ปฏิสัมพันธ์ระหว่างการเลี้ยงวัวและการปลูกป่า ในระบบสังคม-นิเวศพื้นที่สูงจังหวัดน่าน ภาคเหนือของประเทศไทย: กระบวนการแบบจำลองเพื่อนคู่คิดเพื่อปรับปรุงการจัดการภูมิทัศน์

นายพงษ์ชัย ดำรงโรจน์วัฒนา

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
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INTERACTIONS BETWEEN CATTLE RAISING AND REFORESTATION IN THE HIGHLAND SOCIO-ECOSYSTEM OF NAN PROVINCE, NORTHERN THAILAND: A COMPANION MODELLING PROCESS TO IMPROVE LANDSCAPE MANAGEMENT

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A Dissertation Submitted in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy Program in Agricultural Technology
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Thesis Title	INTERACTIONS BETWEEN CATTLE RAISING AND REFORESTATION IN THE HIGHLAND SOCIO-ECOSYSTEM OF NAN PROVINCE, NORTHERN THAILAND: A COMPANION MODELLING PROCESS TO IMPROVE LANDSCAPE MANAGEMENT
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Field of Study	Agricultural Technology
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พงษ์ชัย ดำรงโรจน์วัฒนา : ปฏิสัมพันธ์ระหว่างการเลี้ยงวัวและการปลูกป่า ในระบบสังคม-นิเวศพื้นที่สูงจังหวัดน่าน ภาคเหนือของประเทศไทย: กระบวนการแบบจำลองเพื่อนคู่คิดเพื่อปรับปรุงการจัดการภูมิทัศน์ (INTERACTIONS BETWEEN CATTLE RAISING AND REFORESTATION IN THE HIGHLAND SOCIO-ECOSYSTEM OF NAN PROVINCE, NORTHERN THAILAND: A COMPANION MODELLING PROCESS TO IMPROVE LANDSCAPE MANAGEMENT) อ. ที่ปรึกษาวิทยานิพนธ์หลัก : รองศาสตราจารย์ ดร. นันทนา คชเสนี, อ. ที่ปรึกษาวิทยานิพนธ์ร่วม : Guy Trébuil, Ph.D., 330 หน้า.

การขยายตัวของพื้นที่อนุรักษ์และพื้นที่ปลูกป่าในพื้นที่ต้นน้ำทางภาคเหนือของประเทศไทยที่เคยได้รับผลกระทบอย่างรุนแรงจากการตัดไม้ทำลายป่าในช่วงหลายทศวรรษที่ผ่านมา ส่งผลให้เกษตรกรท้องถิ่นต้องมีการปรับตัวอย่างรวดเร็วและทำให้เกิดความขัดแย้งด้านการใช้ประโยชน์ที่ดินระหว่างเกษตรกรและเจ้าหน้าที่ป่าไม้ โดยเฉพาะประเด็นผลกระทบของการเลี้ยงวัวต่อการฟื้นฟูป่าไม้ งานวิจัยนี้ใช้กระบวนการแบบจำลองเพื่อนคู่คิด ซึ่งเป็นแบบจำลองเชิงบูรณาการที่มีการวิเคราะห์เชื่อมโยงหลายลำดับขั้น ร่วมกับเกษตรกรชาวเขาเผ่าม้งที่เลี้ยงวัวและเจ้าหน้าที่ป่าไม้ในจังหวัดน่าน เพื่อลดข้อขัดแย้งของปัญหาการใช้ประโยชน์ที่ดินเพื่อการเลี้ยงวัวและปลูกป่า การศึกษาแบ่งออกเป็น 3 ขั้นตอนโดยใช้การเล่นเกมสวมบทบาทสมมุติร่วมกับคอมพิวเตอร์ (computer-assisted role-playing game) เป็นเครื่องมือหลักซึ่งมีการพัฒนาร่วมกับผู้มีส่วนเกี่ยวข้องตลอดกระบวนการ โดยมีเป้าหมายเพื่อ i) ปรับปรุงการสื่อสาร แลกเปลี่ยนองค์ความรู้และสร้างความไว้วางใจระหว่างเกษตรกรและเจ้าหน้าที่ป่าไม้ ii) จำลองสถานการณ์การปลูกหญ้าเลี้ยงสัตว์และการหมุนเวียนพื้นที่เลี้ยงวัว โดยเกษตรกรสามารถตัดสินใจด้วยตนเองหรือตัดสินใจร่วมกับเกษตรกรรายอื่น ๆ และ iii) แนะนำเกษตรกรแผนการสร้างแปลงหญ้ารูซี่ (*Brachiaria ruziziensis*) เพื่อพัฒนาการเลี้ยงวัว ผลการวิเคราะห์ปฏิสัมพันธ์ให้คุ้นเคยกับแบบจำลองในคอมพิวเตอร์เพื่อทดสอบสถานการณ์จำลองต่าง ๆ ที่เกษตรกรสนใจ การผสานองค์ความรู้จากผู้มีส่วนเกี่ยวข้องตลอดกระบวนการการสร้างแบบจำลองอย่างมีส่วนร่วมนี้ นำไปสู่การสร้างแบบจำลองพาคีในคอมพิวเตอร์ (agent-based model) เพื่อทดสอบสถานการณ์จำลองในห้องปฏิบัติการเพื่อติดตามการเปลี่ยนแปลงประชากรวัว และพื้นที่ปลูกป่า ผลการศึกษานี้แสดงให้เห็นว่ากระบวนการแบบจำลองเพื่อนคู่คิดสามารถทำให้ผู้มีส่วนเกี่ยวข้องสองกลุ่มที่มีความขัดแย้งกัน ได้พูดคุยและสร้างข้อตกลงร่วมกันในการวางระหว่างผู้มีส่วนเกี่ยวข้องและองค์ความรู้ที่ได้รับนำไปสู่งานวิจัยในอนาคต ได้แก่ การนำแบบจำลองคอมพิวเตอร์ไปใช้กับพื้นที่อื่น ๆ ที่มีความขัดแย้งด้านการเลี้ยงวัว โดยทดสอบสถานการณ์จำลองต่าง ๆ เพื่อเสริมสร้างการเรียนรู้ ตลอดจนใช้การเล่นเกมสวมบทบาทสมมุติร่วมกับคอมพิวเตอร์ ที่ได้พัฒนาระหว่างกระบวนการ ไปใช้ในด้านการสอนและฝึกอบรมผู้มีส่วนเกี่ยวข้องในการจัดการทรัพยากรธรรมชาติแบบฟื้นสภาพโดยเฉพาะในพื้นที่ชนบท

สาขาวิชา เทคโนโลยีการเกษตร ลายมือชื่อนิสิต พงษ์ชัย ดำรงโรจน์วัฒนา

ปีการศึกษา 2552 ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก

ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์ร่วม

4873875723 : MAJOR AGRICULTURAL TECHNOLOGY
KEYWORDS : COMPANION MODELLING / FOREST MANAGEMENT / CATTLE RAISING / VEGETATION DYNAMICS / NORTHERN THAILAND

PONGCHAI DUMRONGROJWATTHANA : INTERACTIONS BETWEEN CATTLE RAISING AND REFORESTATION IN THE HIGHLAND SOCIO-ECOSYSTEM OF NAN PROVINCE, NORTHERN THAILAND: A COMPANION MODELLING PROCESS TO IMPROVE LANDSCAPE MANAGEMENT. THESIS ADVISOR : ASSOCIATE PROFESSOR NANTANA GAJASENI, Ph.D., THESIS CO-ADVISOR : GUY TRÉBUIL, Ph.D., 330 pp.

The expansion of protected and reforestation areas in the head watersheds of northern Thailand, a region severely affected by deforestation during the past decades, is forcing the local farms to adapt rapidly and is at the origin of frequent land use conflicts between farmers and foresters. If the former state that cattle grazing is having a positive effect on forest regeneration, the latter disagree. Based on an interdisciplinary and multi-scale diagnostic analysis, the thesis presents the conception and implementation of a companion modelling (ComMod) process, involving different types of Hmong herders and two government forest agencies, that was designed to mediate such a local land use conflict in Nan province. Three successive sequences of collaborative modelling and simulation activities relying on as many versions of a computer-assisted role-playing game adapted to the evolution of the participants focus of interest were implemented to (i) improve communication, knowledge exchange, and trust between herders and foresters, (ii) simulate the introduction of artificial pastures in the local forest – farm land interface, in association or not with the rotation and collective management of the herds, and (iii) introduce the herders to the use of simulations to explore possible future land use scenarios in their village. Following this collaborative modelling and knowledge integration process, an autonomous agent-based model was built and used to explore, in the laboratory at this stage, several scenarios proposed by the local stakeholders regarding the evolution of livestock rearing practices facing reforestation efforts and the establishment of a new national park. We show how the ComMod process was able to reconcile the two conflicting parties and facilitated the joint adoption of a common action plan relying on an experiment to assess the management of *Brachiaria ruziziensis* pastures under highland environmental conditions. The analysis of interactions between the different types of participants and sources of knowledge involved in this modelling process leads to the proposition of several follow-up activities. One consists in out-scaling this kind of learning by simulating exercises with other communities facing similar land use conflicts, and another deals with the use of the family of models co-constructed with the local stakeholders in teaching and training future renewable resource managers in rural areas.

Field of Study : Agricultural Technology Student's Signature Dumrongrojwatthana P.

Academic Year : 2009 Advisor's Signature ....

Co-Advisor's Signature ....

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LIST OF ABBREVIATIONS

ABM	Agent-Based Model
AGB	Above-Ground Biomass
ARDI	Actors-Resources-Dynamics-Interactions
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement
ComMod	Companion Modelling
CORMAS	Common-Pool Resource and Multi-Agent Systems
CPWF	Challenge Programme on Water and Food
cRPG	Computer-assisted Role-Playing Game
DLD	District Livestock Development
DT-ABM	Doi Tiew Agent Based Model
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographic Information System
LUCC	Land use and land cover change
MAS	Multi-Agent Systems
NKU	Nam Khang Headwater Development and Conservation Unit
NNP	Nanthaburi National Park
RFD	Royal Forest Department
RPG	Role-Playing Game
RTG	Royal Thai Government
RS	Remote Sensing
TAO	Tambon (sub-district) Administrative Organisation
UML	Unified Modelling Language

CHAPTER I
INTRODUCTION

1.1. Justification of research

Forest loss and degradation are important renewable natural resource problems, especially in developing countries, including Thailand, due to the combination of driving forces from bio - physical processes and socio - economic and political factors. Compared with neighbouring countries, such as Lao P.D.R. and Vietnam, Thailand experienced rapid deforestation (FAO, 2006a). Several factors were involved, especially the Royal Thai Government policies (RTG). More than one century ago, expansion of rice growing areas for export and logging by foreign companies were important causes of deforestation and forest degradation (Delang, 2002). Since the establishment of the Royal Forest Department (RFD) in 1896, forest resources still played an important role in the State revenue for national development. Economic tree species continued to be extracted but under a more scientific based management policy than in the past. After the end of World War II, new economic development policies were implemented, such as the promotion of annual cash crops like maize, soybeans and cassava, as well as others, followed by the subsequent promotion of fruit trees (litchi, longan, mango, etc.), which stimulated more forest encroachment and conversion of forest to farm land. Coupled with the population growth, more and more were expanded from the lowlands to the uplands and highlands. During 1970s, the RTG policy against communist insurgents was another factor influencing deforestation. Infrastructures such as roads were built to give access to the highlands to deny the establishment of insurgent's bases. While deforestation and forest degradation continued until the late 1980s, forest management policies were not concentrated on conservation. Forested areas fell sharply from a total of 27.3 million ha (53.33% of the total land area) in 1961 to 14.4 million ha (28.03% of the total land area) in 1988, equal to a deforestation rate of 463,664 ha/year (Royal Forest Department, 2009).

In 1989, the RTG forest management policy shifted to a more conservation-oriented framework instead of the economic-oriented one, due to the flash flood calamity in the Southern Thailand. A national policy on logging ban was announced. Thereafter, more conservation areas (e.g. national parks, forest parks, headwater management units, etc.) were established to preserve the existing forest and recover degraded areas, especially in the highlands where headwater forests are located. However, forest cover still decreased, but at a slower rate. Thus, forest cover decreased gradually from 14.3 million ha (27.95% of the total land area) in 1989 to 12.8 million ha (25.10% of the total land area) in 1999, an average rate of 132,918 ha/year.

The RFD has usually implemented a top-down policy to declare conservation areas without consulting local people. As a result, thousands of people, especially upland farmers and hill tribe’s people, are occupying these areas illegally and are blamed as forest encroachers (Roth, 2004). Moreover, those people’s livelihoods are impacted due to the fact that most of them depend on farm land and non-timber forest products. Since the policy of expansion of conservation areas has been more strictly implemented, it has created more conflict between the RFD and local communities due to their different perceptions and objectives in managing the land resources for conservation and farming, respectively.

Although the conservation areas are increasing, the total forest cover is still decreasing. For example, it decreased from 17 million ha in 2000 to 15.8 million ha in 2006 (Royal Forest Department, 2007). Thus, the establishment of conservation areas has not been sufficiently effective enough to preserve or increase the forest cover. Additional new management frameworks are obviously needed. In recent years, the RTG adopted a new policy to local administrative bodies, especially the Tambon (sub-district) administrative organizations (TAO) created in 1994 in which each village of the sub-district is represented by elected villagers. But villagers still have a limited involvement in decision-making process. In most cases, they are involved only in the public hearing processes or voted on projects already decided by local administrative bodies. Only in a few cases, they were asked about their needs and were involved in the whole process from monitoring and evaluation activities. Therefore, there is a need for innovative participatory approaches which can facilitate communication and dialogue among stakeholders and support collective learning and decision making to improve the resilience and adaptive management capacity of stakeholders.

1.2. Choice of research approach

Recently, collaborative modelling as a type of participatory management approach has been widely used in the field of integrated natural resource management (Renger, 2008; Epstein, 2008). Among several types of collaborative modelling approaches, the innovative Companion Modelling (ComMod) was selected due to its adaptability and suitability to the context of the study site. ComMod belongs to a family of trans-disciplinary participatory modelling approaches. It allows the integration of different types of knowledge (scientific, technical expert and empirical/indigenous) and contributions from different disciplines (mainly social and ecological ones). It aims at developing simulation models, Role-Playing Game (RPG) and associated computer Agent-Based Model (ABM), to facilitate dialogue and shared learning through iterative but evolving cycles of modelling and simulation activities alternating complementary field and laboratory activities. ComMod relies on several key theoretical references such as the science of complexity, constructivist epistemology, post-normal science, resilience and adaptive management, and collective management of multi-actor processes.

1.3. Study site and resource management context: The highlands of Nan province

The highest number of forest conservation areas in the country is found in northern Thailand. Conflicts between government agencies and local people are still common in this region, as in the case of land use conflict in the highland village of Ban Doi Tiew in Tha Wang Pha District, Nan Province, due to the establishment of the Nam Khang Headwater Development and Conservation unit (NKU) and the Nanthaburi National Park (NNP).

Ban Doi Tiew is a Hmong village that was legally registered in 1961. In the past, Hmong farmers cultivated upland rice and maize for family consumption under shifting cultivation practice with long fallow (up to 12 years) periods. They also practiced extensive cattle rearing as a form of household saving and capital accumulation. Since the establishment of the NKU in 1990 and of the NNP in 1996, the agricultural system has been changing due to forest management policies, leading to the limitation of agricultural area and consequently shortening of fallow (2-3 years) periods. Cattle rearing is not allowed anymore in the conservation areas managed by the NNP and NKU. As this limitation of agriculture production does not allow them to meet their subsistence needs, some villagers seasonally migrated to cities to look for employment, while the remained still to raise large herds of cattle.

While extensive cattle rearing is important for highland farmers, there is little research on integrating vegetation dynamics and socio-economic aspects to improve the forest-farm land management. Therefore, the research on the cattle raising in Doi Tiew village is needed to provide better understanding of the interaction between cattle grazing, forest regeneration and stakeholder's decision making. There was no dialogue on collaborative management between the farmers and the foresters, due to their contrasted perceptions about the effects of cattle rearing and reforestation on forest regeneration. Moreover, the setting up of an appropriate learning and negotiation platform could be an important mechanism to involve the concerned stakeholders into a process of collective and adaptive agro-ecosystem management. Therefore, it is relevant to implement a ComMod process at this study site.

1.4. Research questions and hypotheses

Based on the natural resource management context at the study site, the general question of this research was as follows: "Can the ComMod approach improve mutual understanding and sharing of perceptions of the interactions between cattle raising and reforestation by building a shared representation of the system to be managed, integrating empirical/indigenous, scientific and technical knowledge with the main types of concerned stakeholders?"

Following the general question, more specific questions include:

1. What are the effects of the establishment of reforestation units and the new Nanthaburi National Park on the Doi Tiew agrarian system, and *vice versa*?
2. Through what processes do cattle rearing and reforestation activities affect the above-ground biomass (AGB) dynamics in relation to forest recovery? How much and how fast?
3. Can a ComMod process mitigate the land use conflict between herders and foresters by using the tools produced through the collaborative modelling process?:

(i) To exchange and discover new knowledge, particularly on the interactions between cattle raising and forest management.

(ii) To explore future possible scenarios to accommodate their respective needs.

The main related hypotheses are:

1. Negative effects of forest management implemented by the NKU and NNP forest conservation agencies on the agrarian system at this site are the origin of the current land use conflict between local people and NKU and NNP forest conservation agencies, whilst forest management activities have accelerated deforestation in this area.
2. Not only reforestation, but also cattle grazing have positive effects on forest regeneration through the increase of the proportion of woody above-ground biomass.
3. The construction of a shared representation of the interaction between above-ground biomass dynamics and cattle raising, with the concerned stakeholders and its use to explore future land management scenarios can improve communication, collective learning, exchange of perceptions on the problem, and build trust among local actors leading to coordinated action to mitigate the land use conflict between herders and foresters.

1.5. Research objectives

The two general and complementary objectives of this action research are; (i) to improve the understanding of the interactions between cattle rearing, reforestation and forest regeneration by building a shared representation of this sub-system, and (ii) to improve communication and adaptive capacity, and to facilitate collective decision making among the concerned stakeholders regarding the land management problem being examined.

The more detailed specific objectives were:

1. To analyse the effects of the establishment of a national park and the dynamics of reforestation activities on the transformation of the local village agrarian system and their feedback impact on forest.
2. To elucidate the effects of cattle raising and reforestation on the dynamics of above-ground biomass and forest regeneration at the plot scale.

3. To understand the diversity of interest, strategies and decision-making processes among local farming households and government agencies involved in the management of this complex social-ecological system.
4. To build a conceptual model of these interactions between cattle rearing and forest regeneration, integrating agro-ecological and socio-economic processes related to cattle grazing, reforestation and forest regeneration, based on previous diagnostic surveys conducted at a complementary scale (field, farm, village and landscape),.
5. To design and implement a series of evolving multi-agent models (computer-assisted Role-Playing Games and computer Agent-Based Model) to validate the conceptual model with stakeholders, and to integrate scientific, technical and indigenous knowledge on the issue being examined.
6. To identify and simulate co-management of the landscape scenarios identified by the stakeholders in order to facilitate the co-ordination of their actions and to support the inclusive and creative negotiation of consensual collective actions that are acceptable to both the herders and the foresters so as to mitigate the current conflict.

1.6. Conceptual framework

Figure 1.1 shows the schematic conceptual framework of this study, which is composed of three main successive activities; (i) preliminary diagnostic activities corresponding to objectives 1 to 3 of section 1.5 above, (ii) collaborative modelling with local stakeholders corresponding to objectives 4 to 6, and (iii) computer simulations in the laboratory associated with objective 6.

This research took into account a hierarchy of different spatial, temporal and organisational scales because each specific objective requires a suitable scale of investigation to understand the relevant processes and interactions among these different levels (Bürgi *et al.*, 2004). In terms of the modelling process, different types of knowledge and degrees of realism were also considered.

The first specific research objective was investigated through analyses of land use change, farming system and institutions at the landscape and household levels. The main approaches taken were a literature review, remote sensing and GIS (Geographic Information System), ground truthing with GPS (Global Positioning

System) and farm surveys using structured guidelines for interviews, so as to produce a chronological set of land use maps ssupported by a historical account of change to interpret the visual information.

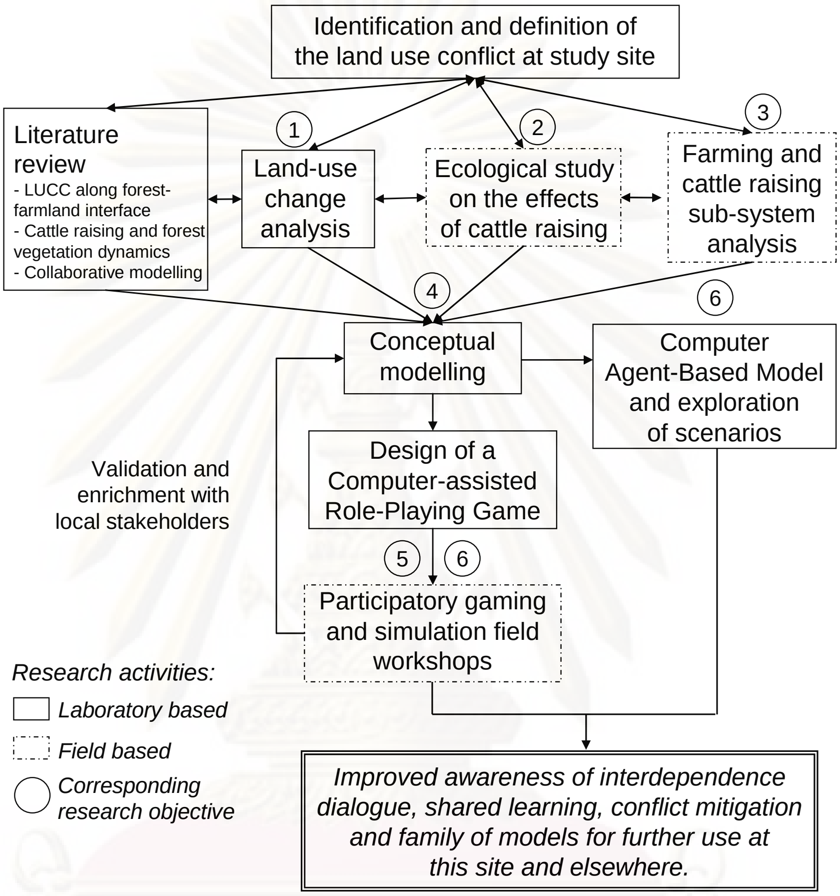

Figure 1.1. Conceptual framework of the research based on the Companion Modelling approach.

The second specific research objective was carried out through ecological studies at the small plot level. Above-ground biomass in different vegetation layers were measured in different land use areas, including cattle grazing, reforestation and natural succession areas, using a stratified plot sampling technique. A first vegetation state transition diagram, based on the results of this plot study, was built and submitted to local stakeholders for validation.

The third specific research objective (see section 1.5) was completed by the analysis of forester institutional, and farming households' and foresters' objectives and strategies regarding land use and forest resources. In-depth interviews under a constructed guideline technique were used. Thereafter, a farmer typology was constructed to display the diversity of the household-based production systems and this was used to represent different types of farming agents in the model.

The fourth research objective focused on the conceptual modelling to represent the sub-system under study and the problem to be examined. Problem-Actors-Resources-Dynamics-Interactions (PARDI) modelling tool was used by researchers to build a first conceptual model and this was then converted into a more formal set of Unified Modelling Language (UML) diagrams.

To investigate the fifth and sixth research objectives, the results from the previous studies were used to design a participatory gaming and simulation tool used and co-improved with local stakeholders along three successive gaming and simulation field workshops. Scenarios proposed by local stakeholders were simulated and explored and then the results were discussed with them, focusing on collaborative and adaptive land management in order to set up a common action plan. The main tool used in the workshops was a successive version of the computer-assisted Role-Playing Game (cRPG) including the computer module implemented under the Common-pool Resources and Multi-Agent Systems (CORMAS) simulation platform. After three workshops, the final computer ABM was built to explore more scenarios in the laboratory.

1.7. Expected outcomes

The outcomes expected from this research are:

1. Scientific innovation and knowledge production:

   (a) Knowledge integration on agro-ecological and socio-economic dynamics, as well as scientific, technique and empirical/indigenous knowledge, pertaining to cattle raising in highland forest conservation areas.

   (b) A family of models built through participatory modelling that could be used for scenarios assessment with stakeholders to explore possible future options and agree upon an acceptable and effective land management joint action plan. Moreover, they could also be used as prototype models to be presented to people at other conservation areas who are facing similar problems.

2. Benefit to local stakeholders:

(a) Awareness, sense of interdependency and urgency regarding the cattle and land management could be improved at both the individual and collective levels.

(b) Communication, dialogue and trust between herders and government conservation agencies in this area could be improved.

(c) Stakeholders will increase their adaptive capacity on agro-ecosystem management. For example, they may be able to anticipate future changes affecting the management of resources.

1.8. Dissertation structure

Following this introduction, this dissertation is organized in three complementary parts, namely; (i) Diagnostic analysis on the socio-ecological system (chapters II to IV), (ii) collaborative modelling process (chapters V to VIII), and (iii) final computer simulations, discussion and conclusion (chapters IX to XI).

Chapter II presents the deforestation problem from the perspective of a global problem and then focuses on the Southeast Asian countries to finally specifically that of Thailand, from the perspective of forest management policies and institutions, and land use conflict. This is followed by the choice and description of the study site; the Doi Tiew forest-farm land interface in Nan Province, Northern Thailand. Chapter III presents the land use and land cover change (LUCC) analysis and the recent agricultural transformations at the study site based on remote sensing and GIS techniques and farm surveys. A synthesis on the farmers' decision-making processes in relation to cattle rearing and the different types of farmers is provided. A review of the literature regarding the effects of cattle grazing and reforestation on forest regeneration is provided in chapter IV, which also contains an analysis of the effects of cattle grazing and reforestation on the above-ground biomass dynamics at the research site.

Chapter V deals with the collaborative modeling methodology. State-of-the-art in collaborative landscape modelling is described and illustrated by the analysis of case studies with different visualization features. The interactive Companion Modeling (ComMod) approach, and its underlying theories, methodological principles and complementary tools are presented and then followed by an overview of the ComMod process as implemented at the study site.

Chapters VI, VII and VIII present the successive use of three evolving gaming and simulations tools with the local stakeholders for achieving three different goals, namely; (i) to build a shared representation on the interactions between cattle raising and reforestation on forest regeneration, (ii) to set up a co-management action plan among concerned stakeholders, and (iii) to sensitize herders to the use of a computer simulator, respectively.

