterion. As previously mentioned there are three types of criteria and indicators i.e. input, process and outcome. The table also shows the type of each item.

Table 4.4. The generic knowledge of SFM

Level	**Text**	**Type**
Principle 1	**Ecosystem integrity is maintained**	
Criterion 1.1	Biodiversity is maintained	Outcome
Indicators	Landscape pattern is maintained	Outcome
	The species richness is maintained	Outcome
	Population sizes do not show significant change	Outcome
	Rare or endangered species are protected	Outcome
Criterion 1.2	Maintenance of ecologically sensitive areas	Outcome
Indicators	Buffer zones along water sources are protected	Outcome
	Representative areas, especially sites of ecological importance, are protected and properly managed	Outcome
	Forest on steep slope areas is maintained	Outcome
Criterion 1.3	Ecosystem function is maintained	Outcome
Indicators	Water quality and flow are maintained	Outcome
	Soil quality is maintained	Outcome

	No chemical contamination to food chains and ecosystem	Outcome
Principle 2	**Forest products and services are sustained**	
Criterion 2.1	Forest has a normal series of diameter size-gradation, a normal volume and a normal increment.	Outcome
Indicators	Normal series of diameter size-gradation of trees	Outcome
	Normal timber stock for each diameter size	Outcome
	Normal volume increment	Outcome
Criterion 2.2	Normality in non-timber forest products and services	Outcome
Indicators	Normal NTFP stock	Outcome
	Normal NTFP growth	Outcome
Principle 3	**Forest is managed in multi-stakeholder environments**	
Criterion 3.1	Rights of all stakeholders are established fairly and acknowledged	Process
Indicators	The existence of effective mechanisms for two-way communication among stakeholders	Process
	The existence of agreement on rights and responsibilities of relevant stakeholders	Process
	Fair access to forest resources	Process
	The relationship between forest maintenance and human culture is acknowledged	Process
Criterion 3.2	Fair benefit distribution among stakeholders	Outcome
	The health of forest actors are acceptable to all stakeholders	Outcome
	Livelihood choices do not decrease significantly	Outcome
	Forest product revenues are shared proportionally	Outcome
Criterion 3.3	Stakeholders have a learning capacity related to the complexity of forest ecosystem management	Process
Indicators	Existence of collaborative monitoring on forest conditions	Process
	Existence of collaborative reflection for improving forest management system	Process
	Space for innovation on forest management	Process

4.1.3. Criteria and Indicator Sets from Internationally Recognized Sources

Internationally recognized institutions and processes, including the ITTO, FSC, Montréal Process, ATO and Finnish process have developed criteria and indicator sets at FMU level for SFM. These different institutions represent four major world continents - Asia, America, Europe and Africa consecutively. The following discusses details of these C&I sets. These would be used to revisit the developed C&I.

4.1.3.1. The International Tropical Timber Organization C&I Set

The International Tropical Timber Organization (ITTO) was created by treaty in 1983 and its headquarters were established in Yokohama, Japan, in late 1986. The primary idea was to provide an effective framework for consultation among producer and consumer member countries on all aspects of the world timber economy within its mandate. Among its multiple objectives is a commitment to assist members to meet the ITTO's unique Year 2000 Objective, which states that by the year 2000 all tropical timber products traded internationally by Member States shall originate from sustainably managed forests (ITTO n.d.). The list of the ITTO's C&I is given in Appendix 2. Table 4.5 shows the comparison of the developed C&I with the ITTO's C&I.

Table 4.5. A comparison of the developed C&I with the ITTO's C&I

		The developed C&I			**ITTO**	
Aspect	Code	Item	No. of Indicators	Code	Item	No. of Indicators
Policy	-	-		C	Enabling Conditions for Sustainable Forest Management	9
Ecology	P. 1	Ecosystem integrity is maintained			-	
	C.1.1	Biodiversity is maintained	4	C	Biological Diversity	8
	C.1.2	Maintenance of ecological sensitive areas	3		Biological Diversity	

	C.1.3	Ecosystem function is maintained	3	C	Forest Ecosystem Health and Conditions; Soil and Water; Forest Resource Security	5 9 5
Production/Economy	P. 2	Forest products and services are sustained			-	
	C.2.1	Forest has a normal series of diameter size-gradation, a normal volume and a normal increment.	4	C	Flow of Forest Products	12
	C.2.2	Normality in non-timber forest products and services	3		Flow of Forest Products	
Social	P. 3	Forest is managed in the multi-stakeholder environments			-	
	C.3.1	Rights of all stakeholders are established fairly and acknowledged	3	C	Economic, Social and Cultural Aspects	18
	C.3.2	Fair benefit distribution among the stakeholders	4		Economic, Social and Cultural Aspects	
	C.3.3	Stakeholders have a learning capacity related to the complexity of forest ecosystem management	3		Economic, Social and Cultural Aspects	

Code ‘P’ is Principle; ‘C’ is Criterion; ‘-‘ Does not exist

The ITTO’s C&I set also emphasizes the importance of existing implementation procedures, guidelines and plans, while the developed C&I set does not. The developed C&I set is more impact-oriented. Another difference is the existence of the policy aspect of the ITTO’s C&I set. The first criterion ‘Enabling Conditions for Sustainable Forest Management’ is more of a government role than an FMU role.

4.1.3.2. Forest Stewardship Council Principle & Criteria set

The Forest Stewardship Council (FSC) is an international non-profit organization founded in 1993 to support environmentally appropriate, socially beneficial, and economically viable management of the world's forests. It is an association of members consisting of a diverse group of representatives from environmental and social groups, the timber trade and the forestry profession, indigenous people's organizations, community forestry groups and forest product certification organizations from around the world. Membership is open to all who are involved in forestry or forest products and who share its aims and objectives.

FSC supports the development of national and local standards that implement the international Principles and Criteria of Forest Stewardship at the local level. These standards are developed by national and regional working groups that work to achieve consensus among the wide range of people and organizations involved in forest management and conservation in each part of the world. FSC has developed guidelines for developing regional certification standards to guide working groups in this process. The list of FSC's P&C is given in Appendix 2. Table 4.6. shows the comparison of the developed C&I with FSC's P&C.

Table 4.6. A comparison of the developed C&I with FSC's P&C

		The developed C&I			**FSC**	
Aspect	Code	Item	No. of Indicators	Code	Item	No. of Criteria
Policy	-	-		P	Compliance with laws and FSC principles	6
	-	-		P	Tenure and use rights and responsibilities	3
Ecology	P. 1	Ecosystem integrity is maintained		P P	Environmental impact; Maintenance of natural forests	9 2
	C.1.1	Biodiversity is maintained	4		-	
	C.1.2	Maintenance of ecological sensitive areas	3		-	
	C.1.3	Ecosystem function is maintained	3		-	
Production/ Economy	P. 2	Forest products and services are sustained			-	
	C.2.1	Forest has a normal series of diameter size-gradation, a normal volume and a normal increment.	4		-	
	C.2.2	Normality in non-timber forest products and services	3		-	

				P	Management plan	4
				P	Monitoring and assessment	5
				P	Plantation	8
Social	P. 3	Forest is managed in a multi-stakeholder environment		P P P	Indigenous people's rights; Community relations and workers' rights; Benefits from the forest	4 5 6
	C.3.1	Rights of all stakeholders are established fairly and acknowledged	3		-	
	C.3.2	Fair benefit distribution among the stakeholders	4		-	
	C.3.3	Stakeholders have a learning capacity in relation to the complexity of forest ecosystem management	3		-	

Note: Code ‘P’ is Principle; ‘C’ is Criterion; ‘-‘ Does not exist; There is no associated indicator for each criterion.

The FSC’s P&C set acts as a standard for certification practice rather than as a scientific P&C set. This set has been quoted by different organizations due to its ease of use in the certification process. The policy P&C set refers to the national level rather than the FMU level.

4.1.3.3. Montréal Process C&I Set

The Montréal Process is the Working Group on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests. It was formed in Geneva, Switzerland, in June 1994 to develop and implement internationally agreed-on C&I for the conservation and sustainable management of temperate and boreal forests (The Montréal Process 1998).

Membership in the Working Group is voluntary and currently includes countries from both hemispheres, with a wide range of natural and social conditions. The members, Argentina, USA, China, Australia, Canada, Chile, Japan, Republic of Korea, Mexico, Russian Federation, New Zealand and Uruguay represent about 90 per cent of the world's temperate and boreal forests in the northern and southern hemispheres. This amounts to 60 per cent of all of the forests of the world. The list of the Montréal Process C&I is given in

Appendix 2. Table 4.7. shows a comparison of the developed C&I with the Montréal Process C&I.

Table 4.7. A comparison of the developed C&I with the Montréal Process C&I

		The developed C&I			**Montréal Process C&I**	
Aspect	Code	Item	No. of Indicators	Code	Item	No. of Indicators
Policy	-	-		C	Legal, institutional and economic framework for forest conservation and sustainable development	20
	-	-				
Ecology	P. 1	Ecosystem integrity is maintained			-	
	C.1.1	Biodiversity is maintained	4	C	Conservation of biological diversity	9
	C.1.2	Maintenance of ecological sensitive areas	3		-	
	C.1.3	Ecosystem function is maintained	3	C C C	Maintenance of forest ecosystem health and vitality; Conservation and maintenance of soil and water sources; Maintenance of forest contribution to global carbon cycles	3 8 3
Production/ Economy	P. 2	Forest products and services are sustained			-	
	C.2.1	Forest has normal series of diameter size-gradation, normal volume and a normal increment.	4	C	Maintenance of productive capacity of forest ecosystems	5
	C.2.2	Normality in non-timber forest products and services	3		Maintenance of productive capacity of forest ecosystems	
Social	P. 3	Forest is managed in the multi-stakeholder environments			-	
	C.3.1	Rights of all stakeholders are established fairly and acknowledged	3		-	
	C.3.2	Fair benefit distribution among the stakeholders	4	C	Maintenance and enhancement of long-term multiple socio economic benefits to meet the needs of societies	19
	C.3.3	Stakeholders have a learning capacity related to the complexity of forest ecosystem management	3		-	

Code ‘P’ is Principle; ‘C’ is Criterion; ‘-‘ Does not exist

The Montréal Process C&I set is clearly close to the developed C&I, except it mentions policy C&I, which are the responsibility of the related government. Another difference is the stakeholders' capacity of learning related to complexity, which is not considered in the Montréal Process C&I set. The set also mentions explicitly FMU contribution to the carbon cycles.

4.1.3.4. Finnish C&I Set

The Finnish certification standards represent suitable performance requirements to which forest organizations can commit when establishing their environmental management systems based on ISO 14001, the European Union regulations and most of the FSC principles, criteria and indicators. It will also conform to the forthcoming Pan-European operational guidelines and will be applied through group certification schemes in Finnish smallholder family forestry. Such a scheme will guarantee that costs remain acceptable for forest owners and an effective system for the promotion of SFM practices. The list of Finnish C&I is given in Appendix 2. Table 4.8. shows a comparison of developed C&I with Finnish C&I.

Table 4.8. A comparison of developed C&I with Finnish C&I

		The developed C&I			Finnish C&I	
Aspect	Code	Item	No. of Indicators	Code	Item	No. of Indicators
Policy	-	-				
	-	-				
Ecology	P. 1	Ecosystem integrity is maintained			-	
	C.1.1	Biodiversity is maintained	4	C	Maintenance, conservation and appropriate enhancement of biological diversity in forest ecosystems.	8

	C.1.2	Maintenance of ecological sensitive areas	3	C	-	
	C.1.3	Ecosystem function is maintained	3	C C C	Maintenance and appropriate enhancement of forest resources and their contribution to global carbon cycles; Maintenance of forest ecosystem health and vitality; Maintenance and appropriate enhancement of protective functions in forest management (notably soil and water).	9 4 5
Production/ Economy	P. 2	Forest products and services are sustained			-	
	C.2.1	Forest has normal series of diameter size-gradation, normal volume and normal increment.	4	C	Maintenance and encouragement of productive of forests (wood and non-wood)	11
	C.2.2	Normality in non-timber forest products and services	3		Maintenance and encouragement of productive of forests (wood and non-wood)	
Social	P. 3	Forest is managed in the multi-stakeholder environments			-	
	C.3.1	Rights of all stakeholders are established fairly and acknowledged	3	C	Maintenance of other socio-economic and cultural functions and conditions (economy and employment, public participation in decision making, cultural and multiple-use of forests)	10
	C.3.2	Fair benefit distribution among the stakeholders	4		Maintenance of other socio-economic and cultural functions and conditions (economy and employment, public participation in decision making, cultural and multiple-use of forests)	
	C.3.3	Stakeholders have a learning capacity related to the complexity of forest ecosystem management	3		-	

Code ‘P’ is Principle; ‘C’ is Criterion; ‘-‘ Does not exist

Finnish C&I set does not include policy C&I. The learning capacity of stakeholders in relation to the complexity of forest ecosystem management is not well considered. Otherwise, the Finnish C&I set is close to the developed C&I set.

4.1.3.5. African Timber Organization C&I Set

Founded in 1976, the African Timber Organization enables members to study ways of influencing prices of wood and wood products by ensuring a continuous flow of information on forestry matters. The organization also harmonizes commercial policies and undertakes training and industrial research. Member countries include: Angola, Cameroon, Central African Republic, Congo, Cote d'Ivoire, Equatorial Guinea, Gabon, Ghana, Liberia, Sao Tome and Principe, Tanzania and Zaire.

Moving in the same direction as other regional initiatives and along the same pattern, the African Timber Organization has developed its own initiatives in identifying the right criteria and indicators for sustainable forest management - through various field tests at forest management unit levels that can be suitably operational in its member countries. The ATO's criteria and indicators can also be used as a scientific tool for classifying, qualifying and certifying the degree of management in any given forest area. The list of ATO's C&I is given in Appendix 2. Table 4.9. shows the comparison of the developed C&I with ATO's C&I.

Table 4.9. A comparison of the developed C&I with ATO's C&I

		The developed C&I			**ATO C&I**	
Aspect	Code	Item	No. of Indicators	Code	Item	No. of Indicators
Policy	-	-		P	Sustainability of the forest and its multiple functions is a high political priority	
	-	-		C	The Government has clear forest development objectives and a realistic action plan to meet them	2
					The Government allocates adequate means for sustainable management of forests	3
					Action is taken by the Government to reduce all types of pressures on the forest	2
					At the international level, the Government has ratified or approved treaties, conventions or recommendations on sustainable development of forests	0

Ecology	P. 1	Ecosystem integrity is maintained		P	The main ecological functions of the forest are maintained	
	C.1.1	Biodiversity is maintained	4		Negative impacts of various interventions on biodiversity are minimized	8
	C.1.2	Maintenance of ecological sensitive areas	3		-	
	C.1.3	Ecosystem function is maintained	3	C	The capacity of the forest for natural regeneration is ensured; The function of water filtration (protection of water and soils) of the forest is maintained.	3 1
Production/ Economy	P. 2	Forest products and services are sustained			-	
	C.2.1	Forest has normal series of diameter size-gradation, normal volume and normal increment.	4	C	-	
	C.2.2	Normality in non-timber forest products and services	3		-	
				P	Areas devoted to forestry activities or the permanent forest estate are not declining	
				C	Areas devoted to forestry activities or the permanent forest estate are clearly delimited and their boundaries well established	2
				C	Efficient measures have been taken by the authorities to monitor the forest and to protect it against clearing, fire, settlements and illegal gathering of forest products	3
				C	The Government implements measures in order to promote the participation of various stakeholders (mainly neighboring villagers) in protecting the forest	2
Social	P. 3	Forest is managed in the multi-stakeholder environments		P	Forests are adequately managed and developed irrespective of their role	
	C.3.1	Rights of all stakeholders are established fairly and acknowledged	3	C	-	
	C.3.2	Fair benefit distribution among the stakeholders	4		-	
	C.3.3	Stakeholders have a learning capacity related to the complexity of forest ecosystem management	3	C	Forestry service and other stakeholders in the sector have enough capacity to properly develop and manage the forest for all its uses (timber production, other forest products, ecology, farmer-forest relationships)	0
				C	A management plan has been established for the sustainable management of the forest taking into account all its components and functions	4
				C	Standards for silviculture and other activities adapted to suit the specific ecology of the forest and to ensure sustainable management have been developed and are operational.	3
				C	Planning and implementation of logging is carried out in conformity with guidelines of the management plan and the contract agreement based on technical and social standards as well as financial specifications	

						9
				C	Deforested areas are regenerated by natural or artificial means	
				C	Infrastructure (roads, bridges, firebreaks, etc…) is designed, established and maintained in such a way that negative impacts on the environment (forest, soil, water course networks) are reduced to a strict minimum	1
				C	Non-timber forest products and their uses are identified	3
				C	Guidelines for rational harvesting of non-timber forest products are defined and put into practice	0
				C	Research is undertaken in order to define the conditions for a sustainable use of non-timber forest products	0
				C	Guidelines for harvesting of non-timber forest products are monitored, evaluated and can be corrected if necessary	0

Code ‘P’ is Principle; ‘C’ is Criterion; ‘-‘ Does not exist

The ATO C&I set includes policy C&I, which are the responsibility of governments. They also mention the importance of plans and guidelines as a means of verifying certified forest management. The security of the FMU area is also mentioned.

4.1.5. Revised Generic Criteria and Indicators

To revise the generic template, C&I from different sources were compared at criteria level. The criteria level is a center of difference of C&I. Indicators are a further elaboration of the criteria. The first attempt is to distinguish between the conditions and C&I of SFM. Conditions are requirements for sustainability, while C&I are things to point out or show sustainability. Hence, conditions are required before SFM C&I is shown. The process types of C&I were categorized into conditions of sustainability. Table 4.10 lists C&I and their types.

Table 4.10. Generic C&I and their types

Level	Text	Type
Principle 1	**Ecosystem integrity is maintained**	
Criterion 1.1	Biodiversity is maintained	Outcome
Indicators	Landscape pattern is maintained	Outcome
	The species richness is maintained	Outcome
	Population sizes do not show significant change	Outcome
	Rare or endangered species are protected	Outcome
Criterion 1.2	Maintenance of ecologically sensitive areas	Outcome
Indicators	Buffer zones along water sources are protected	Outcome
	Representative areas, especially sites of ecologically importance, are protected and properly managed	Outcome
	Forest on steep slope areas is maintained	Outcome
Criterion 1.3	Ecosystem function is maintained	Outcome
Indicators	Water quality and flow are maintained	Outcome
	Soil quality is maintained	Outcome
	No chemical contamination to food chains and ecosystem	Outcome
Principle 2	**Forest products and services are sustained**	
Criterion 2.1	Forest has a normal series of diameter size-gradation, a normal volume and a normal increment.	Outcome
Indicators	Normal series of diameter size-gradation of trees	Outcome
	Normal timber stock for each diameter size	Outcome
	Normal volume increment	Outcome
Criterion 2.2	Normality in non-timber forest products and services	Outcome
Indicators	Normal NTFP stock	Outcome
	Normal NTFP growth	Outcome
Principle 3	**Forest is managed in multi-stakeholder environments**	
Criterion 3.1	Rights of all stakeholders are established fairly and acknowledged	Condition
Indicators	The existence of effective mechanisms for two-way communication among stakeholders	Condition
	The existence of agreement on rights and responsibilities of relevant stakeholders	Condition
	Fair access to forest resources	Condition

	The relationship between forest maintenance and human culture is acknowledged	Condition
Criterion 3.2	Fair benefit distribution among the stakeholders	Outcome
	The health of forest actors are acceptable to all stakeholders	Outcome
	Livelihood choices do not decrease significantly	Outcome
	Forest product revenues are shared proportionally	Outcome
Criterion 3.3	Stakeholders have a learning capacity related to the complexity of forest ecosystem management	Condition
Indicators	Existence of collaborative monitoring on forest conditions	Condition
	Existence of collaborative reflection for improving forest management systems	Condition
	Space for innovation on forest management	Condition

Table 4.11. shows the summary of criteria comparisons and their categories. Two criteria related to policy were adopted in the developed C&I.

Table 4.11. Summary of C&I comparison and their categories

		The developed C&I	**ITTO**	**FSC**	**MP**	**Fin**	**ATO**	**Type**	**Condition type**	**Revisited**
Aspect	Code	Text								
Policy	P	-								
	C	Policy conditions for Sustainable Forest Management	1	1	1	0	1	Condition	Necc.	Adopted
	C	Forest Resource Security	1	1	0	0	1	Condition	Necc.	Adopted
Ecology	P. 1	Ecosystem integrity is maintained								
	C.1.1	Biodiversity is maintained	1	0	1	1	1	Criterion	-	Unchanged
	C.1.2	Maintenance of ecologically sensitive areas	0	1	0	0	0	Criterion	-	Integrated to C.1.3
	C.1.3	Ecosystem function is maintained	1	1	1	1	1	Criterion	-	Unchanged
Production/ Economy	P. 2	Forest products and services are sustained								
	C.2.1	Forest has a normal series of diameter size-gradation, a normal volume and a normal increment.	1	0	0	0	0	Criterion	-	Reformulated to adopt *)
	C.2.2	Normality in non-timber forest products and services	1	0	0	0	0	Criterion	-	Reformulated to adopt *)
	C	Adaptive yield management is implemented	0	1	0	0	1	Condition	Necc.	Adopted

	C	Management plans are available and implemented	0	1	0	0	1	Condition	Necc.	Adopted
	C	Existence of guidelines and procedures	0	1	0	0	1	Condition	Suff.	Adopted
	C	Maintenance capacity of production system*)	0	0	1	1	0	Criterion		-
Social	P. 3	Forest is managed in multi-stakeholder environment								
	C.3.1	Rights of all stakeholders are established fairly and acknowledged	1	1	0	1	0	Condition	Necc.	Unchanged
	C.3.2	Fair benefit distribution among the stakeholders	1	1	1	1	0	Criterion	-	Unchanged
	C.3.3	Stakeholders have a learning capacity in relation to the complexity of forest ecosystem management	1	0	0	0	1	Condition	Necc.	Unchanged
	C	Workers' rights	0	1	0	0	0	Condition	Necc.	Adopted

Note: Necc. is necessary; suff. is sufficient; Fin is Finnish C&I; MP is Montreal Process C&I.

In this case, the ecological criterion 'maintenance of ecological sensitive areas' was removed and integrated into the criterion 'ecosystem function is maintained'. On production or economical criteria, two criteria, the existing 'Management plans' and 'Guidelines and procedures' were added. Another production criterion that was categorized as a sufficient condition was 'adaptive forest yield management'. FSC and ATO mentioned the importance of this criterion. Those three criteria were categorized as sufficient conditions for SFM. The production or economical criteria were formulated as follows:

- Forest has a normal series of diameter size-gradation, a normal volume and a normal increment to maintain and increase the capacity of a production system;
- Normality of non-timber forest products and services.

One social criterion, categorized as sufficient condition is 'workers' rights' are adopted. Thus, all distinct and important criteria from different organizations were integrated to the developed generic C&I.

To determine the type of conditions, definitions of necessary and sufficient were implemented. Conditions that are the only ways towards sustainability are categorized as necessary conditions. In fact, all conditions, but ‘the existence of procedures and guidelines’, were individually categorized as necessary conditions and jointly sufficient conditions for sustainability at FMU level. Sustainability is still achievable without existing procedures and guidelines as long as plans towards sustainability exist and are implemented.

Based on that discussion the developed generic C&I were modified. Table 4.12 shows the modification result.

Table 4.12. Revised Generic C&I

Hierarchy	Text	Type
Principle 1.	Sustainability of the forest and its multiple functions is a high political priority	
Criterion 1.1	Policy conditions for Sustainable Forest Management	Condition
Indicators	Existence of economic instruments and other incentives to encourage sustainable forest management	Condition
	Capacity and mechanisms for planning sustainable forest management and for periodical monitoring, evaluation and feed-back on progress	Condition
	Degree of public participation in forest management, such as in planning, decision-making, data collection, monitoring and assessment	Condition
Criterion 1.2	Forest Resource Security	Condition
Indicators	There is a permanent forest estate governed by laws and regulations which are the basis for its sustainable management	Condition
	Area of the permanent forest estate converted to permanent non-forest use is minimum	Condition
Principle 2	Ecosystem integrity is maintained	
Criterion 2.1	Biodiversity is maintained	Outcome
Indicators	Landscape pattern is maintained	Outcome
	The species richness is maintained	Outcome
	Population sizes do not show significant change	Outcome
	Rare or endangered species are protected	Outcome
Criterion 2.2	Maintenance of ecologically sensitive areas	Outcome
Indicators	Buffer zones along water sources are protected	Outcome
	Representative areas, especially sites of ecologically importance, are protected and properly managed	Outcome
	Forest on steep slope areas is maintained	Outcome
Criterion 2.3	Ecosystem function is maintained	Outcome

Indicators	Water quality and flow are maintained	Outcome
	Soil quality is maintained	Outcome
	No chemical contamination to food chains and ecosystem	Outcome
Principle 3	Forest products and services are sustained	Outcome
Criterion 3.1	Forest has normal series of diameter size-gradation, normal volume and normal increment to maintain and increase the capacity of production system	Outcome
Indicators	Normal series of diameter size-gradation of trees	Outcome
	Normal timber stock for each diameter size	Outcome
	Normal volume increment	Outcome
Criterion 3.2	Normality in non-timber forest products and services	Outcome
	Normal NTFP stock	Outcome
Indicators	Normal NTFP growth	Outcome
Criterion 3.3	High-quality and adaptive management plans, guidelines and procedures towards SFM	Condition
Indicators	The existence of high-quality management plans	Condition
	The existence of high-quality related guidelines and procedures	Condition
	The existence of high-quality of monitoring systems	Condition
Principle 4	Forest is managed in multi-stakeholder environment	
Criterion 4.1	Rights of all stakeholders are established fairly and acknowledged	Condition
Indicators	The existence of effective mechanisms for two-way communication among stakeholders	Condition
	The existence of agreement on rights and responsibilities of relevant stakeholders	Condition
	Fair access to forest resources	Condition
	The relationship between forest maintenance and human culture is acknowledged	Condition
Criterion 4.2	Fair benefit distribution among the stakeholders	Outcome
Indicators	The health of forest actors are acceptable to all stakeholders	Outcome
	Livelihood choices do not decrease significantly	Outcome
	Forest product revenues are shared proportionally	Outcome
Criterion 4.3	Stakeholders have a learning capacity in relation to the complexity of forest ecosystem management	Condition
Indicators	Existence of collaborative monitoring on forest conditions	Condition
	Existence of collaborative reflection for improving forest management system	Condition
	Space for innovation on forest management	Condition
	Workers' rights	Condition

4.2. Local Knowledge for Sustainable Forest Management

4.2.1. Communities' Traditional Practices in Managing Forest Resources

Local communities have inherited traditional practices, fulfilling their needs from their ancestors. The FMU managed by the Inhutani II area overlapped with the local communities' settlement of Dayak Kenyah, Merap and Punan ethnic groups. These groups had been living in Malinau River for 100 years.

Eghenter and Sellato (1999) mentioned that 100 years ago, the Ngorek ethnic group occupied the area of Apo Kayan and Bahau-Pujungan, which was part of a larger society in Kalimantan in that time. In the 17th century, the ethnic group from Serawak called the Modang (and then called the Kayan) came to Apo Kayan. The Kayan were known as diligent cultivators and mastered steel processing, had a social structure and liked war.

In the first half of the 18th century, Kenyah ethnic groups, also from Serawak, came to Apo Kayan and Pujungan. In the second half of the 18th the Kenyah and Kayan attacked the Ngorek and took away the area of Pujungan and Bahau, and expelled the Ngorek. A Ngorek descent called Merap then went to Malinau river, where Punan and Berusu' ethnic groups stayed. Then, however, the Merap ethnic group, which was supported by the Punan, attacked and expelled the Berusu' from the area. In addition, years later some Kenyah people came to this area to join with Merap and Punan people who were considered the landowners.

The FMU where Inhutani II was located, had three ethnic groups, the Merap, Punan and Kenyah. The Punan population was the majority in that area and could be considered natives in Malinau River. However, their influence in society was less powerful than the Merap and Kenyah. This was due to the

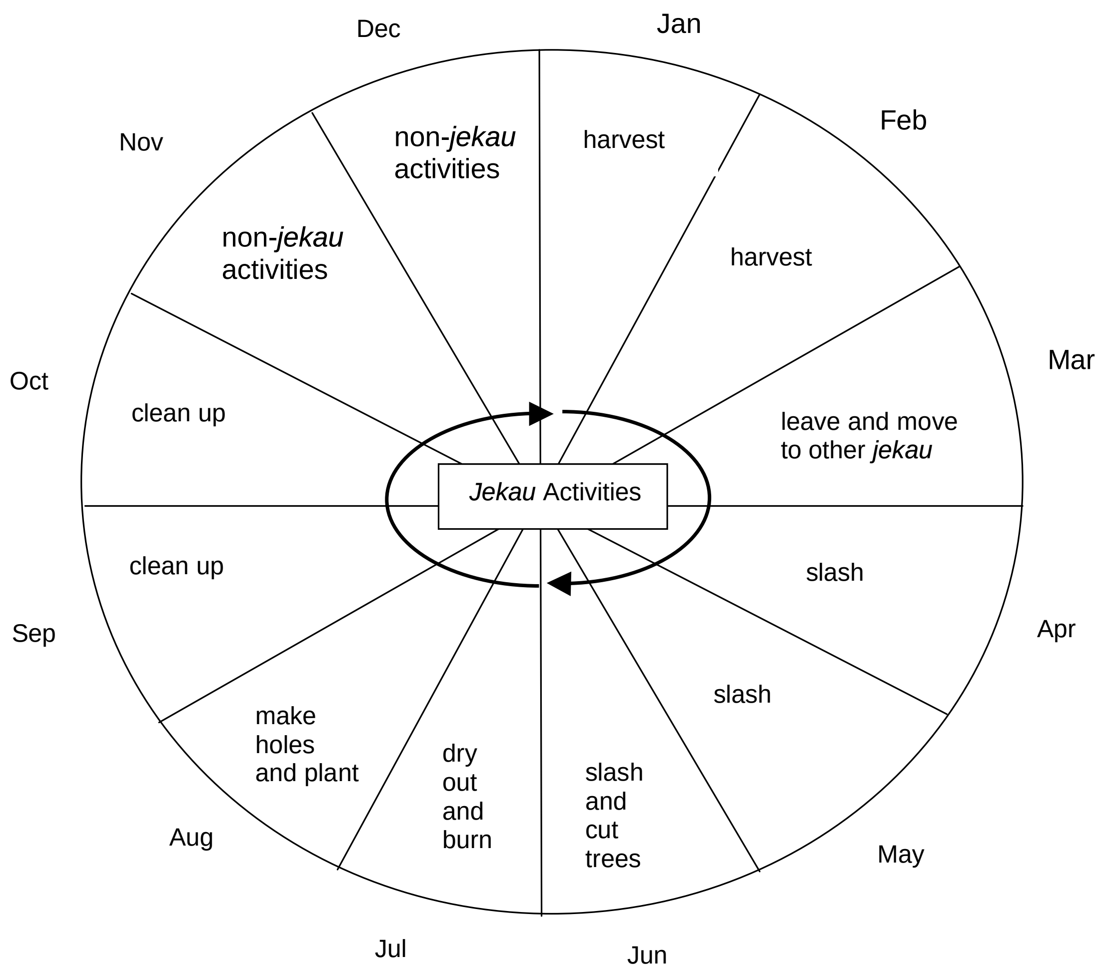
Punan being a nomadic tribe in the upper and downstream areas of the Malinau and Kayan Rivers.

Those communities that lived in the area were subsistent. The primary livelihoods they performed were inherited from their ancestors. Except for the Punan, there was no significant difference in daily life among communities located in Inhutani II. The Punan maintain a habit of frequent travel along the Malinau-Kayan Rivers. The livelihoods of these communities include swidden agriculture, hunting, catching fish and collecting.

4.2.1.1. Rice Field Practice (Shifting Cultivation)

The rice field practice or swidden agriculture became the major activity of most people living in the area. They cut the primary forest and planted non-irrigated rice at the beginning. They now have a limited forest to cut now, as the rotation period which was ideally 10 years became four or five years. The calendar of swidden (or *jekau* in the local language) activities is described in Figure 4.8.

A person or household who cut the forest for the first time was considered as the owner of the jekau. Each family usually has more than one jekau. A jekau irrigated by water from the rivers was called a sawah. There were some sawah in those villages. Jekau could only be planted once a year but sawah could be planted twice a year. In some activities such as slashing, planting or cutting, other community members helped individual households. This traditional arrangement was called *senguyun*. *Senguyun* could be based on money payment or no payment, depending on the agreement among community members. Figure 4.9. shows a layout of a typical village and its swidden agriculture.



Since the fallow period, which was the period between opening the forest (if the *jekau* was new) or cutting trees (if *jekau* was not new) and re-cutting trees, was considered very short (four or five years), it never gave enough time for the trees to grow. This was due to pressures from population growth. In addition, the communities had limited areas for opening new jekau. The pristine forests were limited as most of them had become Inhutani II's concession area. It was also common for those communities to burn the field or jekau after slashing, cutting and drying out - they considered wind direction when burning the field.

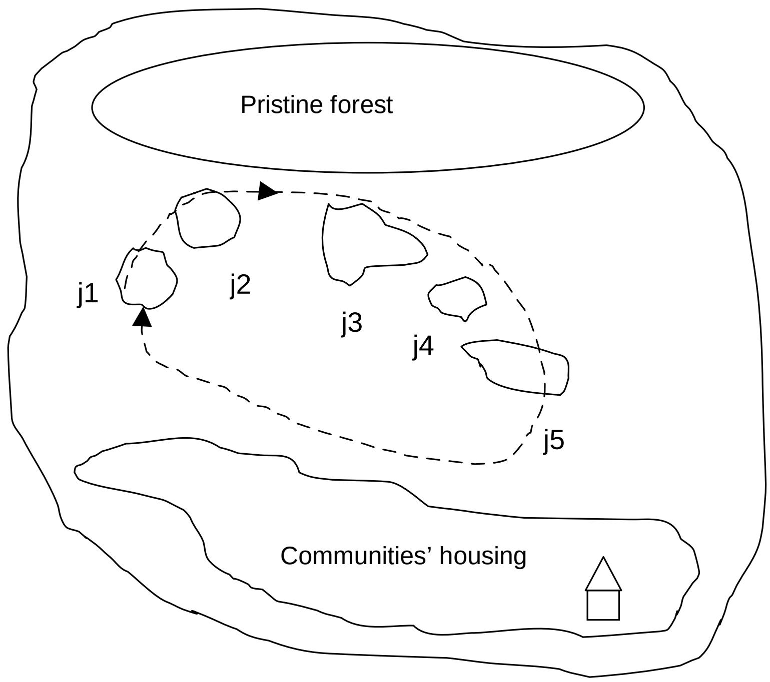


Figure 4.9. A typical village with its swidden agriculture (j is *jekau*)

Community members believed and recognized traditional values and beliefs, including the following:

1. If you are on a canoe in the river going somewhere, and
   - you see the bird crossing in front of you from left to right, it is a good sign. You can continue your journey with the canoe.
   - you see the bird crossing in front of you from right to left, it is a bad sign.
2. Snake
   - If you find a snake on your path or the snake is in front of you, it means you will have bad luck.

3. Eagle
   - If you see an eagle crossing left and right very often, it means you will have bad luck
   - If you see the eagle coming straight toward you, it means you will have good fortune
   - If the eagle comes from behind you and leaves in the same direction you are heading, it means your good fortune will be gone
4. Adat ceremonies, performed when opening the forest through cutting trees and during rice harvesting.

These beliefs at least became a limitation for cutting trees or frequently opening more forest for communities. Communities' beliefs might well be described as a form of animism. If people conduct their lives in accordance with the adat that come from the spirits, they feel comfortable, and that they don't have too much to fear. Those ceremonies are intended to establish good relations with spirits and ensure their blessing.

4.2.1.2. Hunting

One cultural characteristic of the communities is hunting. Hunting was a traditional activity that almost all people were involved in. The Dayak people were considered as good hunters. They hunted mammals, reptiles and birds for their daily living or for selling to other community members. Species mammals they hunted were Pig (*Sus barbatus*), Sambar Deer (*Curvus unicolor*), Common Barking Deer (*Muntiacus muntjac*), Masked Palm Civet (*Paguma larvata*) etc.

Their hunting implements included a lance (*Tombak*), blowpipe (*Sumpit*) and air rifle (*Senapan angin*). It was common for them to use dogs in hunting. Some of their beliefs, described previously, also exist in hunting activities. The

Punan ethnic groups were prohibited by their beliefs to kill lizards (*Biawak*, *Varanus* spp.).