Chapter IX presents the final Doi Tiew computer ABM implemented in the laboratory. Its structure and simulation results from the exploration of land management scenarios are presented and discussed. Chapter X discusses the overall research results obtained from the whole ComMod process implemented in this study, followed by the conclusions and perspectives in chapter XI.

PART I: DIAGNOSTIC ANALYSIS OF THE SOCIO-ECOLOGICAL SYSTEM

CHAPTER II
DEFORESTATION AND FOREST DEGRADATION: NORTHERN THAILAND SITUATION IN PERSPECTIVE

2.1. Dynamics of forest cover: From the global scale to the case of Southeast Asian countries.

In a rapidly changing world, several renewable natural resources have been depleted and/or degraded due to complex interactions between bio-physical phenomena (e.g. fire, flood, storm, global change, etc.) and social conditions (e.g. culture, economics and policy) at different temporal and spatial scales (Lambin *et al.*, 2001; Parker *et al.*, 2003). Among several resources, forests, which can provide numerous goods and services such as biological diversity conservation, poverty alleviation and food security improvement or climate change mitigation, have been rapidly and progressively degrading.

Figure 2.1 displays the extent of deforestation from 1961 to 1991, based on a data set from the world's forest statistics reported by FAO (FAO, 2006c)[1]. Although there is some data inconsistency in this figure[2], it nevertheless shows the trend of continuing global deforestation and the severity of the situation in Southeast Asian countries. According to a recent FAO survey[3], the global forest cover declined only marginally during past years (Table 2.1). However, many European countries have

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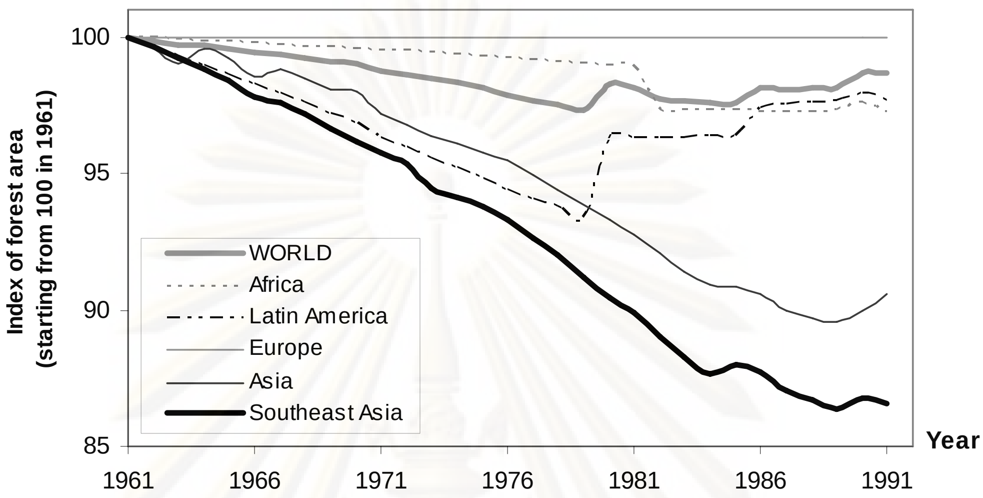
[1] In the Forestry Division of FAO homepage accessed in 2006, a data set of global forest cover from 1961 to 2003 was available, but the following years were not available. However, I found that data for the last decade was not updated in many countries as FAO did not receive their country reports. Therefore, only data from 1961 to 1991 were used to present the past trend in figure 2.1.

[2] This data inconsistency is caused by two important factors related to the fact that FAO receives data from different countries. First, the techniques used for classification of forest areas are different among countries. Since 1980s, as more countries have relied on the use of satellite imagery for estimates, the overall quality of FAO data has improved (Downton, 1995). This resulted in the jump of forest cover between 1979 and 1980. Secondly, the definition of 'forest' used by FAO changed. Before 1990, FAO defines an area as 'forest' when the canopy provided by trees covers at least 10%. But until the 1990s, this ratio of canopy cover was 20% in developed countries but only 10% in the developing ones (Rudel *et al.*, 2005) Moreover, these definition may not fit with the way some countries classify their forest cover. For example, in Thailand, forest cover often reflects the legal status of the land (Fisher and Hirsch, 2008), rather than the actual area of land that is forest covered.

[3] For more recent information, a data source from "State of the Worlds' Forest 2009" (FAO, 2009) was used to observe the current forest cover because several change occurred since the FAO global forest assessment in 2000 (FAO, 2001).

now completed the 'forest transition,' described by Mather (1992), with a change of pattern from a shrinking to an expanding forest area. This author argues that this trend may also occur in some developing countries.



Source: Forest statistics database (FAO, 2006).

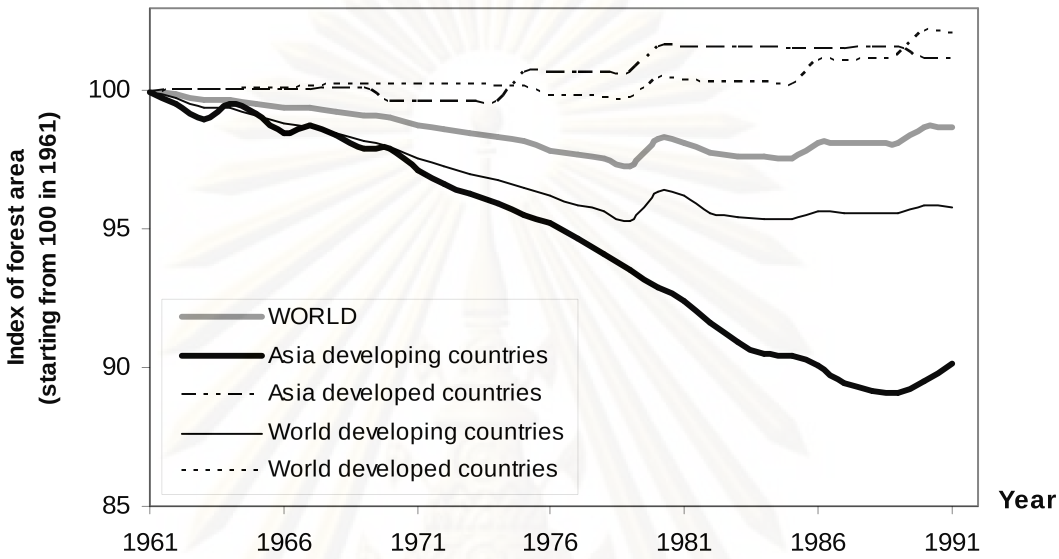
Figure 2.1. Index of forest cover (surface area that is forested compared to that amount in 1961set at 100%) at global and continental and Southeast Asian scales from 1961 to 1991.

Table 2.1. Change in forest cover at global, continental and Southeast Asian scales between 1990 and 2005.

Year	**Forest area (x 10 km^2)**					
	World	**Continent/Sub-continental region**				
		Africa	**Latin America**	**Europe**	**Asia**	**South East Asia**
1990	4,077,291	699,361	923,807	989,320	574,487	245,605
2000	3,988,610	655,613	882,339	998,091	566,562	217,702
2005	3,952,025	635,412	859,925	1,001,394	571,577	203,887

Source: State of the World's Forests (FAO, 2009).

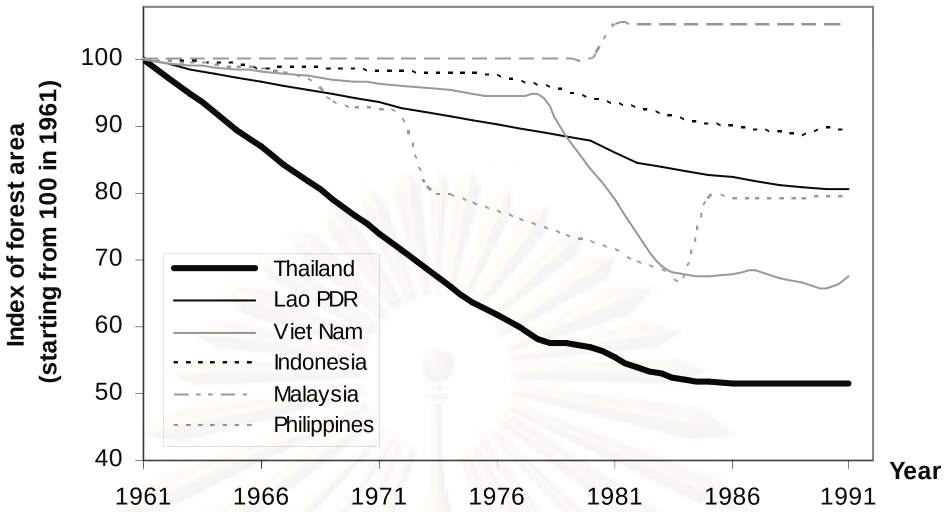
In the case of the Southeast Asia, the reduction of forest cover in these developing countries between 1961-1989 (Figure 2.2) was apparently caused by rapid demographic growth leading to farm land expansion for both crop production and animal husbandry (FAO, 2003). But, apparently, the forest transition seems to have started in Asian developing countries during the late eighties and reversing the trend of deforestation was due to both natural regeneration of abandoned farm land and reforestation efforts (Rudel *et al.*, 2005). This transition happened whereas population is not declining, so it proves that "rapid demographic growth" was only an indirect factor (mediated by policy choices, types of farming systems, agro-industrial strategies, etc.).



Source: Forest statistics database (FAO, 2006).

Figure 2.2. Index of forest cover (surface area that is forested compared to that amount in 1961set at 100%) in the developed and developing countries at a global and Asian scales, form 1961 to 1991.

Among Southeast Asian countries, clear differences in the deforestation rates among the countries in the region are observed, with more forest cover remaining in the least-developed countries such as the Lao P.D.R. (Figure 2.3). Particularly, Thailand displays the most rapid and early loss of forest cover compared with neighbouring countries, such as Vietnam, due to very different socio-economic development conditions throughout this period. Since the 1950s, the expansion of logging concessions and agricultural areas to increase rice production for export and the production of large volumes of annual field crops for the burgeoning Thai agro-industrial sector were important causes of forest loss (Delang, 2002).



Source: Forest statistics database (FAO, 2006).

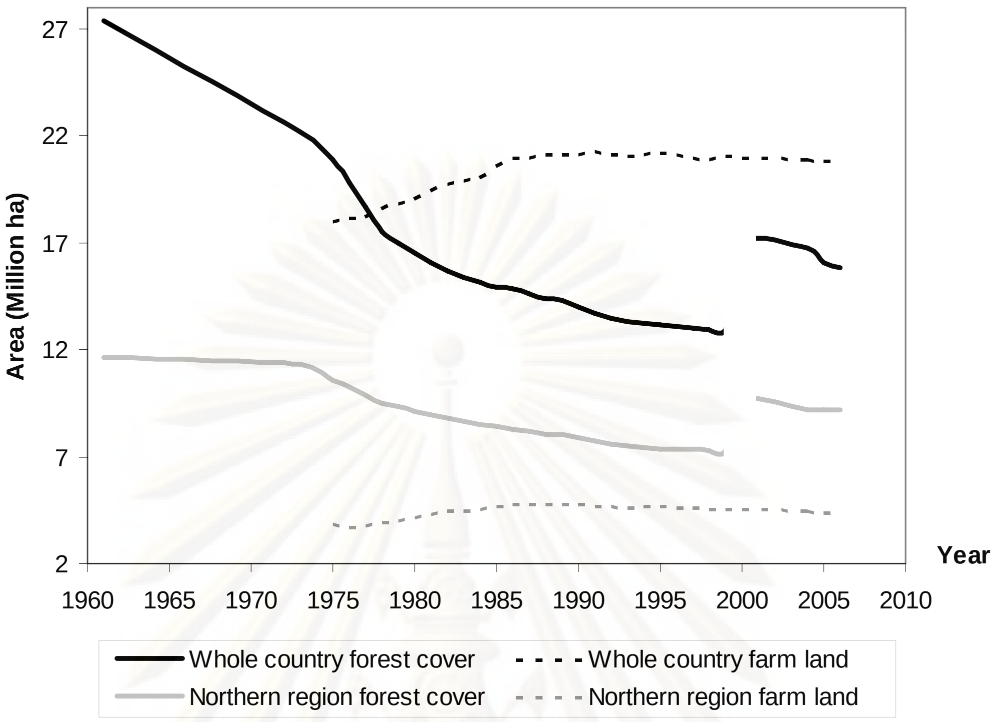
Figure 2.3. Index of forest cover (surface area that is forested compared to that amount in 1961set at 100%) in some Southeast Asian countries from 1961 to 1991.

Fortunately, a stabilization of the Thai forest cover can be seen after the mid-1980s. Therefore, there is the need to analyse in detail how this stabilization happened, so as to evaluate how it may be maintained nationally and expanded locally to improve to stable forest regeneration in selected areas. Regarding this, deforestation and forest degradation in Thailand as well as evolution of forest management policies will be presented in detail in the following sections.

2.2. Deforestation and forest degradation in Thailand and the Northern region

2.2.1. Forest cover at the country level

Thailand has a total land area of 513,115 km^2 (51.3 million ha). Forest areas of the country reported by the Royal Forest Department (RFD) declined sharply from 27.36 million ha (53.3% of the total land area) in 1961 to a low 12.89 million ha (25.3% of the total land area) in 1999 (Figure 2.4)



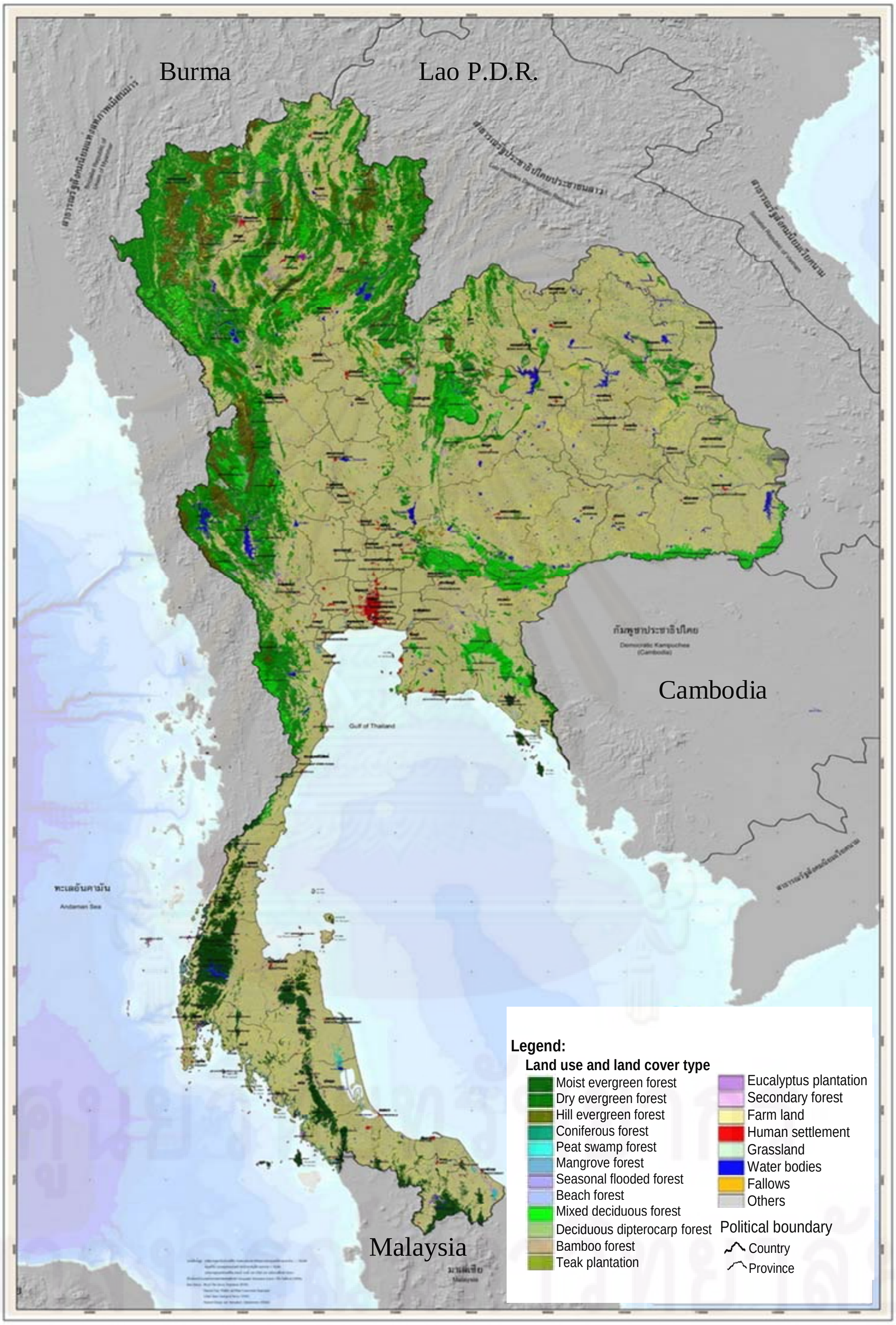
Sources: Forest area from forestry statistics (Royal Forest Department, 2009) and agricultural area from agricultural statistics (Office of Agricultural Economics, 2007) available since 1975.

Note: Since 2000, the Royal Forestry Department of Thailand uses new satellite materials for assessing forest cover (Royal Forest Department, 2006). This is the reason behind the inconsistency of the data set displaying a sharp increase of forest areas between 1999 and 2000.

Figure 2.4. Reduction of forest cover and increase in farm land area in Thailand from 1961 to 2006.

Following the adoption of a new land use classification technique in 2000[4] (Royal Forest Department, 2006), the national forest cover was reported at 33.2% of total land area in 2000. However, forest cover has still been decreasing since 2000. Figure 2.5 shows that a large share (56%) of the remaining forest cover is located in the Northern region in 2000.

[4] A technical reason for this reported increase is based on the interpretation of new sets of satellite images at scale 1: 50,000, without verification through surveys on the ground (Royal Forest Department, 2006).



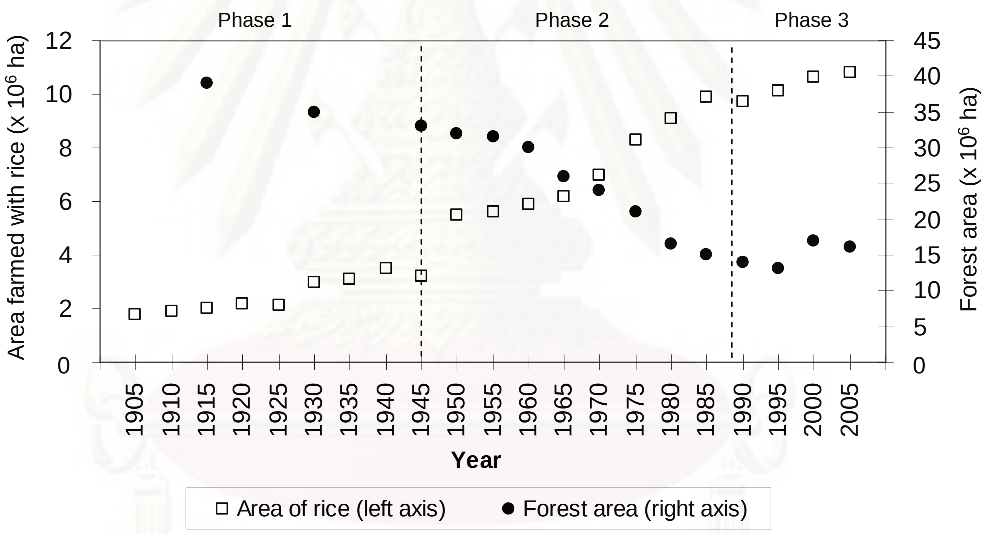
Source: <u>*www.gisthai.org*</u>

Figure 2.5. Distribution of forest cover in Thailand in 2000.

At the whole country level, deforestation was driven by the combination of several factors, particularly the interactions between the RTG's policies and local farming systems dynamics. Historically, three main phases can be distinguished as follows:

- *(1) Before the end of World War II: Deforestation due to rice area expansion.*

Deforestation started when the expansion of rice growing areas in the Chao Phya River Basin occurred due to the economic development based on the exports of rice (Figure 2.6). In 1850, 960,000 ha were planted with rice and the rice-growing areas increased six-fold to 5.6 million ha in 1950 (Delang, 2002). Although the RFD was established in 1896, the forest cover was still decreasing because the agency's mission focused on the regulation of logging of valuable tree species by foreign enterprises and not on forest conservation (Lakanavichian, 2001a).

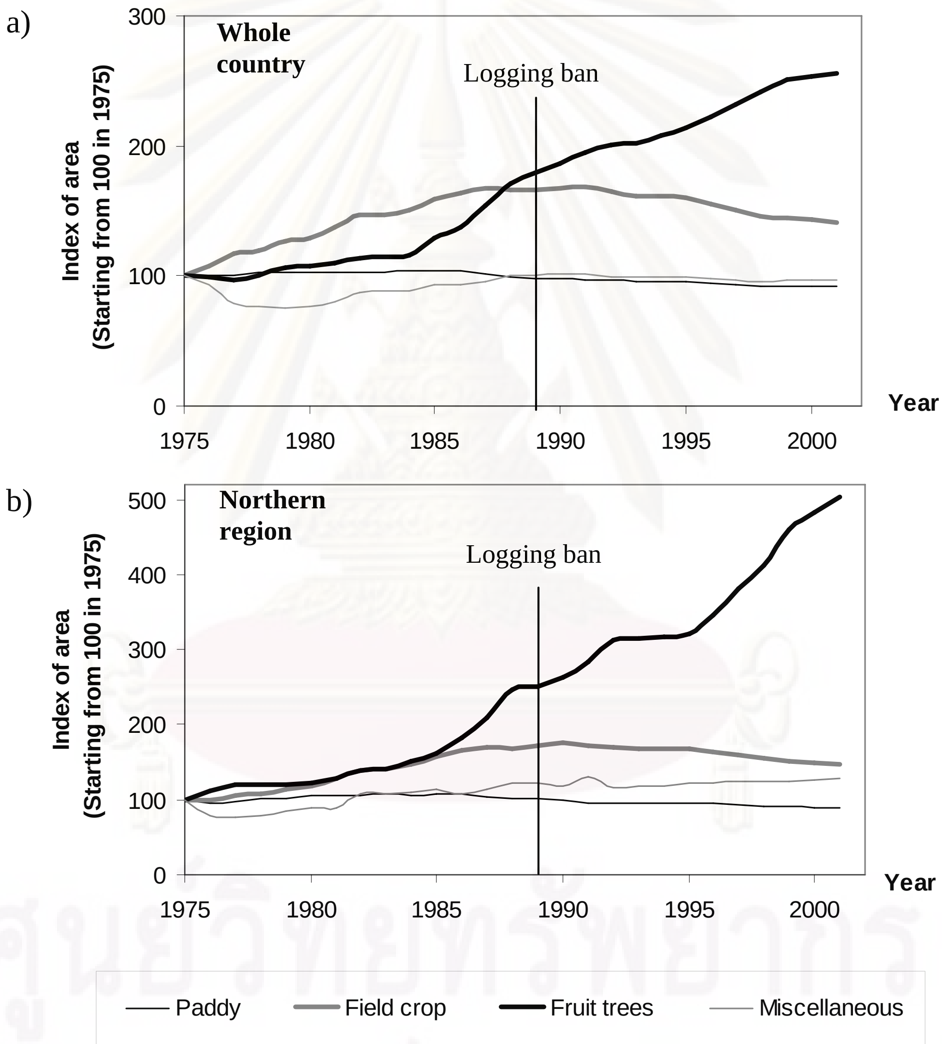


Source: Data from 1905 to 1990 from Delang (2002) and data since 1995 from Office of Agricultural Economics (2001; 2008)

Figure 2.6. Land area for rice cultivation and forest area in Thailand in the period of 1905-1990.

- *(2) 1945-1989: Deforestation based on the rapid economic development.*

After the end of World War II, the RTG adopted economic policies, which caused rapid deforestation due to the combination of several factors. First was the promotion of annual cash crops (e.g. maize, soybeans, cassava and sugarcane) to provide raw materials to agro-industries producing goods for the domestic market and exports. Upland areas planted with these crops expanded rapidly until 1985, then the expansion of perennial fruit tree plantations (e.g. litchi, longan, mango and tangerine) took over, especially in the Northern region (Figure 2.7). This policy accelerated the conversion of forest areas to farm land during the sixties and seventies as shown in (Figure 2.4). As new agricultural areas became scarce in the lowlands due to population growth, farmers had to move to the uplands[5] and the highlands to find unoccupied land to clear and farm (Lakanavichian, 2006).



Source: Agricultural statistics (Office of Agricultural Economics, 2007)

Figure 2.7. The development of the main components of farm areas in Thailand at (a) the country level and (b) Northern region level, during 1975-2006.

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5 Uplands = undulating well-drained land above rice paddies; highlands = hilly to montane sloping land, usually above 400 m amsl in this region.

Secondly, the large amount of logging activity contributed significantly to the rapid deforestation. In 1968, the RTG passed a law allowing 30-year timber concession under the condition that the concession area must be replanted at the end of the concession period. However, due to the lack of law enforcement, some areas were replanted with commercial trees or transformed to farm land by local farmers (Ganjanapan and Kaosa-ard, 1995).

The third factor was the fight against communist insurgents during that period leading to the rapid construction of communication infrastructures by the military regimes of the 1970s which facilitated rapid deforestation, particularly in the highlands where the members of the Communist Party of Thailand had established control bases in the forested areas (Delang 2002). Most of these insurgents belonged to highland minorities and were mainly Hmong ethnics. To secure these "red areas" and get the local people on their side, the RTG built roads to facilitate the control and access to the remote highland areas and rural people were asked to settle along them[6]. During this 'communist insurgents' period, Phongpaichit and Baker (1996) reported that the deforestation rate was 345,600 ha/year in Northern Thailand.

- *(3) Forest degradation after 1990*

During this period, forest encroachment in the highlands has still continued, through a slower rate (Figure 2.4), because of local population growth and the arrival of migrating landless Thai farmers from the lowlands between 1990 and 2000 (Lakanavichian, 2006).

At the same time, the highland farms became more and more integrated into the market economy and crop diversification was on the rise as after the mid-eighties the RTG attempted to promote a wide range of horticultural products (Figure 2.8) to substitute shifting cultivation with small-scale permanent and commercial farming as shown in Figure 2.7 (Trébuil *et al.*, 2006; Turkelboom *et al.*, 2008). Based on the fact that conversion of annual cash crops to permanent cultures requires a high investment, the conversion of forest or secondary forests to farm land in this period was mainly caused by rich farmers who had enough capital.

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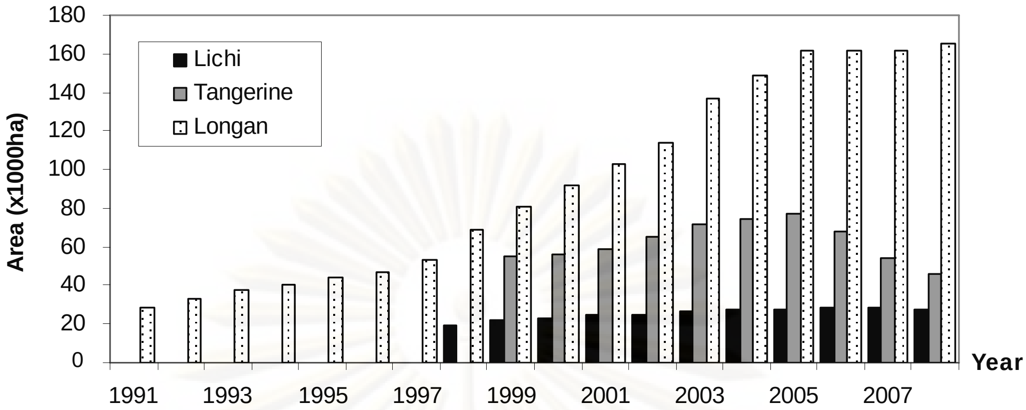
[6] However, in some areas the RTG forced the resettlement in lowlands.

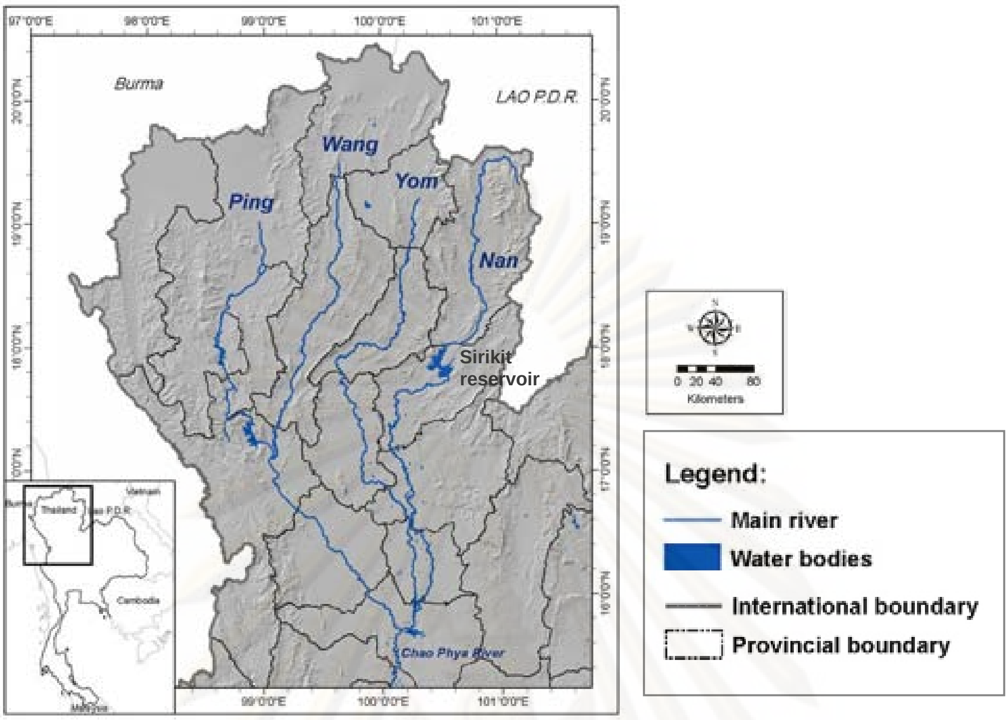


Source: Agricultural statistics (Office of Agricultural Economics, 2000, 2003, 2007, 2008).

Figure 2.8. Areas of land used for litchi, tangerine and longan farming in Northern Thailand during 1991-2008.

2.2.2. Forest cover in Northern Thailand region

Northern Thailand is a subtropical mountainous region which consists of a variety of landscapes. From an ecological point of view, this region is very valuable in terms of biological diversity (Gardner *et al.*, 2000). Moreover, the headwaters in this mountainous region, where most of the remaining forests are found, plays an important role in supplying surface water to lowland areas, especially the irrigated ones. The most well-known and important rivers in Northern Thailand, flowing mostly from North to South, are the Ping, Wang, Yom and Nan waterways (Figure 2.9). The four rivers merge southwards to become the Chao Phaya river supplying water to the central region and the capital city (Bangkok). Some of these rivers feed the reservoirs of major multi-purpose dams (electricity generation, flood control, irrigation of intensively cultivated lowland areas, domestic water consumption in the central region, etc.). Therefore, the protection of the head watersheds of these major rivers is of strategic importance to Thailand's economy.

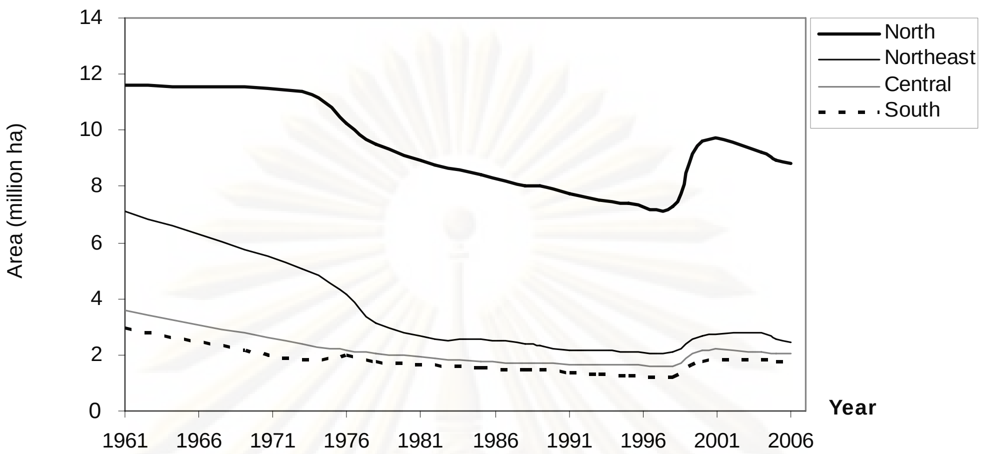


Source: Thailand GIS Database from Land Development Department.

Figure 2.9. The four main waterways in the Northern region.

The Northern region has the largest forest cover in the Kingdom (Figure 2.5). However, deforestation in this region started early, during the colonial period, with the selective logging of teak by British companies as early as the last decades of the 19th century. Britain threatened to annex the northern territories if Bangkok could not control the region and provide a safe access for teak logging and trade (Roth, 2004). However, as the timber operations were based on selective logging, the deforestation was rather limited at that time. The most severe deforestation occurred following the adoption by the RTG of import substitution and export-oriented economic development policies in the 1960s. Many authors have already documented the main causes of deforestation and forest degradation in Northern Thailand during that period through legal and illegal logging, the construction of communication infrastructure and the establishment of new human settlements (Ganjanapan, 1998; Lakanavichian, 2001b), or the farming practices of migrating Thai lowland farmers and some highland ethnic highlanders (Fox *et al.*, 1995; Ganjanapan and Kaosa-ard, 1995; Kaosa-ard, 2000).

During 1961-1999, the forest cover of the Northern region decreased from 11.6 to 7.2 million ha (68.5 to 42.7% of the area), as summarised in Figure 2.10.



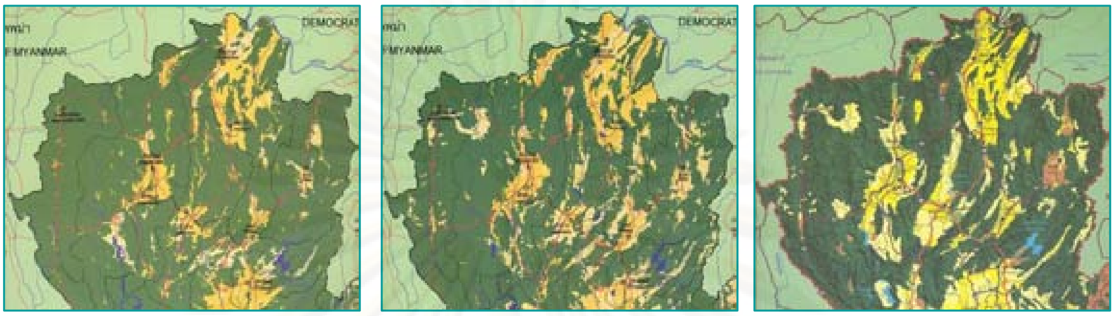
Sources: Forestry statistics (Royal Forest Department, 2009).

Note: Since 2000, the Royal Forestry Department uses new satellite imagery to assess forest cover (Royal Forest Department, 2006). This explains the inconsistency of the data set between 1999 and 2000.

Figure 2.10. Evolution of the forest cover area in the main four regions of Thailand between1961 and 2006.

This is equivalent to a 38 percent forest loss within four decades. However, the deforestation rate in northern region was the lowest among all regions of Thailand during the 1960s due to specific characteristics of the terrain, such as the difficult access to many of the steeply sloping areas (which still applies to some areas today), and the occurrence of endemic disease outbreaks, such as malaria. Thereafter, rapid degradation of the forest cover occurred in the 1970s, in parallel with the above-mentioned development of communication infrastructures under the military regime and the start of opium poppy substitution programmes. The gradual integration of highland farmers into the market economy during the last three decades has also led to the expansion of farm land in sloping areas (Turkelboom *et al.*, 2008).

The dynamics of land use change in the Northern region during the past three decades is visualised in Figure 2.11, where, for example, the steep sloped mountainous regions bordering Myanmar, which are also high malaria regions, are observed to largely remain forested whilst the increase in deforested land and increase in agricultural land use is clearly shown in the remaining regions. As an example of the deforestation of sloped land for permanent agricultural use (as opposed to slash and burn seasonal crops or upland rice farming) Figure 2.12 shows the case of large litchi orchards (*Litchi chinensis*) established on sloping land in the mountainous highlands of Nan province, Northern Thailand.



1980 1990 2000

Source: Land use maps from the Office of Agricultural Economics (Office of Agricultural Economics, 1980; 1990; 2000)

Legend: Green colour denotes forest cover, yellow and orange colours denote agricultural areas.

Figure 2.11. Change in forest cover and farm land areas in Northern Thailand in 1980, 1990 and 2000.

Figure 2.12. Litchi orchards in the highlands of Tha Wang Pha district, in Nan Province, Northern Thailand, in 2008.

Although it has now been clearly established that deforestation and forest degradation are caused by several factors, in Northern Thailand (like in the similarly mountainous areas of neighboring countries, such as Laos and Vietnam) the farming practices of the “hill tribe” people are usually seen as the main culprit by the Thai lowlanders. The mountainous areas of this region are mainly populated by some 800,000 people belonging to diverse ethnic minorities (Delang, 2002). Two main groups are usually distinguished; (i) secondary forest swiddeners, such as the Karen and Lua people, who have been living there for centuries, and (ii) primary forest swiddeners, including the Hmong, Lahu, Akhas, Mien or Yao, H’tin and Lisu ethnic groups, who settled in the area during the last 150 years. They used to practice different types of shifting cultivation systems: either a rotational system with long fallows and no external inputs, or a more destructive pioneer system leading to soil exhaustion and the need to move and clear new farm land in this fragile ecosystem, without any formal and secure land tenure rights (Rerkasem and Rerkasem, 1995). Most of them migrated from neighbouring countries and were denied legal land rights. Since 1989 and the declaration and enforcement of the nationwide ban on commercial logging, these highlanders who used to practice “slash and burn” cultivation are still regularly blamed to be “forest destroyers” (Forsyth and Walker, 2008) of headwater areas, without any discrimination among them according to their different cultivation practices. Although the “slash and burn” system has now almost disappeared (Cramb *et al.*, 2009; Fox *et al.*, 2009; Rerkasem *et al.*, 2009), it is very rare to see the numerous lowlanders, who also colonized the highlands recently and have a far more limited knowledge of this fragile sloping ecology, being blamed for the degradation of this agro-ecosystem (Delang, 2002; Delang, 2005; Mc Kinnon and Vienne, 1995; Roth, 2004).

As deforestation and forest degradation still occurs in the whole country, and particularly in the Northern region, the effective management of the remaining productive forest cover is an important concern. In the next section the evolution of past forest management policies is discussed in order to try to understand the sources of the current conflicts between local people and government agencies, and the need to conduct research in relation to integrated and participatory forest management.

2.3. Past forest management institutions and policies

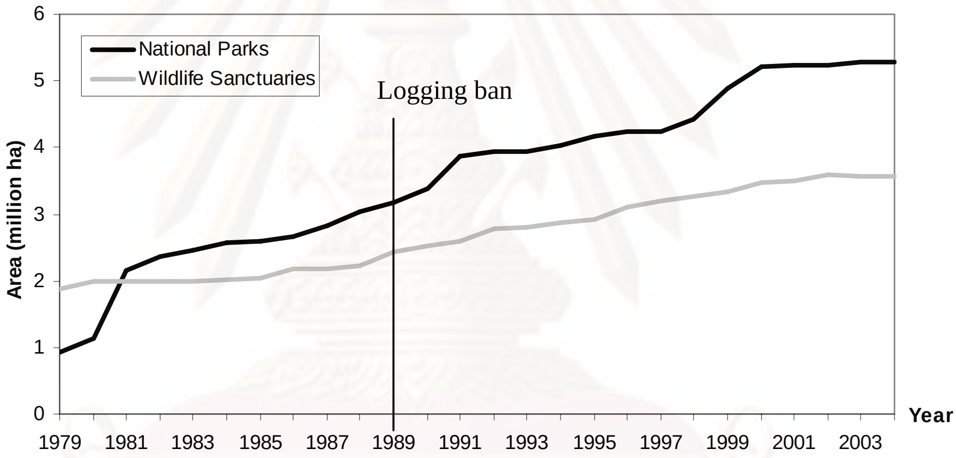
In this section an analysis of the successive forest and land management is presented in terms of the three main phases; (i) the forest management under the exploitation phase before 1989, (ii) state-oriented conservation phase after 1989, and (iii) the current people-oriented conservation phase.

2.3.1. Before 1989: forest management during the exploitation phase

Forest management by the Government in Thailand began more than one century ago when forest resources became an important source of state revenue for national development. Facing the threat of colonization, Thailand ("Siam" at that time) under King Rama V adopted strategies to protect the country from colonial powers. One of them consisted of setting up a scientific and technical management of forest resources following the creation of the Royal Forestry Department (RFD) in 1896. The following year, the Forest Preservation Act and Teak Tree Preservation Act were passed to detail the legal rules for timber harvest. After the abolishment of the absolute monarchy in 1932, more fundamental laws were adopted, such as the 1938 Forest Protection and Reservation Act and the 1941 Forest Act. In particular, the 1938 Act allowed the RFD to map and declare specific territories as either protected or reserved forest (Peluso and Vandergeest, 2001). The main purposes of these laws were to regulate forest access and to secure the long-term generation of national revenue through a logging concession system. According to Vandergeest and Peluso (1995), this was a "territorialisation" process of the central government over the resources and sovereignty in the former Northern Lanna tributary state. It is clear that these laws had no provision for any kind of village forests (Vandergeest, 1996b). Villagers' rights to access forest resources were basically denied.

After 1960, there was a period of struggle between the state promotion of economic development and better scientific and technical management of forest resources already suffering from loss and degradation. Some policies encouraged foreign companies to invest in Thailand and, in 1968, the RTG government passed a law granting 30-year logging concessions to investors on the condition that the area should be replanted (Delang, 2005). At the same time, some policies favoured a better scientific and technical management of forest areas. In particular, the establishment of conservation areas was initiated by Dr. Boonsong Lekagul, the "Father of Nature

Conservation in Thailand" (Buergin, 2003). Roth (2004) indicated that Field Marshal Sarit Thanarat had a significant role in shaping and setting up laws related to conservation areas as he believed that a National Parks suited a modern state. In cooperation with the US government, the concepts of a National Park totally free from human disturbance and a "Protected Area System" were transferred to Thailand. Therefore, several laws were passed, such as the 1960 Wildlife Conservation and Protection Act, the 1961 National Park Act, and the National Forest Reserve Act of 1964 by revision of the 1938 Act. The demarcation of conservation areas was usually carried out by bureaucrats based on the use of 1:50,000 US military topographic maps (Vandergeest, 2003). Figure 2.13 shows the five-fold increase in areas covered by national parks or wildlife sanctuaries between 1979 and 2004.

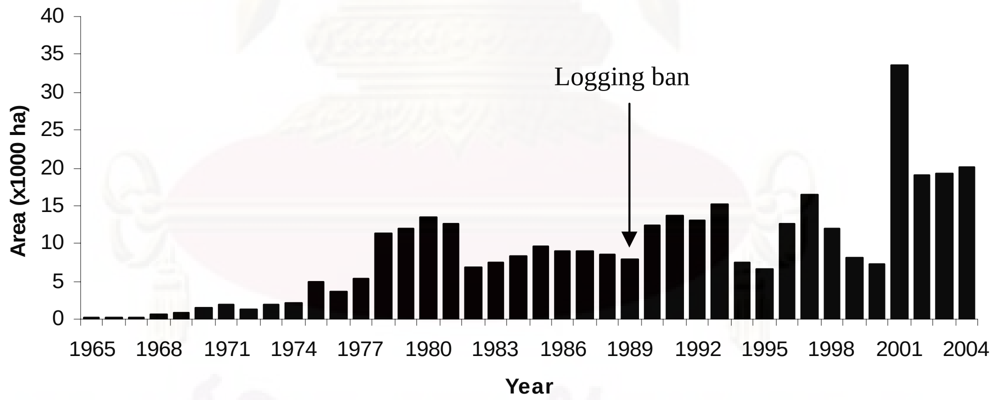


Source: Forest statistics, Royal forest Department, 2006.

Figure 2.13. Increase in the area of land allocated as a National Park and wildlife sanctuaries in Thailand between 1979 and 2004.

In the 1970s, other related policies focusing on the highlands and initiated were dealing with the eradication of opium poppy cultivation practiced above 800 m above mean sea level (amsl) and other crop substitution programmes to reduce shifting cultivation in these remote areas. Thanks to the construction of access roads into the highland areas, many projects promoted cash crops requiring annual low input (maize, beans) or very diverse horticultural crops produced with external inputs and of a higher market value (Trébuil *et al.*, 2006). Tens of highland development projects were implemented with financial support from multilateral agencies, such as the United Nations, and foreign countries like Germany and Australia (Kaosa-ard, 2000).

Reforestation was another forest management policy aiming at reducing deforestation by planting trees for domestic use andincreasing forest cover in degraded areas (Lakanavichian, 2001a). Two techniques were implemented by the Headwater Management Units belonging to the RFD. The first technique, called the "restoration of headwater forest," consisted of planting a few species of fast growing trees at fixed regular intervals (for example, 3 x 3 m, 4 x 4 m or 5 x 5 m) to rapidly rehabilitate highly degraded areas, especially in the sloping highlands. Eucalyptus and two pines (*Pinus kesiya* and *P. merkusii*) were favourite species used in this type of reforestation effort (Delang, 2002). The second and more recent technique, practiced since 1996 is called "reforestation to improve headwater ecosystem" and consists of planting a greater diversity of both native and introduced fast growing species in degraded areas. More recently, non-government reforestation projects were undertaken on the occasion of different national ceremonies, such as the celebration of the King's and the Queen's birthdays.



Sources: Forestry statistics, Royal Forest Department, 2006.

Figure 2.14. The area of reforestation reserves managed by the Royal Forest Department of Thailand during1965 to 2004.

Figure 2.14 shows the area of reforestation land that has been managed by the RFD since the mid-sixties, clearly revealing a low interest in forest conservation by the RTG. A small area of 140,815 ha of forest was planted in the 25 years between 1965 and 1989, compared with the 13 million ha of forest that was lost (92-fold greater loss than replant) during the same period.

The implementation of project activities on the ground was frequently impeded by the different definitions of a given forest area and the related land tenure problems. Differing interpretations created conflicts among local government agencies in charge of various aspects of land management and also between those agencies and local people. Thai farmers tend to consider forests as “land covered with big trees” and once the large trees are noticeably gone, the land is considered as “public” and available for common use (Ganjanapan, 2000). Traditionally, villagers are customary granted the right to cultivate unoccupied land and can pass this right to their descendants or relatives. In situations of land scarcity in lowland areas, these two above-mentioned perceptions stimulated encroachment of forest land, particularly in areas that were abandoned after logging operations. Even though squatters encroaching the degraded forest have no formal land tenure rights, their settlements were often tolerated and it was rather difficult to evict them by enforcing the law.

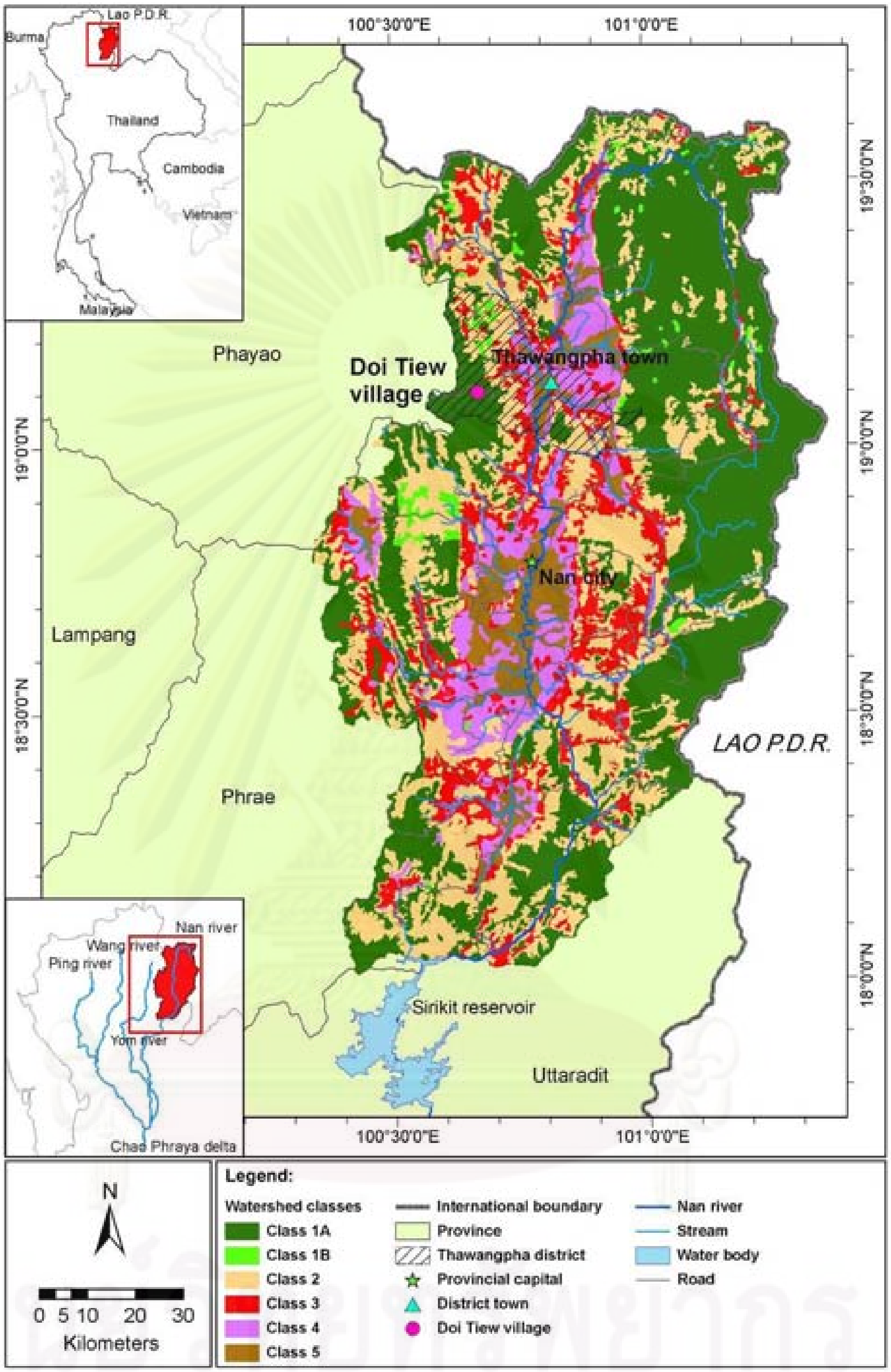
To clarify the situation, a “watershed classification” was set up by the National Environment Board as a specific practice to manage head watershed and highlands areas. Its pilot implementation started in 1982 in the Ping river watershed of Northern Thailand (Tangtham, 1996). The kingdom watersheds are classified into five different classes associated to legal types of human activities in each category of watershed as shown in Table 2.2. For example, Class 1A and 1B watersheds are fully protected as headwater forest areas and no human activity is allowed in the absence of special permission granted in some areas (Department of National Park Wildlife and Plant Conservation, 2008). Figure 2.15 shows the spatial distribution of these watershed classes in the case of Nan, a mountainous province in Northern Thailand, where a large area of highlands falls into the most protected “class 1A” category.

In conclusion, we need to add that during the forest exploitation period, forest management policies were not implemented strictly as law enforcement was difficult in remote areas and with limited human resources. As a result, deforestation and forest degradation were, and still are, continuing as the economic importance of the forest sector decreased rapidly following the rapid take-off and diversification of the kingdom economy, especially after 1986. However, following a deadly flash flood in Southern Thailand, the forest management policy was ripe to shift from the past economic-oriented direction to a new conservation-oriented one.

Table 2.2. Description of the five watershed classes (WSC) used by Thai authorities.