4.2.1.3. Collecting

Gaharu (eaglewood) and rattan were the most frequent goods collected by the communities. *Gaharu* is the resinous, fragrant heartwood formed due to the presence of a fungus (*Cytosphaera mangifera*) in some species of *Aquilaria*. The communities consider *Gaharu* as a source of both timber and resin. Local communities said that currently Gaharu trees are difficult to find.

The men travel in groups (3 to 10 people) to seek *Gaharu*. They stay together at campsites, but sometimes they individually look for *Gaharu* in an area determined by the group. After three or four days in one region, they move campsites and start exploring again. In some cases, when *Gaharu* is found they just mark the tree and then look for the rest of the group. Then, all together, they cut the tree and extract the Gaharu from the fallen trunk. The product is divided among the group members. A belief related to Gaharu is if a collector sees a deer running slowly, it means he will show you the place where you can find a Gaharu tree.

Rattan is an important group of plants of the Plamaceae. The most valued one is rattan *sega'* (*Calamus caesius*). The others are rattan *bala'* (*Daemonorops histrix*) and rattan *seringan* (*Daemonorops sabut*). Rattan was collected from the primary forests, however it also might be found in the secondary forest. Rattan was used for making baskets and handicrafts. It was seldom to be sold as a raw material, especially after the export ban of unprocessed rattan was issued in the year, 1988.

4.2.1.4. Timber Cutting

The communities collected and cut trees for their housing or huts and village needs. Wood species frequently used were Meranti (*Shorea* sp.), Agathis (*Agathis borneensis*), Kapur (*Dryobalanops* sp.) and Ulin or Ironwood (*Eusideroxilon* sp.). They obtained timber from the primary forest or the area that was cut for *jekau*. They used Ulin for the main pillars of housing or for other construction such as the *Balai Desa* (village meeting hall), ceremonial halls and churches. For shelters, they used Meranti, Agathis or Kapur. Each household had boards located under their house for future uses.

Dead tree(s) resulting from a lightening attack, whether located in primary forest or secondary forest, cannot be cut according to the Punan and Merap beliefs. This is because a spirit is believed to occupy the tree(s).

In recent times, they used chainsaws for cutting trees, boards and beams (*balok, tiang*). Although each household had enough timber to sell, they could not sell it due to the lack of transportation.

4.2.2. Communities' Common Perceptions of Good Forest Management

Punan ethnic groups dominate the areas: Long Lake, Metud and Rian Villages. Kenyah and Merap Ethnic Groups live together in Paya Seturan Village. These villages are located in the Long Seturan area. Kenyah Ethnic Group also dominates Long Loreh Villages, while Langap Village is dominated by Merap Ethnic Group (Kaskija 1990). The following is how the communities perceived sustainability. Their perceptions were categorized as indicators of sustainability. During the focus group discussions, communities discussed what factors they thought would indicate good management of the forest surrounding them. These factors were considered as indicators since they indicated good forest management (*ciri-ciri* or *tanda-tanda* in Bahasa Indonesia). However, the term 'criteria' was not easy to understand.

Communities' perceptions of good forest management as recorded through semi-structured interviews are listed in Table 4.13 - 4.16. The Punan ethnic group was located in Long Seturan villages, the Kenyah in Long Loreh villages, and the Merap in Langap village. The tables indicate that the perceptions of the Kenyah and Merap people are quite close to each other compared to the perceptions of the Punan people. The Punan are the longest group to be native and nomadic, and are relatively less economically developed than the others.

Table 4.13. Supernatural indicators of good forest management, as identified by the local communities

No	Supernatural Indicator	Ethnic groups		
		Punan	**Kenyah**	**Merap**
1	Respect supernatural spirits before cutting big trees (for example, dead tree(s) caused by a lightening attack whether located in primary forest or secondary forest cannot be cut)	v	v	v
2	Recognize natural signs (birds, mammals etc.) when going to forest	v	v	v
3	Before cutting trees a religious ceremony should be performed	v	v	v

Table 4.14. Policy indicators of good forest management, as identified by the local communities

No	Policy Indicator	Ethnic groups		
		Punan	**Kenyah**	**Merap**
1	There is clear boundary between concession and customary/community land	v	v	v
2	Community's forests are acknowledged	v	v	v

Table 4.15. Socio-economic indicators of good forest management, as identified by the local communities

No	Socio-Economy Indicator	Ethnic groups		
		Punan	**Kenyah**	**Merap**
1	No occupation on communities' land and forest	v	v	v
2	Bottom-up approach for community development	v	v	v
3	Implementation of agreements between community and concession	v	v	v
4	Electric tools for catching fish are not allowed		v	v
5	Utilization of forest needs permission from communities, not compensation		v	v
6	Communities' land rights to areas such as former villages and graveyards are acknowledged	v	v	v
7	Government should take care of communities		v	v
8	All stakeholders recognize communities' expertise and knowledge in forest management			v
9	Communities' share on forest should never be forgotten			v
10	Concession helps the community prepare land for cultivation	v		
11	Human resource quality is increased	v		
12	Jobs are available for communities	v	v	v
13	Forest management outcomes help poor people	v	v	v
14	Rice fields are available for communities	v		
15	Villages' economy increases	v	v	v
16	*Gaharu*, rattan, and fruit trees must not be cut	v	v	v
17	Communities' lands (i.e. rice field, village forest) are protected	v	v	v
18	Rivers as communities' livelihood sources are not polluted	v	v	v
19	Pristine forests are not disturbed		v	v
20	Irrigation is available for community	v		
21	Community is helped with controlling cacao pests and diseases		v	v
22	Communities' workers in concession feel comfortable		v	
23	Roads to villages are available	v		
24	Funding for communities is available	v	v	v
25	Communities are able to use forest management infrastructures such as transportation vehicles	v	v	v
26	Respect each other in cutting trees			v
27	There is a forum for communication among various stakeholders	v	v	v
28	The log waste can be used by communities		v	v
29	Communities are allowed to make fallow near the roads	v		
30	All do not squander forest resources	v	v	v
31	All do not cut down trees that have many uses for things such as medicines	v	v	v

Table 4.16. Biophysical indicators of good forest management, as identified by the local communities

No	Biophysical Indicator	Ethnic groups		
		Punan	Kenyah	Merap
1	There is a fallow period for secondary forest to grow	v	v	v
2	Fish are available in rivers	v	v	v
3	Traditional medicinal plants are available in the forest	v	v	v
4	Forests have large-diameter trees	v	v	v
5	There are a lot of rattan and Gaharu	v	v	v
6	There are a lot of leaves used for roofing material		v	v
7	There are a lot of trees and tree-types in the forest	v	v	v
8	Dense forest	v		
9	There are a lot of pig, deer and other animals in the forest	v	v	v
10	The soil is black/dark and soft	v	v	v
11	There are big fish		v	v
12	There are a lot of *Tengkawang*		v	v
13	There are many durian trees		v	v
14	The company should carry out a replanting program		v	v
15	There are a lot of Agathis trees in the forest		v	v
16	Trees are in good health condition		v	v
17	There are bears in the forest		v	v
18	There are many, diverse animals in the forest		v	v
19	There are big snakes in the forest		v	v
20	Fishing livelihood is not decreasing	v	v	v
21	Hunting livelihood is not decreasing	v	v	v
22	Mother trees remain	v		
23	Clean rivers so that there are drinkable sources	v	v	v
24	Pristine forest for communities' offspring is available	v	v	v
25	The secondary forest is not re-exploited		v	v
26	Availability of animals to be hunted after logging	v	v	v

Since Christian Missionaries came to the villages in 1971, traditional beliefs no longer dominated their daily activities. The older generation maintained their beliefs, although they did not practice all of them. The younger generation also remembered traditional beliefs but they did not practice most of them. However, they considered some beliefs related to the forest should be respected. The beliefs usually overwhelmed them when it was harvest time or when something bad happened to the communities.

4.3. Testing the First Hypothesis

The comparison of the generic knowledge on the communities is shown in Table 4.17. The table is marked with a zero if the related indicator is absent and a one if it is present. If X_1 is a generic indicator, X_2 is a local indicator, and Y_i (where 'i' is a ethnic group) is the conformity of X_1 and X_2; then Y_i is defined as

$$Y_i = 1 \quad \text{if} \;\; X_1 = 1 \cap X_2 = 1$$

$$Y_i = 0 \quad \text{if} \;\; X_1 = 1 \cap X_2 = 0$$

Table 4.17. The knowledge comparison between scientific and local knowledge

Hierarchy	Text (X_1)		Y_i		
		Type	Y_{Punan}	Y_{Kenyah}	Y_{Merap}
Principle 1	Sustainability of the forest and its multiple functions is a high political priority				
Criterion 1.1	Policy conditions for Sustainable Forest Management	Condition			
Indicator 1.1.1.	Existence of economic instruments and other incentives to encourage sustainable forest management	Condition	0	0	0
1.1.2.	Capacity and mechanisms for planning sustainable forest management and for periodical monitoring, evaluation and feed-back on progress	Condition	0	0	0
1.1.3.	Degree of public participation in forest management, such as in planning, decision-making, data collection, monitoring and assessment	Condition	1	1	1
Criterion 1.2	Forest Resource Security	Condition			
Indicator 1.2.1.	There is a permanent forest estate governed by laws and regulations which are the basis for its sustainable management	Condition	0	0	0
1.2.2.	Area of the permanent forest estate converted to permanent non-forest use is minimum	Condition	0	0	0
Principle 2	Ecosystem integrity is maintained				
Criterion 2.1	Biodiversity is maintained	Outcome			
Indicator 2.1.1.	Landscape pattern is maintained	Outcome	1	1	1
2.1.2.	The species richness is maintained	Outcome	1	1	1
2.1.3.	Population sizes do not show significant change	Outcome	1	1	1
2.1.4.	Rare or endangered species are protected	Outcome	1	1	1
Criterion 2.2	Maintenance of ecologically sensitive areas	Outcome			

Indicator 2.2.1.	Buffer zones along water sources are protected	Outcome	1	1	1
2.2.2.	Representative areas, especially sites of ecologically importance, are protected and properly managed	Outcome	1	1	1
2.2.3.	Forest on steep slope areas is maintained	Outcome	1	1	1
Criterion 2.3	Ecosystem function is maintained	Outcome			
Indicator 2.3.1.	Water quality and flow are maintained	Outcome	1	1	1
2.3.2.	Soil quality is maintained	Outcome	1	1	1
2.3.3.	No chemical contamination to food chains and ecosystem	Outcome	1	1	1
Principle 3	Forest products and services are sustained				
Criterion 3.1	Forest has normal series of diameter size-gradation, normal volume and normal increment to maintain and to increase the capacity of the production system	Outcome			
Indicator 3.1.1.	Normal series of diameter size gradation of trees	Outcome	1	1	1
3.1.2.	Normal timber stock for each diameter size	Outcome	1	1	1
3.1.3.	Normal volume increment	Outcome	1	1	1
Criterion 3.2	Normality in non-timber forest products and services	Outcome			
Indicator 3.2.1.	Normal NTFP stock	Outcome	1	1	1
3.2.2.	Normal NTFP growth	Outcome	1	1	1
Criterion 3.3	High-quality and adaptive management plans, guidelines and procedures towards SFM	Condition			
Indicator 3.3.1.	The existence of high-quality management plans	Condition	0	0	0
3.3.2.	The existence of high-quality related guidelines and procedures	Condition	0	0	0
3.3.3.	The existence of high-quality monitoring systems	Condition	0	0	0
Principle 4	Forest is managed in multi-stakeholder environments				
Criterion 4.1	Rights of all stakeholders are established fairly and acknowledged	Condition			
Indicator 4.1.1.	The existence of effective mechanisms for two-way communication among stakeholders	Condition	1	1	1
4.1.2.	The existence of agreement on rights and responsibilities of relevant stakeholders	Condition	1	1	1
4.1.3.	Fair access to forest resources	Condition	1	1	1
4.1.4.	The relationship between forest maintenance and human culture is acknowledged	Condition	1	1	1
Criterion 4.2	Fair benefit distribution among the stakeholders	Outcome			
Indicator 4.2.1.	The health of forest actors are acceptable to all stakeholders	Outcome	1	1	1
4.2.2.	Livelihood choices do not decrease significantly	Outcome	1	1	1
4.2.3.	Forest product revenues are shared proportionally	Outcome	1	1	1
Criterion 4.3	Stakeholders have a learning capacity in relation to the complexity of forest ecosystem management	Condition			
Indicator 4.3.1.	Existence of collaborative monitoring on forest conditions	Condition	0	0	0
4.3.2.	Existence of collaborative reflection for improving forest management system	Condition	0	0	0
4.3.3.	Space for innovation on forest management	Condition	0	0	0
4.3.4.	Workers’ rights	Condition	1	1	1

As previously discussed, the terms condition and indicator are different. The local communities expressed good forest management indicators, which are outcome indicators. Therefore, the comparison between those knowledge carried out on outcome indicators type only. Table 4.17 shows local communities' indicators on good forest management conform with generic indicators of SFM; In other words, the value of Y_{Punan} ,Y_{Kenyah} and Y_{Merap} are equal to 100 %; Y_i is equal to one for all outcome indicators. Therefore, H_0 of the first hypothesis was accepted. The acceptance of H_0 means that the local knowledge is similar to the generic knowledge by which a forest management scheme is derived.

The communities obtain their knowledge from real-life experience. The knowledge results from their efforts to understand a real and changing world. This equips the communities to adapt and to live in harmony with nature. Thus, they understand how a forest behaves and how to utilize it.

There is no formal inter-generational transmission. The presence of supernatural indicators of SFM is typical in the eastern world, as it is a way to conceptualize the real world. Informal leaders such as customary leaders have a central role in transmitting this informal knowledge to their community members. This transmission process also explains why the community knowledge has a local scale. A local real-life experience is logically valid to use in that area, and is not necessarily valid for another area. An acceptance of the first hypothesis shows that the communities can conceptualize SFM through community knowledge.

Inhutani II ideally believes in implementing generic knowledge of SFM. Inhutani II formally stated this belief. The common stakeholders' perceptions of SFM are a foundation for collaboration in managing the forests. The question of whether such a collaboration will work and provide better outcomes tested the second hypothesis.

Another analysis was to find communities' indicators that were not in the generic indicators. This process, called a falsification process, was aimed at observing what communities' indicators could contribute to scientific indicators. Tables 4.18 – 4.21 shows this process. The table is marked with zero if the related indicator is absent and with one if it is present. If X_1 is a generic indicator, X_2 is a local indicator, and Y_i (where 'i' is a ethnic group) is the conformity of X_1 and X_2; then Y_i is defined as

$$Y_i = 1 \quad \text{if} \; X_1 = 1 \cap X_2 = 1$$

$$Y_i = 0 \quad \text{if} \; X_1 = 1 \cap X_2 = 0$$

Table 4.18. Falsification of supernatural generic indicators

No	Communities' Supernatural Indicator (X_2)	Y_i
1	Respect supernatural spirits before cutting big trees (for example, Dead tree(s) caused by thunder whether located in primary forest or secondary forest can not be cut)	0
2	Recognize natural signs (birds, mammals etc.) when going to forest	0
3	Before cutting trees a religious ceremony should be performed	0

Table 4.19. Falsification of policy generic indicators

No	Communities' Policy Indicator (X_2)	Y_i (list of related X_1)
1	There is clear boundary between concession and customary/community land	1(i121,i421,i411,i413)
2	Communities' forests are acknowledged	1(i121,i413,,i422,i423)

Table 4.20. Falsification of socio-economic generic indicators

No	Communities' Socio-Economy Indicator (X_2)	Y_i (list of related X_1)
1	No occupation on communities' land and forest	1(i121,i413,,i422,i423)
2	Bottom-up approach for community development	1 (i113, i411)
3	Implementation of agreements between community and concession	1 (i131,i412,i413)
4	Electric tools for catching fish are not allowed	1(i321)
5	Utilization of forest needs permission from community, not compensation	0
6	Communities' land rights to areas such as former villages and graveyards are acknowledged	1(i121,i413,,i422,i423)
7	Government should not take care of animals more than community	1 (i421)
8	There is no difference between professors and local experts, except opportunity	1 (i421)
9	Communities' share in the forest should never be forgotten	1(i121,i413,i412,i413,i414)
10	Concession helps community prepare land for cultivation	1(421)
11	Human-resource quality increases	1(421)
12	The company should offer jobs to community	1(421)
13	Company must help poor people	1(421)
14	Company should help community establish rice field	1(421)
15	Concession should increase village economy	1(421,i423)
16	Company must not cut Gaharu, rattan, and fruit trees	1(i423)
17	Company should not take over community's land (i.e. rice field, village forest)	1 (i121,i421,i413)
18	Company should not cause the river to become polluted	1(i231)
19	Company should not disturb the forest (primary forest)	1(i311, i312)
20	Irrigation for community	1(421)
21	Concession and government help community control cacao pests and diseases	1(421)
22	Concession make communities' workers in concession feel comfortable	1(434)
23	Concession builds roads to villages	1(421)
24	Concession supports funding for community	1(421)
25	Community is able to use concession's transportation vehicles	1(421)
26	Respect each other in cutting trees	1 (i422,i423)
27	There is a forum for communication between concession and community	1 (i411)
28	The log waste can be used by community	1(421)
29	Community is allowed to make fallow near the roads	1(i421)
30	All do not squander forest resources	1(i312)
31	All do not cut down trees that have many uses such as medicines	1(i214)

Table 4.21. Falsification of biophysical generic indicators

No	Communities' Biophysical Indicator (X_2)	Y_i (list of related X_1)
1	There is a fallow period for secondary forest to grow	1(i311)
2	Fish are available in rivers	1(i221,i321)
3	Traditional medicinal plants are available in the forest	1(i212,i213)
4	Forests have large-diameter trees	1(i312)
5	There is a lot of rattan and Gaharu	1(i212, i213,i422)
6	There are a lot of leaves used for roofing material	1(i213,i423)
7	There are a lot of trees and tree-types in the forest	1(i212,i213)
8	Dense forest	1(i312,i211)
9	There are a lot of pig, deer and other animals in the forest	1(i213,i422)
10	The soil is black/dark and soft	(i232)
11	There are big fish	1(i321,i231)
12	There are a lot of *Tengkawang*	1(i213,i422)
13	There are many *Durian* trees	1(i213,i422)
14	The company should carry out replanting program	1(i423)
15	There are a lot of Agathis trees in the forest	1(i212,i312)
16	Trees are in good health condition	1(i313)
17	There are bears in the forest	1(i423)
18	Many, diverse animals in the forest	1(i212,i213,i321)
19	There are big snakes in the forest	1(i213,i321)
20	Fishing livelihood is not decreasing	1(i321,i422)
21	Hunting livelihood is not decreasing	1(i321,i422)
22	Mother trees remain	1(i312)
23	Clean rivers so that there are drinkable sources	1(i231,i233)
24	Pristine forest for communities' offspring is available	0
25	The secondary forest is not re-exploited	0
26	Availability of animals to be hunted after logging	1(i321,i322)

The supernatural indicators cannot exist in scientific knowledge because of the nature of scientific knowledge – it is formulated based on hypothesis and experiment. However, these indicators can create a spiritual relationship between forest actors and forests. It can make forest managers act carefully if they cut trees. In other words, it can support forest sustainability.

There are three other communities' indicators not in the scientific indicators (Table 4.20 and 4.21). The first indicator is 'Utilization of forest needs permission from community, not compensation'. This needs clarification of whose forest it is. Certainly, if the forest belongs to the communities, then permission is needed. This needs to be resolved first before managing that forest. The second indicator 'Pristine forest for communities' offspring is available' indicates the future use of the forest. It is important to ensure the inter-generational equity is implemented. This means to keep production forest "unmanaged" from the perspective of current forest production management, it might be inappropriate if the maximum capacity of forest production principle is violated. However, we never know the maximum capacity of forest production from a future perspective.

The last indicator 'The secondary forest is not re-exploited' indicates the communities' awareness of the time needed for forest stands to be back to pristine-like forest stands. Local communities have so far not seen forest stands of Inhutani II logged-over area back to their original state.

4.4. Knowledge Base System of Criteria and Indicators

The local knowledge for SFM was found to be similar to the generic or scientific knowledge of SFM. However, they differed in terms of how to use that knowledge. The generic knowledge was more useful for good argumentation, but sometimes poor for implementation. The local one was more practical but sometimes there was no scientific justification. Thus, a combination of those types of knowledge was useful to work out the knowledge of SFM. Furthermore, the local knowledge was not well structured. An effort to structure the SFM local knowledge in relation to the scientific one would be useful for making local knowledge more scientifically sound in assessing the sustainability of forest management.

The knowledge base system (KBS) was built to combine these types of knowledge. Since the local knowledge was site-specific then an adaptation process was required for combined knowledge. The adaptation process would ensure the combined knowledge worked out in a particular site. The efforts were to make the SFM generic knowledge available in a KBS and to put the SFM local knowledge in the KBS library. The KBS users are then able to combine and adapt that knowledge to meet a particular situation. The KBS development was initiated by a knowledge-elicitation process, as mentioned in previous chapters. Figure 4.10 shows the architecture of the KBS.

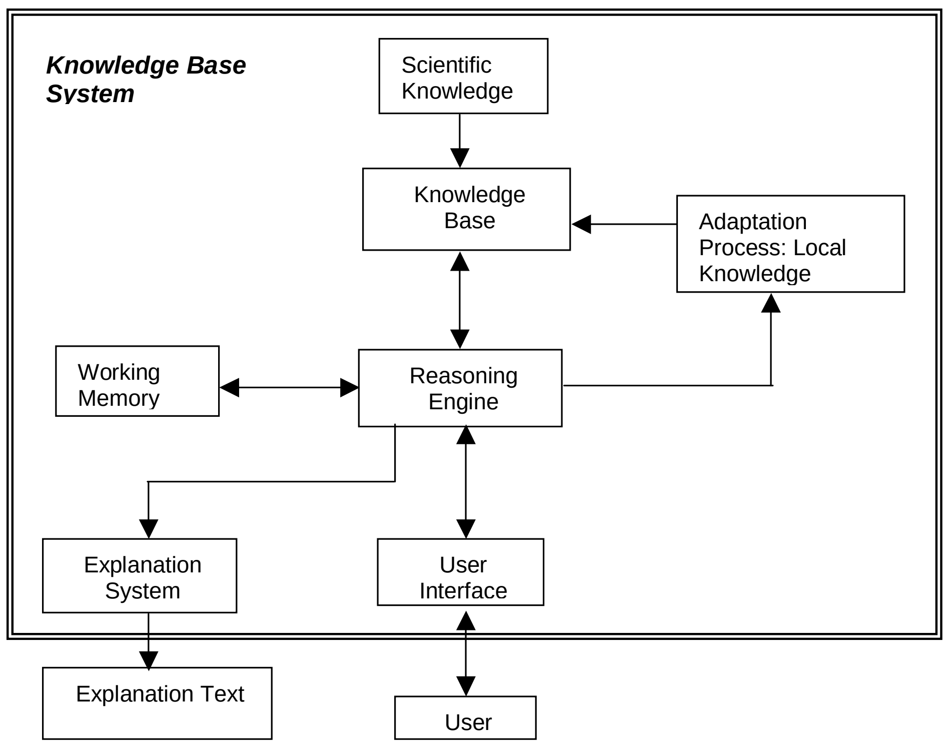


Figure 4.10. The KBS architecture

The reasoning engine comprises rules to infer decisions on sustainability, given the knowledge and user inputs through its interface. In this process, the engine consults its working memory to know what is inside regarding the adaptation process taking place. The KBS explains this process to users using its explanation system. On the user's computer screen, explanatory text about the process of inference will appear.

4.4.1. Knowledge Representation

A network of criteria and indicators, as shown in Figure 4.11, represents the knowledge of SFM. The knowledge was broken down into nodes. Each node represents a concept of sustainability at a particular level. For instance, in Table 4.22 the first principle of generic knowledge is "ecosystem integrity is maintained", and the second level derived into criteria - the criteria are followed by their indicators. A verifier or sub-verifier is needed when its super ordinate cannot represent a single measurement.

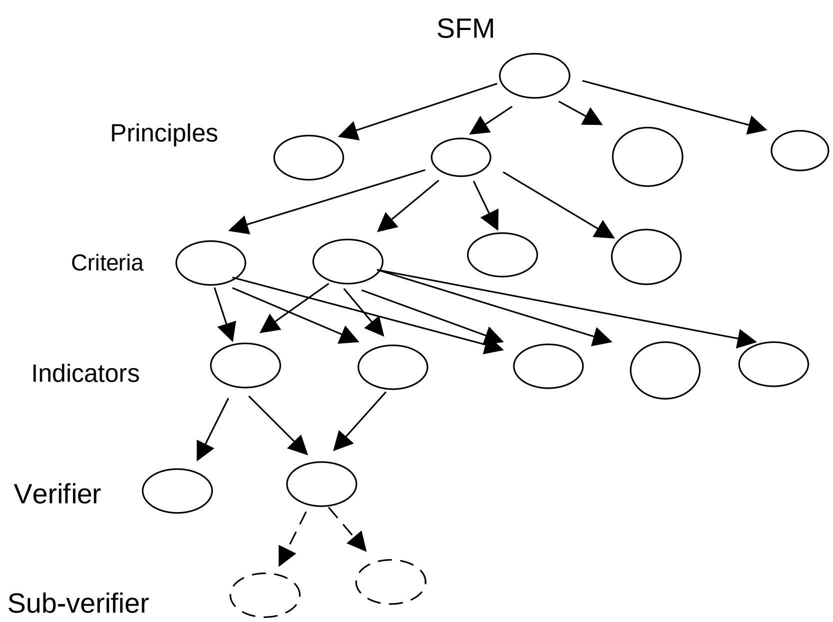


Figure 4.11. Network of nodes that represent criteria and indicators

Each node has attributes such as detail explanation, who created it, when it was created etc. Each node has a series of argumentation processes showing whether a particular node is supported or countered in the network, as shown in Figure 4.12. The argumentation process of each node is stored in its life history that can be tracked by the user. The importance of that history is to enable the user to learn how the knowledge exists in the network.

Table 4.22. The hierarchy of nodes

Principle 1	**Ecosystem integrity is maintained**
Criterion 1.1	Biodiversity is maintained
Indicators	Landscape pattern is maintained
	The species richness of selected groups is maintained
	Population sizes of selected species do not show significant change
	Rare or endangered species are protected
Verifier	………………
Sub-verifier	………………

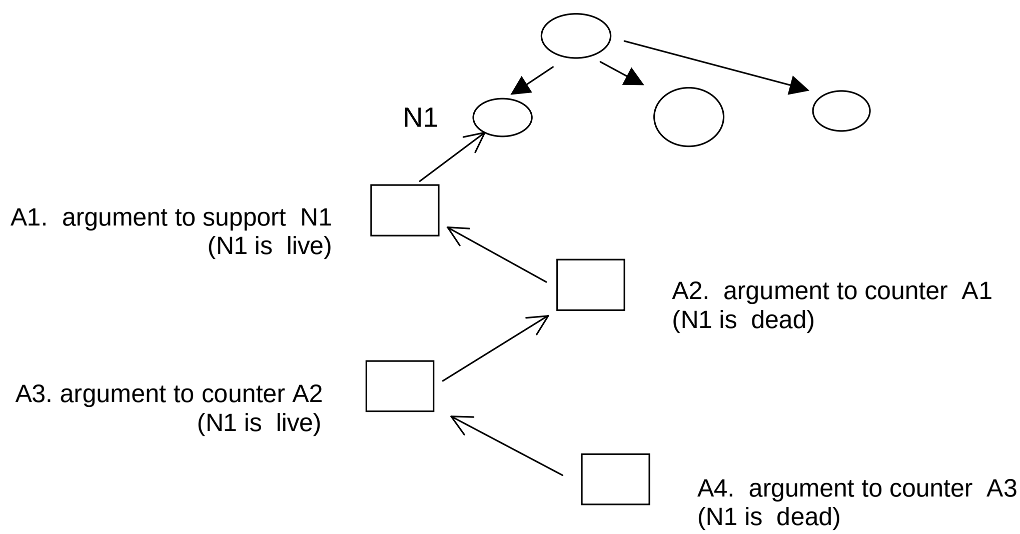


Figure 4.12. The argumentation process

The relation between nodes under one super ordinate is not necessary all ANDs. It might be AND or OR as illustrated in Figure 4.13. N1 has five subordinates. The AND relation connects the first three nodes, and the OR relation relates the fourth and fifth nodes. Thus, N1 comprises three nodes (N.1.1, N.1.2 and N.1.3) and one node either N.1.4 or N.1.5.

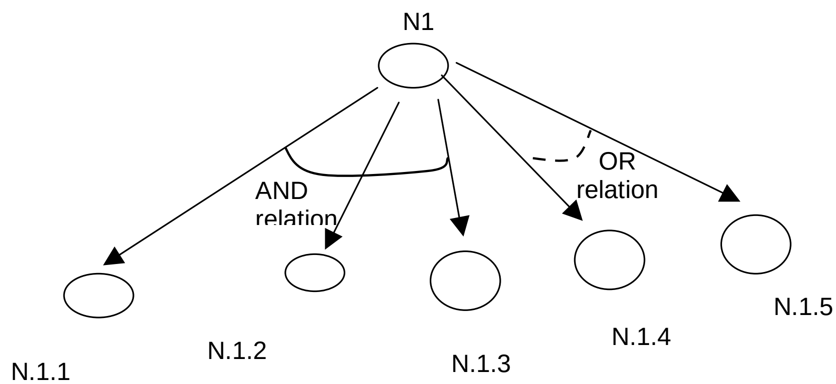


Figure 4.13. The relation between nodes

4.4.2. Reasoning Engine

The inference engine of the "hierarchical network" reasons from the leaves to the root as shown in Figure 4.14. Scores of subordinate nodes determine the score of their super ordinate. The score of a node is determined by multiplying the score of its subordinates with their relative importance. For instance, if a node has three subordinates with scores 5, 6 and 8 and relative importance 0.4, 0.4 and 0.2 subsequently, then the score of that node is

$$(5 \times 0.4) + (6 \times 0.4) + (8 \times 0.2) = 2 + 2.4 + 1.6 = 6$$

A score might represent one's guess, containing words such as true, highly true, likely, unlikely, impossible etc. Those degrees of belief can be expressed by a real number in some interval – for example between zero and one. Such a number is known as a certainty factor. KBS combines the certainties of proposition with rules. If c(N1) and c(N2) denote certainties for N1 and N2, then combinations of N1 and N2 follow

$$c(N1 \text{ AND } N2) = \min(c(N1), c(N2))$$

$$c(N1 \text{ OR } N2) = \max(c(N1), c(N2))$$

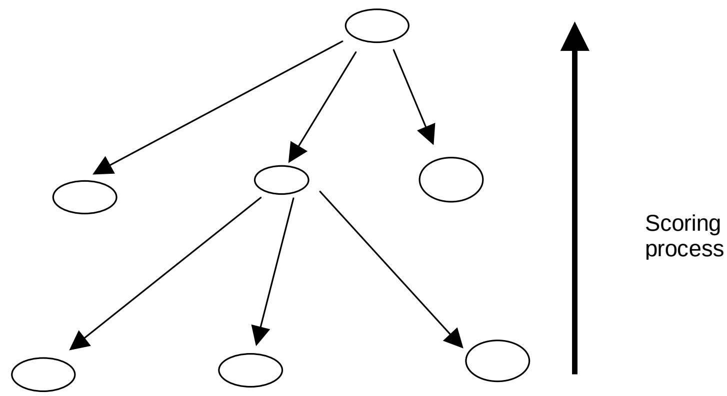


Figure 4.14. Assessment process

4.4.3. Implementation

The KBS has two major capabilities: adapting local knowledge and assessing forest sustainability, based on the combination of scientific and local knowledge. The formal representation of the KBS is as follows

top_goal("SFM")
is_node("SFM")
includes("SFM",Node$_1$)
includes(Node$_1$,Node$_2$)
includes(Node$_2$,Node$_3$)
includes(Node$_{n-1}$,Node$_n$)
attributes(Node,Text_explanation,[Arguments],[Creators],[Context],Remarks)

oritems(Node,[Nodes])
identical_items(Node,[Nodes])

user(Creator_code,[Creator_attributes],[Date],[Time])
context(Context_code,[Context_attributes])

basket(Node_type,Node)
Node_type **è** *Goal|Criterion|Verifier|Sub_verifier|…*

assess(Node,Score,Certainty_factor,Relative_importance,Remarks)

Symbols in the bracket, for instance [Arguments] is a list of data structure. [Arguments] is a list of arguments, which has no length limitation.

The goal of the whole assessment process is sustainability of forest or SFM. It is the root of knowledge hierarchy*, represented by

top_goal("SFM")

In the next level of the hierarchy are the criteria of SFM, which are represented as *includes* statements, as follows:

includes("SFM","Normal timber products and services")
includes("SFM","Normal non-timber products and services")
includes("SFM","Biodiversity")
includes("SFM","Protected areas")
includes("SFM","Stakeholders' rights")
includes("SFM","Stakeholders' learning capacity")

The biodiversity (third statement) comprises indicators, which explain how to measure biodiversity. They are represented as follows:

includes("Biodiversity","Landscape pattern")
includes("Biodiversity","Richness index")
includes("Biodiversity","Genetic diversity")

This hierarchy process can be followed to their verifiers or sub-verifiers whenever possible. Each item or node has attributes explaining the argumentation - who created them, remarks, context etc, as represented in the formal representation.

The adaptation processes are simply whether the scientific knowledge meets biophysical and socio-economic conditions of a specific site. If the scientific knowledge cannot meet the local condition then the adaptation process is performed. So, it depends on what the user wants. The user can also use the local knowledge for an assessment of sustainability. To ensure local knowledge is sufficient, the user can use local knowledge by modifying scientific knowledge through a process called an adaptation of scientific knowledge. The adaptation processes are supported by instructions of *add new node, delete the existing node, reword the node* and *restore the deleted node*. In the adaptation

* Although the knowledge representation forms a network, the term hierarchy is still used to describe the leveling of the knowledge.

process, the user is asked to submit an argument to ensure other users know the reason behind the adaptation process.

The KBS was programmed with a computer language called PROLOG (Programming in Logic), which is a well-known language for Artificial Intelligence. An environment, namely VISUAL PROLOG created by Prolog Development Center, Denmark, was used. Appendix 3 illustrates the screen show of the implementation of KBS. The ultimate goal of KBS creation was combining and structuring knowledge. It was not aimed to distribute it widely, but to create a tool to facilitate the combination of stakeholders' knowledge on C&I.

4.5. Artificial Society of Forest Actors

The common perceptions of SFM between Inhutani II and local communities became the foundation of collaboration in forest management.. To seek scenarios of collaboration an artificial society was built and simulated. This part explains the process of building the artificial society of forest actors in the area currently managed by Inhutani II. The developed model tested the second hypothesis of the research. Grant (1997) and Bousquet *et al.* (1999) described the use of the simulation model for hypothesis testing.

4.5.1. Stakeholder Identification

Local communities definitely were important stakeholders in the research area. The "Who Counts" matrix (Colfer *et al.* 1999), with a few modifications, identified all relevant stakeholders. The actors of the simulation model were a subset of identified stakeholders.

The first step of this method was to create a two-dimensional matrix. Across the top were listed the stakeholders who were initially identified as important. This was based on prior knowledge, interviews with some parties and existing literature. Along the left-hand side were listed stakeholder characteristics as shown in Table 4.23. The second step after the stakeholders had been listed across the top of the page was assigning a score for each one based on the degree to which each characteristic generally applied to them. The score ranged from between one and five (1 = high, 2 = relatively high, 3 = medium, 4 = relatively low, 5 = low). The mean scores for each column were computed across the bottom of each table. The cut-off point for our purposes of defining "Who Counts" was a mean score of less than 3.

For the sake of simplicity, the research grouped stakeholders into eight groups: Inhutani II, Long Seturan Community, Long Loreh Community, Langap Community, Central Government, Local Governments, NGOs and Coal Mining. Table 4.23 shows that the first six stakeholders, Inhutani II, Long Seturan Community, Long Loreh Community, Langap Community, Central Government, and Local Governments had a score of less than 3., Thus they were involved in the simulation.