Class/Characteristics	Land use resolution
WSC1A: Protection Forest Area - this subclass is protected forest areas and includes the headwaters of rivers. Usually at high elevations and very steep slopes, and should remain as permanent forest cover.	- No forest product is permitted to be harvested for any case. It must be strictly kept permanently as headwater source. - Forest protection activity is the first priority of RTG in these areas. - Immediate reforestation programme must be undertaken by RTG on abandoned shifting areas - Areas converted to permanent settlement (but classified as 1A due to misidentify by LANDSAT) must be strictly supervised by the concerned agencies for future development.
WSC1B: Disturbed WSC1 - similar physical and environmental features to class 1A, but portions of the areas are cleared for agriculture and, thus, require special soil conservation measures. Where possible, the areas should be replanted as forest or maintained as permanent agro - forestry.	- Areas converted into agricultural land must be practiced in accordance with the national economic, social and environmental policies. - Those areas which have been developed for recreation and resorts should be managed in harmony with the local ecological balance and natural sceneries. - Reforestation on denuded areas, especially those which are unsuitable for agriculture or any other purposes, should be immediately undertaken by the concerned agencies. - Erosion control measures should be practiced on the areas subjected to road construction and mining by the responsible agencies. - Permission can be made for unavoidable projects which are very important to the national economy and security but the EIA must be prepared by the agencies concerned and approved by the Office of Environmental Policy and Planning (formerly named as: ONEB).
WSC2: Commercial forest - for protection and/or commercial forest, where mining and logging are allowed within legal boundaries. Usually at high elevation with steep to very steep slopes. Maybe used for grazing or crop production with soil conservation measures.	- Forestry and mining activities can normally be allowed but should be closely and strictly supervised by the concerned agencies. - Agricultural practices are strictly prohibited. - Immediate reforestation programme must be conducted by concerned agencies.
WSC3: Fruit-tree plantations - covers uplands with steep slopes and less erosive landforms. Maybe used for commercial forests, grazing, fruit trees or certain agricultural crops with soil conservation measures.	- Land utilization for forestry, mining, agriculture and other uses can be permitted, but soil and water conservation measures are strictly required. - Areas with a soil depth greater than 50 cm are recommended for fruit-tree and orchards or economic plantation or permanent cash crops, but appropriate soil and water conservation practices are needed.
WSC4: Upland farming – covers areas with gentle sloping lands suitable for row crops, fruit trees and grazing with a moderate need for soil conservation measures.	- Forestry, mining and other land-use activities are normally allowed with close supervision of RTG. - Areas with slopes in the range 18 - 25% and a soil depth of less than 50 cm are recommended for fruit-tree plantation and forestry. Those areas having slopes between 6 - 18% should be used for agronomic crops with the application of suitable soil conservation measures.
WSC5: Lowland farming – covers gentle slopes or flat areas needed for paddy fields or other agricultural uses with few restrictions	- All kinds of land use practices can be allowed as usual. - Areas with soil depth less than 50 cm are recommended for agronomic crops, private woodlots, fruit-trees, and ranges or recreational purpose. - Areas having soil deeper than 50 cm should be utilized as paddy field and agronomic production. - Lands with high potential of agricultural production should be avoided for industrial development.

Source: Tangtham (1996).



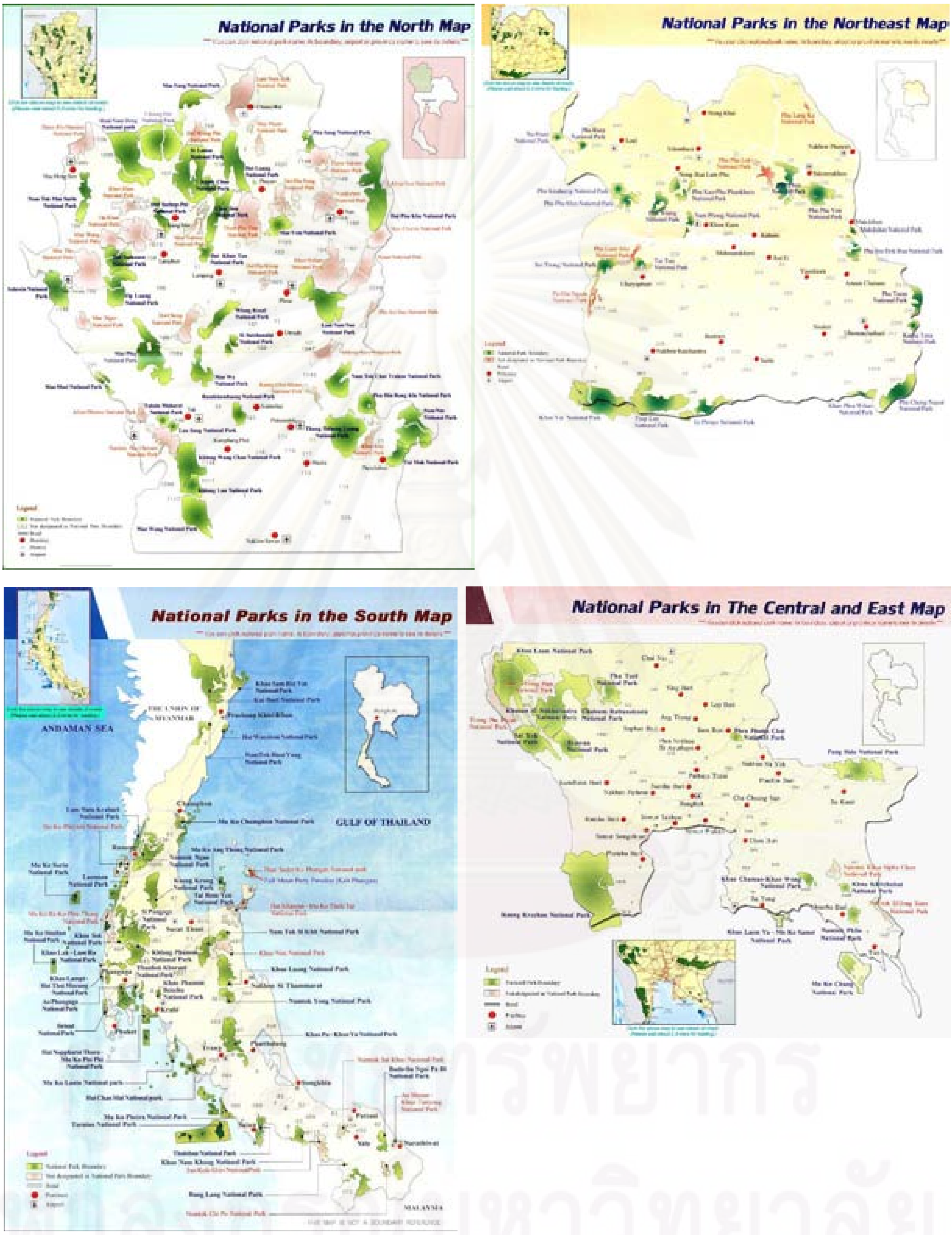
Sources: - Thailand GIS Database from Land Development Department,
- Watershed classification data from Department of Environmental Quality Promotion, 1994.
*Note: **Class 1A**: Protection forest and headwater source areas at higher elevations and steep slopes, **Class 1B**: Similar to Class 1A but some areas cleared for agricultural use or occupied by villages, **Class 2**: Protection and/or commercial forest at higher elevations with steep slopes, **Class 3**: Uplands with steep slopes and less erosive landforms. Areas may be used for commercial forests, mining, grazing, fruit trees or certain agricultural crops with soil and water conservation measures, **Class 4**: Gently slopping lands suitable for row crops, fruit trees and grazing with moderate need for SWC measures, **Class 5**: Gentle to flat areas used for paddy fields or other (Tangtham, 1996).*

Figure 2.15. Distribution of watershed classes in Nan Province, Northern Thailand.

2.3.2. Conservation-oriented government policy after 1989

In November 1988 a major land slide and deadly flashfloods killed hundreds of people in the Southern province of Nakorn Sri Thammarat. Forest degradation and the establishment of rubber plantations on steep slopes by both government agencies and local people were considered as the major causes of this catastrophe. This event can be seen as a tipping point beyond which important changes in the forest management policy were adopted with a new focus on conservation programmes (Lakanavichian, 2001b). As a result, a nationwide logging ban was declared only two months after this tragic event through a Cabinet resolution issued in January, 1989. There was a reason for this fast announcement. A group of military people took advantage of this ban by extending their operation not only into Burma but also into Lao P.D.R. and Cambodia. "Logging concessions were granted to Thai companies after General Chavalit Yongchaiyudh, the army chief and future prime minister, had talks with the Burmese military" (McKinnon, 1997 cited in Delang 2005).

After the logging ban, more protected areas were rapidly established, particularly new wildlife sanctuaries and national parks with, theoretically, strict control of activities within their boundaries. As a result, the total area covered by the main categories of conservation areas (national parks and wildlife sanctuaries) increased from 5.9 to 8.9 million ha between 1990 and 2004 to reach 18.3% of the whole country (Figure 2.13) in 2004 (Royal Forest Department, 2006). Figure 2.16 shows that several new parks were established in the Northern region where the largest share of the forest area remained. Many of them have already been officially declared by law, but more of them are still under the declaration process by the cabinet.



Source: http://www.thaiforestbooking.com/default-eng.htm

Note: Green and pink colour denotes the declared and under declaration parks, respectively.

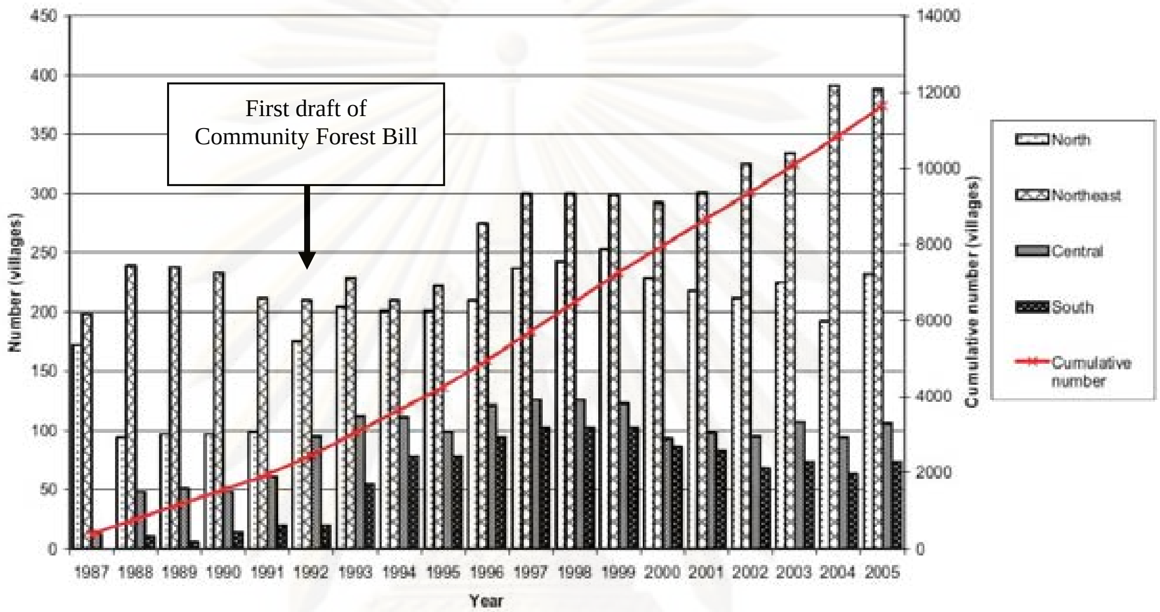
Figure 2.16. Distribution of national parks in the four regions of Thailand in 2004

2.3.3. Steps toward a more decentralized and participatory type of forest management

The past RTG forest management policies have been enforced on "ambiguous lands" as they are legally owned by the state but are used and cultivated by local people, sometimes for decades (Sato, 2000). Hill tribes and Thai lowlanders who settled recently in the uplands and highlands have attempted to claim their rights on this type of land. Their claims have created social tensions with government agencies whose top-down land management policy and implementation has not been successful. To improve this situation, both government officials and local people need to be more flexible in the implementation of new land management rules to avoid violent conflicts (Hares, 2009). Negotiation to achieve compromises is important (Johnson and Forsyth, 2002) and participatory management was recently introduced into the RFD policy-making.

The first concept adopted by the RFD that could be considered as a form of participatory management was the "forestry village." It was introduced to Thailand in the mid-1970s. Villagers are allowed to use forest resources in degraded forest area surrounding their village territories by a set of regulations co-constructed with RFD staffs (Lakanavichian, 2006). In 1988, The Forest Promotion Division, and Community Forestry Subdivision were formed. In 1994, the Tambon Administration Organization (TAO) Act was passed with a mandate to protect and manage local natural resources at the sub-district (*Tambon*) level. Consequently, TAOs have been receiving an increasing share of public funding to implement local projects that meet local needs. TAOs were allowed to use a degraded forest as a community forest.

In 1992, the first draft of the Community Forest Bill was released by the RFD. Then, a "People Version" was produced by a coalition of activists, and NGOs in the following year (Sato, 2003). Figure 2.17 shows that the number of villages managing community forest areas. Before the release of the first draft of the bill, community forests were mostly established in the Northeastern region. However since 1992, the number of villages managing community forests has increased in all regions, which could reflect the need of local people to obtain rights to manage their natural resources. In 2005, almost one out of six villages in the country was looking after a community forest. After 15 years of revisions and debates, the bill was finally passed in late November 2007, and it allows people to participate in forest management and to support government efforts to protect forests (Fox *et al.*, 2009). This long debate on the Community forestry bill illustrates the difficulty to set up an appropriate mechanism for participatory management of the land between the RTG and the civil society.



Source: Lakanavichian, 2006.

Figure 2.17. Increase in the number of villages managing community forest areas in Thailand during 1987 to 2005.

The recent 2007 Constitution also recognised the community right and allowed people to participate in natural resource management and conservation (Hares, 2009). However, so far the level of local participation was limited to receiving information and participating in a consultation process in most cases, while only few projects openly involved local people in monitoring and evaluation processes. For example, the establishment of several national parks also involved local farmers in the co-delineation of the park boundary, but they did not have much opportunity to collaborate with government conservation agencies in setting up the natural resource management plan and monitoring the resource status. It is clear that strengthening participatory management is still needed.

2.4. Effects of forest management activities on the regional agrarian system

In this section the effects of past forest management practices on the dynamics of the agrarian system in the highlands of Northern Thailand, where many resource use conflicts have been recorded, is presented.

2.4.1. Effects of forest government protection on cropping and livestock rearing systems

The demarcation and mapping of protected areas were done without much consultation with the local people. Therefore, many villages suddenly found themselves and their farm land included within the boundaries of these officially protected areas. As a result, they were considered as "illegal occupants" by the RTG even though they had been settled in their homesteads and farming in those areas for many years and sometimes many generations. In remote areas, many people still do not know the legal status of the land they cultivate to make a living. This created numerous land tenure conflicts between government officers and local highlanders, especially the forest-dependent households (Roth, 2004; Roth, 2008; Vandergeest, 1996a; Walker and Farrelly, 2008).

Moreover, the policy of cessation of shifting cultivation and strict control in conservation areas limited local people's access to farm land located in such conservation areas, resulting in the limitation of their farm land expansion and so the shortening of the fallow periods (Emans, 2006). Farmers had to adapt to these new constraints by changing their farming practices, like setting-up more permanent production systems relying on external inputs. Some farmers had to adapt their labour management by developing off-farm, often wage-earning, activities. Some of them simply decided to stop farming and migrated to other areas. As a result, some farm land was abandoned and a secondary forest naturally regenerated on those lands. Recently, several authors found that this trend is widespread in the highlands of Southeast Asia (Cramb *et al.*, 2009; Fukushima *et al.*, 2008; Rerkasem *et al.*, 2009).

Apart from cropping, extensive cattle rearing that was usually practiced in the highlands (Falvey, 1977) has also been affected by the limitation of forest accessibility. In remote areas, cattle play important roles in livelihood systems by providing meat for household consumption, draft animals to till the land or carry goods, and a form of living household savings. Herders usually rely on degraded forest or forest areas located near their villages for free cattle grazing. When national parks or wildlife sanctuaries were established, such extensive cattle raising systems were curtailed because these protected areas do not allow rearing of domestic animals within their boundaries. One argument for such is that diseases carried by domestic cattle could be transferred to the protected wildlife species (Harnsoda, 2004).

2.4.2. Change in socio-economic conditions

In terms of socio-economic effects, the limitation of forest accessibility and use increased the vulnerability of poor and/or landless or near landless people because they usually depend on the collection of non-timber forest products (NTFPs) to make a living. Moreover, an increased socio-economic differentiation among farmers having different investment capacities occurred because some could more easily adapt to the new conditions than others (Vanwambeke *et al.*, 2007). Poor farmers with very limited access to land resources and cash tend to seek off-farm employment (Fisher and Hirsch, 2008; Vandergeest, 1996a). Another important effect created by the forest conservation pressure was the organization of new social networks and institutions to negotiate with the representatives of political power. These networks combine local stakeholders linked by different horizontal (such as different types of farmers) and vertical power relations, and include NGOs and academic scholars. For example, the natural resource protection group in Nan Province, called “Hug Muang Nan” directed by monks and villagers, or “watershed protection network” in upper Nan watershed (Hoare, 2004).

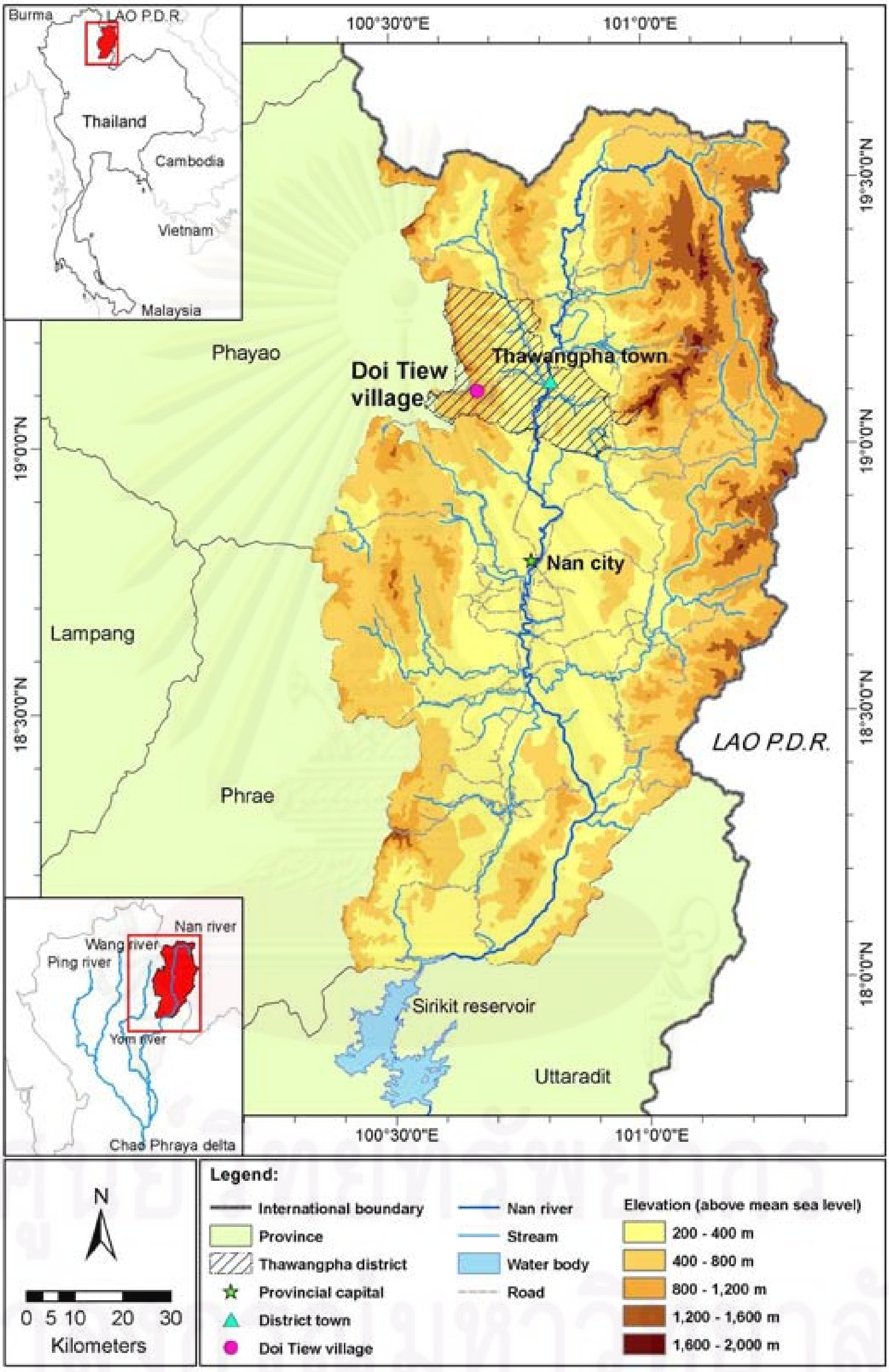
Foresters are also facing more difficulties to work with them in the context of decentralisation. One problem being the difficulty to find new land to establish new conservation and reforestation areas, because most degraded land has already been occupied.

Recently, even under the current context of decentralisation, more conservation areas have been planned by central authorities reluctant to see their power decreasing. To prevent violent conflict between local people and government agencies, therefore, there is a need to design and test truly inclusive and participatory approaches to promote a more adaptive management of forest and land resources. This could be based on the improvement of communication to exchange perceptions and knowledge, joint learning, trust building and collective decision making leading to mutually acceptable action plans. It would ensure appropriate management of the land by involving different types of resource users.

2.5. Justification of study site in Nan Province

Nan Province is located in the eastern part of the Northern region of Thailand and to the east borders with the Lao P.D.R. (Figure 2.18). Nan covers an area of 11,472 km^2 and had a population of 475,984 individuals in 2008, an average population density at the provincial level of 41.5 inhabitants per km^2 (Department of Provincial Administration, 2008). Most of the population lives in the central valley of the Nan River which flows southwards into the large reservoir of the Queen Sirikit dam.

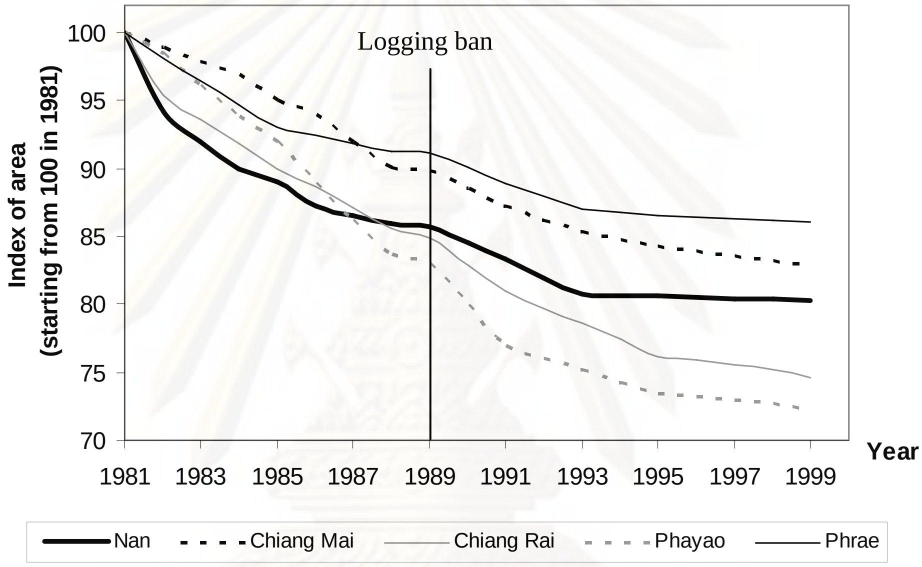
Over the past centuries, Nan Province was somewhat isolated due to its geographical characteristics as approximately 85 percent of the provincial area is hilly or mountainous. It was part of the Lanna Kingdom since 1450 and ruled as part of the RGT since 1932 (Ganjanapan, 1984). It is culturally diverse due to the presence of local lowland (Thai Lue) Thai and many ethnic groups (Hmong, Karen, H'tin, Lawa, etc.), who are well known for their indigenous knowledge of highland agro-ecosystems. Nan is not well connected to the major economic areas of the country and was little affected by the recent decades of economic boom compared to neighboring provinces located on major expressways or railways. As a result, the province has managed to preserve its natural capital far better than other provinces of the Northern region, such as Chiang Mai and Chiang Rai. According to the estimation of provincial standard for poverty, almost one third of the provincial population in Nan was still considered as poor a few years ago (Kaosa-ard, 2000).



Source: Thailand GIS Database from Land Development Department.

Figure 2.18. Topography and location of Doi Tiew village in Tha Wang Pha district of Nan Province in Northern Thailand.

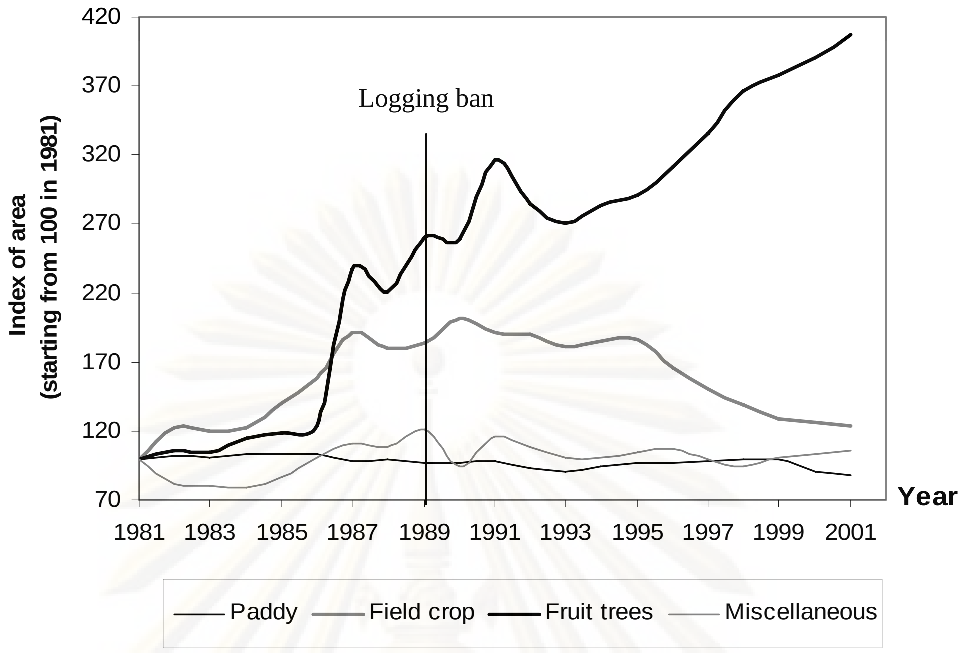
Nan was affected by rapid deforestation and forest degradation before 1989 (Figure 2.19) from the activities of local logging concessions, illegal logging and the conversion of logged areas to farm by large and small smallholders, similar to what happened in the north region (Delang, 2005; Kaosa-ard, 2000). Another reason for the rapid forest loss in Nan was the construction of road networks to access to the highlands during the communism period. Among several provinces in the north region, Nan was an important target for communist insurgents to set up their bases because of the dense forest covers and difficulty to access (Kaosa-ard, 2000).



Sources: Forest area from forestry statistics, Royal Forest Department, 2006.

Figure 2.19. Deforestation levels (forest area relative to that in 1981 set as 100%) in several provinces of Northern Thailand between 1981 and 1999.

Since 1993, deforestation in Nan seems to be more under control, in part due to the recent period of promotion of fruit tree production as an alternative to land degrading farming practices in the highlands (Figure 2.20).



Source: Agricultural statistics (Office of Agricultural Economics, 2007).

Figure 2.20. Growth in farm land areas planted with fruit trees or field crops in Nan Province, Northern Thailand from 1981 to 2006.

Following the years of rapid forest degradation, forest conservation efforts were implemented in Nan by both local organizations and government agencies. The important local institution "Huk Muang Nan" ("Love Nan city") helped local communities to establish maps and social regulations for the use of natural resources in participatory ways (Huk Muang Nan, 2001). In terms of forest management by government agencies, seven national parks, one wildlife sanctuary and several headwater management units are operating in Nan under the RFD management (Maneeratana, 2003). However, most of them still operate in a top-down way and conflicts between local people and the RFD are common.

The Hmong village of Doi Tiew located in the Tha Wang Pha District, some 50 km Northwest of Nan city, was selected as the study site for this research (Figure 2.18). Doi Tiew village is located in a class 1A watershed (Figure 2.15), an area in which class all prohibiting human activities are prohibited but in reality dwelling and some activities, such as agriculture, are still tolerated. In this area, several government conservation and development agencies are in charge of forest management and their interactions with local farmers have been creating conflicts on resource use and management for more than 10 years. For example, government officers shot cattle belonging to villagers or, on the other hand, villagers burned young reforestation plots because they were their fallows. This is why this site was selected, to test the introduction of an integrated participatory management approach to mitigate social tensions among local stakeholders and to establish a form of co-management of the forest-farm land interface involving both local people and forest conservation government agencies.

To better understand the origins and development of the local land use conflict, a land use and land cover change analysis, in relation to the forest management and the RTG development activities, was conducted and is presented in the next chapter. The chapter also describes as well as the characteristics of the different farmer types, and other direct and indirect stakeholders in the local land use conflict.

CHAPTER III
LAND USE AND LAND COVER CHANGE AND RECENT AGRICULTURAL TRANSFORMATIONS AT STUDY SITE

3.1. Introduction

Historical interactions between rural societies and their natural environment lead to landscape transformations and the differentiation of agricultural production systems[7] that depend upon their access to productive resources (Mazoyer and Roudart, 1997). Interdisciplinary knowledge of the history of interactions between socio-economic and agro-ecological changes affecting land use leads to an improved or enabled understanding of their origins, causes and consequences. Key past events, forces, trends, power-relation dynamics, and the respective needs of different individual or institutional stakeholders are revealed and can be used to design better ways to manage the current landscape (Antrop, 2005).

Lambin *et al.* (2003) proposed integrated frameworks and related tools to understand the causes and the relationship of driving factors of land use and land cover change (LUCC) relying on agent-based, systems and narrative perspectives. Agent-based perspectives rely on the individual decision-making and motivations behind it, while a system perspective additionally considers the organization and institutions of the society, and a narrative perspective favours a depth of understanding through historical details. The agrarian systems[8] diagnosis methodology combines such frameworks in the production of dynamic agro-ecological zoning that is linked to an historical agrarian profile and the construction of typologies of local stakeholders/farmers based on their different socio-economic objectives and strategies to achieve them (Trébuil and Dufumier, 1993). Remote sensing techniques can be used to monitor the spatial land use change over large areas and Geographic Information Systems (GIS) provides spatial data management,

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[7] Agricultural production system is defined as the whole structured set of crops, domestic animals and other productive activities selected by a farmer to achieve his objectives (Mazoyer and Roudart, 1997).

[8] Agrarian system is defined as an historically constituted and durable model of exploitation of the environment, a technical system adapted to the bioclimatic conditions of a given area and which complies with its social conditions and needs at that moment (Mazoyer and Roudart, 1997).

analysis and visualization tools that can be linked with other types of models through interfaces to exchange data (Mitasova and Mitas, 1998; Skidmore, 2002), particularly with agent-based models to run dynamic simulations of LUCC (Parker *et al.*, 2003). The interpretation of spatial changes in land use can be supported by the analysis of agricultural production system transformations carried out through interviews of key informants. They focus on the identification of the date, nature, origin, causes, extent and consequences of the main recent agrarian changes. This analysis also aims at understanding the specific motivation and decision making of various types of local stakeholders regarding land use that usually deal with their respective access to means of production and capital. The construction of stakeholder typologies facilitates the vulnerability analysis of, for example, different categories of farming households to their changing environment, such as the sudden establishment of a neighbouring forest conservation area.

We applied such an integrative analytical framework to quantify and explain the effects and impact of a recent forest management policy and its enforcement on the agrarian transformations in the Doi Tiew community. Following a description of this study site and of the data collection and analysis procedures used, the LUCC results are presented in relation to the chronological transformations of local agricultural production systems. This historical analysis leads to the characterization of the diverse local stakeholders who are currently concerned by a local land use conflict. It also supports the discussion of the effects of forest management practices on the local agrarian system dynamics, the effectiveness of the local enforcement of the forest conservation policy and the observed trend in LUCC. The usefulness of such an integrated survey is assessed in the conclusion and its potential use in designing a collaborative modelling process to help mediate the current land use conflict in this forest-farm land ecosystem is finally presented.

3.2. Methodology

3.2.1. Study site

The territory of Doi Tiew village ranges from 900 to 1200 m amsl. This Hmong ethnic farming community, who settled in this area in 1961, is presently almost surrounded by several government forest conservation agencies including several reforestation units (the Nam Khang Headwater Development and Conservation Unit-NKU and Sob Sai, Nam Haen, Doi Kard and Nam Ngao Headwater Management Units) and the newly established Nantaburi National Park (NNP) as shown in Figure 3.1.

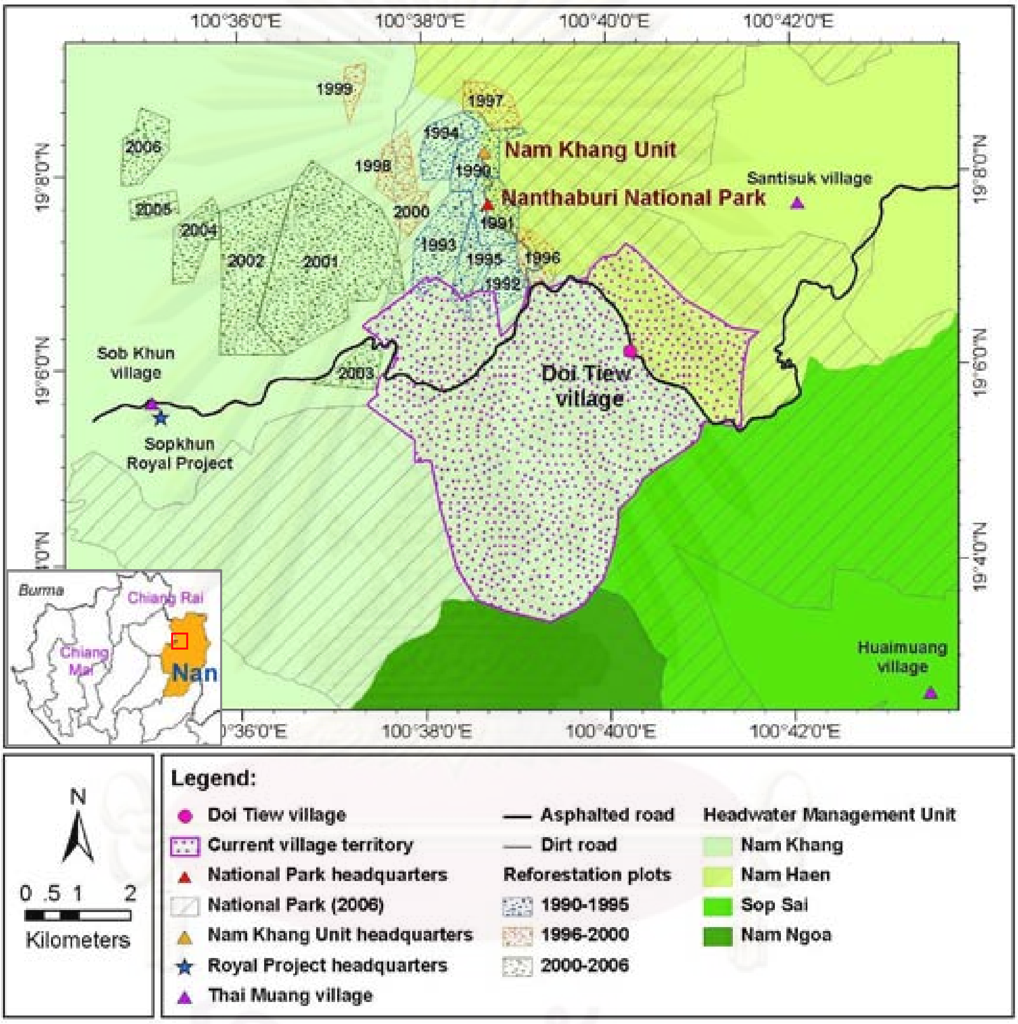

Figure 3.1. Doi Tiew village and of the neighbouring forest management agencies, Nan Province, Northern Thailand.

In 2007, the residential Doi Tiew population comprised of 1,307 individuals belonging to 170 households scattered along 2 km of the main asphalted road (Doi Tiew Village Health Care Center, 2008). The current main farming activities are upland rice production for home consumption, maize and litchi orchards (*Litchi chinensis*) for sale, and extensive cattle rearing in grasslands, fallows and young forest plantations. However, despite their importance to the basic sustenance of the residents, these agricultural activities are increasingly being constrained by the local forest management ones that increasingly limiting the extent of grazing areas available to local herders, establishing the clear conflict of interest.

3.2.2. Spatial data analysis

The remotely sensed data and their sources used in this study were as follows:

i) Satellite imagery downloaded from www.glcf.umiacs.umd.edu: Landsat TM (November 1, 1989), Landsat TM (December 25, 1999) and Landsat ETM + (May 08, 2003). These images correspond to the 1989, 1999, 2003 crop years, respectively,

ii) Aerial photos from the Royal Thai Survey Department (RTSD) dated 1977 and 1996, at the scales of 1:15,000 and 1:50,000, respectively (Appendix A). The 1977 aerial photos were taken at different times between January and December and their quality (brightness, contrast and cloud cover) is different between the successive missions. Therefore, they are difficult to use to construct a complete mosaic, but they are useful to analyze the land use and land cover situation of that period (just over 30 years ago). The photos taken in 1996 display the land use and land cover features in this area in the year that the NNP was first established,

iii) Thailand GIS database and maps from the RTSD, the Land Development Department (LDD), the RFD and the Department of Environmental Quality Promotion (DEQP), and

iv) Digital files displaying the boundaries of the reforestation plots successively established during 1990-2004 were provided by the NKU.

The image preparation and enhancement techniques used in this study relied on more than one hundred GPS coordinates recorded in the different classes of land use and land cover. The three above listed satellite images were rectified to UTM coordinate system and Indian 1975, Zone 47 map datum to make them compatible with other Thai GIS data sets. These satellite images were enhanced by using the histogram equalization function. The Normalized Difference Vegetation Index (NDVI)[9], a non-linear transformation of the visible (red) and near-infrared bands of satellite information, was used to produce a new set of derived images (Appendix B), which were used as an alternative measure of vegetation amount and condition that is associated with vegetation canopy characteristics, such as biomass, leaf area index

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9 NDVI = (nIR - red)/(nIR + red), or (band 4- band 3)/(band 4 + band 3) in Landsat TM.

and percentage of vegetation cover. The aerial photos were converted to digital format by using a scanner with a resolution of 600 x 600 dot per inch (dpi) and were subsequently rectified to the same map datum as the satellite images. All the image processing procedures were performed with the ERDAS Imagine software.

Supervised classification with a maximum likelihood function was used with the satellite images, and a visual interpretation technique was used to classify the aerial photos. The following seven classes of land use and land cover were identified and used to produce maps from both satellite images and aerial photos: dense forest, secondary/degraded forest, shrubby fallow, grassy fallow, rainfed field crop (maize and upland rice), Litchi orchard, and human settlement (see classified in Figure 3.2 and 3.3).

3.2.3. Recent agricultural transformations

A total of 70 people comprised of senior Doi Tiew villagers, NKU foresters, NNP rangers, Sop Khun Royal Project (SKP) managers and the official of the District Livestock Development Office were interviewed with semi-structured guidelines to re-construct the history of LUCC in the area. These discussions were aimed at identifying and dating the main ecological, agricultural, economic, social or policy events that caused any significant LUCC. The origins and characteristics of these key events were also documented as well as the extent of their impact on the land use. When possible, the information provided by these informants was cross checked with similar secondary data available from already published documents, such as provincial statistics and previous research reports. This information was analyzed by constructing a historical agrarian profile for the Doi Tiew village displaying the interactions between key agro-ecological events and socioeconomic changes in the area. This profile was also matched to the results of the spatial analysis to interpret the LUCC during several successive key phases of the local agrarian history (Mazoyer and Roudard 1997).

The elicitation of the local agrarian and environmental changes over the past four decades also led to the identification of the origin and extent of the current diversity of household-based production systems making use of the land in different ways to achieve their respective goals (Trébuil, 1990; Trébuil and Dufumier, 1993).

3.2.4. Analysis of the diverse types of agricultural production systems and their dynamics

Based on the previous reconstruction of the past trajectory of the local forest-farm land interface agrarian system, another complementary series of in-depth individual interviews was carried out with local stakeholders. This set of interviews was based on new semi-structured guidelines to characterize the diversity of Doi Tiew villagers' agricultural production systems and their dynamics at the village level (Barnaud *et al.*, 2008). Two or three visits were made at 45 farming households to improved and consolidate the information gathered. The objectives, strategies and practices of the other non-farmer stakeholders involved in local forest conservation activities were also documented. The interviews with government officials focused on their roles, objectives, and practical enforcement of policies and legal frameworks, including the obstacles met in this endeavor.

The guideline used during the interviews with respondents aimed first at describing the structure and orientation (characterization of the productive assets, combination of different farm and non-farm economic activities) of their respective production systems. A second part aimed at understanding the functioning of these production systems by identifying their respective socio-economic objectives and the selection of related strategies taken to reach them, leading to decision making processes regarding the choice of farming practices, use of forest resources and non-farm activities (Trébuil *et al.*, 1997). The data analysis involved the construction of a farmer typology based on the households' socio-economic objectives, productive assets available, constraints and opportunities determining their respective farming strategies and practices.

This stakeholder analysis identified the origin, causes, and differentiated consequences among several types of farmers-herders of the current land use conflict over the access to grazing land which is opposing Doi Tiew villagers to RTG foresters and rangers. The farmer typology is used to discuss constraints and opportunities of each main type of local livelihood systems to the decreasing access to grazing land. This survey also produced an understanding of the relative importance of this land use conflict among each category of concerned individual or institutional stakeholders, and their respective potential influence (Grimble and Wellard, 1997) in the collective search and implementation of an acceptable land management solution. Moreover, this survey also helped to set up the collaborative modelling process in the next steps of this research.

3.3. Results and discussion

3.3.1. History of local agrarian system and land use change

The historical profile of Doi Tiew village is presented in Table 3.1. This shows the chronological sequence of the key interrelated agro-ecosystem transformations and changes in the local socio-economic conditions since the early 1960’s (AD) that led to the production of the current landscape features managed by different types of farmers and government institutions. Three main phases of agrarian system transformations and related landscape change can be identified and each of them is characterized below.

Table 3.1. Evolution of agro-ecological and socio-economic characteristics of Doi Tiew forest-farm land interface, Tha Wang Pha District, Nan Province

Agro-ecological transformations	Year	Socio-economic changes
Mainly self-subsistence agriculture		
- Natural forest dominates the landscape	Before 1961	- Scattered households of first settlers
- Swiddens of upland rice and maize cleared for family consumption	1961	- Official registration of the village with approximately 50 households
- Opium poppy cultivation for exchange of products with lowland people	1962	- Expansion of the village through immigration from surrounding hamlets
- Rearing of a local breed of cattle in natural forest areas for sacrifice at cultural ceremonies	1968	- Most of tillagers moved to lowland areas by the Royal Thai Government (RTG) for security reasons during the fight against communism
- Same cropping systems but without opium poppy - Logging company enters the area to fell trees of economic value	1972	- Some villagers start to move back - RTG policy to stop opium poppy cultivation
Market economy		
- Villagers convert the logging area to farm land after termination of the logging concession - Introduction of mechanized maize production for animal feed factories - Expansion of farm land - Improvement of local cattle by introduction of lowland breeds	1980	- Construction of a gravel road and more contacts with lowland people - Houses settled along the road for convenient marketing of agricultural products - Some households start to increase the size of their herds and cattle rearing becomes their main source of income
Market economy with increased constraints due to forest conservation		
- Start of reforestation activities in the area	1990	- Establishment of the Nam Khang Headwater Development and Conservation Unit (NKU)
- Introduction of Litchi (*Litchi chinensis*) production in small orchards - Farmers start using chemical fertilizers	1992-1993	- Reduction of the maize price - The Public Welfare Department promotes fruit tree production - Village electrification and increased contacts with external culture via television
- First delimitation of the national park limits agricultural activities - Cultivated areas move closer to the village settlement - Litchi becomes the main economic crop instead of maize	1996	- Establishment of the Nanthaburi National Park (NNP), but it is not yet officially declared - Beginning of the local enforcement of the law on national parks
	2000	- Arrival of the hill irrigation system: piped water is available for domestic use
- Some herders move their herds out of the park area, others still raise cattle on the park land	2005	- Sop Khun Royal Project is established - Migration of workers to lowland areas for daily or monthly wage earning employment
- More than 1,000 heads of cattle are grazing the farm land and (natural, plantation plots) forest areas	2006	- Detailed delimitation of the final NNP boundary with the villagers' agreement
- Some 500 heads of cattle are sold in January-February due to the lack of grazing land	2008	- 170 households live in the village with a total population of over 1,300 inhabitants

3.3.1.1. 1961-1980: an agrarian system abandoning self-subsistence agriculture

Before the official registration of the village in 1961 and its establishment at the top of a ridge, a cultural preference for the location of Hmong ethnic group settlements (Kunstadter *et al.*, 1978), several households of Hmong migrants from Laos were scattered in the area. A self-subsistence economy dominated during the early part (1961-1975) of this period (Table 3.2). The swiddening type of cropping systems with long fallow periods was used to grow mainly upland rice and maize for local households and domestic animal consumption. With a maximum duration of 12 years, this system allowed a succession of secondary forest and nutrient recovery (Uhl, 1987). The amount and location of the farmland per family depended on the households' needs for food products and the family labour available. Opium poppy was planted and the production was exchanged with lowlanders to obtain consumer goods, but some households managed it as a primary cash crop. Small scale cattle rearing was already present in the system, with small herds of 1 to 10 heads per household, but was still largely a cultural activity providing animals for sacrifices performed during important ceremonies (see more details in Table 3.3).

Table 3.2. Evaluation of key variables of Doi Tiew agrarian system, 1961-2008.

Variables	1961-1980	1980-1990	1990-2008
Ecological system	- Scattered agricultural area inside the dense forest cover	- More forests encroachment in the southern part of the system	- Clearly separation between conservation and crops land - More forest encroachment in steep zone.
Technical practices	- Household (HH) - based technique - Long fallow period of up to 12 years	- Using handheld machines, i.e. sprayer - Fallow period became shorter at 5-8 years	- Short fallow period of 2-3 years. Some farmers who own only a small area of land have to repeat cropping every year - Heavy machines, i.e. truck, rice mill
Cropping system	- Upland rice for HH consumption - Opium poppy	- Maize for animal feed is the main economic crop - Upland rice for HH consumption - Start growing litchi in maize or rice field without irrigation system	- Upland rice for HH consumption - Litchis became the main economic crop. Some farms that are close to the stream have an irrigation system
Livestock rearing system*	- Poultry - Cattle raising in natural forest for domestic use and live saving reasons	- Poultry - Cattle raising in natural forest for more economic reasons than live saving	- Poultry - Cattle raising in natural forest, reforestation area and fallows for economic or live saving reason
Non-timber forest products	- Bamboo shoots, mushrooms, other edible vegetables, hunting animals (wild boar, birds, etc.), medicinal plants, palms for making roofs, woods/bamboo for construction		- More limited in what can be harvested by the government laws - Harvest more by the poor HH's aiming at consumption

Variables	1961-1980	1980-1990	1990-2008
Demo-graphic pressure (few data recorded in the village)	- Low (~50 HH, ~200 inhabitants.) - More available agricultural area for illegal occupation	- Medium (~100 HH, ~500 inhabitants) - Suitable agricultural area almost occupied by villagers who are earlier immigrants from the lowlands	- High (~170 HH, 1,300 inhabitants in 2007) - Smaller farm land inherited from parents because expansion of agricultural area is not allowed by law
Access to market	- Low, mainly through opium poppy activity	- Medium in earlier phase and high in late phase due to more experience and connection with lowland farmers and merchants	- High, due to good development of infrastructure and availability of telecommunication - Farmers can negotiate production price or select the merchant before selling
Inputs	- No need for external inputs from outside	- Need external inputs, such as handheld machines and start using fertilizer in maize	- High external inputs (e.g. fertilizers, pesticides, herbicides, heavy machines) due to the repetition of crops.
Rural credit	- None	- Farmers borrow from their neighbours in the same clan without interest	- Loan from the village fund, Bank for Agriculture and Agricultural Cooperatives with low interest rate - Borrow from neighbours in the same clan without interest
Land titles	- No land title due to the location of village is in headwater area (watershed class 1A) - The land occupation is illegal but the farmers have to pay for the utilization tax to the government		
Labour market	- From HH and mutual help		- Lower in mutual help - Hire labours in the village for maize and litchi harvesting - Start working off-farm in town
Agricultural incomes	- Upland rice for consumption	- Gain income from maize in similar proportion to cattle. But for large cattle holders, cattle is the main source of income	- Gain income from litchi and maize more than cattle
State intervention	- In 1965-1972, the government implemented the policy against the Communist Party of Thailand. - Villagers were moved to lowlands for security reasons	- Development projects from government agencies, especially new crops to replace the opium poppy and reduce shifting cultivation	- In 1990, the reforestation policy was implemented by establishment of the Nam Khang Headwater Development and Conservation Unit - In 1996, strong implementation of forest conservation policy due to the establishment of the Nanthaburi National Park - Villagers attempt to negotiate with the park manager about the park boundary - In 2006, the park manager decided to cut-off 46% of park area
Socio-economic differentiation	- Not much difference	- Start accumulation of crop land and cattle - Diverse types of farming occurred	- More diverse type of farmers based on available cropland, cattle asset and investment capacity.

*Note: * More details on cattle raising are provided in Table 3.3.*

Table 3.3. Evolution of cattle raising sub-system in Doi Tiew agrarian system.

Detail	1961-1980	1980-1990	1990-2008
Changing point		- More contact with lowlanders and accumulate more herd in resource rich farmers	- Previous system was not suitable due to constraints by forest conservation activities from NKU and NNP
Herd size/ owner	0 - 10 (mode = 5)	0 - 100 (mode = 20)	0 - 50 (mode = 12)
Objective of cattle raising	- Domestic use - Drought power - Live saving income	- Lower in domestic use - Mixed between live saving and cash income	- Mixed between live saving and cash income (the use of cattle for domestic consumption, sacrifice and wedding ceremonies were replaced by pork and chicken)
Diversity of grazing sites	- Natural forest area - Abandoned field of opium poppy - Fallows	- Natural forest area - Fallows	- Natural forest in conservation and reforestation areas, where cattle have been raised before - Fallows - Litchi orchard (a few herders) - Rotation among litchi and fallow
Rule to access the land	- Free access but not overlap among herders - Each herder knows that which grazing area belongs to whom		- For cattle raising in reforestation and national park area, herders have to negotiate with the NNP and/or NKU managers
Inputs/ investment	- Low	- Low to high, depending on the herd size	- High, especially fuel for motorbike to visit cattle instead of walk - Trend to use wire to build fence instead of bamboo.
Labour	- Use labour in the same household that raising cattle together - No hire labour because no one want to response in case of cattle loss or die		
Technical practices	- Simple	- More management activities due to more economic purpose	- Diverse techniques: Depends on types of herders and constrains from foresters
- Fence	- Bamboo	- Bamboo > wire	- Wire > bamboo
- Genetic improvement	- No, only local breed and inherit cattle from parents	- Lowland breed[10] bull was introduced to increase market value and share male breeds[11]	- Almost hybrid breed in the system
- Health care/ vaccine	- No	- Only a few herders who are interested	- Low: Introduced by District Livestock Development officers and veterinarian volunteer from the village
- Castration	- No castration		
- Supplemen-tary mineral	- Salt (from Bo Kluea village[12])	- Salt (from lowland)	- Salt (from lowland) and supplementary mineral
Loss/thieves	- High, especially in large holders raising cattle in large area - No thieves		
Death (Disease/ epidemic/ natural causes and enemies)	- No records on foot and mouth disease are available - In the dry season: cattle are usually attacked by ticks (can kill 0 - 1 year old calves) - In the dry and wet seasons: calves, 0 - 1 year old, are killed by some canine animals - Sliding and fall down in the steep slope area		

[10] Two types of introduction: i) buy from lowlanders, and ii) there is evidence that cattle die by the thunderbolt, then the farmer asking the compensation from the Tha Wang Pha District Livestock Development Office. After investigated, farmers received 5 American Brahman breed.