Table 4.23. Stakeholder identification using “Who Counts” matrix

Stakeholder / **Charac-teristic**	Inhutani II	Long Seturan Community	Long Loreh community	Langap Community	Central Governments	Local Governments	NGOs	Coal Mining
Proximity	1	1	1	1	4	2	2	1
Pre-existing right	5	1	1	1	5	5	5	5
Dependency	1	1	1	1	3	2	3	5
Knowledge on forest management	1	1	1	1	2	3	2	5
Forestry spirit	1	1	1	1	2	3	2	5
Daily activity on site	1	1	1	1	3	3	2	1
Legal rights	1	5	5	5	1	1	5	1
Total	**11**	**11**	**11**	**11**	**20**	**19**	**21**	**23**
Mean	**1.6**	**1.6**	**1.6**	**1.6**	**2.9**	**2.7**	**3.0**	**3.3**

These groups also represent the primary actors in the forest area: local communities depend on the forest for a range of goods and services on a day-to-day basis; governments regulate and monitor the use of the forest; and the timber company manages the forest to meet commercial goals. NGOs often claim to speak on behalf of local communities, and may assist local communities to articulate their interests. However, NGOs were not directly involved in the management of this forest and were not present in the area all of the time. Miners have opened a small area of forest to mine coal. The mine has influenced the economy of the local communities, by creating a small market for their local products and providing menial jobs for local people, but the miners are not involved in the management of the forest.

The primary goals and activities of the selected stakeholders are shown in Table 4.24 and Table 4.25. The stakeholders were categorized as 'situated' if they were located in the spatial area, i.e. the Inhutani II area. In the simulation, all stakeholders were represented as agents who were able to communicate with the others. The general goals of stakeholders actually were their ideal goals, and not necessararily ones that might happen in real life. Table 4.25. shows stakeholders' primary activities observed in the field as well as their strategies. The stakeholders' secondary activities, the primary communication and the result of focus group analysis, are listed in Appendix 4.

Table 4.24. The stakeholders' characteristics and their primary identified goals

Community Name	Situ ated	Able to commun icate	Number of unit (Household or HH)	Assumed Agent's Number	General Goal(s)
Inhutani II	Yes	Yes	1 company	1	To produce timber products optimally and sustainably
Long Seturan (total)	Yes	Yes	112 HH	1	To fulfill subsistence needs
Paya Seturan			22 HH		
Long Lake			43 HH		
Metud			35 HH		
Rian			12 HH		
Long Loreh (total)	Yes	Yes	253 HH	1	To fulfill subsistence needs
Loreh			121 HH		
Pelancau			58 HH		
Bila Bekayuk			35 HH		
Sengayan			39 HH		
Langap	Yes	Yes	85 HH	1	To fulfill subsistence needs
Central Government	No	Yes	1 (Provincial office)	1	To maintain sustainability
Local Government	No	Yes	2 (Forestry Sub-district, District, Provincial Units)	1	To maintain sustainability and collect taxes

Table 4.25. The stakeholders' primary activities

Stakeholder Name	Primary Activity	Annual Target	Annual Area	Strategy
Inhutani II	Timber cutting	909,328 m^3	1106 ha	Meet all government requirements
Long Seturan	Rice field practice	150 – 350 kg	2 ha/HH	Rice field rotation or open a new pristine forest
Long Loreh	Rice field practice	150 – 350 kg	2 ha/HH	Rice field rotation or open a new pristine forest
Langap	Rice field practice	150 – 350 kg	2 ha/HH	Rice field rotation or open a new pristine forest
Central Government	Regulating, plans' approval	-	FMU	Formulating national policy
Local Governments	Executing and monitoring	-	FMU	Formulating district policy

Management of Inhutani II stated that the survival of Inhutani II under the current district autonomy scheme was the current goal. They realized that they had to participate in improving local communities' well-being, however, as a company Inhutani II wanted to sustain their profit and timber production.

The local communities realized that the forest where they lived had been legally allotted to Inhutani II. They thought this was unfair. However, the improvement of their well-being was very important in the situation. They received some help, such as money, transportation, housing and building materials, sport facilities etc. from Inhutani II. They mentioned the importance of *adat* and communities' forest (a forest managed by them) in the area currently managed by Inhutani II. They were also concerned with the way Inhutani II managed the forest. They did not want the forest to disappear in the future. The continuity of the forest's existence was important, as they lived a life dependent on the forest. The governments stated they would like to maintain their incomes from the forest as well as the existence of the forest.

Those actors agreed to maintain the existence of the forest, and to secure or maintain their incomes. There were indicators used to determine agreed indicators. However, in this simulation, those indicators were simplified into basic indicators, as follows:

a. Forest cover and standing stock;
b. Finance performance of Inhutani II;
c. Income per capita of local communities;
d. Forest-related incomes of central governments;
e. Forest-related incomes of local governments.

The indicator “a” was the primary concern of the SFM biophysical part. The other was the basic interests of forest actors. We defined the actors as an active part of the stakeholders. This research was intended to seek how to increase those indicators given any possible scenarios.

4.5.2. Conceptual Model Formulation

The model used the following assumptions that had the requirement that they must be fulfilled in order to get the right simulation outputs. The basic assumptions of the simulation are as follows:

1. Villages in Long Seturan, i.e. Paya Seturan, Long Lake, Metud and Rian, are grouped into Long Seturan, and it is represented as an agent.
2. Villages in Long Loreh, i.e. Loreh, Sengayan, Bila Bekayuk and Pelancau, are grouped into Long Loreh, and it is represented as an agent.
3. Even though the village of Langap is not in the concession area, it is represented in the simulation as an agent because Langap villagers’ activities are in the concession area.
4. Local Governments comprise sub-district, district, provincial of forestry units (RPH, CDK, Dinas Kehutanan I) and it is represented as an agent.
5. Central Governments comprise the Ministry of Forestry and its provincial office (KANWIL) and it is represented as an agent.

Figure 4.15 describes the model architecture. The simulation seeks possible scenarios so that the indicators of sustainability increase.

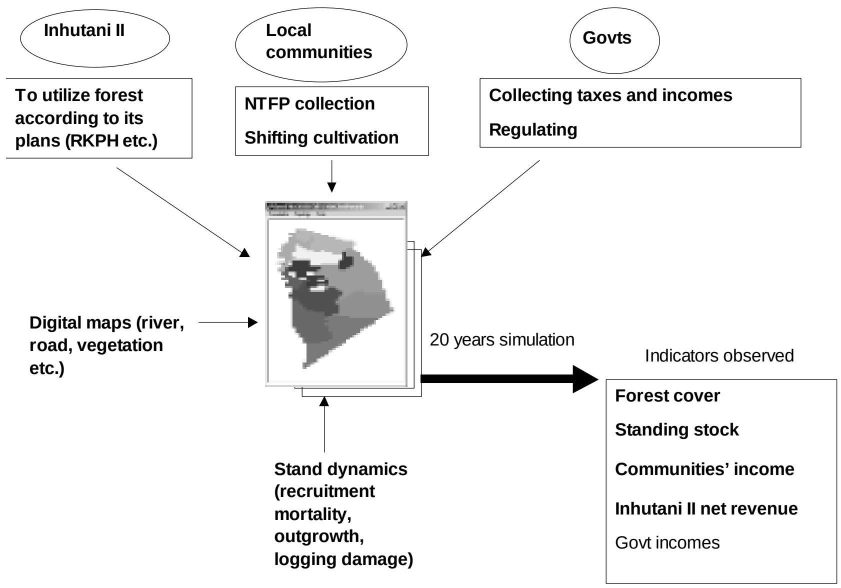


Figure 4.15. The architecture of the simulation model

The simulation was modeled to cover a 20-year period, to meet the concession period. The logic of the simulation is as follows:

1. Through Ministerial Decree No. 64/Kpts-II/1991, dated 30 January 1991, the Central Government allocated Inhutani II a right to utilize 48.300 ha of forest along Malinau River, Bulungan District, East Kalimantan in 1991 for the utilization period 1991/1992 – 2010/2011.
   Pseudocode:
   centralGovernment allocateForest to:inhutaniII

2. Inhutani II made a plan for utilization period 1991/1992 – 2010/2011 called RKPHS that comprises the projection of timber cutting and budget, among other things.
   Pseudocode:
   inhutaniII makePlan.
   inhutaniII send: thePlan to:centralGovernment.
   forestryOffice send:dapproval to: inhutaniII.

3. Based on a TPTI system, a 35-year cutting cycle was used. The concession area was divided into seven blocks of RKL, and each RKL block was divided into five blocks of RKT. Therefore, the concession area comprises 35 blocks of RKT.
   Pseudocode:
   inhutaniII divideConcessionAreaIntoRKL.
   {for each RKL} inhutaniII divideRKLintoRKT.

4. Inhutani II does logging in an approved RKT.

Pseudocode:
{for each year during 35 year) inhutaniII logRKT

5. Inhutani II improves villages through a program called PMDH.
   Pseudocode:
   {for each year during 35 year) inhutaniI villageImprovement

6. Cash flow of Inhutani II
   Pseudocode:
   {for each year during 35 year)
   inhutaniII revenue.
   inhutani cost.

7. Local communities live subsistent lifestyle inside Inhutani II's concession area. They stay in Long Seturan, Long Loreh and Langap.
   Pseudocode:
   {Long Seturan, Long Loreh and Langap} are local communities.
   localCommunities collectingNTFP.
   localCommunities shiftingCultivation.

8. Forest resources continue growing after activities such as cutting, collecting, NTFP, shifting cultivation
   Pseudocode:
   forestResources grow.

9. Local communities propose activities to manage a certain area to Inhutani II
   Pseudocode:
   localCommunities strategy:cooperative.
   localCommunities knowledge: localPerceptionOfC&I..
   localCommunities propose: activities to: inhutaniII.
   inhutaniII evaluateTheProposals.
   inhutaniII send: proposalEvaluation to: localCommunities.
   (if proposal refused) localCommunities changingStrategy(random).
   (if proposal approved)) localCommunities manage:theArea

10. Local governments and central governments collect incomes
    Pseudocode:
    localGovernments collectTaxesAndOthers.
    central governments collectTaxesAndOthers.

11. Indicators monitoring
    Pseudocode:
    ScenarioDevelopment:inhutaniI, localCommunities
    pixels calculate:forestCover, standingStock
    inhutaniII:netRevenue
    localCommunities:incomes
    localGovernments:incomes
    central governments:incomes

Digital maps were used as spatial references of the simulation. They covered forest land use agreement, vegetation and cutting blocks, road and river network (Appendix 5).

4.5.3. Quantitative and Qualitative Specification of the Simulation

4.5.3.1. Costs of Inhutani II

The costs or cash out of Inhutani II consists of fixed investment cost, direct investment and operational cost. Appendix 6 shows elements of each cost.

4.5.3.2. Revenue of Inhutani II

Timber harvesting makes up the revenue of Inhutani II. Direct investment actually represents cost of TPTI system. So that, involved costs of Inhutani II comprise fixed investment, logging cost and operational cost. Logging cost comprises TPTI cost, exploitation cost and other costs related to logging. Appendix 6 shows the distribution of those costs during the period 1991/1992 – 2010/2011. Table 4.26 shows the budget projection. The revenue is constant during 20 years, but the cost varies. Therefore, the net revenue also varies during those years. The total net revenue for 20 years is about 65 billion rupiah (Indonesian currency). This data assumed that the timber price was constant during that time.

4.5.4. Implementation

4.5.4.1. Social and Spatial Entities

A social entity is defined as a people or institution assumed to have a homogeneity of characteristics. An agent represents a social entity. An agent might locate in a spatial entity and has the ability to communicate and act. In the

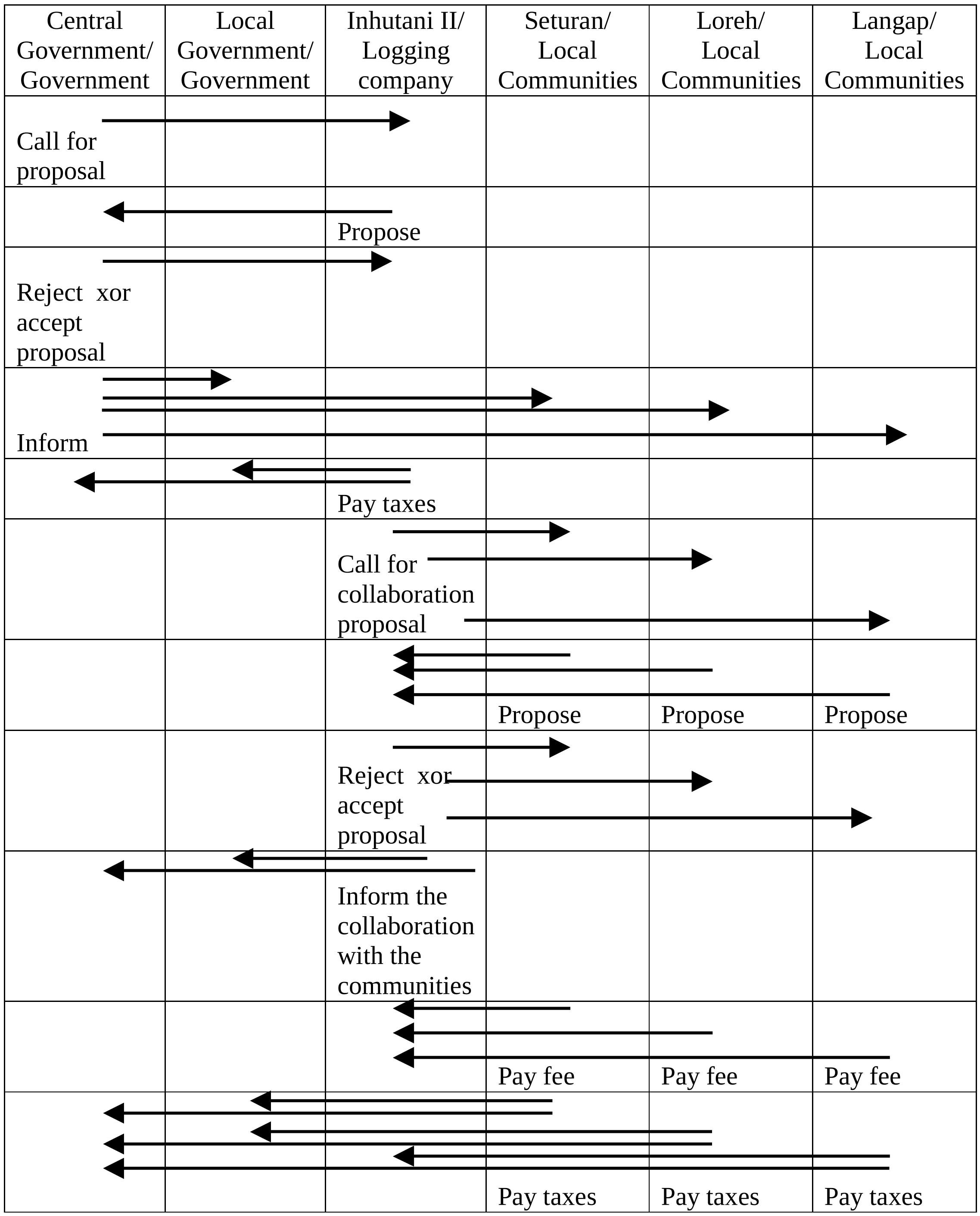
Table 4.26. Budget projection of Inhutani II (in thousand rupiah).

Budget year	Concession year	Revenue	Cost	Net revenue
1990/1991	1	0	10,253,340	-10,253,340
1991/1992	2	9,690,032	3,784,188	5,905,844
1992/1993	3	9,690,032	3,818,068	5,871,964
1993/1994	4	9,690,032	3,940,782	5,749,250
1994/1995	5	9,690,032	3,993,054	5,696,978
1995/1996	6	9,690,032	13,067,137	-3,377,105
1996/1997	7	9,690,032	10,091,512	-401,480
1997/1998	8	9,690,032	4,346,706	5,343,326
1998/1999	9	9,690,032	4,379,136	5,310,896
1999/2000	10	9,690,032	4,403,186	5,286,846
2000/2001	11	9,690,032	13,424,515	-3,734,483
2001/2002	12	9,690,032	4,487,436	5,202,596
2002/2003	13	9,690,032	4,456,036	5,233,996
2003/2004	14	9,690,032	4,478,086	5,211,946
2004/2005	15	9,690,032	4,473,986	5,216,046
2005/2006	16	9,690,032	13,491,361	-3,801,329
2006/2007	17	9,690,032	4,639,606	5,050,426
2007/2008	18	9,690,032	4,281,820	5,408,212
2008/2009	19	9,690,032	4,310,420	5,379,612
2009/2010	20	9,690,032	4,288,970	5,401,062
2010/2011	21	9,690,032	4,344,270	5,345,762
Total		193,800,640	128,753,615	65,047,025

Source: RKPHS Inhutani II 1991/1992 – 2010/2011

simulation research, an agent is an actor or a chosen stakeholder, and a spatial entity is a land or a related land resource. Table 4.27 shows social interactions in the simulation as a sequence diagram. The central government calls for a proposal to manage an area and improve the well-being of local communities surrounding that area. Inhutani II sends a proposal that comprises a management plan. The central government evaluates the plan and explicitly gives approval or disapproval (noted with “xor”; cf. common usage of "or" which implies either or both). Then the central government informs other agents about this approval. Inhutani logs the area according to its plan and generates income. Inhutani II pays taxes to the central and local governments.

Table 4.27. Sequence diagram of agent interactions



Inhutani II calls for proposals for collaboration. Communities in Seturan, Loreh and Langap, may send a proposal. Traditionally these local communities cultivate rice fields and collect non-timber forest products (NTFPs). They extend their rice fields annually to accommodate any population growth or increased needs. If Inhutani II accepts their proposal, they will prefer to collaborate in forest management rather than extending their rice fields. Participating communities pay fees to Inhutani II and taxes to central and local governments.

While governments and Inhutani II work according to the existing regulations and plan, the local communities may act differently. If their proposal is accepted, they can choose whether to cultivate their rice fields, collect NTFPs or participate in logging. The local communities believe in living in harmony with the forest by maintaining the forest and collaborating with other people. Their values and knowledge of the forest encompass ecological, economic, social and supernatural issues. The local communities are represented as belief-desire-intent (BDI) agents, as defined by the following pseudo-code.

```
function community_action(perception) : Action
begin
    Belief := brf (Belief, Perception)
    Desire := options (Belief, Intent)
    Intent := filter (Belief, Desire, Intent)
    return execute (Intent)
end function community_action
```

where perception is an input, and brf (belief-revision-function) simulates any change in belief. Table 4.28 shows the practical implications of this BDI agent. When the proposal is accepted it complies with the belief, ‘wanting to co-operate’ with other stakeholders. To improve welfare, stakeholders ‘collaborate in forest management’, which means they will be able to log agreed areas. If their proposal is rejected, their belief is changed, they continue cultivating rice and collecting NTFPs, and their desire to cooperate decreases. If their proposal is rejected more than twice, their beliefs will be changed, and they may not believe in collaboration, and may no longer submit proposals to Inhutani II.

Inhutani II calls for a collaboration proposal every year, and local communities have the opportunity to respond on each occasion (received in the following year). The area proposed for collaboration may differ from year to year. Local communities may open new rice fields to support their needs. They typically choose a flat area, close to the existing rice field and villages. These things being equal, the simulation makes a random choice.

Table 4.28. Local communities' response to events

Perception	Belief = brf (Belief, Perception)	Desire = options (Belief, Intent)	Intention = filter (Belief, Desire, Intent)	Action
No proposal submitted	Maintain bio-physical condition; Maintain desire to cooperate; Supernatural	Welfare improvement	Cultivate rice; Collect NTFPs	Cultivate rice; Collect NTFPs
Collaboration proposal accepted	Unchanged	Welfare improvement	Collaborate in forest management; Collect NTFPs	Collaborate in forest management; Collect NTFPs
Collaboration proposal rejected	Maintaining bio-physical condition; Decreased desire to co-operate; Supernatural	Welfare improvement	Cultivate rice; Collect NTFPs	Cultivate rice; Collect NTFPs

In Indonesia, forest management and harvesting operations are regulated under the TPTI selective logging system. This system allows for all commercial trees with diameters greater than 50 centimeters of production forests to be harvested within a cutting cycle of 35 years. However, not all trees above the 50-cm minimum diameter limit were harvested, e.g. non-commercial trees, protected trees (e.g. *Dyera costulata, Koompassia excelsa, Eusideroxylon zwagery, Shorea pinanga*), hollow trees, trees at steep slope, and seed trees.

Forest dynamic in the simulation was represented by the dynamic of forest stand, predicted with its diameter class projection. Diameter class projection method is one of the traditional forest growth models particularly suited for selectively-logged forests, particularly in the tropics. The basic concept of this method is that the forest is represented in a stand table containing trees organized by diameter classes. The change in the stand table is calculated over a growth period, usually between 5 to 10 years, using periodic increment data obtained from re-measured growth plots. Based on information generated from the permanent growth plots, upgrowth (i.e. number of trees moving up to higher diameter class), mortality and ingrowth (i.e. number of trees growing into the smallest diameter class) are calculated. Finally, forest growth can be projected within each pixel. The projection method involves estimates of recruitment (R) representing ingrowth, outgrowth (O) or upgrowth, and mortality (M). For each pixel, the projected number of trees at any diameter class ‘j’ and after a growth period ‘t+1’ ($N_{j,t+1}$) is defined as

$$N_{j,t+1} = N_{j,t} + R_j + O_j - M_j$$

where $N_{j,t}$ is the initial number of trees in diameter class j at time t.

Logging damage varies in its form and extent. The method and intensity of logging will influence the degree and type of damage (Alder and Synnott

1992). Sist *et al.* (in prep.) noted that logging in Inhutani II is done using high felling intensity (> 9 trees per ha or about 80 %), that results in high damage to residual trees. The percentage of dead trees due to felling was estimated for the different diameter classes as follows: 50% for 1 to 5 cm, 40% for 20-30 cm, 30% for 30-40 cm, 20% for 40-50 cm 20% for 50-60 cm, and 10% for higher than 60 cm. In contrast, expected mortality in traditional logging done under low-felling intensity (manual harvesting system) is only about 1-2 trees per hectare (or about 10 %). Therefore, it created low damage to the residual stands. Logging (L) and its damage (LD) changes the previous model into:

$$N_{j,t+1} = N_{j,t} + R_j + O_j - M_j – L_j - LD_j$$

The length of a forest concession is 20 years, which may be renewed pending satisfactory compliance of government rules and regulations. During that period, the company logs the area systematically according to approved harvest plans. The concession area is divided into 35 annual cutting blocks consistent with the length of the cutting cycle. Harvesting moves from one block to another every year using the TPTI rule. At the same time, the local communities move alongside, and may open a part of the forest if the current rice field area is not sufficient due to population growth and their goal achievement. For a new rice field area, they generally seek an area closest to the existing rice field area or their villages if possible.

4.5.4.2. SMALLTALK Programming

The simulation was written in SMALLTALK computer language that runs over open code software CORMAS (Common Pool Resources and Multi-Agent System). By using these CORMAS routines, the simulation was developed and executed. Figure 4.16 illustrates the main menu of the multi-agent system simulation which is CORMAS-ForestActors. There are 14 entities specified, comprising three types: spatial, social and passive. The first two entities have been explained previously. The other entity is "passive", consisting of "ActorsMessage", "CandI" and "LongTermPlan".

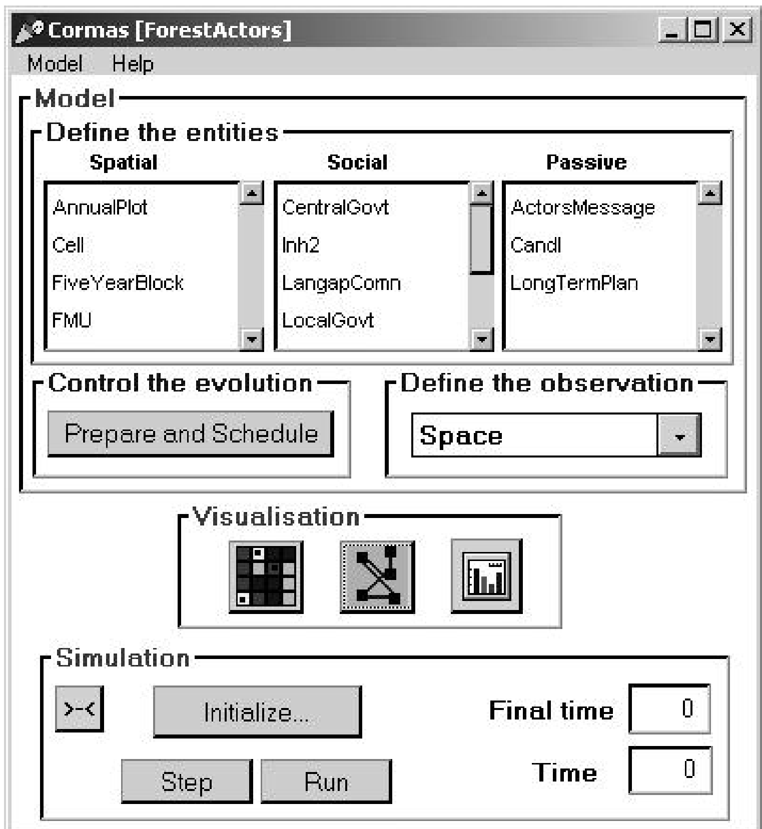


Figure 4.16. Main menu of 'Forest Actors'

"ActorsMessage" is a media of communication between agents, consisting of: symbol, object, sender, receiver, status and amount. These components represent media to deliver messages. Meanwhile "CandI" (Criteria and Indicators) is criteria and indicators for determining the score of forest sustainability under different scenarios. "LongTermPlan" consists of components of forest management plans such as *Rencana Karya Pengusahaan Hutan*

(RKPH, a long-term plan). On the "Visualization" part, three icons represent spatial, communication and diagram of the simulation.

Icon "Spatial" shows map inputs and outputs of simulation. Figure 4.17 shows the map of five-year cutting blocks and rice fields surrounding the villages. This is the situation map of the study area. This map and maps of road areas and networks, annual cutting blocks, forest function and vegetation maps are inputs in the simulation. The five-year cutting blocks were obtained from the company's forest utilization long-term plan, which is one of the government's requirements. The geographic location of the rice field area is depicted on the vegetation map. Using geographic information systems (GIS), the areas are presented spatially as pixels, including rivers, roads, vegetation, logging plans and elevation. Each pixel represents an area of approximately 35.27 hectares.

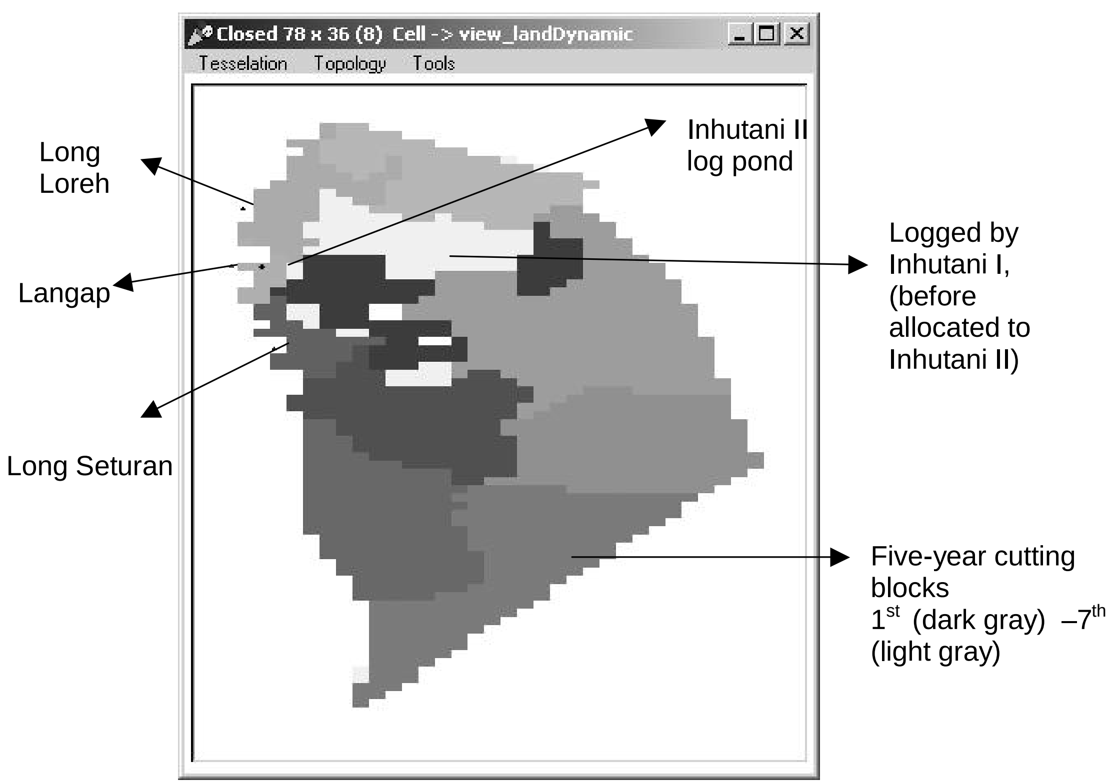


Figure 4.17. The situation map of study area in 1991

Icon "Communication" shows communication links among agents as illustrated in Figure 4.18. The agents are represented with symbols, and the communications are represented with lines between agents. Icon "Diagram" shows the diagram outputs of the simulation. Figure 4.19 shows an example of diagram output.

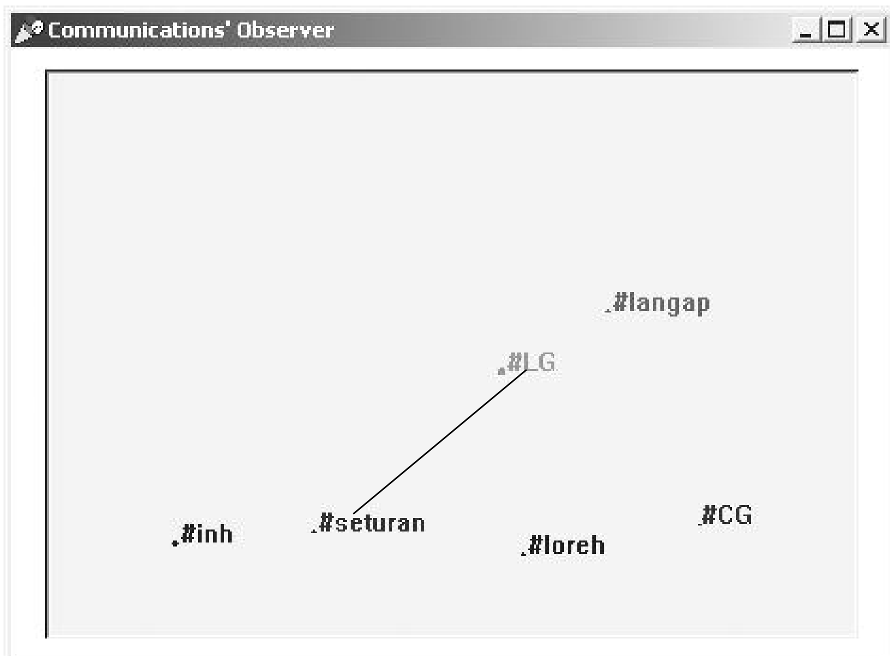


Figure 4.18. The communication observer

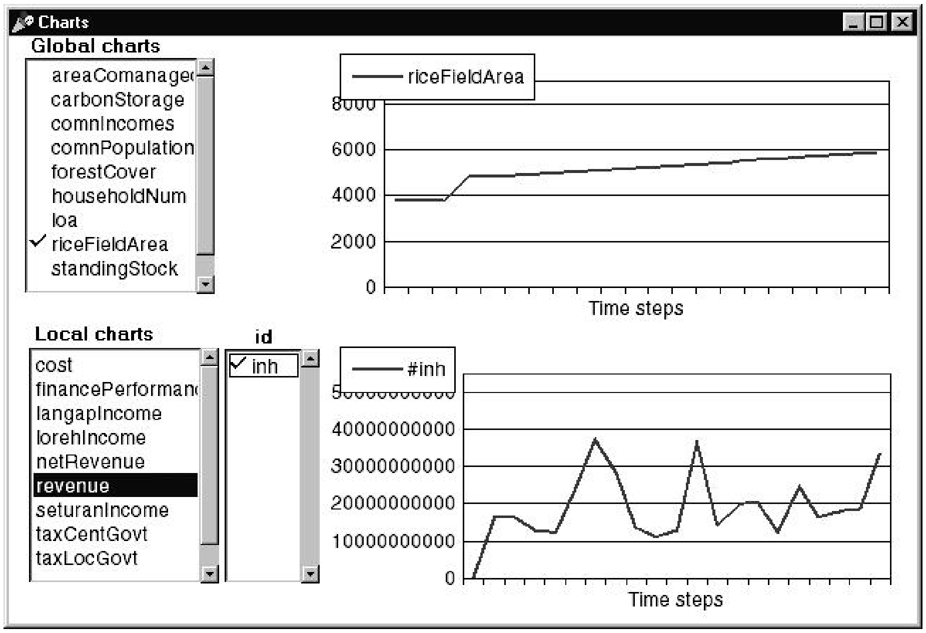


Figure 4.19. The example of simulation output diagrams

4.5.4.3. Baseline Simulation Outputs

The followings discuss the outputs of the simulation using the existing condition. The simulation outputs were also indicators of FMU performance

4.5.4.3.1. Forest Cover

The logic for the FMU forest cover including the area of pristine forest, logged-over forest area (LOA) and rice field area is described as follows:

Function: Calculate forest cover area at the simulation time (year)
Input: Vegetation map
Output: Forest cover, including logged over area (LOA) and rice field area
Algorithm:

WHILE concession time less or equal than 20 DO
    Inhutani II does logging as planned on RKPHS and RKT documents
    Local communities do rice field practice and NTFP collection

initial LOA = LOA of Inhutani I (
Inhutani II does logging
    LOA ¬ LOA + current logging area of Inhutani II

Local communities do rice field practice
    IF rice field area and rotation are adequate
    THEN they do not open a new area
    ELSE
        they open a new area.
        rice field area ¬ rice field area + a new rice field area
        forest area ¬ forest area - a new rice field area

Table 4.29 presents the forest cover at the beginning of the concession period of year 1990/1991. Figure 4.20 and Figure 4.21 show the forest cover map and its diagram after eight years of simulation time. Table 4.30 describes the actual forest cover situation according to Landsat image interpretation, year 1998.

Table 4.29. Forest Cover of Inhutani II year 1991

Coverage	Area (Ha)	Percentage
Pristine forest	38,195	79.08
LOA	5,529	11.45
Rice field area, community housing and karst	4,246	8.79
No data	330	0.68
Total	48,300	100.00

Source: aerial photograph interpretation in RKPHS

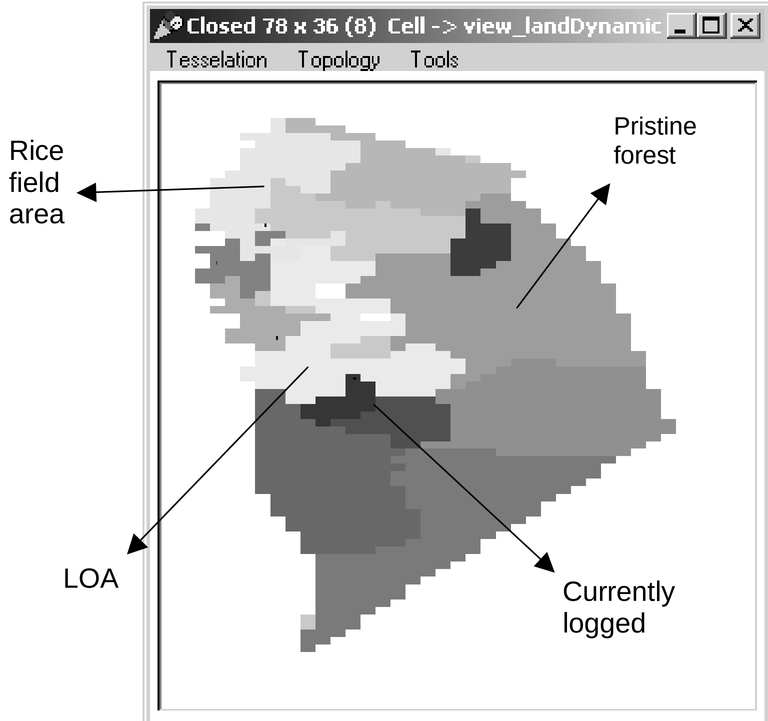


Figure 4.20. The FMU vegetation after eight years simulation

Based on those results there was a significant difference between the simulation results and reality. The illegal logging that was not represented in the simulation might cause the difference. The big percentage of area covered by cloud made this comparison not very useful. A further explanation on this is given in the model evaluation section.

Table 4.30. Landsat image interpretation and simulation results on forest cover, year 1998

No	Type	Actual (Ha)	Simulation results (Ha)
1	Pristine forest	17,900	33,991
2	LOA	15,100	9,679
3	Non-forest	3,500	4,629
4	Cover by cloud (not clear)	11,800	
	Total	48,300	48,300

Source: Annual budget plan (RKAP) of Inhutani II year 1999

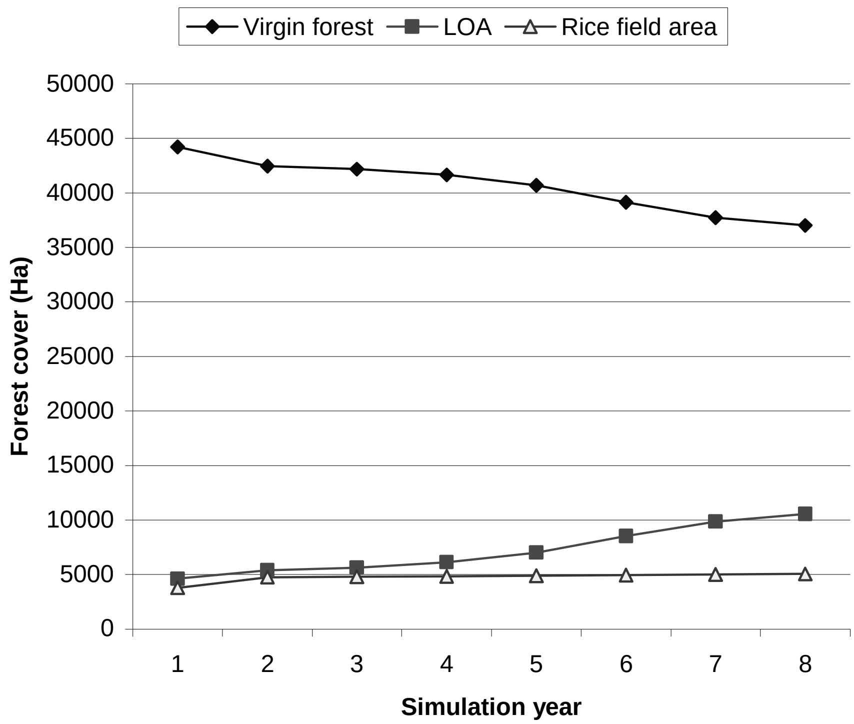


Figure 4.21. Diagram of vegetation areas after eight year's simulation time

4.5.4.3.2. Standing Stock

Standing stock is the total volume (m^3) of the stands at all meaningful diameter classes. The following algorithm formulates the assessment of FMU standing stock based on the number of trees per diameter class (dbh).

```
Function: Assess the forest standing stock at the simulation time (year)
Input: Stand structure of the pristine forest of the FMU
Output: Standing stock of the FMU
Algorithm:

WHILE concession time less or equal than 20 DO
        Inhutani II does logging as planned on RKPHS and RKT

current logging site
        stand structure ¬ f(pristine forest  stand structure, logging diameter
        limit, logging effect)

other LOA sites
        stand structure ¬  f(initial stand structure, recruitment, outgrowth,
        mortality)

standing stock ¬ f (stand structure, stand volume table)

local communities do rice field practice
        IF rice field area and rotation are adequate
        THEN  they do not open a new area
        ELSE
                they open a new area.
                rice field area ¬ rice field area + a new rice field area
```

Table 4.31 and Figure 4.22 describe the pristine stand structure of each cutting block. The tree diameter range is DC1 = 20-29 cm; DC2 = 30 - 39 cm; DC3 = 40-49 cm and DC4 = >50 cm.

Table 4.31. Average number of trees per Ha of pristine forest stand before logging

Diameter Class Annual logging	20-29 cm	30-39 cm	40-49 cm	>50 cm	
1991/1992	16.66	7.2	4.94	14.84	
1992/1993	21.16	8.58	5.32	17.04	
1993/1994	24	7.18	4.5	16.36	
1994/1995	16.01	5.01	2.618	19.63	
1995/1996	17.78	6.3	3.06	21.84	
	20-29 cm	30-39 cm	40-49 cm	50-59 cm	>60 cm
1996/1997	27.8	11.89	9.156	5.156	14.78
1997/1998	22.04	9.733	7.667	3.867	13.27
1998/1999	21.71	7.933	8.311	4.133	12.07
1999/2000	20.73	9.2	6.022	3.489	12.18
2000/2001	19.56	8.933	5.333	3.067	11.6
	20-39 cm		40-49 cm	50-59 cm	>60 cm
2001/2002	10.78		10	3.11	10.78
2002/2003	14.76		8.58	2.78	8.75
2003/2004	13.43		8.48	2.46	9.28
2004/2005	13.43		9.32	3.52	10.05
2005/2006	14.97		10	3.21	10.4
2006/2007	-	-	-	-	
2007/2008	-	-	-	-	
2008/2009	-	-	-	-	
2009/2010	-	-	-	-	
2010/2011	-	-	-	-	

Source: Calculated from RKL I, II, III

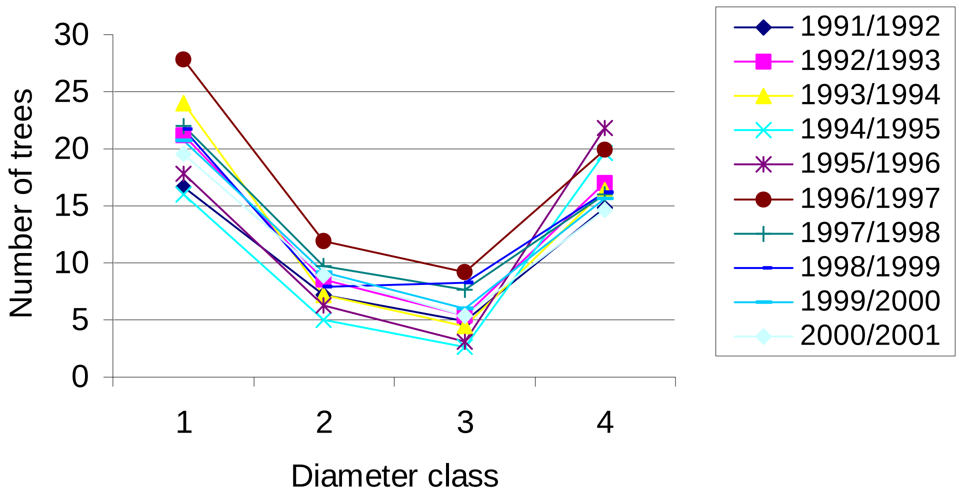


Figure 4.22. Pristine forest stands structure

Septiana (2000) calculated the recruitment, outgrowth and mortality of the compartment no. 154, as shown in Table 4.32. To meet the PUP diameter class, the number of trees of diameter classes 50-59 cm and >60 cm of logging block year 1991/1992 - 1995/1996 were estimated, with the average division of the number of trees of those diameter classes in logging block year 1996/1997 - 2000/2001. Table 4.33 and Figure 4.23 show the results.

Table 4.32. Stand structure Dynamics Components (Septiana, 2000)

Diameter Class Component	DC1	DC2	DC3	DC4	DC5
Recruitment	1.6				
Outgrowth from	0.086	0.115	0.101	0.087	
Mortality at	0.020	0.010	0.020	0.015	0.020
Logging damage (%)	20	25	30	40	40

Note DC1 = dc 20-29; DC2 = dc 30 - 39; DC3 = dc 40-49; DC4 = 50 - 59; DC5 = >60 cm

Table 4.33. Number of trees per Ha of pristine forest stand before logging after estimation of number of trees of diameter class 50-59 cm and >60 cm

Diameter class Logging year	20-29 cm	30-39 cm	40-49 cm	50-59 cm	>60 cm
1991/1992	16.66	7.20	4.94	3.50	11.34
1992/1993	21.16	8.58	5.32	4.02	13.02
1993/1994	24.00	7.18	4.50	3.86	12.50
1994/1995	16.01	5.01	2.62	4.63	15.00
1995/1996	17.78	6.30	3.06	5.15	16.69
1996/1997	27.80	11.89	9.16	5.16	14.78
1997/1998	22.04	9.73	7.67	3.87	13.27
1998/1999	21.71	7.93	8.31	4.13	12.07
1999/2000	20.73	9.20	6.02	3.49	12.18
2000/2001	19.56	8.93	5.33	3.07	11.60

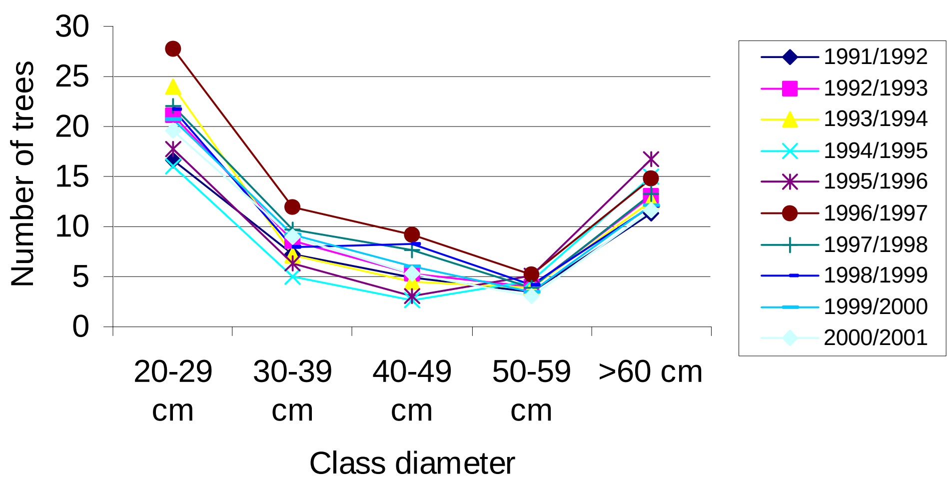


Figure 4.23. . Number of trees per Ha of pristine forest stand before logging after estimation of number of trees of diameter class 50-59 cm and >60 cm

The standing stock is the summary of volume for each diameter class of a certain simulation year. The result of standing stock simulation for 20 years is shown in Figure 4.24. The figures show the FMU standing stock is decreasing. This happens as some areas are converted into rice fields.

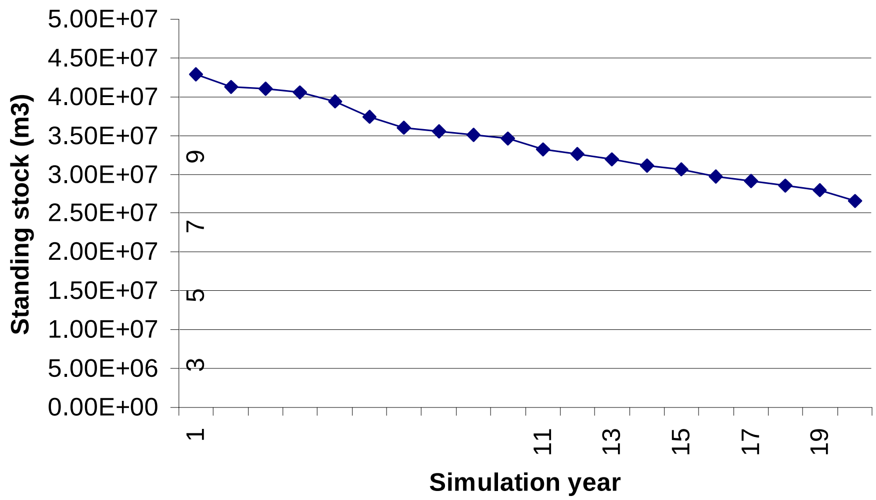


Figure 4.24. The simulation result of standing stock for 20 years

4.5.4.3.3. Net Revenue of Inhutani II

The net revenue simulation of Inhutani II was obtained through the subtraction of its revenue and its costs. The difference of the net revenue plan and the simulated one derives the finance performance. Table 4.34 and Figure 4.25 show the simulation outputs of net revenue.

Table 4.34. Simulation result of the revenue, cost and net revenue (in million rupiahs)

Simulation year	Revenue	Cost	Net revenue
1	16,252	12,486	3,766
2	5,225	974	4,251
3	6,450	1,131	5,319
4	12,038	2,116	9,923
5	23,918	4,535	19,383
6	37,297	17,841	19,456
7	28,619	7,561	21,057
8	13,405	4,417	8,988
9	11,027	3,858	7,169
10	12,956	4,712	8,245

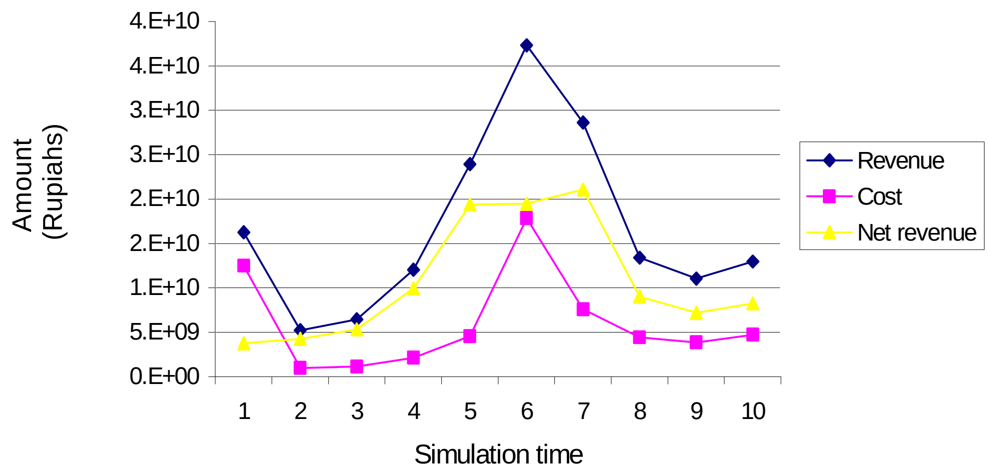


Figure 4.25. Simulation result diagram of the revenue, cost and net revenue

Below describes the logic of the finance performance of Inhutani II simulation

```
Function: Assess the net revenue at the simulation time (year)
Input: Stand structure of the pristine forest of the FMU, timber price, costs, taxes
Output: Net revenue, finance performance
Algorithm:

WHILE concession time less or equal than 20 DO
        Inhutani II does logging as planned on RKPHS and RKT

current logging site
        volume cut ¬ f(initial stand,  stand structure, diameter cutting limit,
        exploitation factor)

revenue ¬ volume cut * timber price

inh2 costSim ¬  fixedInvestmentCostSim + tptiCostSim + operationalCostSim.

fixedInvestmentCostSim ¬ (inh2 fixedInvestmentCostPlan at: t)
tptiCostSim ¬ transportCostSim + loggingCostSim + otherTptiCostSim

loggingCostSim ¬ inh2 calculateLoggingCost: currentPlot
transportCostSim ¬ inh2 calculateTransportCost: currentPlot
otherTptiCostSim ¬ (inh2 otherTptiCostPlan at: t.)
operationalCostSim ¬ (inh2 operationalCostPlan at: t)

cost ¬ inh2 costSim  + taxes
net revenue ¬ revenue – cost
finance performace ¬ net revenue / net revenue plan * 100 %
```

Table 4.35 illustrates the long-term plan (RKPHS), short-term plan (RKT) and the actual timber volume produced. Table 4.36 and Figure 4.26 show the finance performance, defined as the difference of the actual net revenue and the corresponding plan.

Table 4.35. The timber production of Inhutani II

No.	RKPHS		RKT		Actual	
	Area (Ha)	Volume (m3)	Area (Ha)	Volume (m3)	Area (Ha)	Volume (m3)
1991/1992	887	45,592	1,000	30,400	1,000	27,318
1992/1993	874	44,937	900	29,300	900	27,773
1993/1994	802	41,232	900	39,160	900	20,720
1994/1995	789	40,518	700	24,000	700	22,875
1995/1996	1,937	99,519	1100	41,200	1000	33,240
1996/1997	1,182	60,731	1131	41,246	1100	17,632
1997/1998	717	36,835	775	25,444	775	22,757
1998/1999	687	35,321	905	30,942	905	21,365
1999/2000	826	42,438	925	26,183	925	18,817

Table 4.36. The difference between the actual net revenue and its plan

Simulation year	Net revenue simulation result (in million rupiahs)	Net revenue plan taken from RKPHS (in million rupiahs)	The difference
1	3,766	-10,253	14,019
2	4,251	5,906	-1,655
3	5,319	5,872	-553
4	9,923	5,749	4,174
5	19,383	5,697	13,686
6	19,456	-3,377	22,834
7	21,057	-401	21,459
8	8,988	5,343	3,645
9	7,169	5,311	1,858
10	8,245	5,287	2,958

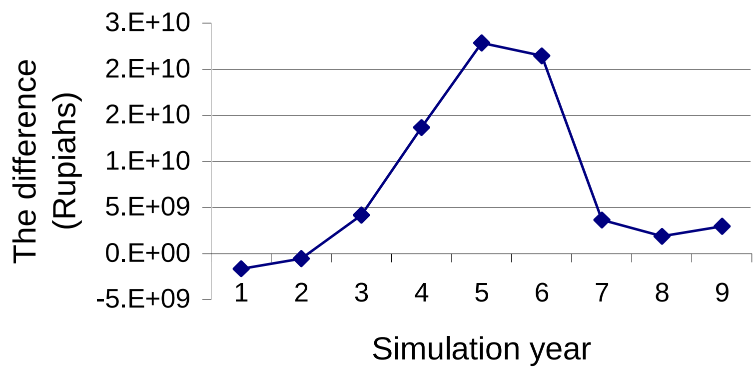


Figure 4.26. Diagram of the difference between the actual net revenue and its plan

The following factors might cause the difference between the simulation result and the actual one:

- A variety of stand structures;
- A difference between the long term plan (RKPHS) and shorter plans (RKL and RKT);
- A difference between plans and actions, so that the impact of actions will have a difference with predictions;
- Not all things in the field can be simulated.

4.5.4.3.4. Communities' incomes

Income per household relates to the communities' income. In the simulation, the assessed income is merely from the forest and ladang (rice field). The incomes from non-forest sources were ignored because of their complexity and irrelevance. The "illegal" logging conducted by the communities was also neglected as there was no transparent market on it, and due to sensitive issues and a lack of reliable data on it obtained during the research. The communities used the timber only for building their houses and for other constructions, such as a meetinghouse. The following algorithm describes communities' behavior and their incomes.

Function: Assess the communities' income at the simulation time (year)
Input: Beliefs, events
Output: Income per household
Algorithm:

```
WHILE concession time less or equal than 20 DO

yearlyTradEvents add:'rice field practice'; add:'NTFP collection'.

mailBox isEmpty ifFalse: [mailBox
                do: [:m| eventQ add:(m status). messageEvent := m ]].
(self experience at:#Event) add:t.
eventQ do:[:event| (self experience at:#Event) add:event].

self initiation.
self grow. self death.
self beliefRevision:eventQ.
self optionGeneration.
self filter.
self actionSelection:messageEvent on:fmu at:t.
self income ¬ actions
self updateIntention:(messageEvent status).
```

Appendix 7 presents the BDI architecture Smalltalk codes of the communities' reasoning and activities. Figure 4.27 and 4.28 show that the simulation outputs of real communities' income under the current scheme are relatively the same during the simulation time.

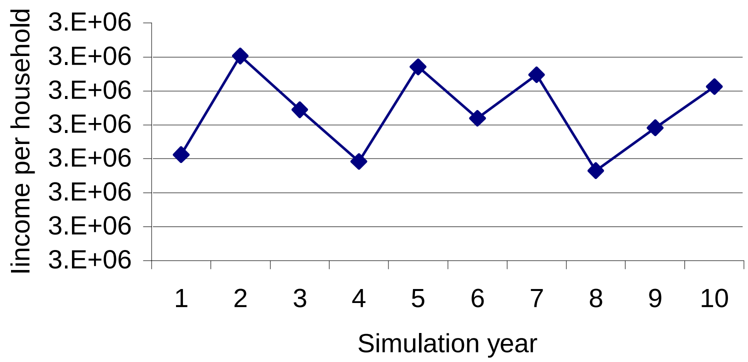


Figure 4.27. The income per household (in rupiahs), showing the communities' products at fixed price in the year 2000.

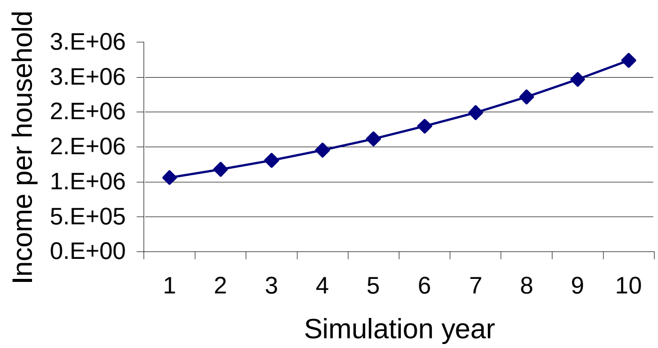


Figure 4.28. The income per household (in rupiahs) using the communities' product prices in the year 2000, with 10 % inflation

4.5.4.3.5. Governments' Incomes

Various financial obligations are applied to concession holders. These are calculated on the basis of the timber logged, as shown in Table 4.37. Table 4.38 shows the amount of money paid by a concession holder to central and local governments.

Table 4.37. Regulations applied to concession holders

Category	Source	Amount	Unit	Target group
Reforestation fund	Presidential Decree no. 29, year 1990, about Reforestation Fund	USD 10	M^3 log	Concession holders
	Presidential Decree no. 40, year 1993, about Reforestation Fund	Kal[3] & Maluku USD 16 for Meranti, USD 13 for Mixed species	M^3 log	Concession holders
	Presidential Decree no. 53, year 1997, about Reforestation Fund	Kal & Maluku Rp 48.000, Rp 39.000 for Mixed species	M^3 log	Concession holders
	Presidential Decree no. 67, year 1998, about Pembagian Iuran Hasil Hutan	45% prov. (30% TK I, 15% TK II), 40% Pusat, 15 % MOF		Concession holders
Resources royalty provision (PSDH) and forest concession holder dues (IHPH)	PP no. 59, year 1998 (May 1998), PSDH IHPH	Kal, Meranti 6 % and Mixed species 6 % Kal, new HPH and expansion Rp 50.000. Prolongation (or have been exploited) Rp 30.000	M^3 log Ha Ha	Concession holders
	Ministerial Decree of Industry and Trade Ministry, No. 636/MPP /6/1998 (June 1998)	Kal, Meranti 59.000 and Mixed species Rp 35.000	M^3 log	Concession holders
	PP No. 74, year 1999 (August 1999)	Kal, Meranti 10 % and Mixed species 10 %	M^3 log	Concession holders
	Ministerial Decree of MOFEC No. 220/Kpts-II/1999 (April 1999)	Kal, Meranti 38.400 and Mixed species Rp 21.600	M^3 log, above 30 cm diameter	Concession holders
	Ministerial Decree of Industry and Trade Ministry No. 268/MPP/Kep/7/2000	Kal, Meranti Rp 640.000 and Mixed species Rp 360.000	Standard price per M^3 log	Concession holders
	Ministerial Decree of Industry and Trade Ministry No. 57/MPP/kep/2/2001 (Feb 2001)	Kal, Meranti Rp 640.000 and Mixed species Rp 360.000	Standard price per M^3 log	Concession holders
Land and building tax (PBB)	Circulation letter of Director of PBB No SE-23/PJ6/1999	0.5 % of 20 % of NJOP (market value of tax object)	Ha	Concession holders
Distribution of incomes to the central and regional governments.	MOFEC Ministerial decree No. 889/Kpts-II/1999	Distribution of IHPH Prov. 80 % (16% Prov., 64% district) Central 20%	HPH	Concession holders

[3] Kal is an abbreviation of Kalimantan

Table 4.38. Amount of money paid by concession holders

Type	Unit	Amount (in rupiahs or percentage) /unit	To local governments (province and district)	To central government
Reforestation fund (DR)	M^3 log, year	48.000	80 %	20 %
Resources royalty provision (PSDH) known as IHH is the past	M^3 log, year	6 %	80 %	20 %
IHPH	Ha, 20 years	30 000	80 %	20 %
PBB	NJOP: 8.5 x 20 % x net revenue	0.5/100 * 20/100 * 8.5 * net revenue	100 %	0 %

Below shows the logic of calculating financial obligations paid by Inhutani II to governments.

```
Function:  Paying taxes to the governments
Algorithm:

"taxes to be paid are DR, PSDH, PBB, IHPH"
priceM3 ¬ 640000.
DR ¬ 48000.  "DR is Reforestation fund"
PSDH ¬ 6/100 * 640000.  "PSDH is Resources royalty  provision, 6 % of the log
price"
PBB ¬ 0.5/100 * 20/100 * 8.5 * ( inh2 revenueActual - inh2 costActual).
IHPH ¬ 30000 * 48300/20.

taxes ¬  (DR + PSDH) * (currentPlot cuttingVolume).
taxToCG ¬ 0.2 * (taxes + IHPH).
taxToLG ¬ 0.8 * (taxes + IHPH) + PBB.

inh2 revenueActual ¬  currentPlot cuttingVolume * priceM3.
inh2 netRevenueActual ¬ inh2 revenueActual - inh2 costActual - taxes - PBB -
IHPH.
```

The governments are comprised of local governments, - East Kalimantan Provincial Government and Malinau District Government - and the central governments, which are the Jakarta-based national Government and its provincial office. Figure 4.29 shows the simulation representing tax payments over 10 years.

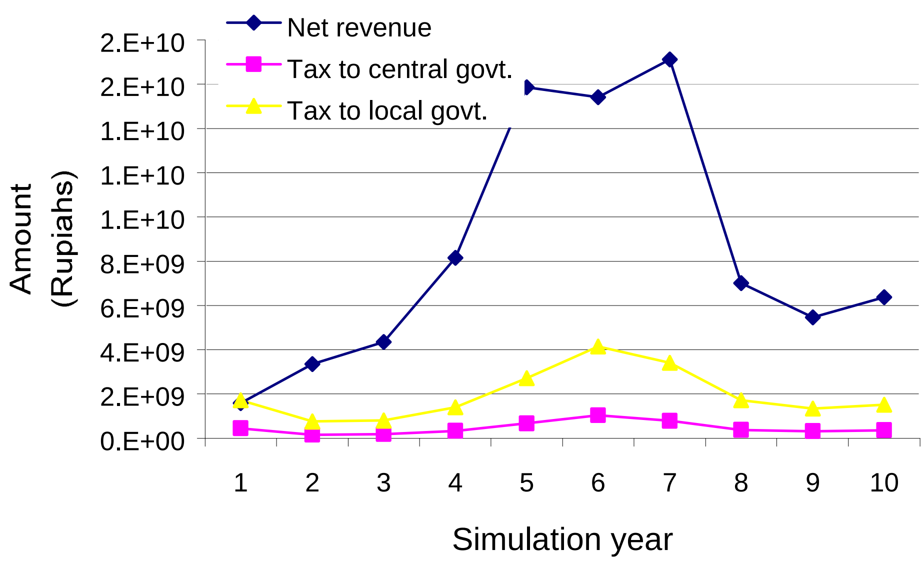


Figure 4.29. Simulation results of financial payments

4.5.5. Model Evaluation

Grant *et al.* (1997) used the term "model evaluation" instead of "model validation" to indicate the process of determining the relative usefulness of a model for a specific purpose. A model that is very useful for one purpose might be useless or, even worse, misleading, when used for other purposes. To evaluate the model three criteria were used: reasonableness; a comparison of the model behaviour and the expected pattern; and a comparison of the model prediction and the real system. These criteria were applied consecutively. Table 4.39 shows the evaluation result of the simulation. This evaluation was hampered by a lack of data, but preliminary findings are shown in this table.

Table 4.39. The overall model evaluation

Evaluation criteria / Component	Reasonableness	Comparison of the model behaviour and the expected pattern	Comparison of the model prediction and the real system
Forest cover	Yes	Yes	Uncertain; Cloud cover
Forest standing stock	Yes	Yes	Not enough data
Net revenue of Inhutani II	Yes	Yes	Match in general
Income per capita of local communities	Yes	Yes	Not enough data
Incomes of the central and local governments	Yes	Yes	Not enough data

The assessment that the model was reasonable was based on systematic scrutiny of all the relationships within the model, from the simplest sub-model (forest stand increment), to the more complex sub-models, (e.g. the interrelationship between stand increment and communal logging). Finally, the overall model performance was assessed. This assessment led to the conclusion that the model complied with the basic principles of ecology and economics.

In trying to model the complexity that involves many variables from different sources, there is no guarantee that measurement can be done accurately. Furthermore, we did not include the illegal logging phenomenon in this simulation – a phenomenon that currently has a big influence on forest sustainability. We did not include it as the model was not aimed at representing the whole phenomena. The model, from the beginning, was not aimed at seeking overall accuracy, but at assessing the impacts of different scenarios. Hence, no quantitative comparison technique was applied to the model. In general, the model is useful, since it can be used for developing scenarios and observing the different impacts of each scenario on forest sustainability. Lee (1993) revealed that the behaviour of natural systems is not completely understood. Predictions of this behaviour are incomplete and often incorrect.

Models of natural systems are rarely precise and reliable. Their usefulness comes from their ability to pursue assumptions made by humans.

It is not always necessary to “prove” that projected outcomes will actually take place, but they do need to be plausible, possible, credible and relevant (Fahey & Randall 1998). To be possible and credible they must pass the logic test. The logic test was similar to the first criterion of the evaluation, which the model passed. The model has been found to be useful, particularly for developing scenarios and observing the likely impacts of each scenario on forest sustainability and stakeholders’ well-being.

4.6. Collaboration Scenarios and Testing the Second Hypothesis

Comparing the current forest management system and scenarios of collaborative forest management tested the research’s second hypothesis, which is: to *get better outcomes of collaborative forest management, all relevant stakeholders must be performed*. The testing required two steps: firstly, a scenario of collaborative management was developed using the model; secondly, it was necessary to compare the simulation outputs of current and developed forest management scenarios.

4.6.1. Collaborative Forest Management

Collaborative forest management (CFM) is defined simply, in this case, as a shared production of timber. Shared production can only occur if there is an agreement between Inhutani II and local communities that is approved by the relevant levels of government. Collaborative management is considered successful if the costs of collaboration are lower than the benefits gained from it. A collaboration is a social phenomenon that might occur because the agents, in this case, the stakeholders, want to achieve their goals. In order to achieve their goals, they might work alone or work together with other agents. Figure 4.30 shows agents under relevant social institutions, communicating with each other to satisfy their goals.

A bounded rational economic behavior was observed in the field as the prime characteristic behind agents' collaboration. This means agents are likely to collaborate if it is economically profitable and supported by, or at least not prohibited by, their belief systems. In the simulation, each agent does two primary things: firstly, agents execute what they usually do or plan to do, in order to achieve their goal; secondly, they communicate with other agents to seek a way to improve their opportunities in relation to their goal. . Figure 4.31 illustrates how the simulation developed scenarios of collaborative management.

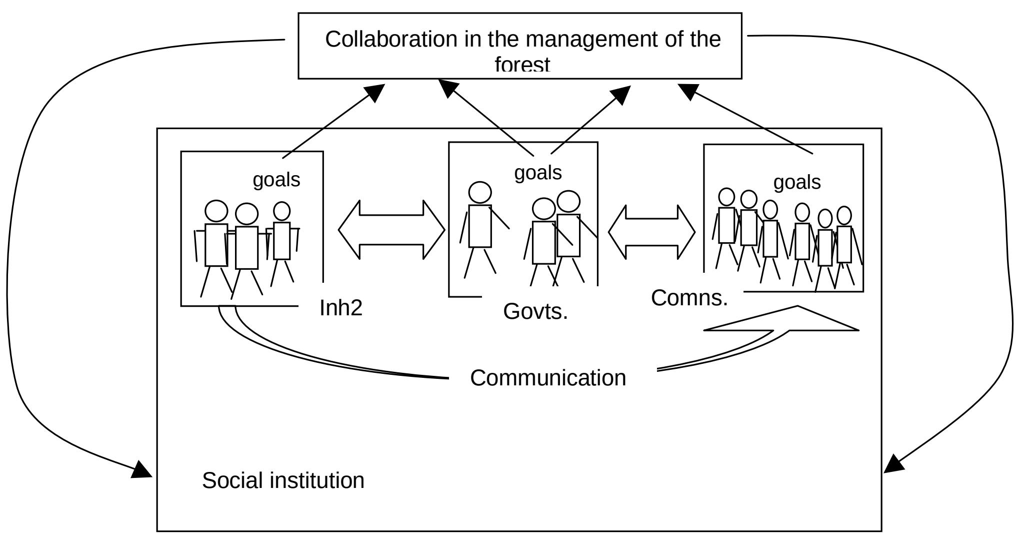


Figure 4.30. A social phenomenon of collaboration

Table 4.40 lists criteria for selecting an area of collaboration according to the perspectives of each agent. Agents implement these criteria in selecting areas of collaboration.

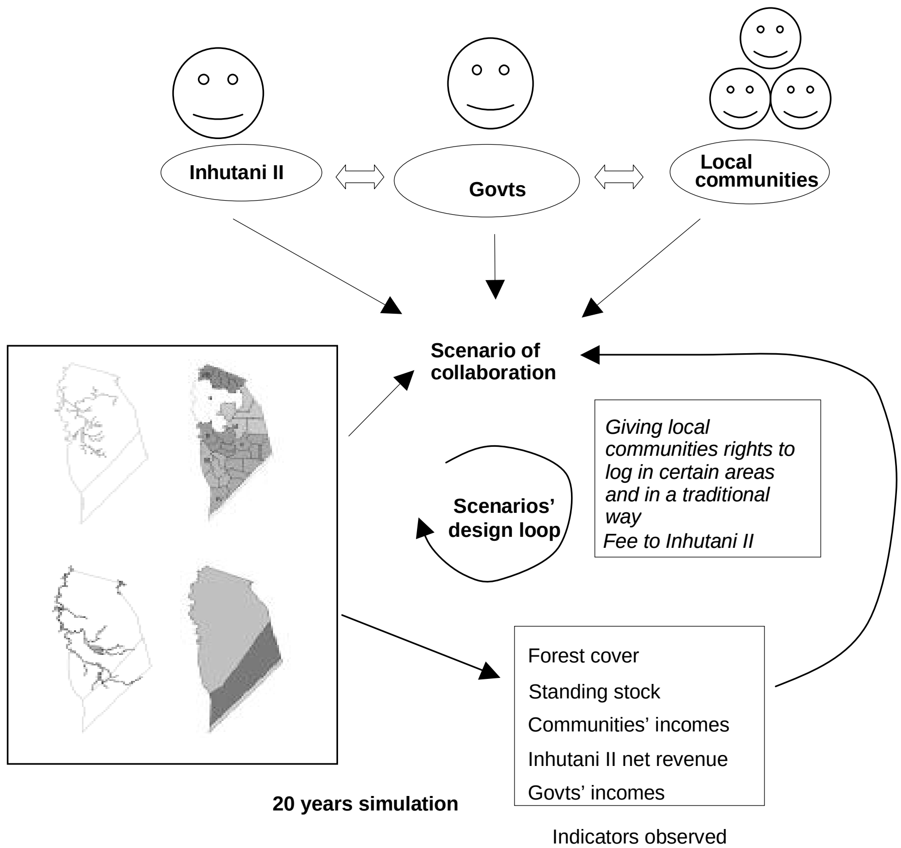


Figure 4.31. Development of collaboration scenarios

Table 4.40. Criteria for collaborative timber harvesting from the perspective of two parties

Communities' criteria	Inhutani II's criteria
Close to the river network	Far from the built road network
Commercially feasible	Communities pay Inhutani II
Close to their villages	Traditional, not mechanized harvesting
-	Medium-sized trees only

Source: Field interview

Below illustrates the logic of representing characteristics of collaboration between agents

Function: Creating social phenomena of collaborative forest management.
Algorithm:

"According to their plan Inhutani II is encouraged, with government enforcement, to collaborate with the communities.
Inhutani II continues seeking for collaboration with communities"
inh2 send: lorehComn.
inh2 send: seturanComn.
inh2 send: langapComn.

"The communities seek collaborations to improve their well being. They respond to Inhutani II's desire, by sending proposals for collaboration"
communities sendProposal:inh2.

"Inhutani II evaluate and replay the proposal sent by communities"
inh2 replay:#CommProposal of:fmu.