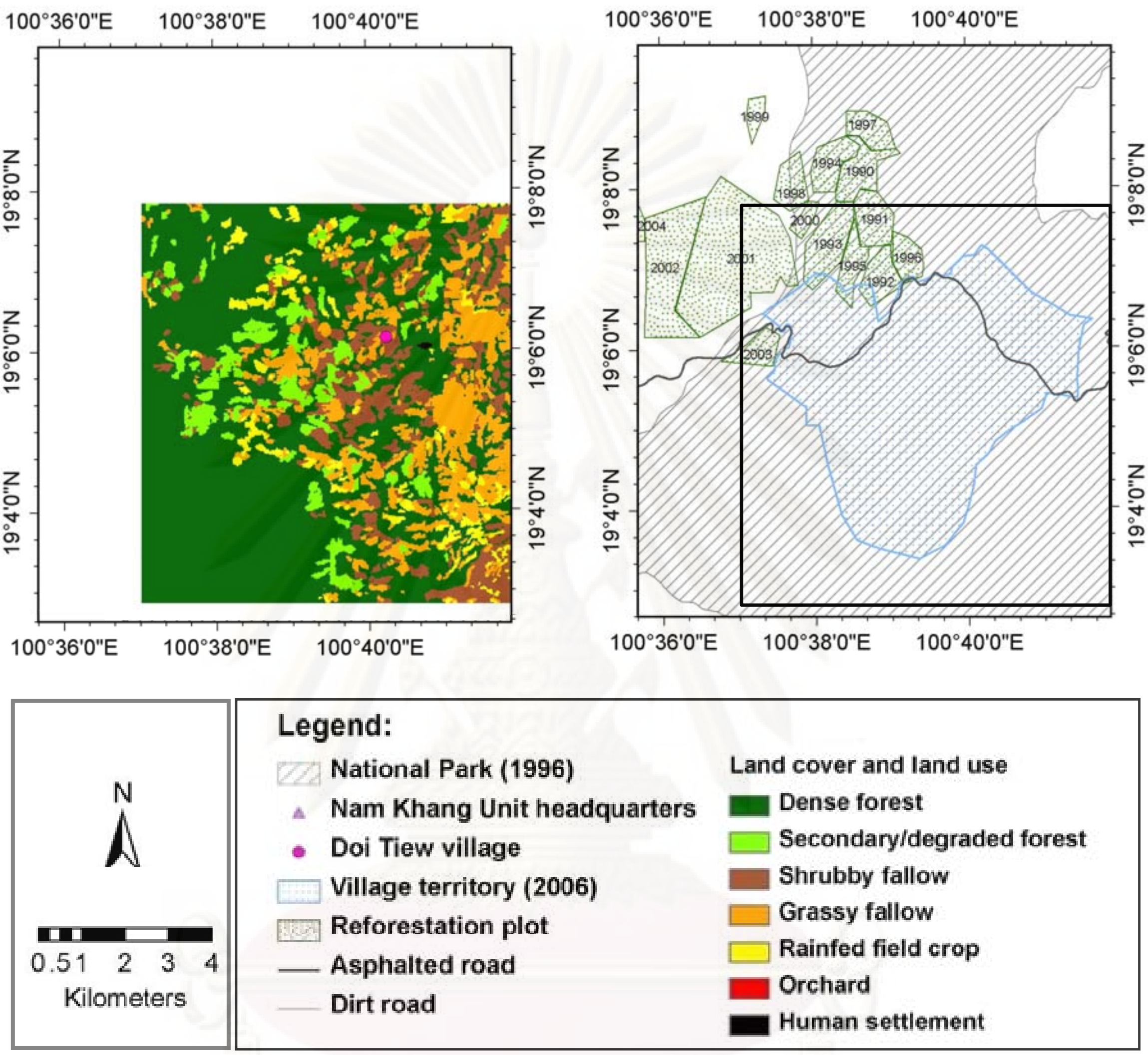
[11] The herders who want to improve their herd genetics can bring their mature female cattle to the herder who has the Brahman male breed and mate without any payment. This usually occurs in the same clan.

[12] Important source of salt (obtained from salty soil where there are underground salt deposits) in Northern Thailand.

Detail	1961-1980	1980-1990	1990-2008
Constraint to increase cattle owning	- Investment capacity		- Available of grazing land
Market and price	- Usually for domestic use	- Lowland merchant(s) come to the village and estimate price (no weighting, just look at the cattle quality), herders can negotiate the price before selling - Price seems stable, herder said 'the highland cattle price is cheaper than cattle in the lowland and not fluctuate too much'	
Socio-economic differentiation	- Low, each family own small herd size	- Some herders accumulate cattle heads for economic reason	- High, due to the number of cattle owning
State intervention	- No		- High due to the RTG forest management policy

In 1968, the RTG classified this area a "red zone" because the Communist Party of Thailand established a base and shelter in the dense forest. For security reasons, most of the the villagers were moved to the lowland village of Ban Pak Klang, also in Tha Wang Pha District, where they were in close contact with lowland farmers and merchants, learning new farming practices, including maize production for sale and livestock marketing.

Following their return to Doi Tiew, the villagers were ready to establish more contacts with the market economy during the remaining (1972-1979) years of this phase. The increasing human population due to natural growth and immigration from other settlements became another important driving force behind the expansion of farm land as the number of households doubled between 1961 and 1980. Following the economic exploitation of a logging concession in the area, lowland villagers with capital and Doi Tiew farmers started to fell small and non-economic trees before burning to expand crop areas. Farmers who returned to Doi Tiew earlier than others attempted to occupy more land for commercial maize production, leaving only small patches of less favorable farm land near the village for the late returnees who, consequently, had to venture farther from the settlement to find more fertile plots to cultivate. This accelerated the socio-economic differentiation among the local farming households and lead to an increase in the degradation rate of the forest landscape, as shown in the results of the spatial analysis towards the end of this first phase (Figure 3.2). A large portion of the local landscape was still occupied by dense Dipterocarp and secondary or degraded forest cover with scattered clearings for annual crop production. Large patches of grassy (e.g. *Imperata cylindrica* and *Thysanolaena* sp.) and shrubby fallows (dominated by *Melastoma* sp. and *Cratoxylum formosum*) could already been found by that time and were produced by opium poppy cultivation since 1961 (Figure 3.2).



Source: Interpretation from aerial photos taken in 1977.

Note: Smaller area was available compare to the satellite images. Therefore, this classification aims at providing the overview of the past.

Figure 3.2. Classified land use map in crop year 1977 from aerial photography of Doi Tiew forest-farm land interface.

3.3.1.2. 1980-1990: deepening the integration of local farming into the market economy

The improvement of logging trails made the access of heavy machinery to the fields and the transportation of farm products to the lowland markets easier, especially the transport of maize to feed mills. This followed a regional trend that saw the area used for maize plantations increase some 79-fold over 30 years, from 10,400 to 825,000 ha between 1958-1960 and 1989-1990 (Delang, 2002; 2005). More and more external farm inputs and equipment were also introduced in the highlands (Table 3.2), as well as lowland breeds of cattle to improve the quality of local animals (Table 3.3). Seeds of new maize varieties, chemical fertilizers, pesticides and sprayers were used to increase crop yields while four-wheel tractors plowed larger fields, preferably along the main road (Figure 3.3a) and small trucks belonging to rich farmers started to be used to transport and market the harvested goods.

Several well-off farmers, who had already accumulated some capital, established small convenience stores in the village to sell basic consumer goods imported from the lowlands to other villagers. This decade also saw the commercialization of cattle rearing on most of the village farms, in parallel with the adoption of a lowland breed. While most of the farmers increased the size of their herds to approximately 20 heads, several households now had to look after up to 100 cattle grazing in the area. Herders belonging to the same clan pooled their herds to graze together in large, and partly bamboo fenced, patches of hilly natural pasture of up to 400 ha in size. However, the natural forest was still a major source of forage.

Towards the end of this decade of agrarian transformations, local farming was integrated in the market economy through annual cash cropping and cattle production. The classified land use map for 1988 crop year shows the expansion of rainfed field crops surrounded by extensive grassy and shrubby fallows in the landscape (Figure 3.3a). New clearings were still visible in areas under dense forest cover, especially in the south-western corner of the map. The observed widespread areas of grassy and shrubby fallows show that a rotational system inherited from previous swiddening practices was still in use (Table 3.4).

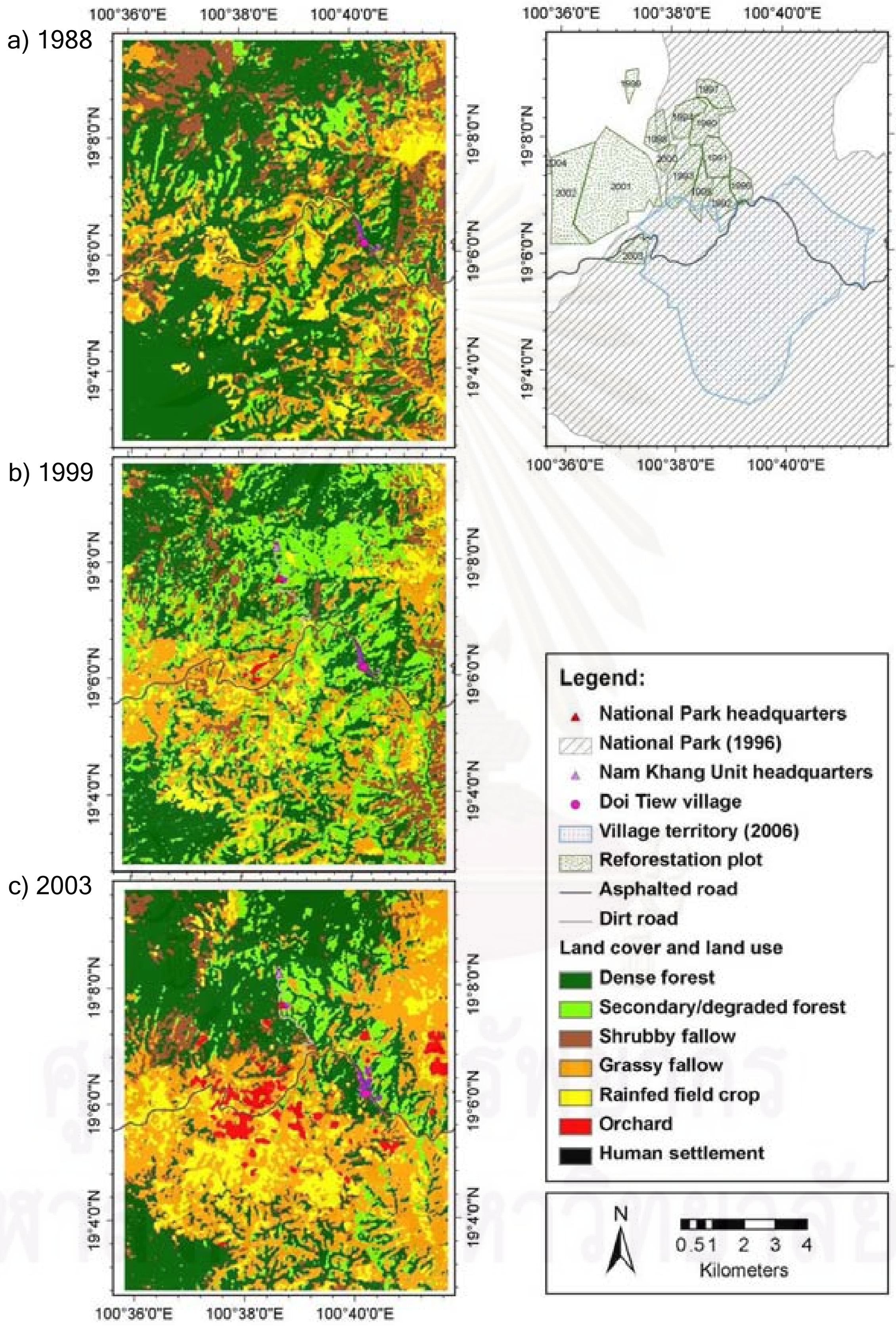


Figure 3.3. Classified land use map crop years 1988, 1999, and 2003 from Landsat satellite imageries of Doi Tiew forest-farm land interface.

Table 3.4. Recent land use and cover change at Doi Tiew village in Tha Wang Pha district of Nan Province, 1988-2003.

Type of land use and land cover	Area (ha) and % of total cover		
	1988	1999	2003
Dense forest	6,288	4,483	4,700
(more than 20 years old)	48.2%	34.4%	36.0%
% change		- 13.8	+ 1.6
Secondary or degraded forest	1,323	3,704	1,099
(10-20 years old)	10.1%	28.4%	8.4%
% change		+ 18.3	- 20.0
Shrubby fallow	2,261	1,537	970
(6-10 years old)	17.3%	11.8%	7.4%
% change		- 5.5	- 4.4
Grassy fallow	2,315	2,252	4,379
(1-5 years old)	17.8%	17.3%	33.6%
% change		- 0.5	+ 16.3
Rainfed field crop	839	1,018	1,472
	6.4%	7.8%	11.3%
% change		+ 1.4	+ 3.5
Orchard	-	18	386
	-	0.1%	3.0%
% change		+ 0.1	+ 2.9
Human settlement	16	29	44
	0.1%	0.2%	0.3%
% change		+ 0.1	+ 0.1

3.3.1.3. Since 1990: a market-oriented system more constrained by forest conservation efforts

In 1990, the NKU was established to reforest the degraded forest cover and to protect the headwater areas from human activities. Reforestation started from the unit headquarters and expanded gradually with new tree plantations being established adjacent to the ones planted in previous years as can be seen in Figure 3.1. During 1990-1995, these reforestation activities did not lead to social tensions with the villagers regarding access to land since the NKU foresters focused instead on the rehabilitation of patches of degraded forest or tree planting in former fallows located far from the village. The NKU manager also discussed with the village headman about the next plot of land to be reforested before it was delimited. But in 1996, the NNP was preliminary established, without any consultation with the local villagers, with its headquarters located 1 km away from the NKU ones. The NNP aimed at forest conservation through the enforcement of the very strict law on national parks (which forbids any such human activities in such parks) and the promotion of tourism. Initially, the NNP covered 84,126 ha, including the totality of Doi Tiew farm land as shown in Figure 3.4a.

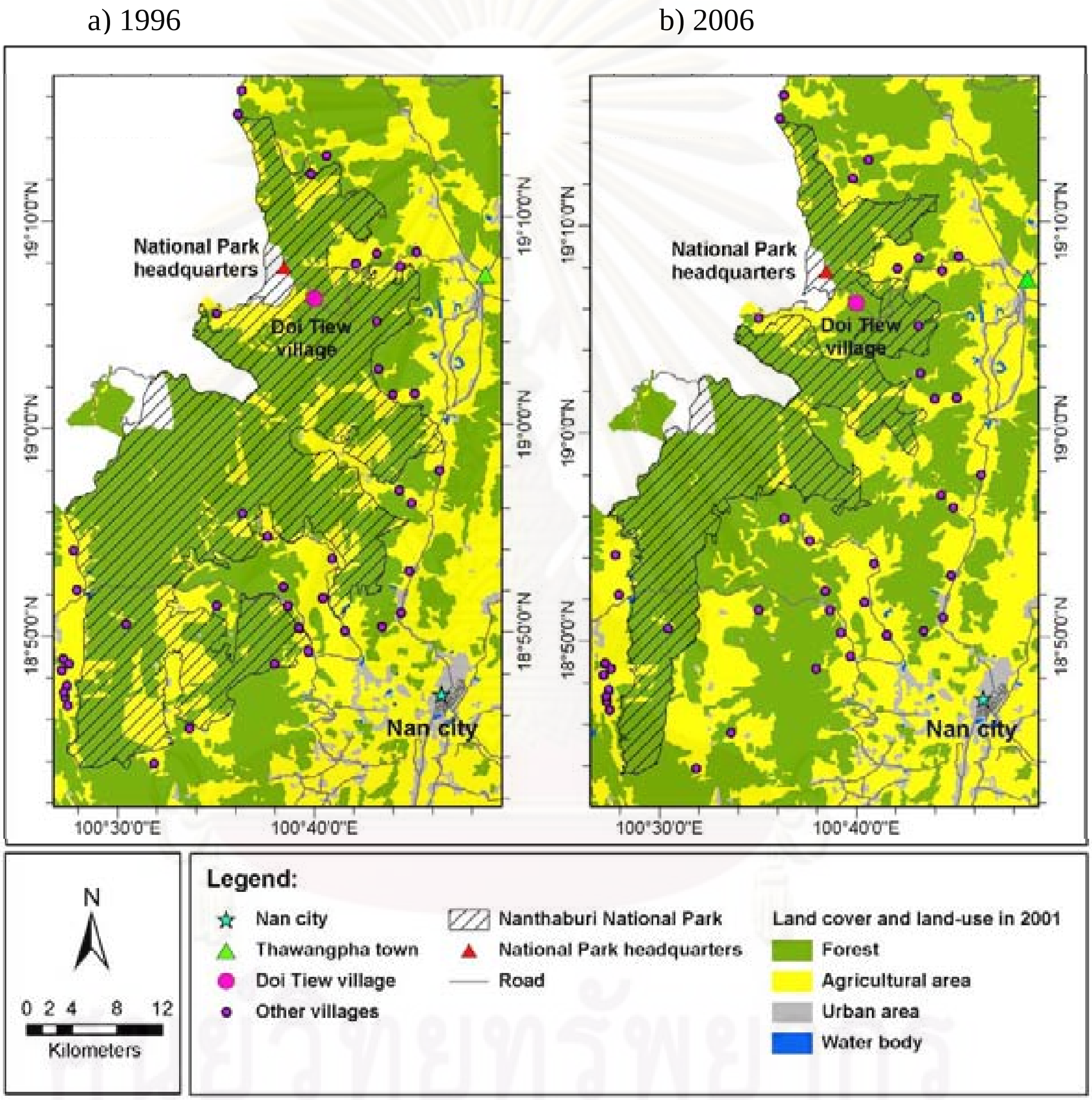


Figure 3.4. Changes in the Nanthaburi National Park boundaries between 1996 and 2006, and the territory of Doi Tiew village after re-demarcation with the park.

Although the park was not officially declared at this stage, the law was partially enforced and the clearing of new swiddens, hunting, gathering of non-timber forest products (NTFPs) for consumption and extensive cattle rearing were no longer allowed inside its boundaries. The effects of these new rules can be seen in Table 3.4 with the increase in the area of secondary or degraded forests that were not used for crops anymore between 1988 and 1999, mainly in the north-western part of the area managed by the NNP (Figure 3.3b). Suddenly, as the entire village territory was included into the park area, the local farmers were not allowed to access about half of their former agricultural land, especially the grazing areas. This is the origin of the current land use conflict between the Doi Tiew villagers and the NNP officials, as the villagers started to claim their rights to continue to farm the land they used to occupy.

On the ground, we assist at the relocation of most of the rainfed field crops to the central to south-western part of the area as shown in Figure 3.3b. But with more limited access to farm land, the fallow periods become shorter and the share of grassy fallows increased recently while areas under older shrubby fallows or secondary forest cover decreased significantly (Table 3.2 and 3.4). Large areas of shrubby fallows (1,201 ha or 9.2% of the total area) located in the vicinity of the NNP headquarters had to be abandoned by local farmers and evolved into secondary forest and a regenerated dense forest cover in some areas during 1988-1999 (Table 3.5).

A few years after the establishment of the NKU, the Public Welfare Department, another government agency well-established in these highland areas across the Northern region that are populated by minority ethnic groups, started promoting the plantation of litchi orchards to reduce the shifting cultivation. The very first orchard was planted in the 1992-1993 crop year and initiated a still on-going diversification of the local cropping systems into fruit trees and a gradual switch from annual to perennial cash crops, a trend that was observed all over the Northern region at that time (Trébuil *et al*., 2006). In Doi Tiew, decreasing maize prices encouraged litchi planting on the slopes along the main road and in the vicinity of the human settlement, making the harvest and its marketing of this fragile and labile crop more convenient (Figure 3.3c This took place on land farmed by relatively well-off villagers who had accumulated enough capital to invest in perennial plantations. Areas planted to litchi orchards increased more rapidly after 1999, mainly through the conversion of grassy fallows and annual field crop, as farmers started to see fruit orchards as a way to secure their rights on the land. The area planted to fruit trees increased some 21.4-fold in four years, from 18 ha in 1999 to 386 ha in 2003 (Figure 3.3b, 3.3c and Table 3.6), and this trend continued for several more years. Being a "large tree", litchi plots located in the park area were tolerated by the NNP and so litchi harvesting became a human activity tolerated in the park area. Indeed, litchi owners are allowed to harvest their fruits every year.

Table 3.5. Quantified change in land use and land cover at Doi Tiew village in Tha Wang Pha district of Nan Province between 1988 and 1999 crop years (in ha and %).

Year		1988						
	Land use & land cover type	Dense forest	Secondary/ degraded forest	Shrubby fallow	Grassy fallow	Rainfed field crop	Orchard	Total
1999	Dense forest	3,515 27%	111 0.9%	626 4.8%	211 1.6%	19 0.1%	- -	4,483
	Secondary/ degraded forest	1,471 11.3%	789 6.1%	575 4.4%	641 4.9%	228 1.8%	- -	3,704
	Shrubby fallow	439 3.4%	196 1.5%	446 3.4%	350 2.7%	105 0.8%	- -	1,537
	Grassy fallow	648 5.0%	109 0.8%	459 3.5%	803 6.2%	234 1.8%	- -	2,252
	Rainfed field crop	204 1.6%	114 0.9%	146 1.1%	302 2.3%	252 1.9%	- -	1,018
	Orchard	8 0.1%	1 -	3 -	6 0.05%	- -	- -	18
	Total	6,288	1,322	2,261	2,315	839	-	13,012

Table 3.6. Quantified change in land use and land cover at Doi Tiew village in Tha Wang Pha district of Nan Province between 1999 and 2003 crop years (in ha and %).

Year		1999						
	Land use & land cover type	Dense forest	Secondary/ degraded forest	Shrubby fallow	Grassy fallow	Rainfed field crop	Orchard	Total
2003	Dense forest	3,241 24.9%	1,247 9.6%	211 1.6%	- -	- -	- -	4,700
	Secondary/ degraded forest	177 1.4%	749 5.7%	147 1.1%	7 0.05%	11 0.1%	- -	1,091
	Shrubby fallow	339 2.6%	334 2.6%	153 1.2%	139 1.1%	4.8 0.04%	- -	970
	Grassy fallow	581 4.5%	1,065 8.2%	729 5.6%	1,416 10.9%	586 4.5%	- -	4,379
	Rainfed field crop	120 0.9%	256 2.0%	256 2.0%	537 4.1%	303 2.3%	0.4 -	1,472
	Orchard	20 0.2%	48 0.4%	38 0.3%	151 1.2%	113 0.9%	18 0.1%	386
	Total	6,288	1,322	2,261	2,315	839	-	13,012

There was as large a decrease in the dense forest during the first 11 year period as during the second four year period since: less-favoured farmers were still converting forest to farm land to expand maize growing, mainly in the more remote south-western part of the area (Figure 3.3b and 3.3c) as seen in the decrease area of dense forest cover and increased area of degraded forest areas between 1988 and 1999 in Table 3.5. During 1988-1999, the dense forest cover decreased as 1,919 ha (11.3% of the total area) as it was converted to secondary or degraded forest, and further 851 ha (6.53% of the total area) was converted to rain fed field crops and grassy fallows (Table 3.3).

After 1997, the adaptation of cattle raising practices to the new conditions saw some herders moving their herds out of areas claimed by the NKU and NNP "forest guardians" (Forsyth and Walker, 2008) to their old fallows and orchards. But other herders decided to sell their cattle and to focus on maize production by clearing new area of more steeply sloping farm land. In recent years, the maximum size of herds has been around 50 heads per household, with poor farmers keeping from one to five heads as a kind of living saving asset, cattle being sold in case of urgent need for cash to face unexpected expenses. Because the collection of NTFPs for household consumption and the opening of new clearings were increasingly difficult in this period, some villagers belonging to small to medium farming units started to migrate to lowland areas and cities to seek daily or monthly wage-earning employment.

In 2006, the limits of the NNP were re-demarcated with the villagers and 3,228 ha of the village farmland being taken out of the park area. This was due to a long negotiation process between the NNP and surrounding villagers whose farming areas were at that time included into the park boundary (Figure 3.4a). To avoid the violent conflict, the NNP decided to reduce the park size by excluding some area and thus relocating them back to those villages.

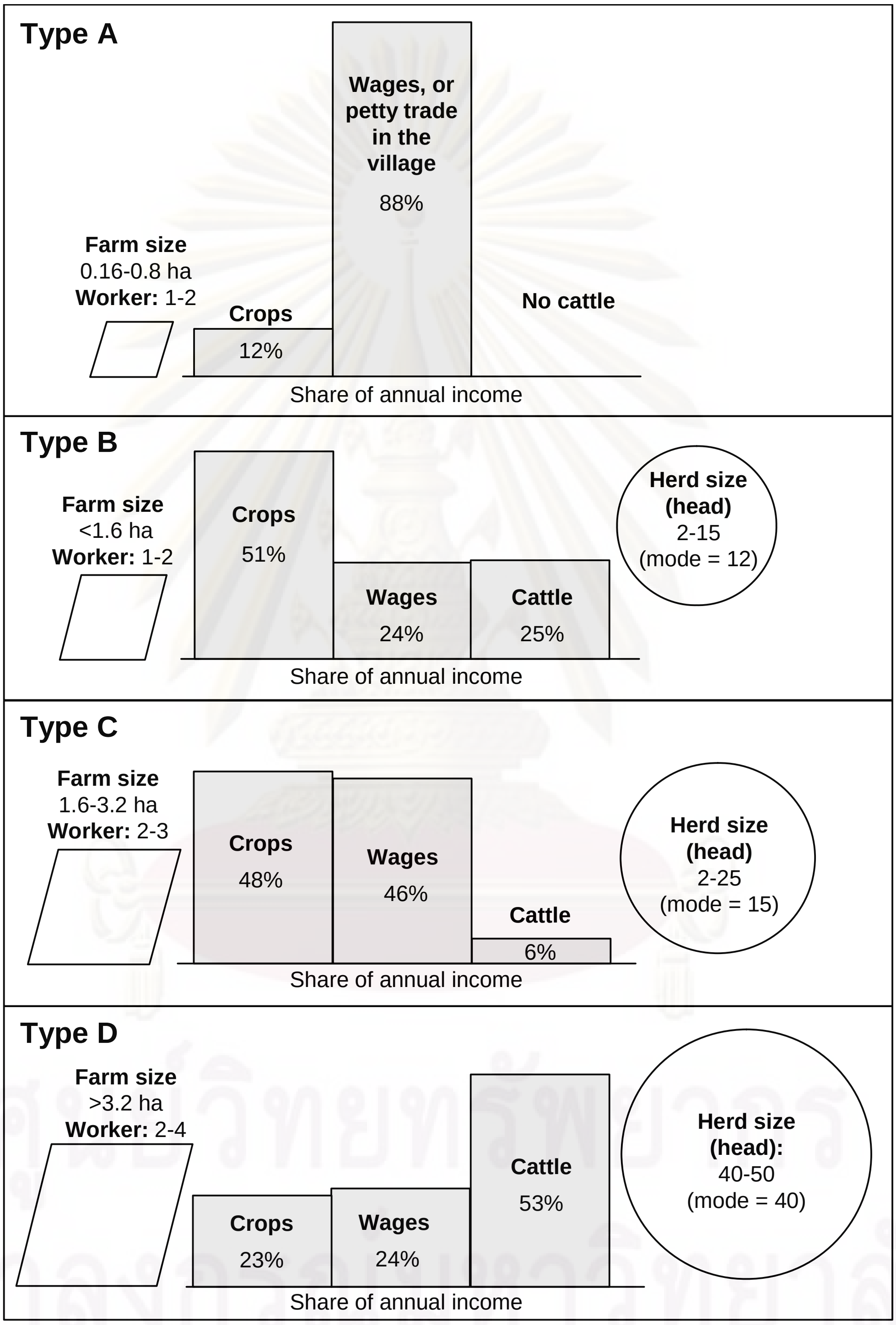
This new delineation saw the size of the NNP shrinking by 46% to 45,331 ha (Figure 3.4b) and was able to mitigate the local land use conflict as the local villagers could continue their cropping and animal rearing activities outside of the park boundary, especially in the south-western part of the human settlement where most of the still increasing production of rainfed field crops was relocated (Figure 3.3c). In 2003, the NNP was still negotiating its definitive boundary with Doi Tiew and the other neighbouring villages by allowed them to delimit the park boundary. Before the end of this process, and possibly to claim their rights on the land and to establish a *fait accompli* (Ganjanapan and Kaosa-ard, 1995), the Doi Tiew villagers rapidly converted large tracks of dense and secondary or degraded forest into farm land in the south-western part of the area, leading to a 20% decrease for this type of land cover between 1999 and 2003 and a related jump by 16% of the areas occupied by grassy fallows during the same period (Table 3.4 and 3.6). In only four years, 1,040 ha of dense forest (or 8% of the total area) were converted to maize fields or different types of fallows, mainly on hilly steep land that had not been used for farming before (Figure 3.4c and Table 3.6). However, all over the mapped area, the dense forest cover increased marginally during this period, because of the areas of regeneration in easy to control areas located close to the NKU and NNP headquarters in the north-western part of the region (Table 3.4 and Figure 3.3c).