"The proposal approval or disapproval becomes an event and is analyzed by beliefRevision:eventQ, a part of BDI (belief-Desire-Intention) function of communities"
beliefRevision:eventQ
"Collaborative logging is a possible output of BDI function"

"If there are agreements between Inhutani II and the communities then the agreement will be internalized into Inhutani II activities"

The following describes the logic of Inhutani II's evaluation of the communities' proposal:

Function: Communities proposal evaluation
Input: communities' proposal
Output: (dis) approval messages of Inhutani II

```
replay:#CommProposal of:fmu.
        areaComanaged := evaluateComnProposal:m of:fmu.
        if (areaComanaged) > 0 then sendMessage:#approval
                to:communities.
        else sendMessage:#disapproval to:communities.

evaluateComnProposal:m of:fmu.
        selectComanageArea:fmu.

selectComanageArea:fmu.
        areaOffered ← Area meet Inhutani II's criteria for collaboration
```

The following describes the logic of collaborative logging and its effects:

> *Function: Collaborative logging*
> *Input: proposal approval*
> *Output: the communities' activities*
>
> *if collaborative logging happens then*
> *the communities do logging traditionally in approved areas*
> *the communities give fees to inh2*
> *decreasing expansion of rice field practice*
> *continue collection of NTFP*

4.6.2. Simulation Outputs of Collaborative Forest Management

The simulation was executed to cover 20 years in order to observe the effect of management scenarios for the duration of the concession. This simulation is assumed to use a 35-year cutting cycle as is currently implemented in the forest management scheme under TPTI system. Economic indicators were estimated by using economic data such as timber price, rice field price, NTFP prices and taxes.

Principally, each stakeholder does not want to be worse off in any possible collaboration. Stakeholders' inputs formulated the scenarios of collaboration, which are:

- Negotiation of areas where local communities can have rights to log the forests;
- Local communities are restricted to only implementing logging in a 'traditional' way;
- Local communities pay a fee to Inhutani II, amounting to 20% of their net revenue of logged timber;
- A 10% fee of the local communities' net revenue from logged timber goes to local and central governments.

Table 4.41. Simulation outputs as biophysical indicators of the model under the collaboration scenario

Simulation year	Remaining pristine forest (In thousand ha)		FMU Standing stock (In million m^3 volume)	
	Non-collaborative	Collaborative	Non-collaborative	Collaborative
1	44.2	44.2	42.8	42.7
2	43.4	42.4	41.9	40.6
3	41.7	42.1	40.2	40.0
4	41.2	41.6	39.7	39.3
5	40.2	40.6	38.5	38.1
6	38.7	39.1	36.5	36.0
7	37.3	37.7	35.2	34.7
8	36.6	37.6	34.6	34.7
9	35.9	37.4	34.2	34.6
10	35.2	37.1	33.7	34.4
11	33.2	35.3	32.3	33.0
12	32.3	34.6	31.8	32.5
13	31.2	33.5	31.1	31.8
14	30.0	32.5	30.4	31.2
15	29.1	31.7	30.1	30.8
16	27.6	30.3	29.2	29.9
17	26.5	29.2	28.6	29.5
18	25.3	28.1	28.1	29.0
19	24.1	26.9	27.5	28.5
20	21.9	24.9	26.3	27.2

Table 4.41 and Table 4.42 show the outputs of the simulation of this collaboration scenario in comparison to a non-collaborative one. When the ‘right to’ log is given to local communities, their income significantly improves. However, since the local communities are permitted to cut 10% of trees at diameter class above 50 centimetres, the logged-over forest can still be considered pristine forest. It can also be assumed that, with this harvesting strategy, the communities can implement logging activities with low damage levels. Figure 4.32 shows the maps of two different forest management schemes.

The remaining “pristine forest” is higher in a collaborative scheme than the non-collaborative scheme area. This happens due to the re-allocation areas

Table 4.42. Simulation outputs (In million rupiahs per year) as economic indicators of the model under the collaborative scenario

Year	Inhutani II net revenue		Communities' income		Incomes of central govt.		Incomes of local govt.	
	Non-collaborative	Collaborative	Non-collaborative	Collaborative	Non-collaborative	Collaborative	Non-collaborative	Collaborative
1	1,600	1,800	2.2	3.2	453	503	1,710	1,760
2	12,200	12,700	2.2	5.1	458	592	1,950	2,090
3	9,270	3,600	2.5	4.8	363	270	1,580	851
4	8,200	8,730	2.5	4.7	340	455	1,450	1,500
5	16,600	16,800	2.5	3.4	660	706	2,710	2,760
6	14,500	14,600	2.5	2.9	1,020	1,040	4,140	4,160
7	17,600	17,600	2.5	2.6	787	793	3,410	3,410
8	6,680	-359	2.5	3.1	376	84	1,710	473
9	5,190	265	2.5	2.8	312	105	1,330	314
10	5,840	2,260	2.5	3.0	364	237	1,510	745
11	6,790	5,660	2.5	2.8	1,000	1,000	3,900	3,630
12	5,620	5,840	2.5	2.6	409	459	1,890	1,920
13	6,350	6,450	2.5	2.5	550	575	2,230	2,260
14	4,080	4,080	2.5	2.4	567	567	2,320	2,320
15	1,700	1,740	2.5	2.4	349	359	1,500	1,510
16	63	99	2.5	2.4	686	695	2,670	2,680
17	3,590	3,590	2.5	2.4	456	456	1,950	1,950
18	4,870	4,910	2.5	2.4	501	510	2,050	2,060
19	2,130	2,130	2.5	2.3	516	516	2,100	2,100
20	386	595	2.5	2.5	927	980	3,620	3,670
Average	6,660	5,650	2.4	3.0	555	545	2,290	2,110

Inhutani II planned to log to communities for the collaborative scheme. As mentioned before, the communities are restricted by Inhutani II to using traditional ways to log these areas. The communities are therefore assumed to inflect less damage in logging. As a consequence of these areas being re-allocated to the communities, the net revenue of Inhutani II decreases - however fees paid by the local communities could cover this decrease. The amount of fee per cubic meter of timber determines the additional revenue of Inhutani II. The above collaborative scheme uses 20% of their net revenue as a fee paid by local communities to Inhutani II. This amount is a primary variable of collaborative management scenarios, and it would be tested for different amounts. The local communities pay another 10% to the central local and local governments.

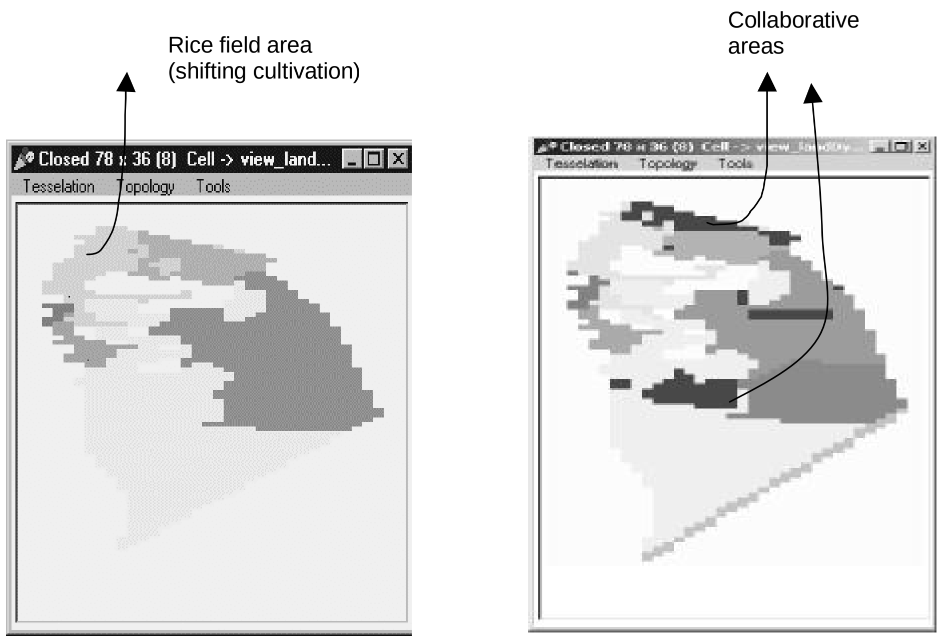


Figure 4.32. The simulation map showing results of non-collaborative and collaborative management

Under this scenario, the average income of communities is higher, but other stakeholders' revenue and incomes are lower. A statistical test is needed to determine the significance of these differences. The cost of collaboration, particularly the transaction cost, is not included here as it is difficult to assess.

4.6.3. The Hypothesis Testing

Non-parametric tests were used to evaluate the model to avoid any assumptions about the distribution of simulated outcomes. The hypothesis is formulated formally as follows:

$$H_0: m_{ci} = m_0$$

$$H_1: m_{ci} \neq m_0$$

Where "m" is median, "ci" is collaborative management indicators, and "m_0" is non-collaborative indicators resulting from a deterministic model. Those indicators are LOA, pristine forest area, and rice field area, forest standing stock, the communities' income, the concession revenue and taxes. Several tests involved use of the non-parametric sign test, which performs a one-sample sign test of the median tested in the hypothesis.

To test the hypothesis the simulation was replicated several times for collaborative management, and once for non-collaborative - one for each formulated scenario. The non-collaborative scheme did not have random variables in the simulation, since it was deterministic model. Whereas there is only one baseline simulation for deterministic models, the baseline for stochastic models actually consists of a set of replicate simulations (n).

To test hypothesis of collaboration, different scenarios of collaboration were formulated. Table 4.43 shows the different scenarios of collaboration based on stakeholders' inputs during the fieldworks. In all the collaboration scenarios, (i.e. scenarios A, B and C), the local communities gained rights to log forests that are currently allocated to Inhutani II. These areas were negotiated between local communities and Inhutani II, based on criteria listed in Table 8. The local communities were restricted to 'traditional' logging. In scenario A, no fees were paid to Inhutani II or to governments. In scenario B, the local communities paid fees to Inhutani II amounting to 20% of their net revenue. In Scenario B, fewer taxes were paid to the local governments than in scenario C, and the same amount of taxes were paid to the central Government. Under Indonesian law, local governments have more flexibility to determine the amount of taxes than the central Government.

Table 4.43. Scenarios examined using simulation

Issue	Scenario A	Scenario B	Scenario C
Location and area available	Negotiated	Negotiated	Negotiated
Nature of logging permitted	Traditional	Traditional	Traditional
Fees to PT Inhutani II	None	10%	12.5%
Taxes to Local Government	None	10%	12.5%
Taxes to Central Government	None	10%	10%

The simulation was replicated several times for the collaborative management scenario. The appropriate number of replications was determined by: guessing an arbitrary value for n (initially 14); calculating γ; and solving equation for n. In our case, the initial guess (n = 14, suggested by Grant at al. 1997) was sufficient for all collaboration scenarios. Table 4.44 - 4.46 show the simulation outputs of non-collaboration and different scenarios of collaborative management.

Table 4.44. The simulation outputs for non-collaboration and scenario A

Scenario	Replication number	Collaborative management area (10^3 Ha)	Remaining pristine forest (10^3 Ha)	LOA (10^3 Ha)	Rice field area (10^3 Ha)	FMU Standing stock (10^6 m^3 volume)	Average communities' income (10^6 Rp/year)	Average Inhutani II net revenue (10^6 Rp/year)	Average income of the central govt. (10^6 Rp/year)	Average income of the local govt. (10^6 Rp/year)
Non-collab.	1	0.0	21.9	24.8	6.0	26.3	2.4	6,661	555	2,286
Collab	1	7.0	25.3	23.6	3.8	22.5	5.6	6,217	532	2,188
Collab.	2	9.2	25.6	23.2	3.8	20.7	6.8	5,984	518	2,132
Collab.	3	3.1	25.3	23.5	3.8	26.3	5.5	6,098	524	2,158
Collab.	4	3.0	25.1	23.7	3.8	26.3	5.1	6,193	530	2,180
Collab.	5	6.1	25.9	23.0	3.8	23.8	7.3	5,933	515	2,120
Collab.	6	3.3	25.5	23.3	3.8	26.3	6.1	5,992	518	2,132
Collab.	7	3.3	25.5	23.3	3.8	26.2	5.7	6,061	523	2,150
Collab.	8	5.6	25.2	23.7	3.8	23.8	6.1	6,147	527	2,169
Collab.	9	7.1	25.7	23.1	3.8	22.7	6.2	6,102	524	2,158
Collab.	10	5.8	25.0	23.8	3.8	23.5	5.6	6,296	535	2,203
Collab.	11	3.4	25.6	23.3	3.8	26.2	5.7	6,113	525	2,162
Collab.	12	6.6	25.4	23.5	3.8	22.9	6.8	6,147	527	2,169
Collab.	13	6.1	25.6	23.2	3.8	23.6	7.1	6,024	520	2,139
Collab.	14	6.3	25.8	23.0	3.8	23.5	6.7	6,106	525	2,162

Table 4.45. The simulation outputs for non-collaboration and scenario B

Scenario	Replication number	Collaborative management area (10^3 Ha)	Remaining pristine forest (10^3 Ha)	LOA (10^3 Ha)	Rice field area (10^3 Ha)	FMU Standing stock (10^6 m^3 volume)	Average communities' income (10^6 Rp/year)	Average Inhutani II net revenue (10^6 Rp/year)	Average income of the central govt. (10^6 Rp/year)	Average income of the local govt. (10^6 Rp/year)
Non collab.	1	0.0	21.9	24.8	6.0	26.3	2.4	6,661	555	2,286
Collab	1	4.1	24.9	22.6	5.1	27.2	3.0	5,654	545	2,107
Collab.	2	7.9	25.0	22.5	5.1	25.6	3.2	6,816	634	2,329
Collab.	3	3.8	24.9	22.6	5.1	27.2	2.9	5,778	546	2,132
Collab.	4	7.6	24.7	22.8	5.1	25.9	3.0	6,012	582	2,180
Collab.	5	3.9	25.0	22.5	5.1	27.2	3.0	6,552	582	2,265
Collab.	6	6.7	25.0	22.5	5.1	26.1	3.1	6,822	621	2,327
Collab.	7	4.3	25.1	22.4	5.1	27.2	3.1	6,526	583	2,261
Collab.	8	6.5	24.9	22.6	5.1	26.1	3.1	6,833	621	2,332
Collab.	9	6.6	24.5	23.0	5.1	25.9	3.0	6,146	591	2,210
Collab.	10	5.4	25.3	23.6	3.8	24.1	4.7	6,541	748	2,382
Collab.	11	2.9	25.1	23.8	3.8	26.4	3.9	6,463	654	2,307
Collab.	12	3.5	25.6	23.2	3.8	26.1	4.2	6,402	663	2,302
Collab.	13	6.3	25.0	23.8	3.8	23.0	4.2	6,717	742	2,413
Collab.	14	2.9	25.1	23.7	3.8	26.3	3.9	6,458	656	2,309

Table 4.46. The simulation outputs for non-collaboration and scenario C

Scenario	Replication number	Collaborative management area (10^3 Ha)	Remaining pristine forest (10^3 Ha)	LOA (10^3 Ha)	Rice field area (10^3 Ha)	FMU Standing stock (10^6 m^3 volume)	Average communities' income (10^6 Rp/year)	Average Inhutani II net revenue (10^6 Rp/year)	Average income of the central govt. (10^6 Rp/year)	Average income of the local govt. (10^6 Rp/year)
Non-collab.	1	0.0	21.9	24.8	6.0	26.3	2.4	6,661	555	2,286
Collab	1	5.9	25.4	23.5	3.8	23.6	5.0	6,438	759	2,459
Collab.	2	6.2	25.0	23.8	3.8	23.1	4.4	6,564	744	2,466
Collab.	3	6.9	25.2	23.6	3.8	22.6	4.7	6,542	765	2,483
Collab.	4	6.6	25.7	23.1	3.8	23.1	5.2	6,353	750	2,435
Collab.	5	3.0	25.2	23.7	3.8	26.3	3.8	6,453	655	2,355
Collab.	6	7.1	25.3	23.5	3.8	22.5	5.0	6,477	781	2,490
Collab.	7	3.3	25.3	23.6	3.8	26.1	4.3	6,285	663	2,334
Collab.	8	7.1	25.8	23.0	3.8	22.9	5.3	6,206	738	2,396
Collab.	9	8.3	25.2	23.6	3.8	21.2	5.0	6,498	781	2,492
Collab.	10	7.9	25.4	23.5	3.8	21.7	4.0	6,456	679	2,380
Collab.	11	3.4	25.6	23.3	3.8	26.2	4.7	6,157	664	2,314
Collab.	12	8.0	25.9	22.9	3.8	21.9	4.7	6,247	685	2,350
Collab.	13	3.7	25.4	23.5	3.8	25.7	4.2	6,375	664	2,351
Collab.	14	3.6	25.7	23.1	3.8	26.2	4.7	6,178	664	2,312

The indicators of the model tested the second hypothesis. Some of those indicators also acted as indicators of sustainable forest management. The testing was to reveal whether generated scenarios were better in contrast to the existing one. Table 4.47 describes scenario A, B and C testing results.

Table 4.47. Sign Test for median of simulation outputs of different scenarios

Indicator	**Alternative hypotheses and hypotheses testing**		
	Scenario A	Scenario B	Scenario C
Remaining pristine forest	H_1: $mi>m_0$; H_1 accepted **)	H_1: $mi>m_0$; H_1 accepted **)	H_1: $mi>m_0$; H_1 accepted **)
LOA	H_1: $mi<m_0$; H_1 accepted **)	H_1: $mi<m_0$; H_1 accepted **)	H_1: $mi<m_0$; H_1 accepted **)
Rice field area	H_1: $mi<m_0$; H_1 accepted **)	H_1: $mi<m_0$; H_1 accepted **)	H_1: $mi<m_0$; H_1 accepted **)
FMU Standing stock	H_1: $mi\neq m_0$; H_1 accepted *)	H_1: $mi\neq m_0$; H_1 rejected **)	H_1: $mi\neq m_0$; H_1 accepted **)
Inhutani II net revenue	H_1: $mi<m_0$; H_1 accepted *)	H_1: $mi<m_0$; H_1 rejected **)	H_1: $mi<m_0$; H_1 accepted **)
Communities' income	H_1: $mi>m_0$; H_1 accepted **)	H_1: $mi>m_0$; H_1 accepted **)	H_1: $mi>m_0$; H_1 accepted **)
Income of central govt.	H_1: $mi<m_0$; H_1 accepted **)	H_1: $mi>m_0$; H_1 accepted **)	H_1: $mi>m_0$; H_1 accepted **)
Income of local govt.	H_1: $mi<m_0$; H_1 accepted **)	H_1: $mi\neq m_0$; H_1 rejected **)	H_1: $mi>m_0$; H_1 accepted **)

*) $\alpha = 0.05$ or 95 % level of confidence
**) $\alpha = 0.01$ or 99 % level of confidence

Figure 4.33 illustrates how the spatial pattern of negotiated arrangements may vary according to the random numbers used. However, some consistent trends emerged. The three local communities continue to extend their rice cultivation near their villages. They propose areas of collaboration close to their villages and rivers that are commercially feasible. Inhutani II favors community use of areas with low timber yields, far from the road network. Thus, there is scope to find outcomes that minimizes conflict between these differing objectives.

Figure 4.33. Nine different simulation outputs of the best scenario (Scenario B).
The collaboration area is black.

Scenario B is the most promising rights arrangement towards SFM. The LOA was not included because remaining pristine forest and FMU standing stock indicators already reflected it. Table 4.48 shows the SFM indicators' assessment of Scenario B. The Scenario B of collaborative management shows better results on most indicators, and the same on FMU Standing stock, Inhutani II net revenue indicators and income of local governments. This implies the hypothesis that involving local communities of forest-dependent people in the forest management scheme would achieve better sustainability outcomes, was accepted. This means collaboration between stakeholders should be encouraged and specified to get achieve better forest management outcomes.

Table 4.48. SFM indicators of Scenario B of collaborative management

SFM Indicators	The Scenario B compared to the non-collaborative scenario	Toward SFM
Remaining pristine forest	Significantly bigger	+
Rice field area	Significantly lower	+
FMU Standing stock	The same	The same
Inhutani II net revenue	The same	The same
Communities' income	Significantly bigger	+
Income of central govt.	Significantly bigger	+
Income of local govt.	The same	The same

The way communities log forest is critical to sustainability in the simulation. Therefore, when communities take a portion of the forest only at a very small level, at about 10% of harvestable trees, it will give the forest time to grow. The communities can do this frequently if there are harvestable trees available in that site. They do not need heavy equipment like the logging company.

V. GENERAL DISCUSSION AND POLICY LINKS

The ability of local forest communities to define their own sustainable forest management criteria and indicators (C&I) means that SFM can be defined locally. Their ability has evolved from their life-long experience with adapting to the dynamics of forests. As the local communities live in a specific region their indigenous knowledge is locally specific. They always try to live in harmony with nature. Although, their knowledge is not tested through formal hypothesis and experiment methods, this knowledge could be used to conceptualize the sustainability of forests within the complexity of forest ecosystems and social systems.

While indigenous knowledge is locally specific, scientific knowledge has a universal scale, obtained from hypothesis and experiment methods. Scientists around the world have been working very hard to understand the complexity of forests to formulate sustainability concepts. This knowledge is evolving. This direction conforms to indigenous knowledge of forest-dependent people as revealed in the acceptance of the first hypothesis.

Our knowledge of forests is never complete, no matter how hard we work and what type of knowledge we believe. There is always room for another type of knowledge to increase our understanding of the forests in all their complexity. The developed knowledge base system proposes a way to combine that knowledge to conceptualize and assess the sustainability of forests. It is an answer of 'what' sustainability is. Another question is 'how' to achieve it. Current forest actors - local communities, concession holders and governments - have legitimate interests in using forests. A partnership arrangement between those actors is a promising option, as revealed in the acceptance of the second hypothesis. However, it would not be necessary to involve an actor who has illegitimate rights to using forests.

In saving forests, there are three types of people: first, those who believe in full protection of the forests at all costs; second, those who link forest conservation to poverty alleviation; third, those who believe in sustainable utilization. The research results reveal there is a good foundation to believe in sustainable use of forests and poverty alleviation. This belief in the capacity of local communities to manage forests in a sustainable manner is the first attempt to alleviate their poverty through sustainable forest use. Therefore, transferring the rights of managing forests from the central government to local communities provides conducive conditions for poverty alleviation and forest sustainability.

Increasing public concern over forests and the environment, pressures to downsize government in the economic crisis, and the recognition that local people should play an active role in management have all encouraged the decentralization of forest management responsibilities in Thailand (Pragtong n.d.). Over the last three years, the Indonesian government has raised issues relating to several important pieces of legislation aimed at transferring authorities to the provincial and district governments, and allowing resource-rich regions to retain a larger share of the fiscal revenues generated within their jurisdictions. The most important of these were Law 22 on Regional Governance and Law 25 on Fiscal Balancing, both of which were issued in May 1999. These laws have been supported by a variety of implementing regulations and sector-specific decentralization laws, including Law 41 of 1999, a revised version of Indonesia's Basic Forestry Law, which outlines administrative authority in the forestry sector under regional autonomy (McCarthy 2001).

5.1. Incorporating Local Knowledge in Decentralization Policy

The ability of local communities to define local C&I implies a belief in devolution. Devolution or democratic decentralization means transferring rights from central governments to local stakeholders including local communities. The complexity of the ecosystem and social system in each site and the capacity of local communities makes devolution a necessary policy condition for SFM at a national level. Here, we name decentralization as a general term of decentralization and devolution.

The available literature provides little empirical evidence about whether decentralization is good for forests and people who depend on them. A possible advantage of decentralized natural resource management mentioned in the literature is management decisions can incorporate local knowledge about the resource base (Brandon and Wells 1992; Carney 1995; Poffenberg 1990; Utting 1993 in Kaimowitz et al. 2002). Dubois (1999) described the imbalance of power relationships and conflict of interest between states, private sectors and local communities in forest management. Colfer *et al.* (1999) mentioned local knowledge as one of six dimensions in determining the relative importance of forest stakeholders. Therefore, incorporating local knowledge in the management of forest can increase the power of local communities in managing forests.

Ignoring the role of traditional knowledge in the decentralization policy in Zimbabwe caused the failure of that policy (Lalonde 1993). Zimbabwe has recently undertaken an innovative wildlife co-management program. The program recognizes and includes traditional indigenous knowledge (Thomas 1991 in Lalonde 1993). Dubois (1999) stated that local people's participation alone is not sufficient to induce sustainable development. It needs to be accompanied by their adequate representation in decision-making bodies and their empowerment. Both are necessary to ensure local communities have enough bargaining power in negotiation over resources and the establishment of partnerships. It would, however, be misleading to suggest that existing indigenous knowledge is sufficient for rural development. Combining knowledge of local circumstances with modern science and technology is a crucial prerequisite for developing more efficient, sustainable infrastructure (Ostrom *et al.* 1993).

Empowering local communities through stating clearly that traditional knowledge of sustainable forest management or local C&I, shall be incorporated into forest management strategies will enhance the possible success of the decentralization or devolution policy. Figure 5.1 shows the plausible connections and influences related to a decentralization policy that incorporates the use of traditional knowledge. The degradation of forests the poverty of local communities surrounding the forests enforces the need for the formulation and implementation of decentralization policy. The negative loop indicates that there is a stable level of decentralization.

The management of forest means a lot more, however, than the knowledge of forest management, defined in the SFM C&I list. It includes the institutional capacity to manage forests. In relation to this, the capacity of local or traditional institutions needs to be examined. *Adat*, a primary traditional institution varies from site to site. *Adat* rules and norms are inherited from ancestors without change or question. The younger generation of local communities now behaves in a different way to the older generation. They do not implement *adat* rules and norms in their daily activities. They know and only use them for ceremonial purposes such as the celebration of marriage, harvesting paddy, death ceremonies etc. The reform of *adat* rules and norms is required to make them more relevant to the fast-changing world. The adaptability of *adat* is quite low.

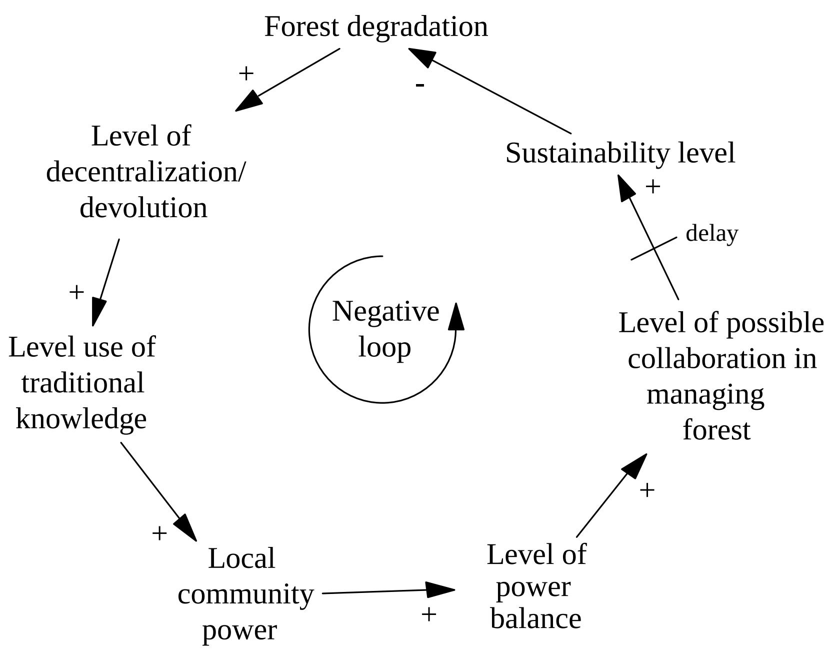


Figure 5.1. Plausible connections in a decentralization policy that incorporates traditional knowledge

One possible reform of *adat* is in the way of elites step into power. Seldom do local communities elect *adat* elites. The *adat* elites are in power because of their blood. If someone is the head of *adat*, then his sons will become the *adat* head or elite for the next generation. This likes components that are arranged or modeled serially. In the serial arrangement, if there is a person who behaves badly then the total output caused by those components is also bad. This means the probability of having a good result from this arrangement is very low.

From those arguments, let communities themselves manage forests to meet full production capacity of forests should be carefully recommended. This is not caused by a lack of knowledge of sustainable forest management, but by a lack of power or influence in local institutions, and a capacity to change it. Empowering local institutions, including democratization of them, is a way to help local communities manage forests in an appropriate way.

5.2. Collaborative Forest Management

Collaborative Forest Management (CFM) is essentially a new management paradigm that seeks to draw on the experience and knowledge of both professional foresters and local people in a partnership arrangement that may also involve other stakeholders (Carter n.d.). Other terms related to CFM are joint forest management (JFM), shared forest management, co-management and participatory forest management. Co-management connotes a collaborative institutional arrangement among diverse stakeholders for managing or using a natural resource (Castro and Nielsen 2001). ‘Model forestry’ normally means collaborative forest management (Sukwong, 2000). ODA (1996) stated that shared forests management is not just about local communities. It is also about a coalition of interested parties. Levels of participation in natural resource management vary considerably. Matching the degree of participation to local circumstances is an essential strategy. ‘Full’ participation at community level may not always be appropriate – or even wanted.

Ghate (2000) stated that JFM in Buldhana, India, spread fast to many villages because of it demonstrated successful cooperation between the forest department and local communities. Five factors important to the wide acceptance of JFM are: the taking up of activities to generate income in the short term; the freedom given to locals to make decisions according to their priorities; coordination between various development agencies working in the area; and the introduction of an element of flexibility and continuous learning. Castro and

Nielsen (2001) mentioned that the major justification for co-management is the belief that increased stakeholder participation will enhance the efficiency and perhaps the equity of the intertwined common property resource management and social systems. A publication by the Food and Agriculture Organization asserts: "The promotion of collaborative management is based on the assumption that effective management is more likely to occur when local resource users have shared or exclusive rights to make decisions about and benefit from resource use" (Ingles *et al.* 1999).

As far as decentralization enables local communities to have a greater voice in how resources are managed, delegating decision-making power to district government could enable forest-dependent people to gain greater control over and enjoy more benefits from local resources. However, if regional autonomy occurs without the emergence of democratic controls at the district level, it is possible that local elites will extend their control over local forest resources. In other words, regional autonomy could improve the situation of local communities and/or lead to greater control of resources by regional elites (McCarthy 2001)

To make CFM work, it needs a transfer of rights from the central government to local stakeholders. This what we call the decentralization or devolution process. Local stakeholders can do nothing if the rights, not necessarily the ownership, still lies with the central government. Many argue that the transfer of forest resources to community ownership is a necessary condition for success. However, this remains unproved. Sharing forest management is not necessarily about transferring ownership (ODA 1996). Sukwong (2000) said that model forestry has been discussed as one way to bring multiple stakeholders together, but if there are not supportive policies, scaling up experiences will prove difficult and frustrating.

Indonesian production forests have been legally allotted to timber-logging companies. These companies have invested in the areas. This situation creates a constraint against policymakers making new arrangements for forest management. Policymakers need to consider existing arrangements in order to make a smooth change. Collaboration between forest logging companies and local communities is a possible recommendation. However, the arrangement of this collaboration, including rights, responsibilities, returns and relations, should be as fair as possible. An inappropriate arrangement of collaboration can make one stakeholder better off, but the others worse off. This scenario cannot be implemented in the field effortlessly. An appropriate collaboration scenario is challenging.

Basic similarities in stakeholders' perception of criteria and indicators provides a foundation for collaborative forest management with better outcomes expected. Specifying the details of collaboration might differ from site to site. Each forest management unit (FMU) might have a different collaboration scheme or arrangement. Effective communication between stakeholders is an initial step towards collaboration. Stakeholders must compare the benefits and costs of collaboration, in every possible collaborative arrangement. Collaboration does not necessarily provide better outcomes in terms of forest sustainability, as shown in the research results. If the outcomes are greater then collaboration is feasible. The benefits and costs might include tangible and intangible benefits. Stakeholders must be aware of the existence of different collaboration costs, such as the costs of specifying the rights and obligations of each stakeholder; the costs of enforcing these rights, and the costs of monitoring collaboration. Ingles *at al.* (1999) stated that collaborative management of natural resources refers to: the arrangement for management negotiated by multiple stakeholders and based on a set of rights and privileges (tenure) recognized by the government and widely accepted by resource users; the process of sharing power among stakeholders in making decisions and exercising control over resource use. Since simulation is a robust way to determine the impact of a positive arrangement scenario (Painch and Hinton 1998) then we propose to use it in the implementation of collaborative forest management. Figure 5.2 shows the influences of any selected decentralization policy.

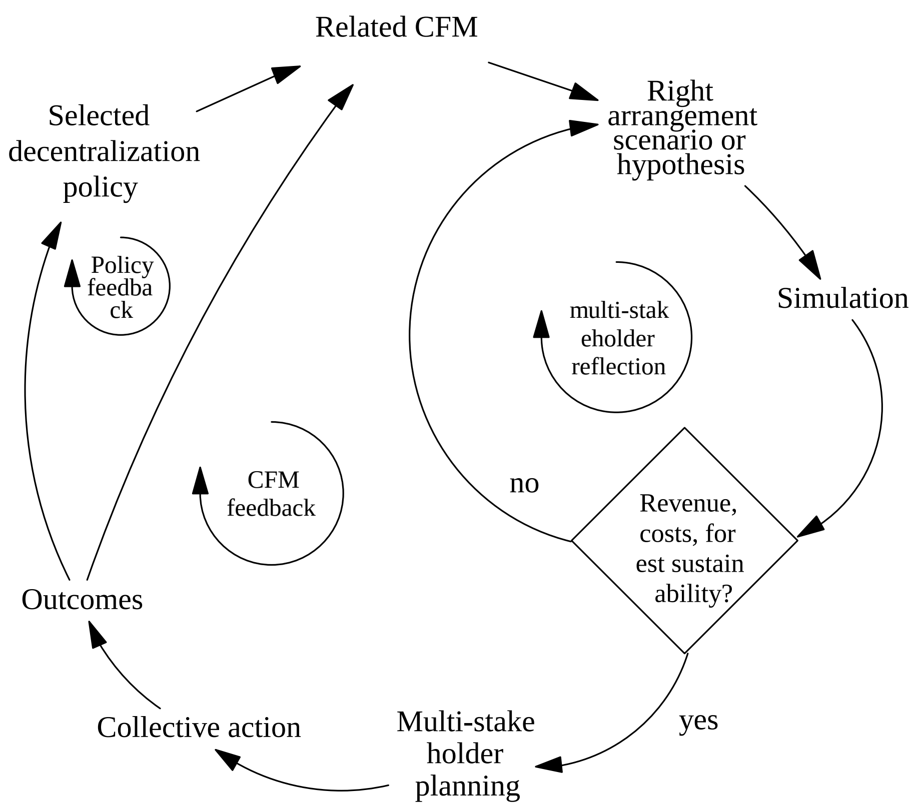


Figure 5.2. Influences of a selected decentralization policy

There are many possible ways to implement decentralization, relating to the level of its implementation, what rights are to be decentralized etc. Whatever the selected scheme, it will affect the CFM arrangement. A multi-stakeholder process for seeking appropriate rights arrangements is needed. A simulation can be used to determine the possible impact of its different scenarios. Plans and collective actions follow a selected scenario. The action outcomes provide feedback to the decentralization option, as well as the CFM.

To ensure forestry decentralization policy leads to better results, it should be linked with CFM and its implementation. A simulation can facilitate the way CFM is implemented in the field by showing multi-stakeholders' understandings and commitments. A link between decentralization policies and CFM outcomes is necessary. The policymakers can use the outcomes to seek an appropriate decentralization policy.

5.3. Adaptive Decentralization policy

Sukwong (2000) realized that a forestry program, even where there are community forestry programs and policies (India and Nepal), should not be like a blanket blue-print that has to be implemented rigidly - but should be something open to specific local conditions. Right now, there is a big debate in India as to how to move the JFM program forward and provide this flexibility, so that the diversity of local forest management practices can be reflected. Bass *et al.* (1997) stated that an element that makes policies work for forests and people is an appropriate decentralization, devolution and strengthening capacity.

Sarin (2001) illustrated the failure of a top-down 'participatory' forestry project conducted by the Uttar Pradesh Forest Department under devolution. The project ended up disempowering women and the poorest. Instead of validating the rich diversity of indigenous knowledge, land use and management systems, the village JFM reinforced the Forest Department's claim to being the monopoly holder of technical forestry knowledge and forestry being the best use even for remaining commons. Similarly, instead of devolving greater authority and decision-making control to autonomous self-governing institutions, forest guards are being placed inside *Van Panchayats* to extend the Forest Department's control over its functioning.