3.3.2. Current farmer typology and extent of socio-economic differentiation

Over the last four decades, the above-mentioned history of agrarian change has led to a rather extensive socio-economic differentiation among the local farming households in Doi Tiew village. And different categories of agricultural production systems were not affected in the same way by the implementation of the recent forest conservation practices.

The analysis of similarities and differences among the 45 agricultural production systems surveyed led to grouping them into four main types of farms. Figure 3.5 displays the key differences among these four different farming units regarding their strategies to meet their household objectives, the composition of their respective household incomes, and the relative importance of livestock rearing in the farm assets. Each of these main types of farms could be briefly described as follows:

a) Type A farmers generate most of their income from off-farm activities such as wage-earning employment in urban areas or petty trade. One sub-type used to depend on gathering NTFPs for home consumption but stopped this activity to avoid conflicting relations with the foresters. The other sub-type corresponds to a few households of near-landless recent migrants. Both sub-types have never raised livestock or have not reared cattle for many years, and they represent only about 6% of the total number of farms in the village. Relatively, they do not feel much negative impact from the forest conservation practices compared with the other three categories of farmers of farmers because they do not deal much with the forest and land resources.



Note: Typology was constructed from 45 respondents from in-depth individual interview.

Figure 3.5. Recent farmer typology in Doi Tiew village (2007).

The sustainability of this groups livelihood, formerly strongly dependent on the forest resources that acted as their ‘safety net’ as they had no other alternative choice to make a living locally, has decreased dramatically as the quantity and diversity of available forest products/ NTFPs and resource security declined. Given that these people, with a relatively high dependency on forests, are poor, the impact of forest conservation that limits their right to access these resources increases their economic marginality as the loss of income and subsistence from forest resources can lead to high rates of indebtedness. With the increasing numbers of household members and increasing difficulty in gaining access to farmland this leads to accelerate their departure from the village to become full time wage earners on lowland farms or in urban areas in the near future.

b) Type B farmers are resource-poor farmers growing upland rice for self-subsistence and maize and litchi for sale on small holdings (usually less than 1.6 ha), and managing a cattle herd of about 2-15 heads. Their cattle graze mostly in the forest and reforestation areas and the sale of these animals is a significant source of their cash income (Table 3.7). With 60% of the holdings belonging to this type of farm, it is by far the most frequent one. Due to the very small size of their holdings, they are sensitive to the rarefaction of common grazing land and the very limited opportunities to expand their holdings due to forest conservation and reforestation activities. Those households in this category showing a poor performance in terms of land and labour productivity are liable to abandon farming in the future.

c) Type C farmers generate their income from the sales of maize and litchi grown on 1.6 to 3.2 ha of farmland, and daily wages. Their cattle herds (2 to 25 heads per household), which graze in forest or reforestation areas and on fallow land, also provide a secondary source of cash income (Table 3.7). Compared with type B farmers, these production units have a higher capacity to invest in feeding and caring for their cattle. Supplementary minerals and vaccines purchased from lowland areas are used to improve the quality of their animals. In total, 28% of the local farms belong to this type of somewhat economically stronger farming households.

Table 3.7. Different characteristics of cattle rearing practices among the three principal farm types in 2007.

Details	**Type B:** Cattle is important source of income	**Type C:** Cattle is an alternative source of income	**Type D:** Large cattle holder, cattle is main source of income
Herd size/ owner	2 - 15 (mode = 12)	2 - 25 (mode 15)	> 40 (mode = 40)
Strategy	- Individual or pool cattle from 3 - 4 households from the same clan and located in natural or conservation areas with large fence	- Similar to type B but some herders are available to rotate their cattle to graze between natural areas to their own fallows or orchards	- Mainly locate cattle in natural forest under conservation area and large fallows far from village settlement area
Technical practices	- More time spent managing the cattle	- Balancing between cattle and cropping activities	- More time spent on build and/or repair large fence
- Fence	- Bamboo	- Bamboo or wire	- Wire
- Genetic improvement	- Low	- Low to medium	- High and fast due to the large number of cattle
- Health care/ vaccine	- Few vaccine use	- Medium to high	- Medium to high
- Supplementary minerals	- No (only salt)	- Supplementary mineral from lowland, - Providing in dry season to attract cattle back to paddock	
Inputs/ investment	- Low to medium		- High, such as wire for fence building
Death and loss	- Low to high, depending upon the herd size, grazing area and level of care. - In small grazing areas, cattle death and loss is very low (if any)		- High, especially in young calves (0 - 1 year old) where loss to predators is about 40 - 60%
Market	- Lowland merchants come to buy cattle at village (herders have their mobile phone number)		
Decision making on selling	- Depends upon the herders' need to use money. - Sell at a good price (if they know that the market price is low, they keep their cattle to the next selling time)		- Select the good or undesired (aggressive or weak) cattle to sell in order to maintain the stock
Selling frequency	- Once every 1 - 2 years	- Once every 1 - 3 years	- Every year
Selling time	- Usually in the dry season between November and February because: i) it is easy to move cattle from the raising area that usually have a dirt road and so is inconvenient to access in the rainy season, and ii) the cattle weight is still high enough to fetch a good price, after that the weight will decrease due to the lack of grass. - In case money is needed, the herders will sell cattle as and when needed.		
Socio-economic differentiation	- Poor to medium herders		- Usually rich herders
Constraint to increase cattle owning	- Lack of investment capacity - Lack of available of grazing land		- Lack of available of grazing land
Impact from forest conserva-tion policy	- Low	- High - Some herders decide to sale their cattle wholesale	

d) Type D farmers get their cash income from the same range of crops as type B and C farmers, but harvested on usually more than 3.2 ha per holding. However, cattle rearing is their main source of income and the size of their herds can exceed 40 heads per household. These well-off large herders, that comprise 6% of all farming households, have a stronger capacity to invest in agriculture. They acquire cattle breeds from the lowlands, such as the American Brahman, for the genetic improvement of their herds, and they use more durable barbed wire to fence their paddocks instead of bamboo. Because their large herds graze mainly in the forest and reforestation areas, these farmers are at the forefront of the local land use conflict between farmers and those officials opposing herders using the park and reforestation units. They believe that the lack of natural pastures will force them to re-orient their production systems in the future. But these well-off herders have the economic means to adapt their livelihoods.

At maize and litchi harvests, type C and D farmers hire labourers from smaller A and B farms. Some of these smallholders also secure informal loans from larger C and D farms belonging to the same clan.

These four farm types have developed over time and for Doi Tiew village are summarised in Figure 3.6.

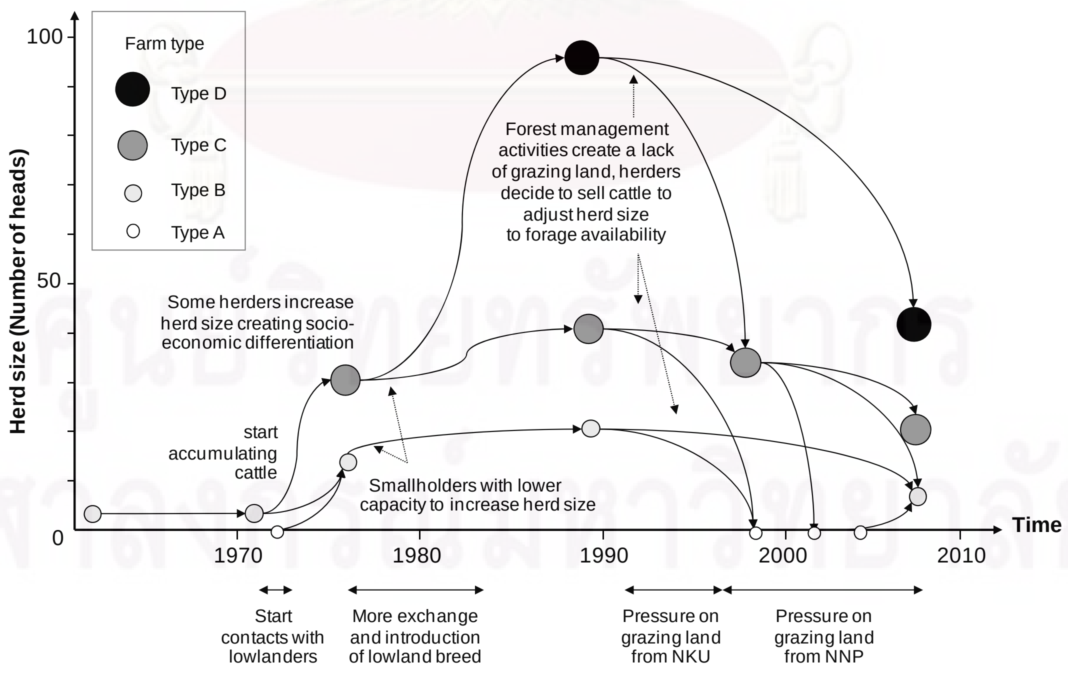


Figure 3.6. Evolution of cattle raising system in Doi Tiew village.

Many herders decided to sell their cattle to avoid the conflict, which accounts for the sharp decline in the total cattle population and the changes in farm type of herders at that time. However, many of them still continue to rear cattle, the main reason being that they have been raising cattle in this area since before the NNP and NKU arrived. This created the land use conflict at the Doi Tiew village study site.

3.3.3. Key land use conflict at study site

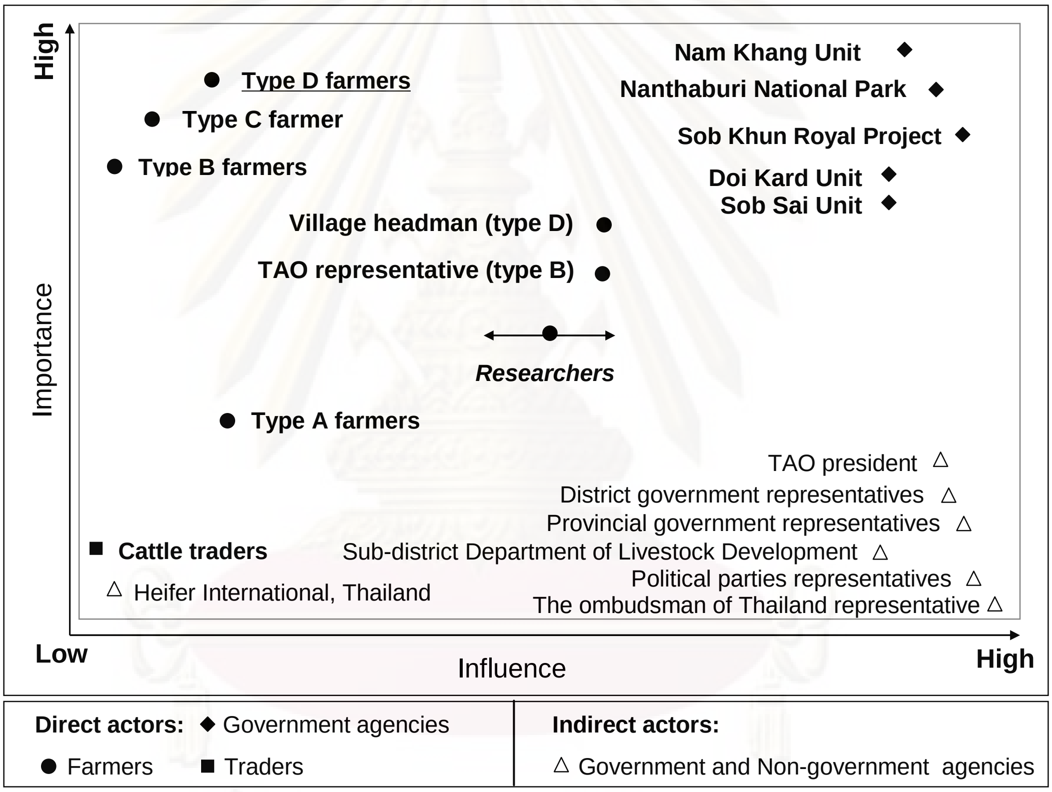
From interviews, we found that in recent situations only the NKU foresters and NNP rangers are having conflicts with the villagers because the other forest restoration units' headquarters are located very far from the village and their managers do not implement the law in a strict way. We found that the park manager used the strategy of excluding their farmland before any official declaration in late 2009, so as to avoid violent protests from the villagers and to make them more content. Therefore, no violent conflict occurred in relation to cropping activity.

However, there was a conflict on land use for cattle grazing and forest conservation, especially reforestation, due to the contrasted perceptions between villagers and foresters. From the villagers' point of view, cattle raising benefits conservation efforts in terms of preventing forest fires and accelerating forest regeneration. On the other hand, according to the NKU and NNP's point of view, this activity causes man-made forest fires and damages plant seedlings and saplings, especially in reforestation areas. The high social tension between the two government forestry agencies and the villagers occurred when the NNP shot the cattle belonging herders in mid 2007 because the cattle had gained access into the park area. Therefore, a collaborative management process was urgently needed to mitigate this land use conflict.

3.3.4. Concerned stakeholders and their relative and influence on the conflicting issue

The various direct and indirect (those who can influence the behaviour of direct actors) stakeholders were plotted on Figure 3.7 according to the relative importance of the problem at stake for each of them and their level of influence on the outcome of the issue being examined. For example, for type A farmers the importance of cattle problems was not too high because they have currently have no cattle.

Likewise type B farmers usually had low political and social power compared to type C and D farmers who work closely with government agencies as a village headman or village committees. The local government agency, such as the NKU, considered that the cattle rearing is an importance problem because it caused sapling and seedling destruction. The NKU has the authority to solve the problem by implementation of the law, but less authority than the NNP. This heterogeneity among local farmer types needs to be taken into account when setting up a management plan towards social equity and sustainable management (Buchy and Hoverman, 2000; Trébuil, 1997).



Note: TAO = Tambon (sub-district) Administrative Organisation.

Figure 3.7. Importance of the current land use conflict to the different categories of concerned stakeholders and their potential influence to mitigate it.

3.3.5. Effects of forest conservation practices on forest-farm land dynamics and *vice versa*

The recent development in land use goes towards an increasingly clear separation between forest and farmland in this watershed head. This trend is similar to what was recently observed in a neighbouring area (Barnaud *et al.*, 2008), and elsewhere in the upper highlands of Northern Thailand, where similar changes occurred earlier (Ganjanapan and Kaosa-ard, 1995). The limitation of access to land for the farmers without prior consultation between the farmers and government agencies encouraged the farmers to open new clearings to maintain their farm incomes and expand their cropping as a precaution when they were confronted with the closure of their former fallows. This was a similar situation as the one described by Delang (2002). Following the final demarcation of the park boundary, the cropping area tended to be more intensively used, although some farmers used some of their own plots for cattle grazing. This allowed them to rear cattle for at least 6 - 7 years before the grass availability was reduced too much due to secondary forest succession.

In terms of forest conservation, at this early stage, the establishment of the national park in this area was not very successful. Since 1996, the dense forest cover has increased only marginally in areas close to the park and the reforestation unit headquarters, while large tracks of secondary forest were still being converted to farmland. Moreover, the reduction in park size and the fragmentation of its shape (Figure 3.4), with only a few large patches and wide corridors, may seriously reduce its effectiveness for wildlife conservation (Bolen and Robinson, 1999). The new policy has even created further deforestation in parts of the area and increased social tensions and harassed the ethnic minority residents. Again, these trends are similar to the observations made elsewhere by Delang (2002).

For reforestation, there are no available records on the growth and survival of replanted trees. However, from the forester's points of views, the expansion of reforestation plots is an indicator of the success of this activity in this area.

We found that some of the young reforestation plots had been set alight by the farmers to prevent reforestation, since they had farmed those lands before. Thus, the reforestation unit had to then replant those areas again. Therefore, based on this feedback, NKU foresters also face difficulties to find new areas for reforestation. They need to negotiate with the villagers to meet their conservation objectives.

3.3.6. Toward a better co-viability of forest conservation and farming in this agrarian system

Based on the difficulties faced by both sides, that is the local farmers and foresters, there is a need for more concerted and negotiated forest-farm land management strategies. National park and reforestation efforts need to engage local people and to take into account the diversity of interests among farmers (van-Paassen *et al.*, 2008). The strict implementation of the National park law should be replaced by more adaptive rules designed with the involvement and participation of all the local resource users (Roth, 2004). Such an approach would allow all stakeholders to express their respective needs and join in the collective search for acceptable solutions based on the exploration of possible future land use scenarios. For example, what should foresters do if they still need more land for reforestation? What should villagers do if the cattle price is increasing and they want to increase their herd size in the limited land area?

To do so, collaborative dynamic agent-based modelling and simulation approaches is increasingly seen as a promising way for the joint exploration of scenarios of change in the field of renewable resource management and land use analysis (Parker *et al.*, 2003; Verburg *et al.*, 2004). Such approaches could be useful at this study site to facilitate communication, information sharing and learning with the ultimate goal of improving the adaptive capacity of local stakeholders in managing their common socio-ecosystem.

3.4. Conclusion and next steps

An interdisciplinary analysis allows the researchers to understand the dynamics of a complex social-ecological system, to identify the current conflicts that need to be solved, and recognise the diversity of perceptions, objectives, interests, actions and strategies of stakeholders on the resources, as well as their requirements for conflict mitigation. It is helpful for the researchers to select direct stakeholders carefully before involving them into the participatory management project. Results from this study confirmed that the NNP and NKU past practices in this highland headwater area, without consulting with local resources, were not very successful in terms of conservation because they had created problems with the local people rather than acceptance and co-management of the natural resources. As a consequence villagers and foresters are still facing difficulties in managing natural resources to meet their own objectives. Villagers still need land for cropping and animal rearing, whereas foresters need land for reforestation and subsequent protection. The rigid implementation practices of the past had also made them lose trust of each other because both of them have their own but different strategies and actions. Moreover, there was still no real dialogue between the concerned stakeholders and villagers to manage this forest-farm land ecosystem. Therefore, participatory management techniques that facilitate learning and communication among concerned stakeholders were needed.

Regarding further steps, before implementation of a participatory management activity, there was a need to conduct a plot level study on the vegetation dynamics, due to the cattle raising and reforestation activities in the different land use types, in order to build the researchers' own understanding on the effect of cattle grazing and forest regeneration.

CHAPTER IV
ECOLOGICAL SURVEY ON THE EFFECTS OF CATTLE GRAZING AND REFORESTATION ON FOREST REGENERATION

4.1. Introduction

Forest regeneration occurs after disturbances caused by either natural phenomena or anthropogenic activities (Barnes *et al.*, 1997). Natural disturbances such as forest fire, storm and insect outbreaks amongst others, are difficult to predict and control. Anthropogenic disturbance is the most important cause of landscape change over the last 10,000 years, since humans have controlled fire and domesticated plants and animals (Lambin *et al.*, 2003). Examples of human disturbances leading to deforestation and forest degradation have been mentioned in the previous two chapters, such as logging and the conversion of forest to farm land.

Disturbed forest areas can recover many of their structures and functions through the regeneration process, depending on the initial type of forest, and the intensity and frequency of disturbances (Barnes *et al.*, 1997). In tropical agricultural systems, forest regeneration by natural process occurs after the cessation of agricultural activities or when the areas are fallowed. Forest regeneration by natural process is usually slow and takes many years or decades to reach the state of a mature forest (Kimmins, 1987). Another process carried out by humans is reforestation. In the case of our study site, we needed to better understand the vegetation dynamics under the influence of both cattle grazing and reforestation activities from a researcher's point of view to be able to confront this scientific analysis to the local stakeholders' own perceptions of these phenomena. The following sections present the results from our research activities on the effects of cattle grazing and reforestation on the forest ecosystem, followed by the bio-physical characteristics of the study site and the reforestation techniques implemented by NKU foresters.

4.1.1. Possible effects of cattle grazing on forest regeneration (literature review)

Cattle rearing is an important farming sub-system that generates alternative sources of income for farmers (FAO, 2006b; Siegmund-Schultze *et al.*, 2007). Two main types of cattle rearing, intensive and extensive systems, can be found in tropical regions. The intensive system is usually implemented in the lowlands by relatively resource rich farmers. Here, farmers usually raise genetically improved dairy and/or beef breeds with a high level of care. They have to find forage to feed their cattle and provide vaccines and supplementary minerals. Therefore, this system does not affect the forest ecosystem. The extensive system can be divided into two sub-types, grazing and mixed farming sub-systems (de Haan *et al.*, 2002). The grazing sub-system provides both positive and negative effects (see details below) on the forest ecosystem because the sources of forage are mainly based on natural grasslands, while the mixed farming type has lower effects because it uses crop residues to feed the cattle. In the highlands, farmers usually practice more extensive systems requiring low cash and labour investments. They rear cattle as a form of domestic use (i.e. drought power and, in the case of the Hmong, sacrificial ceremonies) and a kind of "living savings" and primary capital accumulation. They usually leave their cattle foraging freely in natural areas, such as secondary forests or old fallows, and the level of care is usually low. Sometimes, they visit their herd once a month only to provide salt and to check the cattle population as losses (by diseases or due to predators) are common in these remote areas. The local breed is usually raised because of its high adaptive capacity to mountainous areas and low level of care compared to improved breeds (Falvey, 1977).

The various effects of extensive cattle grazing on the forest ecosystem and forest regeneration have been recorded in the literature, depending on different types of grazing lands and grazing pressure, and are presented below.

4.1.1.1. Positive effects

Positive effects on forest regeneration of extensive cattle grazing under low grazing pressure were recorded by several authors. Regarding the survival of seedlings and saplings, Vieira *et al.* (2007) found that a low cattle grazing intensity (0.5 head/ha) did not affect the survival rate of one year old seedlings in a tropical forest of Central Brazil. Posada *et al.* (2000) reported that a low cattle grazing intensity (0.4-0.7 head/ha/year) increased the establishment of shrubby and woody seedlings in a tropical montane rainforest of Columbia due to the dispersion of plant seeds by cattle dung (Toniato and Oliveira-Filho, 2004). More locally, in Thailand, Sathapornpong (1979) found that cattle grazing in a 3-year-old pine plantation increased the survival rate of young saplings because of a reduction in the risk of forest fire. While cattle grazing removed the dense grass cover, it also allowed light to reach the small seedlings and to stimulate the growth of many small plants. In terms of biodiversity, grazing usually reduces the number of palatable species including both grasses and other small plants (Barnes *et al.*, 1997; Scimone *et al.*, 2007).

4.1.1.2. Negative effects

Many authors have reported that both low and high cattle grazing intensity can generate negative effects on the forest structure and species composition, particularly through cattle trampling and selective grazing and browsing. Tasker and Bradstock (2006) mentioned that cattle grazing decreased the complexity of the under-storey species and reduced or eradicated shrub layers in a eucalypt forest. Harnsoda (2004) studied the impact of grazing by a local breed of cattle in the Phu Mieng-Phu Thong Wildlife Sanctuary in Phitsanulok Province, Northern Thailand, and found that cattle grazing decreased the number of seedlings and saplings of tree species. Another mechanism linked to the reduction in numbers of plants and plant diversity in grazing areas is forest fire, either generated by natural processes or man-made. In many areas of Northern Thailand, farmers burn large patches of dry grass to stimulate the growth of a more palatable source of forage (Cheva-isarakul and Cheva-isarakul, 1990). The reduction in species diversity, population density and disturbance by fire can change the ecosystem by altering the litter supply, nutrient retention and water infiltration processes, which all impact upon the forest regeneration ability and rate (Barnes *et al.*, 1997).

4.1.2. Effect of reforestation on forest regeneration

In areas where anthropic reforestation has been successful with no damage by fire, diseases, and so on, reforestation increased the above-ground biomass (AGB) and accelerated dense tree cover. The rate of the biomass recovery depends on the density of the plants and how fast they grow (Table 4.1). Nevertheless, in conditions not suitable for the growth of replanted seedlings (occurrence of fire, unsuitable climate or soil), the AGB may not increase rapidly.

Table 4.1. Volumes of AGB under different vegetation cover types in Thailand.