Ostrom (n.d.) explained the limits of fully decentralized systems, including a failure to organize properly in some localities, local tyrannies, stagnation, limited access to scientific organizations, conflict among groups and inability to cope with large-scale problems. In contrast to the centralized and decentralized structure, a polycentric governing structure offers citizens to organize not one but many governing authorities (Ostrom 1993). Governance systems exist at multiple levels with some autonomy at each level. Polycentric systems are complex adaptive systems. Agent-based models or multi-agent system models are aimed at understanding the properties of complex social systems through the analysis of simulations.

In order to deal with the complexity of ecosystems and social systems, including micro and macro politics in each district, decentralization must be adapted for each district. A predefined decentralization scheme is easier said than done. A democratic process of decentralization, through the involvement of all stakeholders, is necessary. This process will determine which parts of the governing process need to be decentralized, or remain centralized, or self-governed by the people.

A district parliament, established democratically through a general election, is the most appropriate place for a decentralization process. This process needs catalysts to take place and to take hold. If the parliament cannot facilitate the process, then facilitators are needed. Appropriate facilitators behave as mediators between stakeholders' interests. Neutral organizations stand a good chance of acting as successful facilitators.

VI. CONCLUSIONS AND FUTURE WORKS

6.1. Conclusions

a. Local communities living in Inhutani II's area were able to define the knowledge of sustainable forest management (SFM). The research results showed that this local knowledge conforms to the generic or scientific knowledge of SFM. Inhutani II, in general, believes in implementing generic knowledge of SFM. The developed knowledge base system (KBS) found a way to harmonize this knowledge. The common perceptions or knowledge between these stakeholders became the foundation for collaboration in managing the forest.

b. Collaboration between concessionaires and the communities appeared to be the most suitable alternative for sustainable forest management, in particular for improving communities' incomes without decreasing the quality of the forest. This means collaboration between stakeholders must be encouraged and specified in order to get better outcomes for the management of forests. However, the collaborative arrangement might differ from site to site. Each FMU might have a different collaborative arrangement. Decentralization is a policy conducive to collaborative forest management. An appropriate decentralization process is a necessary condition for achieving better outcomes.

6.2. Future Works

This research was limited to the stakeholders located in the Inhutani II area, so that any general conclusion relating to a similar situation of scientific and community knowledge needs to be carefully derived. Further study on the roles of non-government organizations (NGOs) in influencing communities is necessary. This influence might change communities' perceptions of sustainability and their willingness to collaborate with other stakeholders.

The benefit and cost types of collaborations need to be studied more. Paying careful attention to different collaboration costs prior to a collaborative arrangement will avoid desperation. The collaboration costs may include costs of specifying rights and obligations, monitoring and enforcing of collaboration. Considering a forest is a complex ecosystem, and the social lives associated with it can also be complex, any arrangement or scenario of collaboration for a specific site requires extra study in order to produce generalizations.

REFERENCES

Adelson B. 1999. Developing strategic alliances: a framework for collaborative negotiation in design. J. Research in Engineering Design. 11:133-144.

Alder D. 1995. Growth modeling for mixed tropical forests. University of Oxford Tropical Forestry Papers: 30.

Alder D, Synnott TJ. 1992. Permanent sample plot techniques for mixed tropical forests. University of Oxford Tropical Forestry Papers: 25.

Anau N. 1998. Sejarah Leppo' Ke dan Ngibun Apau Ping Kecamatan Long Pujungan. (*The History of Leppo' Ke dan Ngibun Apau Ping at Sub-district Kecamatan Long Pujungan*). Samarinda: Pusat Kebudayaan dan Alam Kalimantan WWF-I Proyek Kayan Mentarang.

[ATO] The African Timber Organization. Africaland. http://www.focusintl.com/whos0008.htm [12 February 2002]

Axelrod R. 1997. The Complexity of Cooperation: Agent-Based Models of Competition and Collaboration. New Jersey: Princeton Univ. Press.

Bass S, Mayers J, Ahmed J, Filer C, Khare A, Kotey NA, Nhira C, Watson V. 1997. Polices affecting forests and people: ten elements that work. Commonwealth Forestry Rev 76:3. p186-190

Becker B. 1997. Sustainability Assessment: A Review of Values, Concepts, and Methodological Approaches. Issue in Agriculture 10. Washington DC: CGIAR Publ.

Barreteau O, Bousquet F, Attonaty J. 2001. Role-playing games for opening the black box of multi-agent systems: method and lessons of its application to Senegal River Valley irrigated systems. J Artificial Soc & Soc Sim 4 [serial online]. http://jasss.soc.surrey.ac.uk/4/2/5.html. [20 May 2001].

Bernard HR. 1994. Research Methods in Anthropology: Qualitative and Quantitative Approaches. Second ed. Thousand Oaks: SAGE Publications.

Bousquet F, Bakam I, Proton H, and Le Page, C. 1998. Cormas: Common-pool Resources and Multi-Agent Systems. International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems. J. M. a. M. A. A.P. del Pobil, Lecture Notes in Artificial Intelligence 1416: 826-838. Springer-Verlag.

Bousquet F, Barreteau O, Le Page C, Mullon C and Weber J. 1999. An environmental modelling approach: the use of multi-agent simulations. in: Blasco F, Weill A, editor. Advances in environmental and ecological modelling: Paris:Elsevier. p 113-122. http://cormas.cirad.fr/pdf/gowith.pdf. [15 January 2001].

T.J.B. Boyle, M. Lawes, N. Manokaran, R. Prabhu, J. Ghazoul, S. Sastrapradja, H.-C. Thang, V. Dale, H. Eeley, B. Finegan, J. Soberon and N.E. Stork. 1998. Criteria and Indicators for Assessing the Sustainability of Forest Management: A Practical Approach to Assessment of Biodiversity

Bueren EML de, Blom EM. 1997. Hierarchical Framework for the Formulation of Sustainable Forest Management Standards: Principle, Criteria and Indicators. The Netherlands: The Tropenbos Foundation.

[CACI]. Consolidated Analysis Centers Incorporated International Inc. Modeling & Simulation Basics. (http://www.caciasl.com/ms_basics.cfm). [11 January 2001]

Carter J. n.d. Recent experience in collaborative forest management approaches: a review of key issues. Switzerland: Intercooperation.

Castro AP, Nielsen E. 2001. Indigenous people and co-management: implications for conflict management. J Environ Sci & Pol 4:229-239.

[CIRAD] Centre de coopération internationale en recherche agronomique pour le développement. 2001. Natural resources and multi-agent simulations. http://cormas.cirad.fr/en/outil/outil.htm. [25 February 2002]

Clayton, M. H and N. J. Radcliffe. 1996. Sustainabilitry: A Systems Approach. London: Eartscan Publication Ltd.

Colfer CJP, Brocklesby MA, Diaw C, Etuge P, GÜnter M, Harwell E, McDougall C, Porro NM, Prabhu R, Salim A, Sardjono MA, Tchikangwa B, Tiani AM, Wadley R, Woelfel J, Wollenberg E. 1999. The BAG: Basic Assessment Guide for Human Well-Being. Bogor: CIFOR Publ.

Curtis GN. 2001. Critical thinking on the web: a directory of quality online resources. http://gncurtis.home.texas.net/glossary.html. [10 February 2001]

Eghenter C, Sellato B, editor. 1999. Kebudayaan dan Pelestarian Alam: Penelitian Interdisipliner di Pedalaman Kalimantan. Jakarta: WWF.

Elands BHM, Wiersum KF. 2001. Forestry and rural development in Europe: an exploration of socio-political discourses. J Forest Pol and Econ 3:5-16

Everitt, B. S. 1993. Cluster Analysis. New York: Halsted Press.

Fagin, R. , J. Y. Halpern, Y. Moses and M. Y. Vardi. 1995. Reasoning About Knowledge. Cambridge: The MIT Press.

Fahey L, Randall RM. 1998. What is Scenario Learning? In: Fahey L, Randall RM, editor. Learning from the Future: Competitive Foresight Scenarios. New York: John Wiley & Sons, Inc. p 3-21.

Flores-Mendez, R. A. 1999. Towards a standardization of multi-agent system frameworks. ACM Crossroads Student Magazine. http://www.acm.org/crossroads/xrds5-4/multiagent.html [13 September 2001]

Fowler HW, Fowler FG. editors. 1995. The Concise Oxford Dictionary of Current English 9th edition. Oxford: Clarendon Press.

Forrester JW. 1999. System dynamics: the foundation under systems thinking. Sloan School of Management MIT. Cambridge, MA 02139. ftp://sysdyn.mit.edu/ftp/sdep/papers/D-4828.html [13 September 2001]

Freeman DH. 1987. Applied Categorical Data Analysis. New York: Marcel Dekker, Inc.

[FSC] The Forest Stewardship Council. 2000. FSC Principles and Criteria http://www.fscoax.org/principal.htm [10 February 2002]

Ghate R. 2000. Joint forest management: constituting new commons: a case study from Maharashtra, India. Paper submitted for the eighth biennial conference of the IASCP; Indiana University, Bloomington, June 2000.

Grant JW, Pedersen EK, Marin SL. 1997. Ecology and Natural Resource Management: System Analysis and Simulation. Reading: Addison-Wesley.

Guangxing Wang, 1997. An expert system for improving forest inventory and monitoring. Department of Forest Resource Management, University of Helsinki, Finland.

Guerrin F. 1991. Qualitative Reasoning about an Ecological Process: Interpretation in Hydroecology. *Ecological Model*. Elseiver Sci. Publ. B. V., Amsterdam. p 165-201.

Haeruman H. 1995. Strategy for Sustainable Forestry Management. In: E. Suhendang, Haeruman H, Soerianegara I, editor. Pengelolaan Hutan Produksi Lestari di Indonesia: Konsep, Permasalahan dan Strategi Menuju Era Ekolabel. Fakultas Kehutanan IPB, Yayasan Gunung Menghijau dan Yayasan Ambarwati. Jakarta. p. 100-126.

Haines-Young R, Green DR, Cousins SH (eds.). 1993. Landscape Ecology and GIS. London: Taylor & Francis.

Helms JA, editor. 1998. The Dictionary of Forestry. Bethesda: The Society of American Foresters (SAF).

Ingles AW, Musch A, Qwist-Hoffmann H. 1999. The participatory for supporting collaborative management of natural resources: an overview. Food and Agriculture Organization, UN. Rome.

Inhutani II, PT. 1993. Studi Diagnostik HPH Bina Desa Hutan PT. Inhutani II Sub Unit Malinau. Kalimantan Timur.

Inhutani II, PT. 1996. Rencana Karya Pengusahaan Hutan Sementara PT. Inhutani II Sub Unit Malinau. Kalimantan Timur.

Inhutani II, PT. 1997. Rencana Karya Tahunan Pengusahaan Hutan 1998/1999 PT. Inhutani II Sub Unit Malinau. Kalimantan Timur.

[ITTO] International Tropical Timber Organization. 1992. Criteria for the measurement of sustainable tropical forest management. Yokohama: Pol Dev Ser 3

International Tropical Timber Organization. 1998. Criteria and indicators for sustainable management of natural tropical forests. Yokohama: Pol Dev Ser 7.

International Tropical Timber Organization. International Tropical Timber Organization Index. http://www.itto.or.jp/Index.html [12 February 2002]

Johannes F. 1993. Integrating traditional ecological knowledge and management with environmental impact assessment. In: Inglis JT, editor. Traditional Ecological Knowledge: Concepts and Cases. International Program on Traditional Ecological Knowledge and International Development Research Centre. Canada.

Kaimowitz D, Vallejos C, Pacheco P, Lopez R. 1998. Municipal governments and forest management in lowland Bolivia. J Env. & Dev 7(1) 45-59.

Kaskija L. 2000. Punan Malinau and the Bulungan Research Forest. A Research Report. Bogor: CIFOR Internal Report.

Kennedy JJ, Thomas JW, Glueck P. 2001. Evolving forestry and rural development beliefs at midpoint and close of the 20th century. J Forest Pol and Econ 3:81-95.

Kerney RA, G. Bradley, Kaplan R, Kaplan S. 1999. Stakeholder perspectives on appropriate forest management in the Pacific Northwest. J Forest Sci 45:62– 73.

Klosowski R, Stevens T, Kittredge D, Dennis D. 2001. Economic incentives for coordinated management of forest land: a case study of southern New England. J Forest Pol and Econ . 2:29-38

Lalonde A. 1993. African indigenous knowledge and its relevance to sustainable development. In: Inglis JT, editor. Traditional Ecological Knowledge: Concepts and Cases. International Program on Traditional Ecological Knowledge and International Development Research Centre. Canada.

Lee KN. 1993. Compass and Gyroscope: Integrating Science and Politics for the Environment. Washington D.C.: Island Press.

[LEI] Lembaga Ekolabel Indonesia. 1997. Usulan Rancangan Standar Nasional Indonesia: Program Sertifikasi Ekolabel Pengelolaan Hutan Produksi Alam Lestari pada Tingkat Manajemen Unit. Jakarta.

Madrah, Dalmasius, Karaakng. 1997. Tempuutn: Mitos Dayak Benuaq & Tunjung. Jakarta: Puspa Swara.

McCarthy JM. 2001. Decentralization, Local Communities and Forest Management in Barito Selatan District, Central Kalimantan. Case Studies on Decentralization and Forests in Indonesia. Bogor: CIFOR Publ.

[MIT] Massachusset Institute of Technology Sloan School of Management. 1996. Road Maps: A Guide to Learning Systems Dynamics.

Munasinghe M. 1992. Environmental economics and valuation in decisionmaking process. *Environment Working Paper*. Environment Department, The World Bank, Washington D.C.

Neufeldt V, Guralnik DB, editor. 1988. Webster's New World Dictionary of American English . Third College Edition. New York: Webster's New World.

[ODA] Overseas Development Agency of UK. Sharing Forest management: Key Factors, Best Practice & ways forward.

Osmaton FC. 1968. The Management of Forests. London: George Allen and Unwin Ltd.

Ossowski S. 1999. Co-ordination in Artificial Agent Societies: Social Structure and Its Implications for Autonomous Problem-Solving Agents. Berlin: Springer-Verlag.

Ostrom E, Schroeder L, Wynne S. 1993. Institutional Incentives and Sustainable Development: Infrastructure Policies in Perspective. Boulder: Wesview Press.

Ostrom E. 1999. Self-governance and forest resources. CIFOR Occasional paper no. 20. Bogor: CIFOR Publ.

Ostrom E.-. Policentric Intututions: Blending Local and global knowledge. Indiana University. http://www2.ids.ac.uk/gdnet/fulltxt/ostrom%5B1%5D.ppt [25 April 2002]

Painch M, Hinton R. 1998. Simulation Models: A Tool for Rigorous Scenario Analysis. In: Fahey L, Randall RM, editor. Learning from the Future: Competitive Foresight Scenarios. New York: John Wiley & Sons, Inc. p. 157-174.

Fahey L, Randall RM. 1998. What is Scenario Learning? In: Fahey L, Randall RM, editor. Learning from the Future: Competitive Foresight Scenarios. New York: John Wiley & Sons, Inc. p 3-21.

Pandey, D. N. 1998. Ethnoforestry: Local Knowledge for Sustainable Forestry and Livelihood Security. Asia Forest Network & Forestry Development Project, Rajasthan. Udaipur: Himanshu Publications.

Panigrahi S. 1998. Neuro-fuzzy systems: Potential and applications in biology and agriculture. AI Application. 12. Nos.1-3: 83-95.

Pellow DN. 1999. Negotiation and confrontation: environmental policy making through consensus. Int J Soc Nat Res 12:189-203.

Pearce D. 1995. Economic valuation and the natural world. *Policy Reserach Working Paper*. Office of the Vice President, Development Economics, The World Bank.

Pinard MA, Putz FE. 1996. Retaining forest biomass by reducing logging damage. Biotropica 28:278-95.

Prabhu R, Colfer CJP, Venkateswarlu P, Tan LC, Soekmadi R, Wollenberg E. 1996. Testing Criteria and Indicators for the Sustainable Forest Management of Forest: Phase I. Final Report. Bogor: CIFOR Special Publ.

Pradhan M, Suryahadi A, Sumarto S, Pritchett L. 2000. Measurements of Poverty in Indonesia: 1996, 1999, and Beyond. SMERU Working Paper.

Pragtong K.-.Recent decentralization plans on the royal forest department and its implications forest management in Thailand. http/www.fao.org/

Pykäläinen J, Pukkala T, Kangas J. 2001. Alternative priority models for forest planning on the landscape level involving multiple ownership. J Forest Pol and Econ 2:293-306.

Saaty TL. 1994. Fundamentals of Decision Making: Priority Theory with the Analytic Hierarchy Process. Pittsburgh: RWS Publications.

Saaty TL. 1996. Multicriteria Decision Making - The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation. Pittsburgh: RWS Publications.

Sarin, M. (2001). Disempowerment in the name of 'participatory' forestry? – Village joint forest management project in Uttarakhand. Forest Tree and People no 44.

Scapple S. 1998. Is consensus necessary for effective environmental treaties. J Environ Develop 1:364–386.

Schmoldt DL. 1998. Knowledge acquisition using linguistic-based knowledge analysis. J AI Appl 1:1-20.

Schtivelman J, Russel HC. 1989. Sustainable development, human resources and technology. In: Nef J, Vanderkop J, Wisema H, editor. Ethics and Technology: Ethical Choices in the Age of Pervasive Technology. Toronto: Wall & Thomson.

Sekher M. 2001. Organized participatory resource management: insights from community forestry practices in India. J Forest Pol and Econ 3:137-154.

Septiana AR. 2000. Simulasi Pengaturan Hasil Hutan [skripsi]. Institut Pertanian Bogor, Fakultas Kehutanan.

Sist P, Kartawinata K, Priyadi H, Sheil D, in prep. Comparison of logging impacts with conventional and Reduced-impact logging techniques in mixed dipterocarp forest of North-East Borneo.

[SPWD] Society for Promotion of Wastelands Development. Joint Forest Management: Concepts and Opportunities. Proceeding of the National Workshop; Surajkund, August 1992. New Delhi.

Society for Promotion of Wastelands Development. 1997. Guidelines for the Study of Community Institutions in Forest Management. New Delhi.

Stone P, Veloso M. 1997. Multiagent systems: a survey from a machine learning perspective. Computer Science Department. Carnegie Mellon University.Pittsburgh, PA 15213. http://www-2.cs.cmu.edu/afs/cs/usr/pstone/public/papers/97MAS-survey/revised-survey.html [20 October 2001]

Suhendang E. 1999. Pembentukan Hutan Normal Tidak Seumur Sebagai Strategi Pembenahan Hutan Alam Produksi Menuju Pengelolaan Hutan Lestari di Indonesia: Sebuah Analisis Konsepsional dalam Ilmu Manajemen Hutan [Orasi Ilmiah Guru Besar]. Bogor. Institut Pertanian Bogor, Fakultas Kehutanan.

Sukadri D. 1997. A prototype expert system model for assessing sustainable forest management policy. Proceeding of XI World Forestry Congress; Antalya, Turkey, 13 to 22 October 1997.

Sukwong S. 2000. Linking local lessons to policy developmet. Paper presented at the 4th International Workshop on Model Forests for Filed Level Applications of SFM; Japan, 23-27 October 2000.

Suoheimo J. 2001. Criteria and indicators for sustainable forest management in Finland. Ministry of Agriculture and Forestry in Finland. http://www.rinya.maff.go.jp/mar/Dr.Suoheimo%20%20Paper.pdf. [14 February 2002]

Swartz N. 1997. First set of practice exercises on necessary and sufficient conditions. Simon Fraser University, Department of Philosophy.

Sycara K. 2000. Multi-agent systems (a subtopic of agents). American Association for Artificial Intelligence (AAAI) website. http://www.aaai.org/AITopics/html/multi.html [19 September 2001]

Tadjudin D. 2000. Manajemen Kolaborasi. Bogor: Pustaka Latin.

Tarumingkeng RC. 1994. Dinamika Populasi: Kajian Ekologi Kuantitatif. Jakarta: Pustaka Sinar Harapan dan Universitas Kristen Krida Wacana.

[The Montréal Process] Montréal Process Working Group. 1998. Criteria and indicators for the conservation and sustainable management of temperate and boreal forests. http://www.mpci.org/meetings/santiago/santiago1_e.html [10 February 2002]

[USDA] United State Department of Agriculture Forest Service. 2001. Managing for sustainable ecosystems: the local unit criteria and indicator development project. LUCID Update 5. http:/www.fs.fed.us/institute/lucid/project_overview.html. [10 August 2001].

Vanclay JK. 1994. Modelling Forest Growth and Yield: Applications to Mixed Tropical Forests. Wallingford UK: Cab International.

Walker DH. 1994. A Knowledge-Based Systems Approach to Agroforestry Research and Extension. Dissertation. School of Agricultural and Forest Sciences, University of Wales. Bangor.

Wavey R. 1993. international worskhop on indigenous knowledge and community-based resource management. In: Inglis JT, editor. Traditional Ecological Knowledge: Concepts and Cases. International Program on Traditional Ecological Knowledge and International Development Research Centre. Canada.

Weiss G, editor. 1999. MultiAgent Systems: A Modern Approach to Distributed Artificial Intelligence. Cambridge: MIT Pr.

[YAP] Yayasan Adat Punan. 1999. Laporan Sementara Raker II Yayasan Adat Punan Seturan 10-14 Mei 1999. (*Interim Report of the 2nd Program Meeting of Punan Customary Foundation, 10-14 May 1999*).

APPENDICES

Appendix 1. Interview guide of local knowledge on forest management

Respondent group	
Date and day	
Place	
Time	

A. Identification of respondent group member

Name	Age (yr)	Sex (M/F)	Job	Educational level
1.				
2.				
3.				
4.				
5.				
6.				

B. Identification of respondent group's perception

Procedure

1. Everyone in the group is asked to think of factors that are important to be considered in order to achieve good forest management. They must put those factors on a piece of paper using marker
2. Those factors are then sticked on the wall and discussed with the group member. Finally those factors are grouped (i.e. social, ecological, etc.).
3. In the discussion facilitator should ask why those factors are important for them, what are their reason for mentioning those factors

Other notes:

Appendix 2. List of criteria and indicators from internationally recognized sources

1.1. List of ITTO C&I

POLICY

P.1 SUSTAINABLE FOREST MANAGEMENT RELATED TO POLICY ASPECT

C.1.1 Enabling Conditions for Sustainable Forest Management

I.1.1.1 Existence of a framework of laws, policies, and regulations to govern: (a) national objectives for forest including production, conservation and protection, (b) the establishment and security of the permanent forest estate, (c) land tenure and property rights relating to forests, (d) the control of forest management, (e) the control of forest harvesting, (f) the control of encroachment, (g) the health and safety of forest workers, and (h) the participation of local communities

I.1.1.2 Amount of investment and reinvestment in forest management, administration, research, and human resource development from: (a) national and sub-national government sources, (b) the Bali Partnership Fund (not applicable at the Forest Management Unit level), (c) other international governmental contribution, and (d) private sources, domestic and foreign

I.1.1.3 Existence of economic instruments and other incentives to encourage sustainable forest management

I.1.1.4 Number and adequacy of institutions to support sustainable forest management

I.1.1.5 Number and adequacy of trained professional and technical personnel at all levels to perform and support management, implementation, research and extension

I.1.1.6 Existence and application of appropriate technology to practice sustainable forest management and the efficient processing and utilization of forest produce

I.1.1.7 Capacity and mechanisms for planning sustainable forest management and for periodical monitoring, evaluation and feedback on progress

I.1.1.8 Degree of public participation in forest management, such as in planning, decision-making, data collection, monitoring and assessment

I.1.1.9 Adequacy and timeliness of information to increase public awareness about forest policies, legislation and sustainable forest management practices

ECOLOGY

P.2 SUSTAINABLE FOREST MANAGEMENT RELATED TO ECOLOGY ASPECT

C.2.1 Forest Resource Security

I.2.1.1 Extent (area) and percentage of total land area under: (a) natural forest, (b) plantation forest, (c) permanent forest estate, and (d) comprehensive integrated land-user plans

I.2.1.2 Extent (area) and percentage of total land area under each forest type

I.2.1.3 Length and percentage of external boundaries of the permanent forest estate demarcated or clearly defined

I.2.1.4 Area of the permanent forest estate converted to permanent non-forest use

I.2.1.5 Existence of procedures to control encroachment, fire, grazing and illegal exploitation of forests

C.2.2 Forest Ecosystem Health and Condition

I.2.2.1 Within the permanent forest estate, the extend and nature of: (a) encroachment, (b) agriculture, (c) roads, (d) mining, (e) dams, (f) unplanned fire, (g) shifting agriculture, (h) nomadic grazing, (i) illegal exploitation, (j) inappropriate harvesting practices, (k) harvesting more than once during the cutting cycle (re-entry), (l) hunting, and (m) other forms of forest damage such as change in hydrological regime, pollution, introduction of harmful exotic plant and animal species, browsing and grazing. (These should be specified)

I.2.2.2 Within the permanent forest estate, the extent and nature of forest damage, caused by: (a) wild fire, (b) drought, (c) storms or natural catastrophes, (d) pests and diseases, and (e) other natural causes

I.2.2.3 Existence and implementation of quarantine and phytosanitary procedures to prevent the introduction of pests and diseases

I.2.2.4 Existence and implementation of procedures to prevent the introduction of potentially harmful exotic plant and animal species

I.2.2.5 Availability and implementation of procedures covering: (a) use of chemicals in the forest, and (b) fire management

C.2.3 Biological Diversity

I.2.3.1 Statistics of protected areas in each forest type: (a) number, (b) extent, (c) percentage of forest type covered, (d) range of sizes and average size of protected area, and (e) percentage of boundaries demarcated or clearly defined

I.2.3.2 Percentage of total number of protected areas connected by biological corridors or stepping-stones between them

I.2.3.3 Existence and implementation of procedures to identify endangered, rare and threatened species of forest flora and fauna

I.2.3.4 Number of endangered, rare and threatened forest-dependent species

I.2.3.5 Percentage of original range occupied by selected endangered, rare and threatened species

I.2.3.6 Existence and implementation of a strategy for in situ and/or ex situ conservation of the genetic variation within commercial, endangered, rare and threatened species of forest flora and fauna

I.2.3.7 Existence and implementation of management guidelines to: (a) keep undisturbed a part of each production forest, (b) protect endangered, rare and threatened species of forest flora and fauna, and (c) protect features of special biological interests such as seed trees, nesting sites, niches and keystone species

I.2.3.8 Existence and implementation of procedures for assessing changes of biological diversity of the production forests, compared with areas in the same forest type kept free from human intervention

C.2.4 Soil and Water

I.2.4.1 Extent and percentage of total forest area managed primarily for the protection of soil and water

I.2.4.2 Extent and percentage of area to be harvested for which off-site catchments values have been defined, documented and protected before harvesting

I.2.4.3 Extent and percentage of area to be harvested which has been defined as environmentally sensitive (e.g. very steep or erodible) and protected before harvesting

I.2.4.4 Extent and percentage of area to be harvested for which drainage systems have been demarcated or clearly defined and protected before harvesting

I.2.4.5 Percentage of length of edges of watercourses, water bodies, mangroves and other wetlands protected by adequate buffer strips

I.2.4.6 Existence and implementation of procedures to identify and demarcate sensitive areas for the protection of soil and water

I.2.4.7 Availability and implementation of guidelines for forest road layout, including drainage requirements and conservation of buffer strips along streams and rivers

I.2.4.8 Availability and implementation of harvesting procedures: (a) to protect the soil from compaction by harvesting machinery, and (b) to protect the soil from erosion during harvesting operations

I.2.4.9 Existence and implementation of procedures for assessing changes in the water quality of streams emerging from production forests as compared with streams emerging from the same forest type kept free from human intervention

SOCIAL

P.3 SUSTAINABLE FOREST MANAGEMENT RELATED TO SOCIAL ASPECT

C.3.1 Economic, Social and Cultural Aspects

I.3.1.1 Value and percentage contribution of the forestry sector to the Gross Domestic Product

I.3.1.2 Quantity (volume) and value of wood and non-wood forest products traded in: (a) the domestic market, and (b) the international market

I.3.1.3 Quantity (volume) and value of wood and non-wood forest products for subsistence use, including fuel wood

I.3.1.4 Ratio of domestic log production to the processing capacity of wood-based industries

I.3.1.5 Efficiency of utilization in terms of the percentage of felled volume processed

I.3.1.6 Existence and implementation of mechanisms for the effective distribution of incentives and the fair and equitable sharing of costs and benefits among the parties involved

I.3.1.7 Existence and implementation of procedures to ensure the health and safety of forest workers

I.3.1.8 Employment in the forestry sector: (a) number employed, (b) percentage of total work force (not applicable at the Forest Management Unit level), (c) average wage rate (not applicable at the Forest Management Unit level), and (d) injury rate

I.3.1.9 Number and extent of forest sites available primarily for: (a) research (not applicable at the Forest Management Unit level), (b) education (not applicable at the Forest Management Unit level), (c) the direct use and benefit of local communities, and (d) recreation

I.3.1.10 Number of people dependent on the forest for subsistence uses and traditional and customary lifestyles

I.3.1.11 Area of forest upon which people are dependent for subsistence uses and traditional and customary lifestyles

I.3.1.12 Number of visitors to forest for recreational purposes

I.3.1.13 Total amount of carbon stored in forest stands

I.3.1.14 Number of important archaeological and cultural sites identified, mapped and protected

I.3.1.15 Extent to which tenure and user rights over the forest are documented and recognized

I.3.1.16 Extent to which forest planning and management practices and processes consider and recognize legal or customary rights with respect to indigenous people and local communities, forest dwellers and other forest-dependent communities

I.3.1.17 Extent or participation by indigenous people and local communities, forest dwellers and other forest-dependent communities in forest-based economic activities

I.3.1.18 Number of agreements involving local communities in co-management responsibilities

PRODUCTION OF GOODS AND SERVICES

P.4 SUSTAINABLE FOREST MANAGEMENT RELATED TO PRODUCTION OF GOODS AND SERVICES ASPECT

C.4.1 Flow of Forest Produce

I.4.1.1 Extent and percentage of forest for which inventory and survey procedure have been used to define: (a) the quantity of the main forest products, and (b) resource rights and ownership

I.4.1.2 Estimate of level of sustainable harvest for each main wood and non-wood forest product for each forest type

I.4.1.3 Quantity (volume) of wood and important non-wood forest products harvested for each forest type

I.4.1.4 Existence and implementation of: (a) forest management plans, and (b) forest harvesting (operational) plans

I.4.1.5 Existence and percentage of: (a) production forest covered by management plans, and (b) compartment/coupes harvested according to harvesting (operational) plans

I.4.1.6 Existence of long-term projections, strategies and plans for production, including the use of tree plantations

I.4.1.7 Availability of historical records on the extent, nature and management of forest

I.4.1.8 Availability and implementation of management guidelines for each of the main wood and non-wood forest products to be harvested, to cover: (a) the assessment of natural regeneration, and (b) measures to supplement natural regeneration where necessary

I.4.1.9 Availability and implementation of procedures to monitor and review the management guidelines

I.4.1.10 Availability and implementation of guidelines for reduced/low impact logging to minimize damage to residual stand

I.4.1.11 Availability and implementation of: (a) procedures for comprehensive evaluation of the implementation of management guidelines, (b) procedures to assess damage to the residual stand, and (c) post-harvest surveys to assess the effectiveness of regeneration

I.4.1.12 Percentage of area harvested for which: (a) management guidelines have been completely implemented, and (b) post-harvested surveys have been conducted to assess the effectiveness of regeneration

1.2. List of Forest Stewardship Council P&C

POLICY

P.1 COMPLIANCE WITH LAWS AND FSC PRINCIPLES

C.1.1 Forest management shall respect all national and local laws and administrative requirements.

C.1.2 All applicable and legally prescribed fees, royalties, taxes and other charges shall be paid.

C.1.3 In signatory countries, the provisions of all binding international agreements such as CITES, ILO Conventions, ITTA, and Convention on Biological Diversity, shall be respected.

C.1.4 Conflicts between laws, regulations and the FSC Principles and Criteria shall be evaluated for the purposes of certification, on a case-by-case basis, by the certifiers and the involved or affected parties.

C.1.5 Forest management areas should be protected from illegal harvesting, settlement and other unauthorized activities.

C.1.6 Forest managers shall demonstrate a long-term commitment to adhere to the FSC Principles and Criteria.

P.2 TENURE AND USE RIGHTS AND RESPONSIBILITIES

C.2.1 Clear evidence of long-term forest use rights to the land (e.g. land title, customary rights, or lease agreements) shall be demonstrated.

C.2.2 Local communities with legal or customary tenure or use rights shall maintain control, to the extent necessary to protect their rights or resources, over forest operations unless they delegate control with free and informed consent to other agencies.

C.2.3 Appropriate mechanisms shall be employed to resolve disputes over tenure claims and use rights. The circumstances and status of any outstanding disputes will be explicitly considered in the certification evaluation.

ECOLOGY

P.3 ENVIRONMENTAL IMPACT

C.3.1 Assessment of Environmental impacts shall be completed - appropriate to the scale, intensity of forest management and the uniqueness of the affected resources - and adequately integrated into management systems. Assessments shall include landscape level considerations as well as the impacts of on-site processing facilities. Environmental impacts shall be assessed prior to commencement of site-disturbing operations.

C.3.2 Safeguards shall exist which protect rare, threatened and endangered species and their habitats (e.g., nesting and feeding areas). Conservation zones and protection areas shall be established, appropriate to the scale and intensity of forest management and the uniqueness of the affected resources. Inappropriate hunting, fishing, trapping and collecting shall be controlled.

C.3.3 Ecological functions and values shall be maintained intact, enhanced or restored, including: 1) Forest regeneration and succession, 2) Genetic, species, and ecosystem diversity, 3) Natural cycles that affect the productivity of the forest ecosystem

C.3.4 Representative samples of existing ecosystems within the landscape shall be protected in their natural state and recorded on maps, appropriate to the scale and intensity of operations and the uniqueness of the affected resources.

C.3.5 Written guidelines shall be prepared and implemented to: control erosion; minimize forest damage during harvesting, road construction, and all other mechanical disturbances; and protect water resources.

C.3.6 Management systems shall promote the development and adoption of environmentally friendly non-chemical methods of pest management and strive to avoid the use of chemical pesticides. World Health Organization Type 1A and 1B and chlorinated hydrocarbon pesticides; pesticides that are persistent, toxic or whose derivatives remain biologically active and accumulate in the food chain beyond their intended use; as well as any pesticides banned by international agreement, shall be prohibited. If chemicals are used, proper equipment and training shall be provided to minimize health and environmental risks.

C.3.7 Chemicals, containers, liquid and solid non-organic wastes including fuel and oil shall be disposed of in an environmentally appropriate manner at off-site locations.

C.3.8 Use of biological control agents shall be documented, minimized, monitored and strictly controlled in accordance with national laws and internationally accepted scientific protocols. Use of genetically modified organisms shall be prohibited.

C.3.9 The use of exotic species shall be carefully controlled and actively monitored to avoid adverse ecological impacts.

P.4 MAINTENANCE OF NATURAL FORESTS

C.4.1 Trees planted in natural forests may supplement natural regeneration, fill gaps or contribute to the conservation of genetic resources. Such plantings shall not replace or significantly alter the natural ecosystem.

C.4.2 The use of replanting as a technique for regenerating stands of certain natural forest types may be appropriate under certain circumstances. Guidelines on the acceptable intensity and spatial extent of tree planting will be addressed in national and regional forest management standards to be approved by the FSC. In the absence of such national or regional standards, guidelines developed by the certifier and approved by the FSC will prevail.

SOCIAL

P.5 INDIGENOUS PEOPLE'S RIGHTS

C.5.1 Indigenous peoples shall control forest management on their lands and territories unless they delegate control with free and informed consent to other agencies.

C.5.2 Forest management shall not threaten or diminish, either directly or indirectly, the resources or tenure rights of indigenous peoples.

C.5.3 Sites of special cultural, ecological, economic or religious significance to indigenous peoples shall be clearly identified in cooperation with such peoples, and recognized and protected by forest managers.

C.5.4 Indigenous peoples shall be compensated for the application of their traditional knowledge regarding the use of forest species or management systems in forest operations. This compensation shall be formally agreed upon with their free and informed consent before forest operations commence.

P.6 COMMUNITY RELATIONS AND WORKERS' RIGHTS

C.6.1 The communities within, or adjacent to, the forest management area should be given opportunities for employment, training and other services.

C.6.2 Forest management should meet or exceed all applicable laws and/or regulations covering health and safety of employees and their families.

C.6.3 The rights of workers to organize and voluntarily negotiate with their employers shall be guaranteed as outlined in Conventions 87 and 98 of the International Labor Organization (ILO).

C.6.4 Management planning and operations shall incorporate the results of evaluations of social impact. Consultations shall be maintained with people and groups directly affected by management operations.

C.6.5 Appropriate mechanisms shall be employed for resolving grievances and for providing fair compensation in the case of loss or damage affecting the legal or customary rights, property, resources, or livelihoods of local peoples. Measures shall be taken to avoid such loss or damage.

PRODUCTION OF GOODS AND SERVICES

P.7 BENEFITS FROM THE FOREST

C.7.1 Forest management should strive toward economic viability, while taking into account the full environmental, social and operational costs of production, and ensuring the investments necessary to maintain the ecological productivity of the forest.

C.7.2 Forest management and marketing operations should encourage the optimal use and local processing of the forest's diversity of products.

C.7.3 Forest management should minimize waste associated with harvesting and on-site processing operations and avoid damage to other forest resources.

C.7.4 Forest management should strive to strengthen and diversify the local economy, avoiding dependence on a single forest product.

C.7.5 Forest management operations shall recognize, maintain and, where appropriate, enhance the value of forest services and resources such as watersheds and fisheries.

C.7.6 The rate of harvest of forest products shall not exceed levels, which can be permanently sustained.

P.8 MANAGEMENT PLAN

C.8.1 The management plan and supporting documents shall provide: 1. Management objectives; 2. Description of the forest resources to be managed, environmental limitations, land use and ownership status, socioeconomic conditions, and a profile of adjacent lands; 3. Description of silvicultural and/or other management system, based on the ecology of the forest in question and information gathered through resource inventories; 4. Rationale for rate of annual harvest and species selection; 5. Provisions for monitoring of forest growth and dynamics; 6. Environmental safeguards based on environmental assessments; 7. Plans for the identification and protection of rare, threatened and endangered species; 8. Maps describing the forest resource base including protected areas, planned management activities and land ownership; 9. Description and justification of harvesting techniques and equipment to be used

C.8.2 The management plan shall be periodically revised to incorporate the results of monitoring or new scientific and technical information, as well as to respond to changing environmental, social and economic circumstances.

C.8.3 Forest workers shall receive adequate training and supervision to ensure proper implementation of the management plan.

C.8.4 While respecting the confidentiality of information, forest managers shall make publicly available a summary of the primary elements of the management plan, including those listed in Criterion 7.1.

P.9 MONITORING AND ASSESSMENT

C.9.1 The frequency and intensity of monitoring should be determined by the scale and intensity of forest management operations as well as the relative complexity and fragility of the affected environment. Monitoring procedures should be consistent and replicable over time to allow comparison of results and assessment of change.

C.9.2 Forest management should include the research and data collection needed to monitor, at a minimum, the following indicators: 1. Yield of all forest products harvested; 2. Growth rates, regeneration and condition of the forest; 3. Composition and observed changes in the flora and fauna; 4. Environmental and social impacts of harvesting and other operations; 5. Costs, productivity and efficiency of forest management

C.9.3 Documentation shall be provided by the forest manager to enable monitoring and certifying organizations to trace each forest product from its origin, a process known as the 'chain of custody'.

C.9.4 The results of monitoring shall be incorporated into the implementation and revision of the management plan.

C.9.5 While respecting the confidentiality of information, forest managers shall make publicly available a summary of the results of monitoring indicators, including those listed in Criterion 8.2.

P.10 PLANTATIONS

C.10.1 The management objectives of the plantation, including natural forest conservation and restoration objectives, shall be explicitly stated in the management plan, and clearly demonstrated in the implementation of the plan.

C.10.2 The design and layout of plantations should promote the protection, restoration and conservation of natural forests, and not increase pressures on natural forests. Wildlife corridors, streamside zones and a mosaic of stands of different ages and rotation periods, shall be used in the layout of the plantation, consistent with the scale of the operation. The scale and layout of plantation blocks shall be consistent with the patterns of forest stands found within the natural landscape.

C.10.3 Diversity in the composition of plantations is preferred, so as to enhance economic, ecological and social stability. Such diversity may include the size and spatial distribution of management units within the landscape, number and genetic composition of species, age classes and structures.

C.10.4 The selection of species for planting shall be based on their overall suitability for the site and their appropriateness to the management objectives. In order to enhance the conservation of biological diversity, native species are preferred over exotic species in the establishment of plantations and the restoration of degraded ecosystems. Exotic species, which shall be used only when their performance is greater than that of native species, shall be carefully monitored to detect unusual mortality, disease, or insect outbreaks and adverse ecological impacts.

C.10.5 A proportion of the overall forest management area, appropriate to the scale of the plantation and to be determined in regional standards, shall be managed so as to restore the site to a natural forest cover.

C.10.6 Measures shall be taken to maintain or improve soil structure, fertility, and biological activity. The techniques and rate of harvesting, road and trail construction and maintenance, and the choice of species shall not result in long term soil degradation or adverse impacts on water quality, quantity or substantial deviation from stream course drainage patterns.

C.10.7 Measures shall be taken to prevent and minimize outbreaks of pests, diseases, fire and invasive plant introductions. Integrated pest management shall form an essential part of the management plan, with primary reliance on prevention and biological control methods rather than chemical pesticides and fertilizers. Plantation management should make every effort to move away from chemical pesticides and fertilizers, including their use in nurseries. The use of chemicals is also covered in Criteria 6.6 and 6.7.

C.10.8 Appropriate to the scale and diversity of the operation, monitoring of plantations shall include regular assessment of potential on-site and off-site ecological and social impacts, (e.g. natural regeneration, effects on water resources and soil fertility, and impacts on local welfare and social well-being), in addition to those elements addressed in principles 8, 6 and 4. No species should be planted on a large scale until local trials and/or experience have shown that they are ecologically well-adapted to the site, are not invasive, and do not have significant negative ecological impacts on other ecosystems. Special attention will be paid to social issues of land acquisition for plantations, especially the protection of local rights of ownership, use or access.

1.3. List of Montréal Process C&I

CRITERIA AND INDICATORS FOR THE CONSERVATION AND SUSTAINABLE MANAGEMENT OF TEMPERATE AND BOREAL FORESTS
http://www.mpci.org/whatis/criteria_e.html

The Montréal Process Working Group agreed on a framework of criteria and indicators that provide member countries with a common definition of what characterizes sustainable management of temperate and boreal forests. The framework identifies seven criteria that are further defined by 67 associated indicators which are aspects of the criteria that can be identified or described.

The following six criteria and associated indicators characterize the conservation and sustainable management of temperate and boreal forests. They relate specifically to forest conditions, attributes or functions, and to the values or benefits associated with the environmental and socio-economic goods and services that forests provide. The intent or meaning of each criterion is made clear by its respective indicators. No priority or order is implied in the alpha-numeric listing of the criteria and indicators.

Indicators followed by an "a" are those for which most data are available. Indicators followed by a "b" are those which may require the gathering of new or additional data and/or a new program of systematic sampling or basic research.

IUCN categories include: I. Strict protection, II. Ecosystem conservation and tourism, III. Conservation of natural features, IV. Conservation through active management, V. Landscape/Seascape conservation and recreation, VI. Sustainable use of natural ecosystems.

Criterion 1: Conservation of biological diversity

Biological diversity includes the elements of the diversity of ecosystems, the diversity between species, and genetic diversity in species.

Indicators:
Ecosystem diversity
a. Extent of area by forest type relative to total forest area-(a);1
b. Extent of area by forest type and by age class or successional stage-(b);
c. Extent of area by forest type in protected area categories as defined by IUCN2 or other classification systems-(a);
d. Extent of areas by forest type in protected areas defined by age class or successional stage-(b);
e. Fragmentation of forest types-(b).

Species diversity
a. The number of forest dependent species-(b);
b. The status (threatened, rare, vulnerable, endangered, or extinct) of forest dependent species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment-(a).

Genetic diversity
a. Number of forest dependent species that occupy a small portion of their former range-(b);
b. Population levels of representative species from diverse habitats monitored across their range-(b).

Criterion 2: Maintenance of productive capacity of forest ecosystems

Indicators:
a. Area of forest land and net area of forest land available for timber production-(a);
b. Total growing stock of both merchantable and non-merchantable tree species on forest land available for timber production-(a);
c. The area and growing stock of plantations of native and exotic species-(a);
d. Annual removal of wood products compared to the volume determined to be sustainable-(a);
e. Annual removal of non-timber forest products (e.g. fur bearers, berries, mushrooms, game), compared to the level determined to be sustainable-(b).

Criterion 3: Maintenance of forest ecosystem health and vitality

Indicators:
a. Area and percent of forest affected by processes or agents beyond the range of historic variation, e.g. by insects, disease, competition from exotic species, fire, storm, land clearance, permanent flooding, salinisation, and domestic animals-(b);
b. Area and percent of forest land subjected to levels of specific air pollutants (e.g. sulfates, nitrate, ozone) or ultraviolet B that may cause negative impacts on the forest ecosystem-(b);
c. Area and percent of forest land with diminished biological components indicative of changes in fundamental ecological processes (e.g. soil nutrient cycling, seed dispersion, pollination) and/or ecological continuity (monitoring of functionally important species such as fungi, arboreal epiphytes, nematodes, beetles, wasps, etc.)-(b).

Criterion 4: Conservation and maintenance of soil and water resources

This criterion encompasses the conservation of soil and water resources and the protective and productive functions of forests.

Indicators:
a. Area and percent of forest land with significant soil erosion-(b);
b. Area and percent of forest land managed primarily for protective functions, e.g. watersheds, flood protection, avalanche protection, riparian zones-(a);
c. Percent of stream kilometres in forested catchments in which stream flow and timing has significantly deviated from the historic range of variation-(b);
d. Area and percent of forest land with significantly diminished soil organic matter and/or changes in other soil chemical properties-(b);

e. Area and percent of forest land with significant compaction or change in soil physical properties esulting from human activities-(b);
f. Percent of water bodies in forest areas (e.g. stream kilometres, lake hectares) with significant variance of biological diversity from the historic range of variability-(b);
g. Percent of water bodies in forest areas (e.g. stream kilometres, lake hectares) with significant variation from the historic range of variability in pH, dissolved oxygen, levels of chemicals (electrical conductivity), sedimentation or temperature change-(b);
h. Area and percent of forest land experiencing an accumulation of persistent toxic substances-(b).

Criterion 5: Maintenance of forest contribution to global carbon cycles

Indicators:
a. Total forest ecosystem biomass and carbon pool, and if appropriate, by forest type, age class, and successional stages-(b);
b. Contribution of forest ecosystems to the total global carbon budget, including absorption and release of carbon (standing biomass, coarse woody debris, peat and soil carbon)-(a or b);
c. Contribution of forest products to the global carbon budget-(b).

Criterion 6: Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies

Indicators:
Production and consumption
a. Value and volume of wood and wood products production, including value added through downstream processing-(a);
b. Value and quantities of production of non-wood forest products-(b);
c. Supply and consumption of wood and wood products, including consumption per capita-(a);
d. Value of wood and non-wood products production as percentage of GDP-(a or b);
e. Degree of recycling of forest products-(a or b);
f. Supply and consumption/use of non-wood products-(a or b).

Recreation and tourism
a. Area and percent of forest land managed for general recreation and tourism, in relation to the total area of forest land-(a or b);
b. Number and type of facilities available for general recreation and tourism, in relation to population and forest area-(a or b);
c. Number of visitor days attributed to recreation and tourism, in relation to population and forest area-(b).

Investment in the forest sector
a. Value of investment, including investment in forest growing, forest health and management, planted forests, wood processing, recreation and tourism-(a);
b. Level of expenditure on research and development, and education-(b);
c. Extension and use of new and improved technologies-(b);
d. Rates of return on investment-(b).

Cultural, social and spiritual needs and values
a. Area and percent of forest land managed in relation to the total area of forest land to protect the range of cultural, social and spiritual needs and values-(a or b);
b. Non-consumptive use forest values-(b).

Employment and community needs
a. Direct and indirect employment in the forest sector and forest sector employment as a proportion of total employment-(a or b);
b. Average wage rates and injury rates in major employment categories within the forest sector-(a);
c. Viability and adaptability to changing economic conditions, of forest dependent communities, including indigenous communities-(b);
d. Area and percent of forest land used for subsistence purposes-(b).

Criterion 7: Legal, institutional and economic framework for forest conservation and sustainable management

Indicators:
Extent to which the legal framework (laws, regulations, guidelines) supports the conservation and sustainable management of forests, including the extent to which it:

a. Clarifies property rights, provides for appropriate land tenure arrangements, recognizes customary and traditional rights of indigenous people, and provides means of resolving property disputes by due process;
b. Provides for periodic forest-related planning, assessment, and policy review that recognizes the range of forest values, including coordination with relevant sectors;
c. Provides opportunities for public participation in public policy and decision-making related to forests and public access to information;
d. Encourages best practice codes for forest management;
e. Provides for the management of forests to conserve special environmental, cultural, social and/or scientific values.

Extent to which the institutional framework supports the conservation and sustainable management of forests, including the capacity to:
a. Provide for public involvement activities and public education, awareness and extension programs, and make available forest-related information;
b. Undertake and implement periodic forest-related planning, assessment, and policy review including cross-sectoral planning and coordination;
c. Develop and maintain human resource skills across relevant disciplines;
d. Develop and maintain efficient physical infrastructure to facilitate the supply of forest products and services and support forest management;
e. Enforce laws, regulations and guidelines.

Extent to which the economic framework (economic policies and measures) supports the conservation and sustainable management of forests through:
a. Investment and taxation policies and a regulatory environment which recognize the long-term nature of investments and permit the flow of capital in and out of the forest sector in response to market signals, non-market economic valuations,

and public policy decisions in order to meet long-term demands for forest products and services;
b. Non-discriminatory trade policies for forest products.

Capacity to measure and monitor changes in the conservation and sustainable management of forests, including:
a. Availability and extent of up-to-date data, statistics and other information important to measuring or describing indicators associated with criteria 1-7;
b. Scope, frequency and statistical reliability of forest inventories, assessments, monitoring and other relevant information;
c. Compatibility with other countries in measuring, monitoring and reporting on indicators.

Capacity to conduct and apply research and development aimed at improving forest management and delivery of forest goods and services, including:
a. Development of scientific understanding of forest ecosystem characteristics and functions;
b. Development of methodologies to measure and integrate environmental and social costs and benefits into markets and public policies, and to reflect forest-related resource depletion or replenishment in national accounting systems;
c. New technologies and the capacity to assess the socio-economic consequences associated with the introduction of new technologies;
d. Enhancement of ability to predict impacts of human intervention on forests;
e. Ability to predict impacts on forests of possible climate change.

1.4. List of Finnish C&I

ECOLOGY
C.1. Maintenance and appropriate enhancement of forest resources and their contribution to global carbon cycles Instruments to regulate the maintenance of forest resources

Forest rights
Regulation of the forest resource through land use
Forest and other wooded land and their proportion of total land area
Total volume of growing stock
Age structure of forest
Managing the carbon balance
Carbon balance
Use of wood-based energy

C.2. Maintenance of forest ecosystem health and vitality Instruments to regulate the maintenance of forest ecosystems health and vitality

Deposition of air pollutants
Changes in the defoliation of forests using the UN?ECE and EU defoliation classification
Damages causes by biotic or abiotic agents

C.3. Maintenance, conservation and appropriate enhancement of biological diversity in forest ecosystems Instruments to regulate the maintenance,conservation and appropriate enhacement of biodiversity in forest ecosystems

Threatened and vulnarable species of flora and fauna

Protected forests with felling restriction
Valuable forest habitats and their protection
Tree species composition
Pure and moxed forest stands
Reserved and decayed trees in commercial foersts and conservation areas
Gene reserved forest

C.4. Maintenance and appropriate enhancement of protective functions in forest management (notably soil and water) Instruments for the maintenance and appropriate enhancement of protective functions in forest management
Water protection in harvesting snd site preparation
Phosphor and nitrogen load on waters systems caused by logging
Water protection plans in drainage projects
Area of forestry land in protected forests

SOCIAL
C.4. Maintenance of other socio-economic and cultural functions and conditions (economy and emplyment, public participation in decision making, cultural and multiple-use of forests) Instruments for securing the operating conditions of the forest sector in the national and regioanal economy
The proportion of the forest sector of gross national product
Domestic and foreign trade of the forest sector
Labour and employment support in the forest sector
Small and mediumisized enterprises in the forest sector by branch
Social factors of the the forest workforce
Instruments for securing and maintaning equitable opportunities for the public to participate in the decision making
Instruments to maintain the multiple use and cultural values of forests
Cultural values - archeological monuments and landscape values
Recreational use of forest

PRODUCTION OF GOODS AND SERVICES
C.5. Maintenance and ecouragement of productive of forests (wood and non-wood) Intruments for safeguarding wood production
Increment of growing stock
Total drain
Coverage of forest advisory services
Coverage of forest management planning
Silviculture and forest improvement
Profitability of private forestry
Structure of roundwood production
Instruments to safeguard the management of forests related to non-wood products
Quantity and economic significance of non-wood forest products
Ecotourism

1.5. List of African Timber Organization C&I

POLICY

P.1 (GENERAL POLICY). SUSTAINABILITY OF THE FOREST AND ITS MULTIPLE FUNCTIONS IS A HIGH POLITICAL PRIORITY.

C.1.1 The Government has clear forest development objectives and a realistic action plan to meet them.

I.1.1.1 There is a permanent forest estate governed by laws and regulations which are the basis for its sustainable management. This permanent forest estate is the result of negotiation between all stakeholders within the framework of a procedure of coordinated planning of the allocation of lands, based on appropriate and updated information.

I.1.1.2 The Government has a system of reliable, adequate and updated information on the forestry sector (especially a national forest inventory), which enables it to update its action, plans and adjust the means of implementation.

C.1.2 The Government allocates adequate means for sustainable management of forests.

I.1.2.1 There is a mechanism for sustained and adequate funding for the management of Government forests.

I.1.2.2 There is a forestry service in charge of the management of all the forests, with adequate staffing to fulfill its mandate.

I.1.2.3 Forest research is allocated sufficient means (human and material) and its results are applied.

C.1.3 Action is taken by the Government to reduce all types of pressure on the forest.

I.1.3.1 Existing, on-going and future plantations in the national forest plantation plan can contribute to supply the timber sector

I.1.3.2 The Government implements appropriate programmes to stabilize agriculture.

C.1.4 At international level, the Government has ratified or approved treaties, conventions or recommendations on sustainable development of forests issued especially by such organizations as ILO, CITES, ITTO, FAO, UNCED.

ECOLOGY

P.2 THE MAIN ECOLOGICAL FUNCTIONS OF THE FOREST ARE MAINTAINED

C.2.1 The capacity of the forest for natural regeneration is ensured.

I.2.1.1 Logging is not authorized if the vertical stratification of forest is disturbed.

I.2.1.2 Light demanding (pioneer) species do not form dense stands within the forest.

I.2.1.3 Actions are taken to assure natural regeneration when necessary.

C.2.2 Negative impacts of various interventions on biodiversity are minimized.

I.2.2.1 Zones of biological protection where no interference is authorized are created in the permanent forest estate.

I.2.2.2 The size of biological reserves is adapted to suit the object of preservation.

I.2.2.3 Selection of biological preservation areas should take into account their potential for effective protection.

I.2.2.4 Special provisions for the protection of sensitive areas, plains, stream banks, steep slopes should be defined in the management plan.

I.2.2.5 The management plans of forest only provide for single - specie or exotic specie plantations when other types of silviculture action have been considered by forest management experts and abandoned for justified reasons.

I.2.2.6 If enrichment plantings are carried out in logged over forests, preferences will be given to species that were actually harvested in the forest.

I.2.2.7 Rare or endangered species are protected.

I.2.2.8 Non-timber forest products in high demand are the object of conservations and domestication trials.

C.2.3 The function of water filtration (protection of water and soils) of the forest is maintained.

I.2.3.1 Water system (regime) and quality do not decrease.

PRODUCTION OF GOODS AND SERVICES

P.3 AREAS DEVOTED TO FORESTRY ACTIVITIES OR THE PERMANENT FOREST ESTATE ARE NOT DECLINING.

C.3.1 Areas devoted to forestry activities or permanent forest estate are clearly delimited and their boundaries have been well established.

I.3.1.1 There exists a map showing the boundaries of the permanent forest estate.

I.3.1.2 The boundaries of the permanent forest estate are well marked in the field.

C.3.2 Efficient measures have been taken by the authorities to monitor the forest and to protect it against clearing, fire, settlements and illegal gathering of forest products.

I.3.2.1 There is a control mechanism (direct or delegated control, type and frequency of control) complied with by the forest service.

I.3.2.2 The procedure of control is followed by results. (Mission reports, case files, transactions, condemnations, etc…).

I.3.2.3 There is collaboration between the forestry service, agricultural service, public order authorities and other public services concerned in forest management.

C.3.3 The Government implements measures in order to promote the participation of various stakeholders (mainly neighboring villagers) in protecting the forest.

I.3.3.1 There is a direct, sustainable, efficient system to interest various stakeholders in protecting the forest against clearing, fires and poaching.

I.3.3.2 Programmes for the enlightenment and education of the rural population are implemented.

P.4 FORESTS ARE ADEQUATELY MANAGED AND DEVELOPED IRRESPECTIVE OF THEIR ROLE.

C.4.1 A management plan has been established for the sustainable management of the forest taking into account all its components and functions such as timber production, other forest products, contribution to the well-being of the local people, ecology.

I.4.1.1 There is a management plan comprising: (1) Definition of the forest area subjected to sustainable management (2) Key findings of studies and analyses on all the functions and uses of the forest (timber production, other forest products, farmer-forest relationship, forest ecosystem) (3) Definition of objectives in these various uses, their spatial organization and their hierarchy (4) Relevant action plans to meet these objectives (5) Reference to laws and regulations governing such actions (particularly the national directives on management) (5) Economic and financial evaluation (6) A set of maps allowing a clear summarized overview of the results of studied (vegetation map, forest settlement map, etc.), the objectives (map of working circles) and the action plans (map of blocks for harvesting, coupes, replanting, etc.).

I.4.1.2 Management is approved by the Minister in charge of forests.

I.4.1.3 Management is effectively implemented.

I.4.1.4 The follow-up and the control of the implementation of the management plan are done based on the information included in the appropriate documents.

C.4.2 Forestry service and other stakeholders of the sector have enough capacity to properly developed and manage the forest for all its roles (timber production, other forest products, ecology, farmer-forest relationship).

C.4.3 Standards for silviculture and other activities adapted to the specific ecology of the forest and ensuring sustainable management have been developed and are operational.

I.4.3.1 Adequate effort of investigation is undertaken to define, validate or adjust silviculture and work standards.

I.4.3.2 Silviculture and work standards are explicit and easy to implement, easy to control.

I.4.3.3 In the area of harvesting, the standards are explicit on: (1) Minimum number of large trees to be retained as seed producers (mother trees) per ha and species (2) Maximum number of trees to be harvested per ha (3) Harvesting techniques for large trees to be removed should be such as to avoid too large gaps (4) The minimum exploitable diameter for each species.

C.4.4 Planning and implementation of logging are carried out in conformity with guidelines of the management plan and the contract agreement based on technical and social standards as well as financial specifications.

I.4.4.1 Operational law-impact felling and skidding techniques are available.

I.4.4.2 Fully consistent with silviculture standards, and based on previous inventory, the area to be harvested over the management plan period is assessed and mapped.

I.4.4.3 Calculations of allowable cut and rotation period are clearly detailed in the management plan and are consistent with silviculture standards, increment data, prior inventory and harvestable areas, and are established at levels considered compatible with sustainable production of the forest.

I.4.4.4 The felling and work programme is operational, clear and realistic. Each harvest is subject to prior validation and design.

I.4.4.5 Felling programmes are adjusted rapidly if the change in data collected on the field is significantly different from that on which the manager's initial estimate is based. The management plan is amended to be consistent with the true data.

I.4.4.6 Trees to be felled are previously plotted on a map and marked. Their selection is in compliance with silviculture standards and protection measures specific to the particular coupe.

I.4.4.7 Trees to be felled are previously plotted on a map and conspicuously marked, prior to harvest.

I.4.4.8 Financial clauses, technical standards for logging and specific arrangements to protect the forest are clearly specified in the management plan compartment register.

I.4.4.9 The application of provisions of the contract agreement is to be assessed periodically. Non-compliance is penalized.

C.4.5 Deforested areas are regenerated by natural or artificial means.

I.4.5.1 Reforestation is implemented with chosen species in conformity with the specifications of the management plan.

C.4.6 Infrastructure (roads, bridges, firebreaks, etc…) is designed, established and maintained in such a way that negative impacts on the environment (forest, soil, water course network) are reduced to a strict minimum.

I.4.6.1 The planning and establishment of infrastructure (primary and secondary roads, timber yards, skidding tracks) takes into consideration the topography of the forest area and the needs of exploitation.

I.4.6.2 Sizes of infrastructure (primary and secondary roads, timber yards, skidding tracks) are reduced to the barest minimum possible.

I.4.6.3 Minimum infrastructure required for logging is made permanent.

C.4.7 Non timber forest products and their uses are identified.

C.4.8 Guidelines for rational harvesting of non-timber forest products are defined and put into practice.

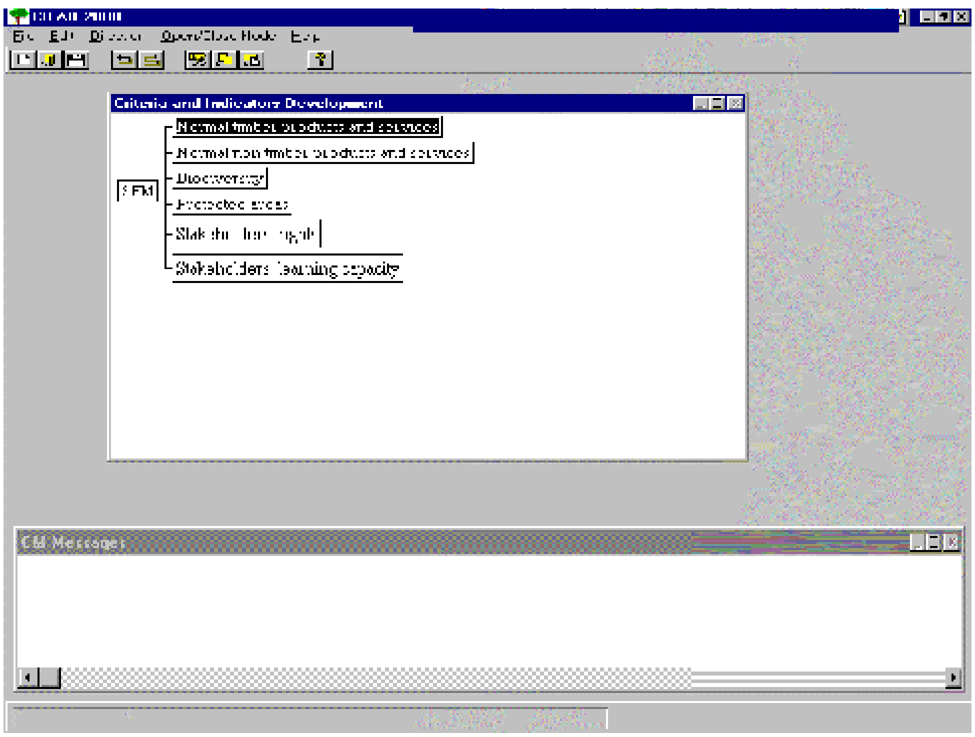
C.4.9 Research is undertaken in order to define the conditions for a sustainable use of non-timber forest products.

C.4.10 Guidelines for harvesting of non-timber forest products are monitored, evaluated and can be corrected if necessary.

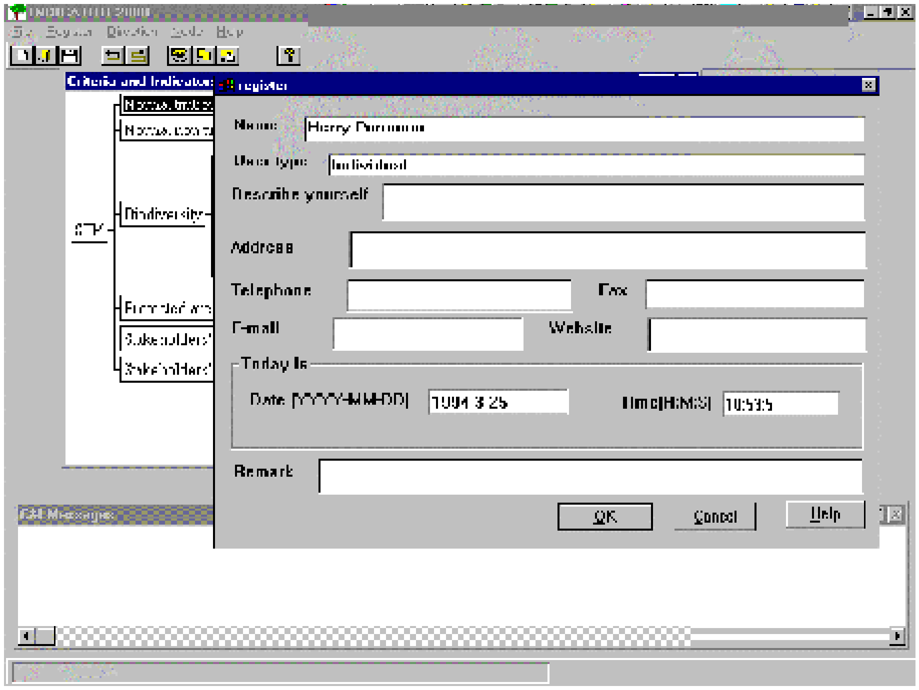
Appendix 3. The screen shows of the implementation of the built KBS

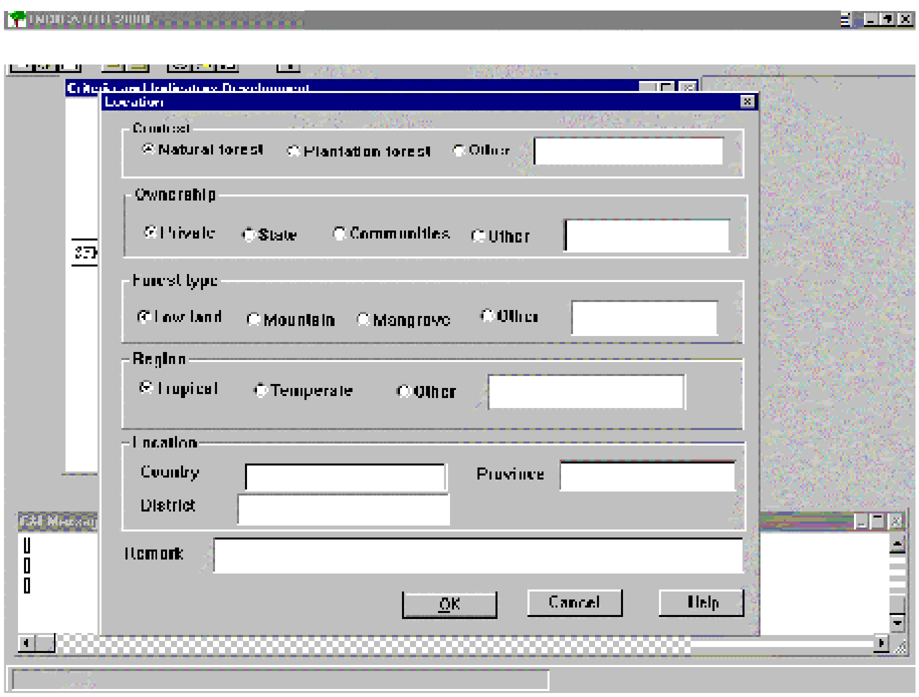
The Knowledge Base System was designed to be easily understood and used. Good interfaces allow users to maximize its capability in supporting the development and assessment criteria and indicators for sustainable forest management. Below are the main interfaces for the KBS.

a. Main Menu

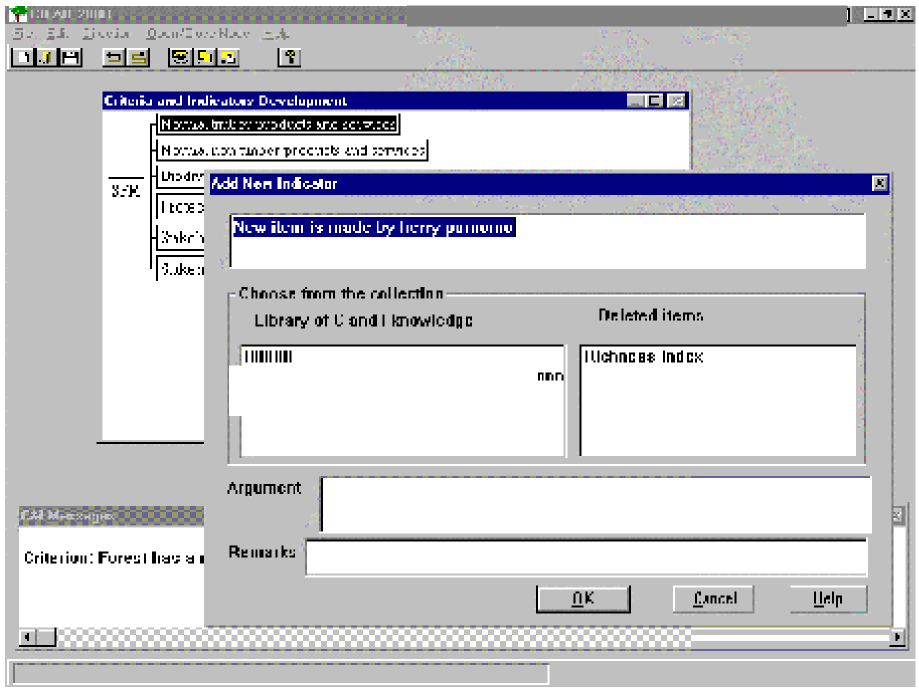


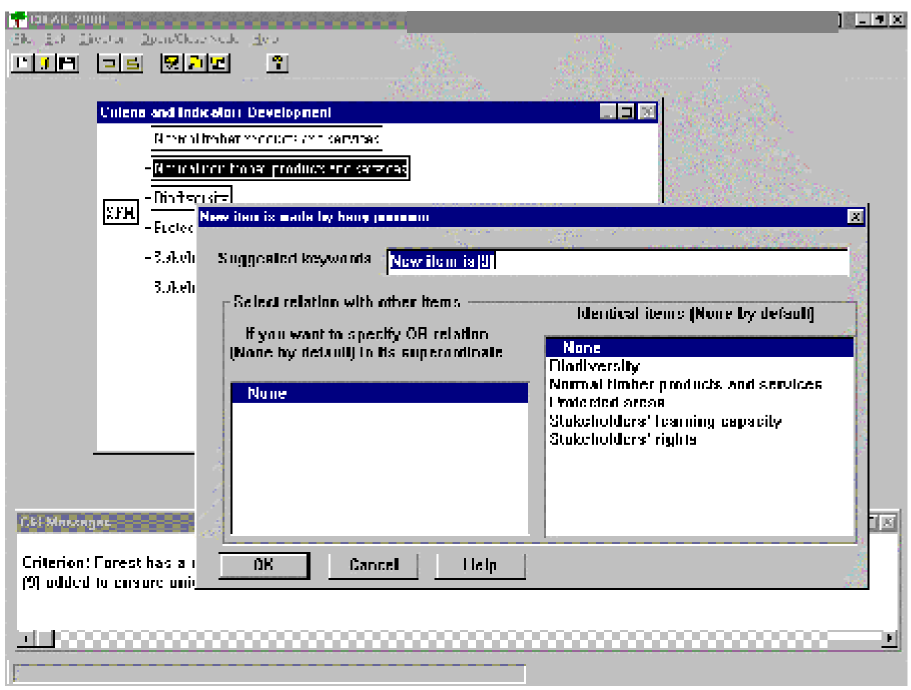
b. Registration



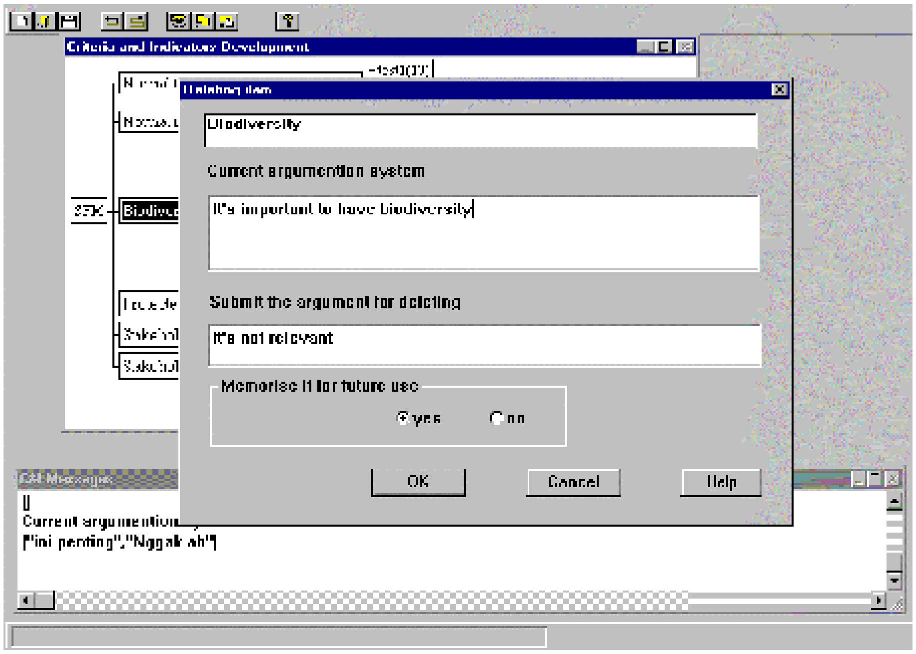


c. Dialog for Adding Criterion or Indicator

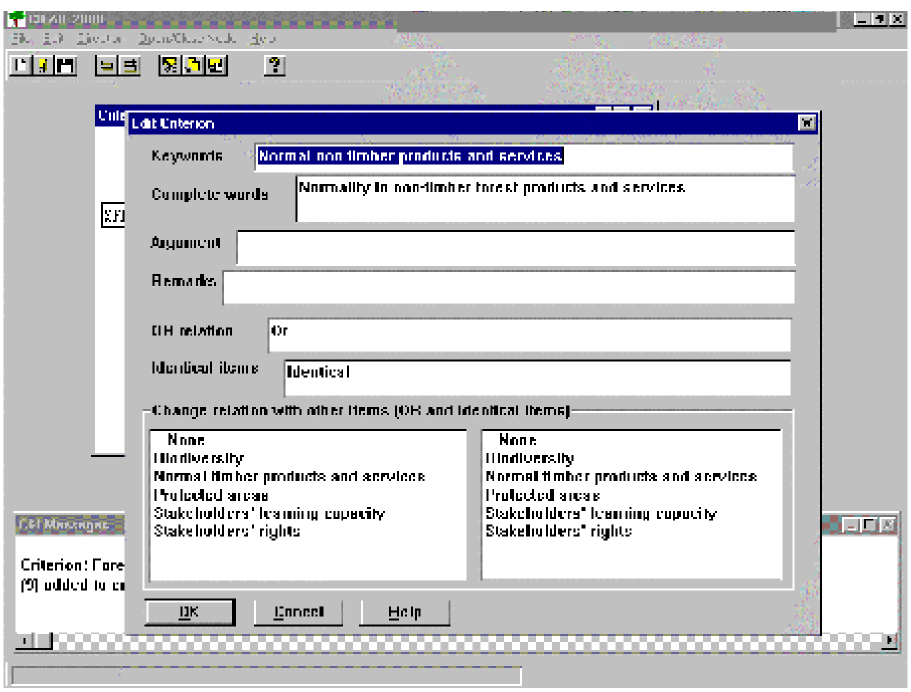




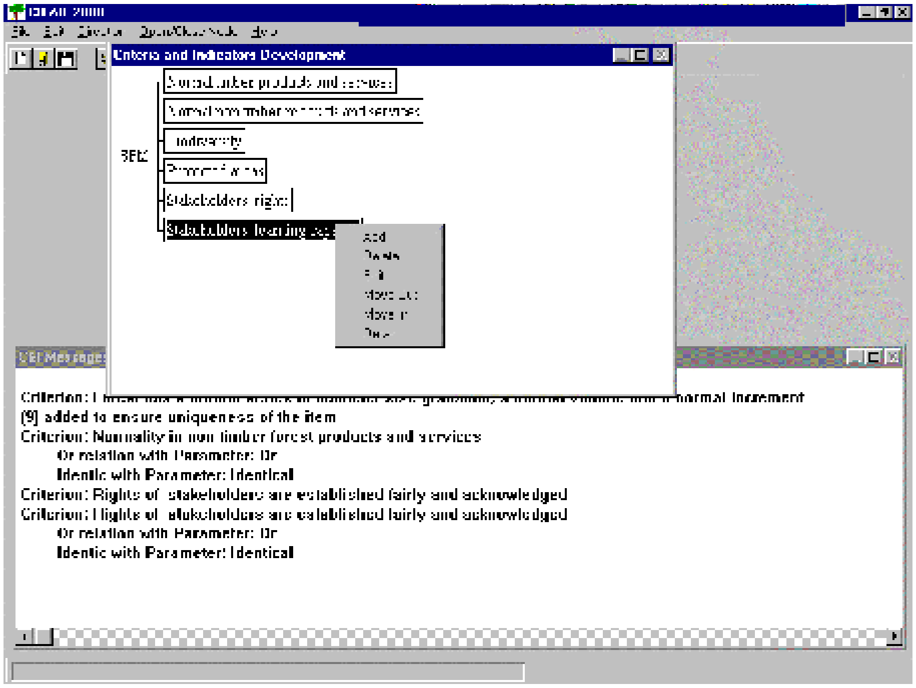
d. Dialog for Deleting Criterion or Indicator



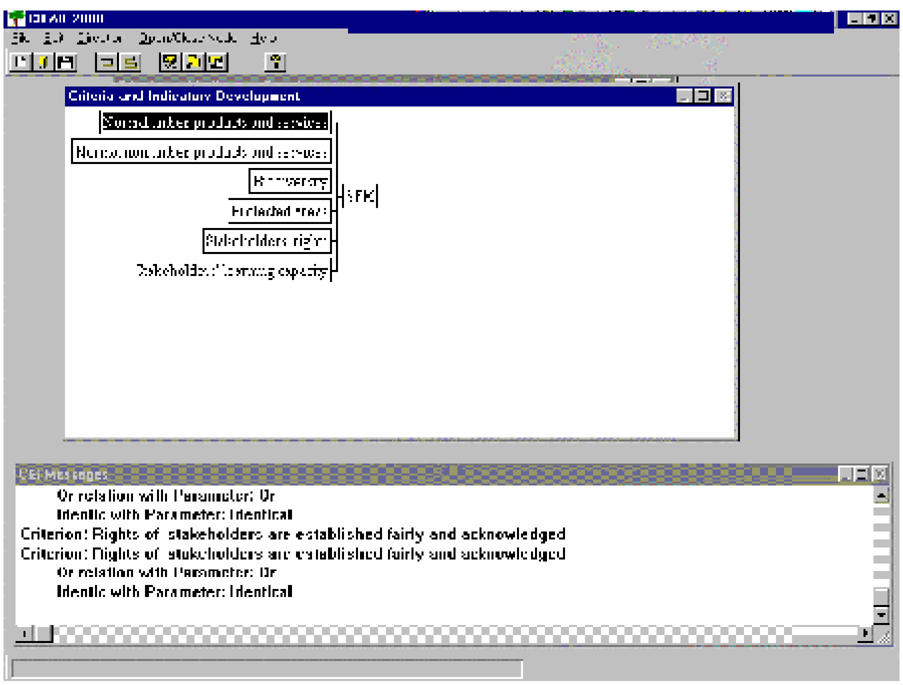
e. Dialog for Editing Criterion or Indicator



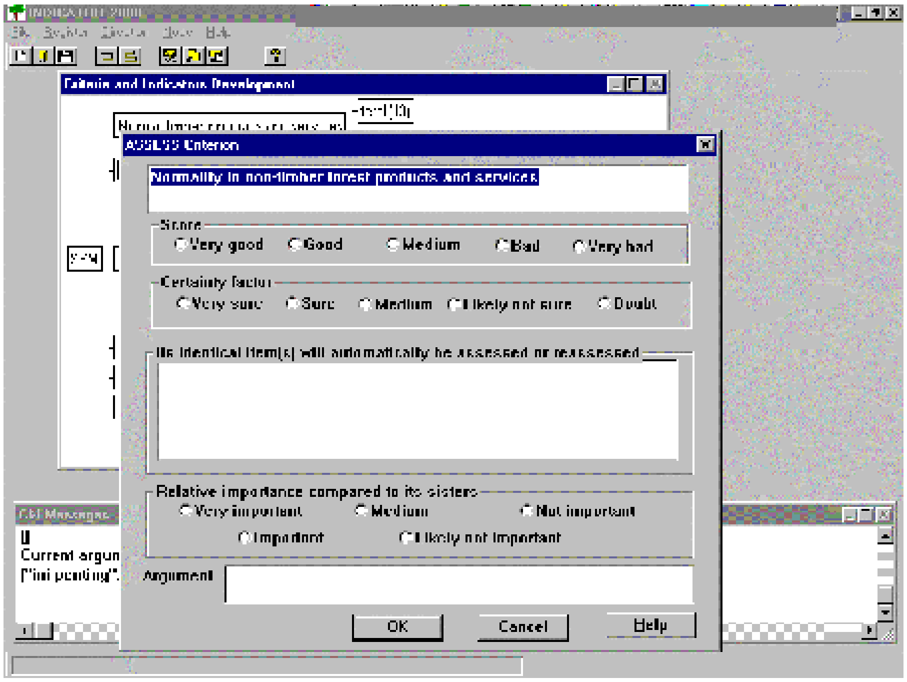
e. Detail Explanation of Criteria and Indicators



f. The Hierarchy of Decision Making Process



g. Direct Assessment



Appendix 4. The selected stakeholders' characteristics

Table 1. Stakeholders' secondary activities

Stakeholders	**Secondary Activity**	**Annually target**	**Area**	**Strategy**
Inhutani II	Community development	-	Villages	PMDH
Long Seturan	Collecting NTFP	-	FMU	Using traditional knowledge and tools
Long Loreh	Collecting NTFP	-	FMU	Using traditional knowledge and tools
Langap	Collecting NTFP	-	FMU	Using traditional knowledge and tools
Central Government	Provide information	-	FMU	Direct communication
Local Governments	Monitoring	-	FMU	Field observation

Table 2. Primary communication of the stakeholders

***Row* to *column* communication**	Inhutani II	Long Seturan	Long Loreh	Langap	Local Governments	Central Government
Inhutani II	x	PMDH	PMDH	PMDH	reporting	reporting
Long Seturan	Propose activities	x	Village boundaries	Village boundaries	Budgeting for village development	x
Long Loreh	Propose activities	Village boundaries	x	Village boundaries	Budgeting for village development	x
Tanjung Lapang	Propose activities	Village boundaries	Village boundaries	Village boundaries	Budgeting for village development	x
Langap	Propose activities	Village boundaries	Village boundaries	x	Budgeting for village development	x
Local Governments	monitor	coordination	coordination	coordination	x	coordination
Central Government	regulate	x	x	x	coordination	x

Note: 'x' is no communication between related stakeholders

Table 3. Focus group analysis

No	Stakeholder	Why is this group important?	What does this major user group do?				
			Role in Forest Management	Positive activities	Negative activities	Impacts of inclusion	Impacts of exclusion
1	Inhutani II	Has legal rights	Timber cutting and planting	Infrastructure development	Over cutting	Damage forest, erosion, infrastructure available	Better forest condition, less erosion, slow infrastructure development
2	Long Seturan	Live subsistent	Practice shifting cultivation and collecting NTFP	Collect NTFP wisely	Open too much virgin forest shifting cultivation	More opened forest	Less opened forest
3	Long Loreh	Live subsistent	Practice shifting cultivation and collecting NTFP	Collect NTFP wisely	Open too much virgin forest shifting cultivation	More opened forest	Less opened forest
4	Long Loreh	Live subsistent	Practice shifting cultivation and collecting NTFP	Collect NTFP wisely	Open too much virgin forest shifting cultivation	More opened forest	Less opened forest
5	Langap	Live subsistent	Practice shifting cultivation and collecting NTFP	Collect NTFP wisely	Open too much virgin forest shifting cultivation	More opened forest	Less opened forest
6	Local Governments	Has legal rights	Execute and monitor regulations	Develop good regulation	KKN	KKN will go on	No formal regulation in forest management
7	Central Government	Has legal rights	Provide regulations	Develop good regulation	KKN	KKN will go on	No formal regulation in forest management

Appendix 5. Digital maps used in the simulation

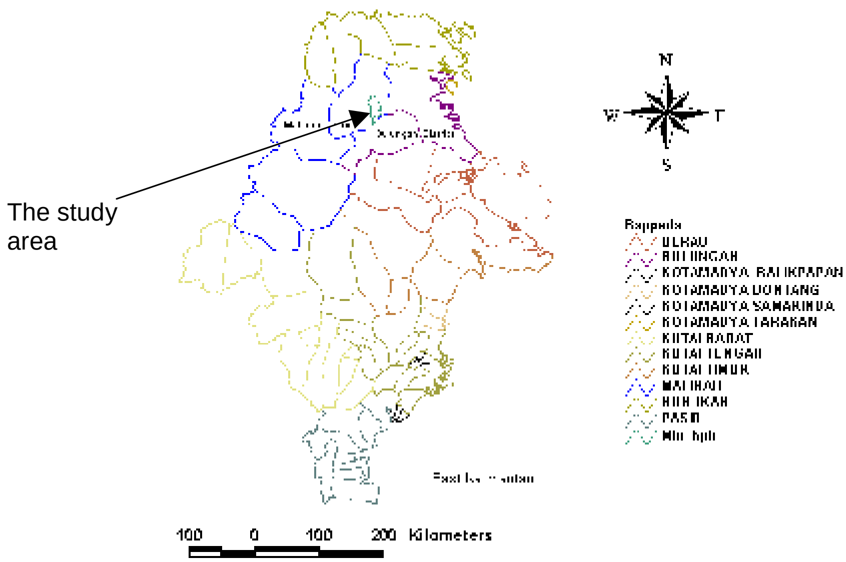


Figure 1. The study area in the East Kalimantan map

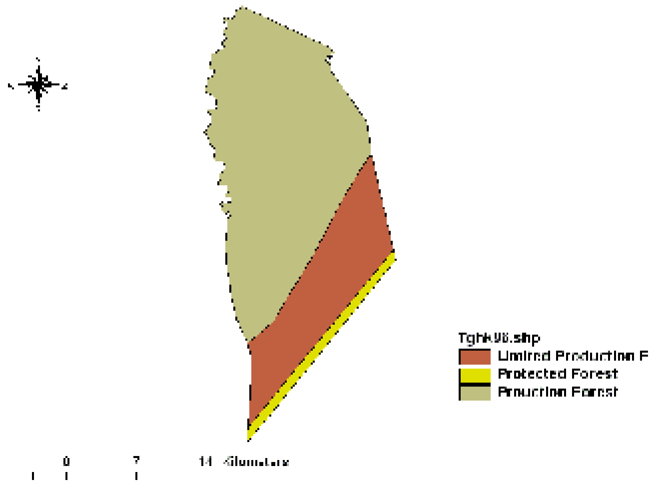


Figure 2. Forestland use agreement map

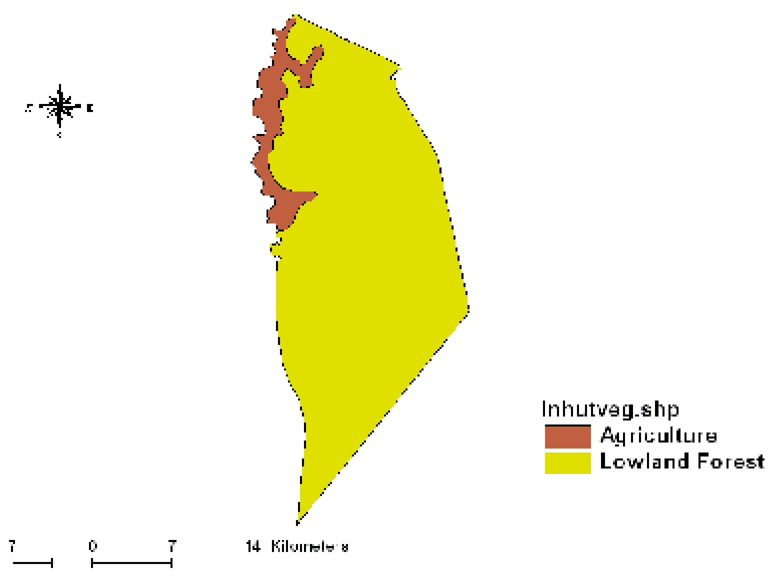


Figure 3. Vegetation map

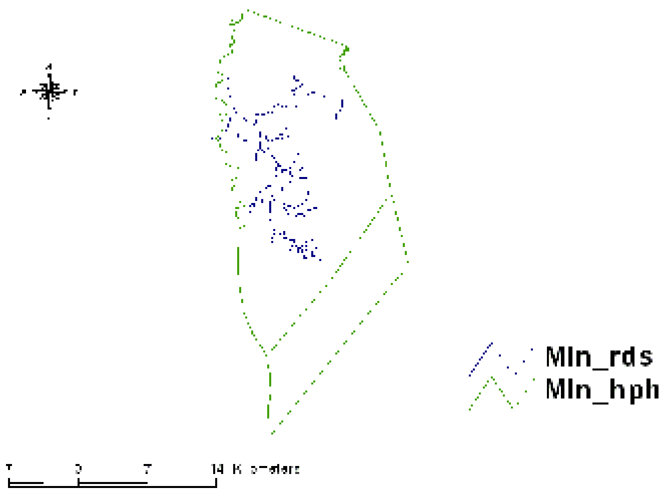


Figure 4. Main road map

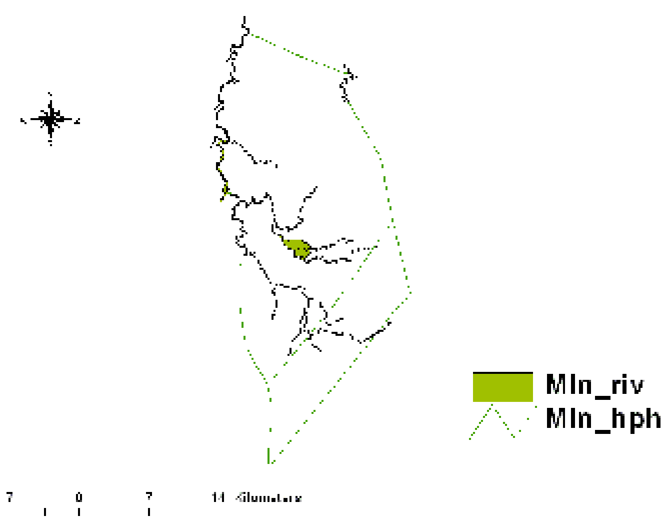


Figure 5. Main road map

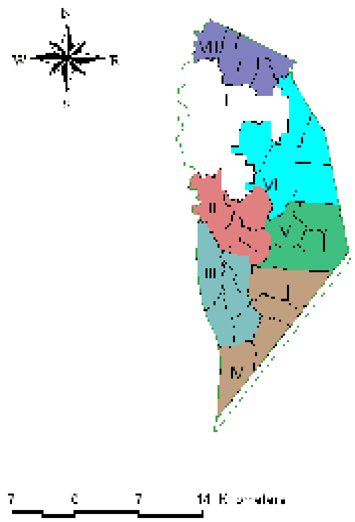


Figure 6. Five-year-plan map

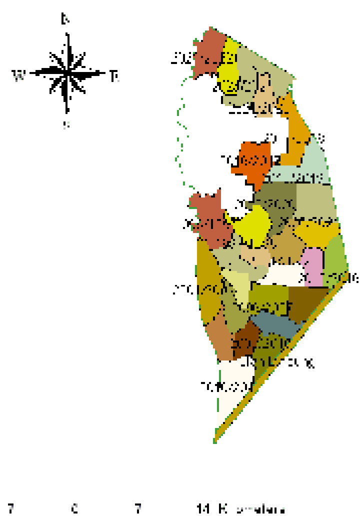


Figure 7. Annual plan map

Appendix 6. Costs and revenues of Inhutani II

Table. 1. Fixed investment

Element	Cost (xRp. 1000/Ha)
1. Master plan	8,835
2. Boundary mark	1,389
3. Five-year plan documents (I - IV)	4,000
4. Main road construction	96,000
5. Building	11,365
6. Fire protection	3,617
7. Vehicles purchasing	12,297
8. Exploitation tools	742,676
9. Communication tools	9,042
10. Electricity and water	18,083
11. Stationary	4,589
12. Tools for survey	900

Source: RKPH 1991/1992 – 2010/2011

Table. 2. Direct investment

Element	Cost (xRp. 1000/ha)
1. Working area establishment	25,000
2. Pre-logging inventory	20,000
3. Pre-logging field preparation (*pembukaan hutan*)	147,165
4. Exploitation	2,730,114
5. Post-logging liberation (*perapihan)*	30,000
6. Post-logging inventory	22,000
7. Liberation cutting I	30,000
8. Seedling procurement	36,000
9. Enrichment planting/rehabilitation	20,000
10. Planting road sides	20,000
11. Plant maintenance	48,000
12. Liberation cutting II	18,000
13. Liberation cutting III	18,000
14. Thinning I	50,000
15. Thinning II	50,000
16. Thinning III	50,000
17. Protection and Research & Development	45,000
18. Costs for Environmental plans	17,000
19. Community development	18,160

Source: RKPH 1991/1992 – 2010/2011

Table 3. Operational cost

Element	Cost (xRp. 1000/ha)
1. Annual year plan document	10,000
2. Building maintenance	1,130
3. Road maintenance	14,720
4. Vehicle maintenance	18,445
5. Tools replacement	74,270
6. Salary	273,420
7. General costs (office tools, traveling etc.)	45,210
8. Electricity and water cost and maintenance	5,425

Source: RKPH 1991/1992 – 2010/2011

Table 4. Timber cutting projection of Inhutani II (in thousand rupiah).

Budget year	Concession year	Area (ha)	Volume (m3)
1990/1991	1	878	45,101
1991/1992	2	887	45,592
1992/1993	3	874	44,937
1993/1994	4	802	41,232
1994/1995	5	789	40,518
1995/1996	6	1,937	99,519
1996/1997	7	1,182	60,731
1997/1998	8	717	36,835
1998/1999	9	687	35,321
1999/2000	10	826	42,438
2000/2001	11	1,940	99,671
2001/2002	12	806	41,419
2002/2003	13	1,113	57,201
2003/2004	14	1,076	55,316
2004/2005	15	888	45,645
2005/2006	16	1,477	75,921
2006/2007	17	1,616	83,050
2007/2008	18	1,220	62,693
2008/2009	19	1,631	83,792
2009/2010	20	2,494	128,159
2010/2011	21	1,397	71,794
Total		25,237	1,296,885

Source: RKPHS Inhutani II 1991/1992 – 2010/2011

Table 5. Cost distribution over 21 years

Budget year	**Concession year**	**Fixed investment**	**Logging Cost**	**Operational cost**	**Total Cost**
1990/1991	1	9,650,941	212,534	389,865	10,253,340
1991/1992	2	0	3,294,651	489,538	3,784,189
1992/1993	3	0	3,326,531	489,538	3,816,069
1993/1994	4	29,586	3,421,659	489,538	3,940,783
1994/1995	5	0	3,503,517	489,538	3,993,055
1995/1996	6	9,051,875	3,525,725	489,538	13,067,138
1996/1997	7	0	3,526,275	489,538	4,015,813
1997/1998	8	0	3,545,383	489,538	4,034,921
1998/1999	9	0	3,543,633	489,538	4,033,171
1999/2000	10	0	3,543,233	489,538	4,032,771
2000/2001	11	9,024,429	3,543,233	489,538	13,057,200
2001/2002	12	0	3,598,333	489,538	4,087,871
2002/2003	13	0	3,599,083	489,538	4,088,621
2003/2004	14	0	3,596,683	489,538	4,086,221
2004/2005	15	0	3,595,583	489,538	4,085,121
2005/2006	16	9,014,375	3,595,583	489,538	13,099,496
2006/2007	17	0	3,651,483	489,538	4,141,021
2007/2008	18	0	3,651,483	489,538	4,141,021
2008/2009	19	0	3,651,483	489,538	4,141,021
2009/2010	20	0	3,651,483	489,538	4,141,021
2010/2011	21	0	3,706,783	489,538	4,196,321
Total		36,771,206	71,284,354	10,180,625	118,236,185

Table 6. Logging Costs distribution over 21 years

Concession year	TPTI Cost	Exploitation cost	Other TPTI costs
1	212,534	0	212,534
2	3,294,651	2,989,644	305,007
3	3,326,531	2,989,644	336,887
4	3,421,659	2,989,644	432,015
5	3,503,517	2,989,644	513,873
6	3,525,725	2,989,644	536,081
7	3,526,275	2,989,644	536,631
8	3,545,383	2,989,644	555,739
9	3,543,633	2,989,644	553,989
10	3,543,233	2,989,644	553,589
11	3,543,233	2,989,644	553,589
12	3,598,333	2,989,644	608,689
13	3,599,083	2,989,644	609,439
14	3,596,683	2,989,644	607,039
15	3,595,583	2,989,644	605,939
16	3,595,583	2,989,644	605,939
17	3,651,483	2,989,644	661,839
18	3,651,483	2,989,644	661,839
19	3,651,483	2,989,644	661,839
20	3,651,483	2,989,644	661,839
21	3,706,783	2,989,644	717,139
	71,284,354	59,792,880	11,491,474

Appendix 7. The Smalltalk codes of the communities' reasoning and activities

```
Function:  Initiation of the communities
Smalltalk representation:

self mailBox: OrderedCollection new.
transaction:= OrderedCollection new.
belief := Dictionary new.
transaction:= OrderedCollection new.
ciSupernatural := OrderedCollection new.
ciSosec := OrderedCollection new.
ciBiophysic := OrderedCollection new.

ciSupernatural add:'respect supernatural spirits'; add: 'recognize natural signs'.
ciSosec add:'recognizing other stakeholders'; add: 'collaboration'.
ciBiophysic add:'there is fallow period'; add: 'normality of NTFP'.

belief at: #CIsupernatural put: ciSupernatural.
belief at: #CIsosec put: ciSosec.
belief at: #CIbiophysic put: ciBiophysic.
belief at: #Transaction put: transaction.
self beliefs: belief.

initDesires:= OrderedCollection new.
initDesires add:'to have better income'.
self desires: initDesires.
initIntentions:= OrderedCollection new.
initIntentions add: 'rice field practice'; add:'NTFP collection'.
self intentions: initIntentions.

experience := Dictionary new.
event := OrderedCollection new.       event add: 'noEvent'.
action := OrderedCollection new.       action add: 'noAction'.
feedback := OrderedCollection new. feedback add: 'noFeedback'.
experience at:#Event put:event.
experience at:#Action put:action.
experience at:#Feedback put:feedback.
```

Figure 1. Initiation of community agents

Function: to revise communities' beliefs
Smalltalk representation:

```
beliefRevision:eventQ
"B := brf(B,p)"
	| revisedBeliefs revisedTransaction |
	revisedBeliefs:= self beliefs.
	revisedTransaction:=  (self beliefExplore:eventQ).
	revisedBeliefs at: #Transaction put:  revisedTransaction.

	self beliefs: revisedBeliefs.


beliefExplore:eventQ
|eventCat sosecBeliefs currBeliefs bioBeliefs supraBeliefs consistency
newTransaction eventCatColl newTransactionColl |
currBeliefs := self beliefs.
eventCatColl := OrderedCollection new.

eventQ do:[:event|
		eventCat :=  self eventCategory:event.
		eventCatColl add:eventCat.].

sosecBeliefs := currBeliefs at:#CIsosec.
bioBeliefs := currBeliefs at:#CIbiophysic.
supraBeliefs := currBeliefs at:#CIsupernatural.

newTransactionColl:= OrderedCollection new.
eventCatColl do:[:ec |
	((sosecBeliefs includes:ec) | (bioBeliefs includes:ec) | (supraBeliefs
includes:ec))
		ifTrue:[consistency := #yes] ifFalse:[consistency := #no].
	(consistency == #yes) ifTrue:[newTransaction := #consistent]
ifFalse:[newTransaction := #notConsistent].
	newTransactionColl add:newTransaction. ].
```

Figure 2. Beliefs revision function smalltalk codes

```
Function:  to generate posiible options
Smalltalk representation:

optionGeneration
"D := options(B,I)"
"Desires could be consistent (=goals) and inconsistent, but without commitments"
"intentions are conditions that inevitably hold on each selected paths"

| currentBeliefs currentIntentions transactionBelief options temp |

options := OrderedCollection new.
currentBeliefs := self beliefs.
currentIntentions := self intentions.
transactionBelief := currentBeliefs at:#Transaction.

(transactionBelief first = #consistent)
ifTrue:
        [(currentIntentions  includes:'rice field practice')
        ifTrue:
                [options add:'rice field practice']
        ].

temp:=transactionBelief.
"temp removeFirst."
(temp first = #consistent)
ifTrue:
        [(currentIntentions  includes:'NTFP collection')
        ifTrue:
                [options add:'NTFP collection']
        ].

(transactionBelief last = #consistent)
ifTrue:
        [(currentIntentions  includes:'co-logging')
        ifTrue:
                [options add:'colaboration']
        ].

self desires: options.
```

Figure 3. Options generation smalltalk codes

Function: to choose intentions among available options
Smalltalk representation:

```
filter
"I := filter(B,D,I)"
"Itentions are chosen options and the agent is committed "
| currentBeliefs currentDesires currentIntentions revisedIntentions transactionBelief
temp |
currentBeliefs := self beliefs.
currentDesires := self desires.
currentIntentions := self intentions.
revisedIntentions:= OrderedCollection new.
transactionBelief := currentBeliefs at:#Transaction.

(transactionBelief first = #consistent)
ifTrue:
        [(currentDesires includes:'rice field practice')
        ifTrue:
                [(currentIntentions includes:'rice field practice')
                ifTrue:
                        [ revisedIntentions add:'rice field practice'.  ]
                ]
        ].
temp:=transactionBelief.
"temp removeFirst."
(temp first = #consistent)
ifTrue:
        [(currentDesires includes:'NTFP collection')
        ifTrue:
                [(currentIntentions includes:'NTFP collection')
                ifTrue:
                        [ revisedIntentions add:'NTFP collection'.]
                ]
        ].
(transactionBelief last = #consistent)
ifTrue:
        [(currentDesires includes:'colaboration')
        ifTrue:
                [(currentIntentions includes:'co-logging')
                ifTrue:
                        [ revisedIntentions add:'co-logging'.]
                ]
        ].
self intentions: revisedIntentions.
```

Figure 4. Options filtering smalltalk codes

```
Function:   to select action(s) among available intentions
Smalltalk representation:

actionSelection:m on:fmu at:t
"execute intention(s)"
| currentIntentions actionColl |
currentIntentions := self intentions.
actionColl := self action.

actionColl add:t.
(currentIntentions includes:'co-logging')
        ifTrue:[self cologging:m on:fmu at:t.  actionColl add:'co-logging' ].
(currentIntentions includes:'rice field practice')
        ifTrue:[self ricefieldPractice:t.  actionColl add:'rice field practice'].
(currentIntentions includes:'NTFP collection')
        ifTrue:[self collectNTFP.  actionColl add:'NTFP collection'].

self action: actionColl.
```

Figure 5. Action selection smalltalk codes

```
Function:   to update  intentions
Smalltalk representation:

updateIntention:event

| currentIntentions currBeliefs sosecBeliefs bioBeliefs supraBeliefs eventCat |

currentIntentions := self intentions.
currBeliefs := self beliefs.

eventCat := self eventCategory:event.
sosecBeliefs := currBeliefs at:#CIsosec.
bioBeliefs := currBeliefs at:#CIbiophysic.
supraBeliefs := currBeliefs at:#CIsupernatural.

((sosecBeliefs includes:eventCat) | (bioBeliefs includes:eventCat) | (supraBeliefs
includes:eventCat))
                ifTrue:[currentIntentions add:'co-logging'].

self intentions: currentIntentions.
```

Figure 6. Intention updating smalltalk codes

```
Function:   Rice field practice
Smalltalk representation:

ricefieldPractice:t
| currentRiceFieldSites rotation  currentRiceFieldSites1 currentRiceFieldSites2 size1
size2 |
"there are two possibilities in doing ricefieldPractice, whether they back to the previous
field (assumed 5-year rotation) or open new forest"

rotation := 5.

t\\rotation=1  ifTrue: [
"t>1 ifTrue:[currentRiceFieldSites do: [:c|c ladangGrow]]."
currentRiceFieldSites1 := (self riceFieldArea select:[:x|x riceFieldRotationTh =1])
asOrderedCollection.
size1 := currentRiceFieldSites1 size.
size1 >0 ifTrue:[
                                        currentRiceFieldSites1  do:
                                                  [:s| self leave.  self moveTo: s.
                                                  self openOrNot]]
                    ifFalse: [self openNewLadang].
                    ].

t\\rotation= 2 ifTrue: [
"t>1 ifTrue:[currentRiceFieldSites do: [:c|c ladangGrow]]."
currentRiceFieldSites2 := (self riceFieldArea select:[:x|x riceFieldRotationTh =2])
asOrderedCollection.
size2 := (currentRiceFieldSites2 size).
size2 > 0 ifTrue:[
 currentRiceFieldSites2  do:
          [:p| self leave.  self moveTo: p. self openOrNot]]
                    ifFalse: [self openNewLadang].
                    ].

t\\rotation = 3 ifTrue: [
currentRiceFieldSites := (self riceFieldArea select:[:x|x riceFieldRotationTh =3])
asOrderedCollection.
currentRiceFieldSites size > 0
          ifTrue:[
                    1 to: currentRiceFieldSites size do:
                    [:s| self leave.  self moveTo: (currentRiceFieldSites at:s). self
openOrNot.]]
          ifFalse: [self openNewLadang].
                    ].
```

Figure 7. Rice field practice smalltalk codes

```
t\\rotation = 4 ifTrue: [
currentRiceFieldSites := (self riceFieldArea select:[:x|x riceFieldRotationTh =4])
asOrderedCollection.
currentRiceFieldSites size > 0
           ifTrue:[
                    1 to: currentRiceFieldSites size do:
                    [:s| self leave.  self moveTo: (currentRiceFieldSites at:s). self
openOrNot.]]
          ifFalse: [self openNewLadang].
                    ].

(t\\rotation = 0) & (t>1) ifTrue: [
currentRiceFieldSites := (self riceFieldArea select:[:x|x riceFieldRotationTh = 5])
asOrderedCollection.
currentRiceFieldSites size > 0 ifTrue:[
1 to: currentRiceFieldSites size do:
          [:s| self leave.  self moveTo: (currentRiceFieldSites at:s). self openOrNot.]]
                    ifFalse: [self openNewLadang].
                    ].
self riceFieldIncome.
```

Figure 8. Rice field practice smalltalk codes (continued)

```
Function:   Rice field practice
Smalltalk representation:

collectNTFP
          | collect ntfpIncome |
          "hunting, rattan collecting, fishing, eagle wood collecting"
          collect := (self  perception:5)  asOrderedCollection.
          collect removeAllSuchThat:[:n|n landDynamic ~= 1 ].

          (collect isEmpty)
                    ifTrue: ["self halt"]
                    ifFalse:[
                    "destination := Cormas selectRandomlyFrom: collect.
                    self leave. self moveTo: destination."

          "income from  hunting,  fishing, eagle wood collecting (langap HH survey)"
                    ntfpIncome:= 112667.
                    self income: self income + ntfpIncome].
```

Figure 9. NTFP collection smalltalk codes

Function: collaborative logging between communities and Inhutani II
Smalltalk representation:

```
cologging:m on:fmu at:t

| theSender mShare areaComanage |
areaComanage := m object.
areaComanage do:[:a| a vegetation: 7].

self calculateCuttingVolume:areaComanage at:fmu.
self income: areaComanage size.

"(t\\35 = 5) & (t//35 = 1)"
t>=1
ifTrue:[
theSender := m sender.
 mShare:= ActorsMessage new.
                                mShare symbol: #moneyCollaboration; object: m object;
amount: 0; sender: self; receiver: theSender.
                               self sendMessageAsynchronously: mShare.
          ]
```

Figure 10. Collaborative logging Smalltalk codes