Land use/land cover type	AGB (x 1,000 kg/ha)			Source
	Tree	Sapling	Seedling	
Hill evergreen forest				
Kaeng Krachan National Park, Petchburi	257.98			Jampanin, 2004
Pa Nam Yao and Pa Nam Suad National Reserves forest, Nan	289.60	6.53	3.77	Pibumrung, 2007
Kaeng Krachan National Park, Petchburi (Secondary forest)	217.02			Jampanin, 2004
Dry evergreen forest				
Pa Nam Yao and Pa Nam Suad National Reserves forest, Nan	268.32	5.88	3.36	Pibumrung, 2007
Kaeng Krachan National Park, Petchburi (Secondary forest);	70.79			Jampanin, 2004
Thong Pha Phum National forest, Kanchanaburi	140.58			Terakunpisut *et al.*, 2007
Sakaerat Environment Research Station, Nakhon Ratchasima	394.04			Sangtongpraow and Sukwong, 1990
Mixed deciduous forest				
Pa Nam Yao and Pa Nam Suad National Reserves forest, Nan	166.42			Pibumrung, 2007
Queen Sirikit Botanic Garden, Chiang Mai	113.84			Nuipakdee, 1999
***Gmelina arborea* plantation**				
Pak-Chong, Nakhon Ratchasima (8-yr, 2 x 2 m interval)	85.20			Pridee, 1979
Pak-Chong, Nakhon Ratchasima (10-yr, 2 x 2 m interval)	120.18			Sritulanont *et al.*, 2004
Pa Nam Yao and Pa Nam Suad National Reserves forest, Nan (10-yr)	67.40	2.42	2.31	Pibumrung, 2007
Pa Nam Yao and Pa Nam Suad National Reserves forest, Nan (14-yr)	43.51	3.64	2.33	Pibumrung, 2007
Pa Nam Yao and Pa Nam Suad National Reserves forest, Nan (19-yr)	23.94	3.49	2.26	Pibumrung, 2007
Pa Nam Yao and Pa Nam Suad National Reserves forest, Nan (26-yr, 4 x 4 m interval)	71.75	2.94	2.50	Pibumrung, 2007
Teak plantation				
Thong Pha Phum National forest, Kanchanaburi (6-yr, 4 x 4 m interval)	17.52			Sumuntakul and Viriyabuncha, 2007
Pa Nam Yao and Pa Nam Suad National Reserves forest, Nan (14-yr, 2 x 8 m interval)	43.51			Pibumrung, 2007
Pine forest				
Boluang, Hod district, Chiang Mai (10-yr)	201.28			Sahunalu, 1995
Boluang, Hod district, Chiang Mai (12-yr)	166.60			Sahunalu, 1995
Boluang, Hod district, Chiang Mai (14-yr)	152.64			Sahunalu, 1995
Fallow				
Pa Nam Yao and Pa Nam Suad National Reserves forest, Nan (6-yr)	10.42	0.10	0.09	Pibumrung, 2007

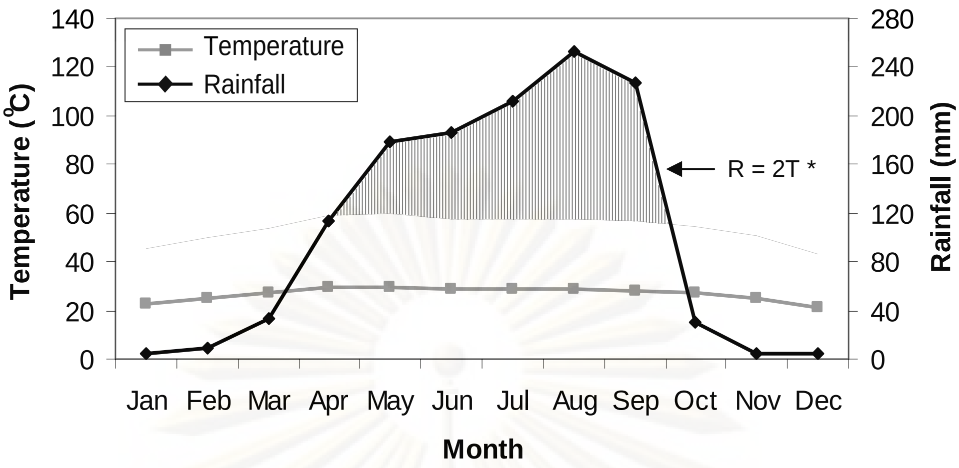
Although the AGB can increase rapidly in reforestation areas, species diversity and ecosystem goods and services may not recover well compared with the natural forest. Ruiz-Jaén and Aide (2005) argued that vegetation recovery alone is not enough for successful reforestation until ecosystem processes allowing a long term persistence of the forest ecosystem have also recovered. To do so, multiple species are needed. Erskine *et al*. (2006) reported that reforestation areas with four to five mixed species have better improved productivity, nutrient cycling and reduced intra-specific competition in a reforestation area compared to a monoculture.

In summary, the results from previous studies show that either positive or negative effects of extensive cattle rearing systems and reforestation can result upon forest regeneration and that these are very site specific based on the intensity of cattle grazing, occurrence of fire and the reforestation technique implemented. Therefore, it is important to study the local effects of cattle grazing and reforestation in Doi Tiew highlands to improve our understanding of the interactions among cattle grazing, reforestation and forest regeneration. Before conducting the field study, preliminary information was gathered, including regarding the bio-physical characteristics, cattle raising practices and reforestation techniques used at the study area.

4.1.3. Bio-physical characteristics of the study site

4.1.3.1. Topography, climate and natural vegetation cover

The study area is characterised by hilly and steeply slopping topography. Based on a NKU (2006) report the elevation ranges from 500 to 1,674 m amsl. The local tropical monsoon climate is successively affected by the dry north-eastern (November to April) and the wet south-western (May to October) monsoons. Peaks of rainfall are in August or September (Figure 4.1). The average amount of rainfall received in the provincial capital is 2,707 mm/year and the mean monthly temperature ranges from 18.1 to 27.1 ºC.



** Based on Cocheme and Franquin (1967), wet season defined by "Rainfall > 2 Temperture."*

Source: Based on climatic data (2003-2006) from the Thai Meteorological Department (2006).

Figure 4.1. Mean monthly temperature and precipitations in Nan Province, based on data from 2003-2006.

Vegetation cover in this area is classified into three main forest types. The first type is hill evergreen forest observed at higher elevations (above 1,200 m amsl). It is dominated by *Castanopsis spp*., *Chukrasia velutina, Toona ciliata* and many species of ferns. The second type is a dry evergreen forest dominated by *Gmelina arborea, Dipterocarpus alatus, Afzelia xylocarpa, Pterocarpus macrocarpus, Albizia lebbeckoides, Oroxylum indicum* and different species of bamboos. The third type is a deciduous forest distributed in lowlands and flat areas. Its main species are *P. macrocarpus, Xyllia derrii, Orosylum indicum, Dalbergia rimosa, Salmalia insignis,* and *Terminalia tomentosa.*

4.1.3.2. Main cattle raising technical systems

Two main cattle rearing systems are implemented by Doi Tiew herders. In the first, and most frequently practiced system, herders build a small fence and a hut in the cattle grazing area, usually a secondary forest, a fallow or a reforestation area (Figure 4.2). The hut is used to feed salt to the animals and to look after the cattle (population counting and diagnosis of diseases). It is a regular meeting point between the herder and his herd. In the wet season, herders can also stay over night in the hut when the access to the grazing area is difficult.

Figure 4.2. A fenced salt feeding spot and small hut in a grazing area near Doi Tiew village, Nan Province, Northern Thailand.

The other system is based on cattle rearing in litchi orchards and is practiced by only a few herders because the cattle not only graze the grass but also browse the young leaves and flowers of the litchi trees (Figure 4.3). Therefore, many herders are afraid that fruit production will be negatively affected by this practice. A small fence is also built in the orchard with the same purpose as in the previous system.

Figure 4.3. Cattle foraging in a litchi orchard (left) and browsing behaviour (right) near Doi Tiew village, Nan Province, Northern Thailand.

4.1.3.3. Reforestation techniques implemented since 1990

Since the establishment of the NKU in 1990, two main reforestation techniques have been in use (Figure 4.4). Between 1990 and 1996, a monoculture system at a fixed interval was implemented. The main tree species were pine (*Pinus kesiya*) and *Prunus cerasoides*. Then in 1997, a mixed species system was introduced with fixed intervals or at random, being based on the characteristics of the area. In Doi Tiew area, the tree species used were *Prunus cerasoides, Cassia fistula*, *Senna garrettiana, Tectona grandis, Pterocarpus macrocarpus, Afzelia xylocarpa*, *Acacia mangium, Irvingia malayana* and *Bauhinia variegate*.

Figure 4.4. View of a 17-year-old pine (*Pinus kesiya*) reforestation plot established by the Nam Khang Headwater Development and Conservation Unit.

Based on the information available at this study site, the selected research methodology was as follows.

4.2. Methodology

The common definition of "forest" for local herders and foresters refers to an area with mature trees. Therefore, the AGB in different vegetative layers of a given plot was selected as an indicator to determine the speed of forest regeneration. Because of the limited time available for this ecological survey, a survey protocol allowing the comparison of AGB between different land use types and age of vegetative cover was adopted (Toniato and Oliveira-Filho, 2004).

4.2.1. Sampling design and description of plots

Different land-use classes (fallow, fruit tree, tree plantation and natural forest), grazing status (grazed or non-grazed), grazing duration (in years), and grazing intensity (livestock units/ha; LSU/ha) were the main criteria used to select the plots for the measurement of AGB. A list of possible sites was drafted based on various combinations of these criteria and the plot selection process was implemented in consultation with the villagers and NKU foresters who knew the land use history of the existing plots available. Finally, a total of 32 plots were selected and their characteristics, especially their land use history, are presented in Table 4.2.

Based on the data in Table 4.2, the grazing pressure included in this study ranges from non-grazed (18 plots) of course, to between 0.16 to 1.37 LSU/ha for the 14 grazed plots with an average value of 0.44 LSU/ha for the 14 grazed plots. More plots were available to carry out measurements in the dry season because of the difficult access to some sites in the rainy season. Only two grazed reforestation plots were found and included in this study because the other young reforestation plots, planted respectively in 2001, 2002 and 2004, were burned by farmers who claimed that those areas were their fallows. As a result, the vegetation dynamics between the two seasons could not be compared for some plots. Nevertheless, the main purpose of this survey was to obtain information on the AGB in different land use types and, when feasible, compare the measured values to assess the effects of cattle grazing and reforestation techniques.

Table 4.2. Characteristics of the 32 plots selected to study the effects of cattle grazing and reforestation on the AGB dynamics at Doi Tiew village, Nan Province, Northern Thailand, in 2007.

Plot	Grazing intensity (LSU/ha)[1]	Plot code	Elevation (m amsl)[2]	Fallow/ Plantation age	Grazing duration (up to June 2007)	Occurrence of fire	Previous land use	Available for observaton (season)	Description
1	0.16	Fa6mo_G6mo	840	6 mo	6 mo	6 mo before grazing	Maize	Dry	Fallow that was first burned for upland rice crop but it was not cultivated and abandoned for 6 mo. Then, grazing started continuously for 6 mo
2	0.18	Fa_G1y	845	2 - 3 mo	1 yr	No	Upland rice	Wet & Dry	Grazing was introduced by moving from reforestation area.
3	1.37	Fa2y_G2moH	827	2 yrs	2 mo	No	Upland rice	Wet & Dry	Grazing was introduced by moving from reforestation area.
4	0.44	Fa_G2y	835	2 - 3 mo	2 yrs	No	Upland rice	Wet & Dry	Grazing was introduced by moving from reforestation area.
5	0.38	Fa_G3y	840	2 - 3 mo	3 yrs	No	Maize	Wet & Dry	Grazing was introduced by moving from reforestation area.
6	0.75	Fa4y_G8mo	876	4 yrs	8 mo	One time in the 1^{st} yr	Upland rice	Wet & Dry	Grazing was introduced by moving from reforestation area.
7	0.18	Fa4y_G2yNf	867	4 yrs	2 yrs	No	Upland rice	Dry	Four years natural succession, then grazing was introduced from reforestation area.
8	0.17	Fa_G7y	750	2 - 3 mo	7 yrs	No	Upland rice and maize	Wet & Dry	Grazing was introduced by moving from reforestation area.
9	0.28	Fa_G10y	920	*Imperata* fallow	10 yrs	No	*Imperata* fallow	Dry	Belongs to a large land owner, located approximately 6 km from the village, access by small dirt road. Many trees and saplings were cut for domestic use and to make an open area to increase grass biomass.
10	0.38	Fa_G12y	880	*Imperata* fallow	12 yrs	No	*Imperata* fallow	Dry	Belongs to a large land owner, located approximately 7 km from the village, access by small dirt road.
11	0.38	Fa_G15y	937	*Imperata* fallow	15 yrs	No	*Imperata* fallow	Dry	Belongs to a large land owner, located approximately 8 km from the village, access by small dirt road. This area has been used for cattle raising for a long time.
12	0.64	Orc6y_G6mo	732	6 yrs	6 mo	No	Maize	Wet & Dry	Six-year-old litchi orchard planted at 8 x 8 m intervals.
13	0.40	Pl4y_G4y	738	4 yrs	4 yrs	Every yr	Grassy fallows	Wet & Dry	Herders claim that it was fallow land. Grazing after reforestation, and burned every year. Re-planted in 2007 with *Cassia fistula*, *Senna garrettiana*, *Irvingia malayana* and *Pterocarpus macrocarpus* (3 x 3 m intervals).
14	0.46	Pl6y_G2y	805	6 yrs	2 yrs	Every yr	Grassy fallows	Wet & Dry	Herders claim that it was fallow land. Grazing just after reforestation for 2 years only. Burned every year. Replanted in 2007 with *Cassia fistula, Senna garrettiana* and *Acacia mangium* (4 x 4 m intervals).
15	Non-grazed	Ruzi	850	2 mo	-	No	Upland rice	Wet & Dry	Ruzi (*Brachiaria ruziziensis*) pasture planted for soil protection.

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Plot	Grazing intensity (LSU/ha)[1]	Plot code	Elevation (m amsl)[2]	Fallow/ Plantation age[3]	Grazing duration (up to June 2007)[3]	Occurrence of fire	Previous land use	Available for observation (season)	Descriptions
16	Non-grazed	Fa2mo_Rice	838	2 mo	-	No	Upland rice	Dry	Two months natural succession after upland rice harvest.
17	Non-grazed	Fa2mo_Maize	852	2 mo	-	No	Maize	Dry	Two months natural succession after maize harvested.
18	Non-grazed	Fa1y	840	1 yr	-	No	Upland rice	Wet & Dry	One year natural succession after upland rice harvest, then grazing was performed.
19	Non-grazed	Fa2y	820	2 yrs	-	No	Upland rice	Wet & Dry	Two years natural succession. The land had been used for upland rice and maize productions before..
20	Non-grazed	Fa3y	867	3 yrs	-	No	Upland rice and maize	Wet & Dry	Three years natural succession. The land had been used for upland rice and maize productions before.
21	Non-grazed	Fa4y	862	4 yrs	-	One time in the 2nd year	Upland rice	Wet & Dry	Four years natural succession. Owner plans to grow upland rice again.
22	Non-grazed	Fa6y	820	6 yrs	-	No information	Upland rice	Wet & Dry	The owner of the land migrated to another province a long time ago.
23	Non-grazed	Fa7y	832	7 yrs	-	No information	Upland rice	Wet & Dry	The owner of the land migrated to another province a long time ago.
24	Non-grazed	Orc	727	9 yrs	-	No	Maize	Wet & Dry	Nine-year-old litchi plot, 6m x 6m planted interval.
25	Non-grazed	Pl1 (palm)	746	1 yr	-	No	Upland rice	Wet & Dry	Planted to *Livistona speciosa* palm (3m x3m interval).
26	Non-grazed	Pl1 (teak)	734	1 yr	-	No	Upland rice	Wet & Dry	Planted to teak (4m x4m interval).
27	Non-grazed	Pl2	716	2 yrs	-	No	Maize	Wet & Dry	Planted to*Cassia fistula* and *Senna garrettiana* in degraded forest (4m x4m interval).
28	Non-grazed	Pl4	690	4 yrs	-	No	*Chromolaena* fallow	Dry	Planted to teak (4 x4 m interval).
29	Non-grazed	Pl6	915	6 yrs	-	No	*Chromolaena* fallow	Wet & Dry	Planted to *Prunus cerasoides* (2 x2 m interval).
30	Non-grazed	Pl11	820	11 yrs	-	No	*Chromolaena* fallow	Wet & Dry	Planted to *Prunus cerasoides* (2 x2 m interval).
31	Non-grazed	Pl17	1,150	17 yrs	-	No	*Imperata* fallow	Wet & Dry	Planted to *Pinus kesiya* (2 x 4 m interval).
32	Non-grazed	Nat	1,260		-	No	-	Wet & Dry	Natural old forest.

Note: [1] "LSU" refers to "Livestock Unit." For local breed or cross-breed with American Brahman grazing in highlands, 1 LSU is equal to 250 kg of live weight of cattle (Praprutsri, 1995). Live weight is typically calculated from the girth circumference of cattle (Falvey, 1977). Howevert, in this study it was very difficult to measure the girth of cattle due to their aggressive behaviour. Therefore, only the age and sex of cattle were recorded. Then, live weight was estimated based on an abacus designed for Thai cattle of different age and sex provided by Praprutsri (1995).

[2] " amsl" = above mean sea level.

[3] mo and yr(s) = months and year(s), respectively.

4.2.2. Data collection and analysis

The AGB was investigated in both seasons, in late June and in late December 2007, under wet and dry conditions, respectively.

Five different vegetation layers were considered as follows:

- "Tree" referred to woody plants with a diameter at breast height (DBH) equal to or exceeding 4.5 cm.
- "Sapling" referred to woody plants with a DBH smaller than to 4.5 cm and more than 130 cm in height, and shrubby plants with branches.
- "Seedling" referred to woody plants with a DBH smaller than 4.5 cm and less than 130 cm in height.
- "Grass" referred to plants belonging to the monocotyledonae family.
- "Herb" referred to other herbaceous non-woody and non-grass species.

The DBH and height of all trees and saplings of trees species were measured. Then, the allometric equation for evergreen forest (Tsutsumi *et al.*, 1983) was used to estimate AGB according to the following equations:

$$\text{Stem biomass (Ws)} = 0.0509*(D^2H)^{0.919} \quad \text{kg}$$

$$\text{Branch biomass (Wb)} = 0.00893*(D^2H)^{0.977} \quad \text{kg}$$

$$\text{Leave biomass (Wl)} = 0.0140*(D^2H)^{0.669} \quad \text{kg}$$

$$\text{AGB} = Ws + Wb + Wl \quad \text{kg}$$

Where, D = DBH (cm) and H = Height (m)

Due to the limited change in tree diameters over six months (Kutintara, 1999), the diameter of trees in a sampling plot was measured only once per season. To investigate the other vegetation layers, the destructive method was used. The samples were collected and oven-dried at 80 ºC and weighted. For grass and herb, the ratio of fresh and dry weight was calculated and used to estimate the dry weight for the entire samples.

In each site, the area selected for the AGB measurement was far enough from the small hut where the vegetative cover is usually damaged. Three replicates of quadrats (Figure 4.5) were set up along a line transect and at 20 m interval between plots. A plot size of 10 x 10 m was used for "Tree," 4 x 4 m for "Sapling", and 1 x 1 m for the other layers. In the dry season, new 4 x 4 m and 1 x 1 m plots were delimited.

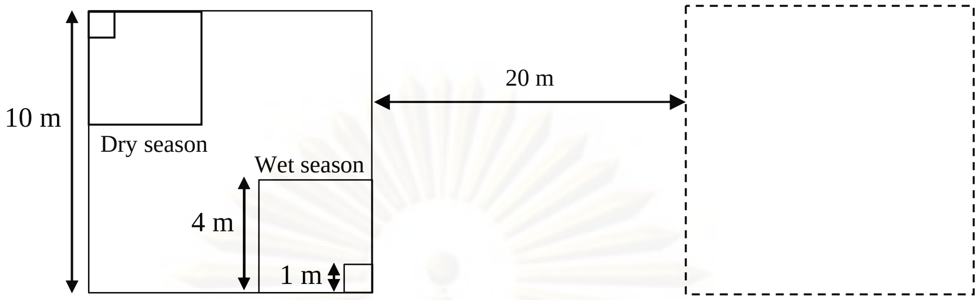


Figure 4.5. Map of a sampling plot used along a line transect during the survey.

Statistical differences in the AGB between different land use types were analysed by Analysis of Variance (ANOVA). Post-hoc multiple comparisons (Duncan's multiple means test) was used to compare the mean difference in the AGB values among land use types. The comparison between grazed and non-grazed plots was evaluated with the *t*-test at a 95% confidence level to assess the statistical significance of the observed differences.

4.3. Results

4.3.1.1. AGB and dynamics between two seasons in different sites

Mean ± 1 standard deviation (SD) of the AGB measured in all the selected plots for the wet and dry seasons are provided in Appendix C. Heterogeneity of AGB inside the same land use type, especially in the young fallows (two to four years old) was observed, which resulted in the large standard deviation.

The maximum observed AGB was in a natural forest plot, 489,639 ± 420,476 kg/ ha (the large SD value is due the present of big trees). This very high AGB was similar to the one measured in old deciduous forest (500,500 kg/ha) in Kaeng Krachan National Park of Southern Thailand (Jampanin, 2004). More details on the AGB in each land use type and its dynamics are presented in the following sections.

4.3.1.2. AGB in ruzi pastures

Only the two-year-old ruzi (*Brachiaria ruziziensis*) pasture in non-grazed area was available to investigate the AGB. Figure 4.6 shows the AGB of only the grass and herb layerswhilt the, sapling and seedling layers were not found in this plot. The total AGB in the wet season was 6,271 ± 524 kg/ha, which is less than the production observed in lowland areas where it could reach up to 7,700 kg/ha (Phaikaew *et al.*, 1996). The AGB of the herb layer was very low at 5 ± 9 kg/ha (less than 0.1% of the total AGB) because the dense cover of the ruzi grass inhibits their growth.

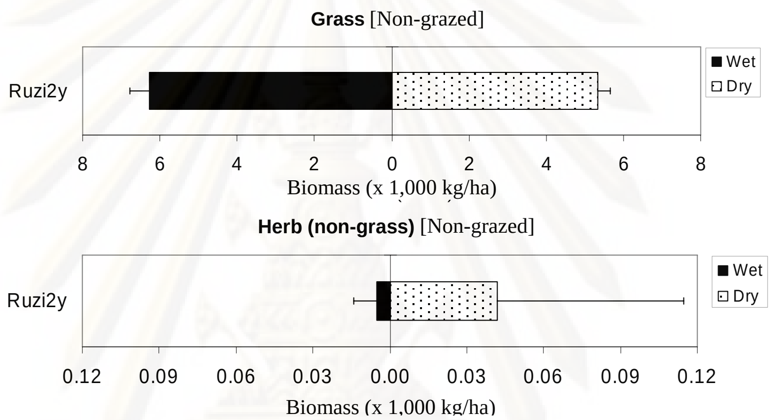
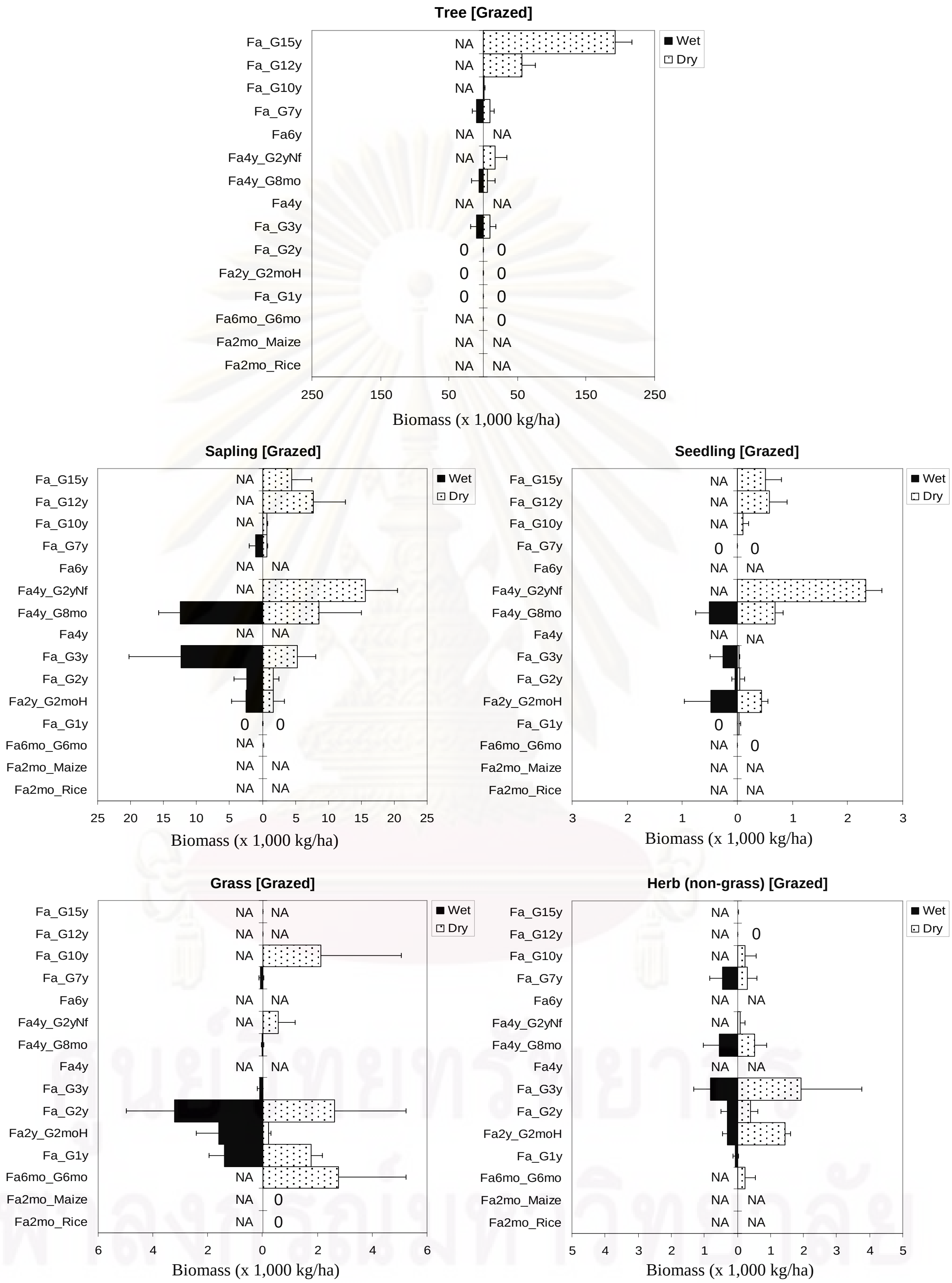


Figure 4.6. AGB in ruzi pastures in Doi Tiew village, Nan Province, in 2007.

In the dry season, the AGB of the grass layer decreased a little because of drying of some of the grass leaves and stems. These dried hills created small gaps in the ruzi cover and allowed other herbaceous plants to grow in those particular spots during that period of the year, as shown in Figure 4.6.

4.3.1.3. AGB in fallows of different ages

The dynamics of the AGB in fallows of different ages are presented in Figure 4.7. In the grazed area, it was found that the trees first appeared in a three-year-old grazed fallow with an average AGB at this age of 9,938 ± 8,046 kg/ha, and this increased with fallow age up to 192,521 ± 23,929 kg/ha in the 15-year-old grazed fallow.



Note: NA = Not available plot for measurement.

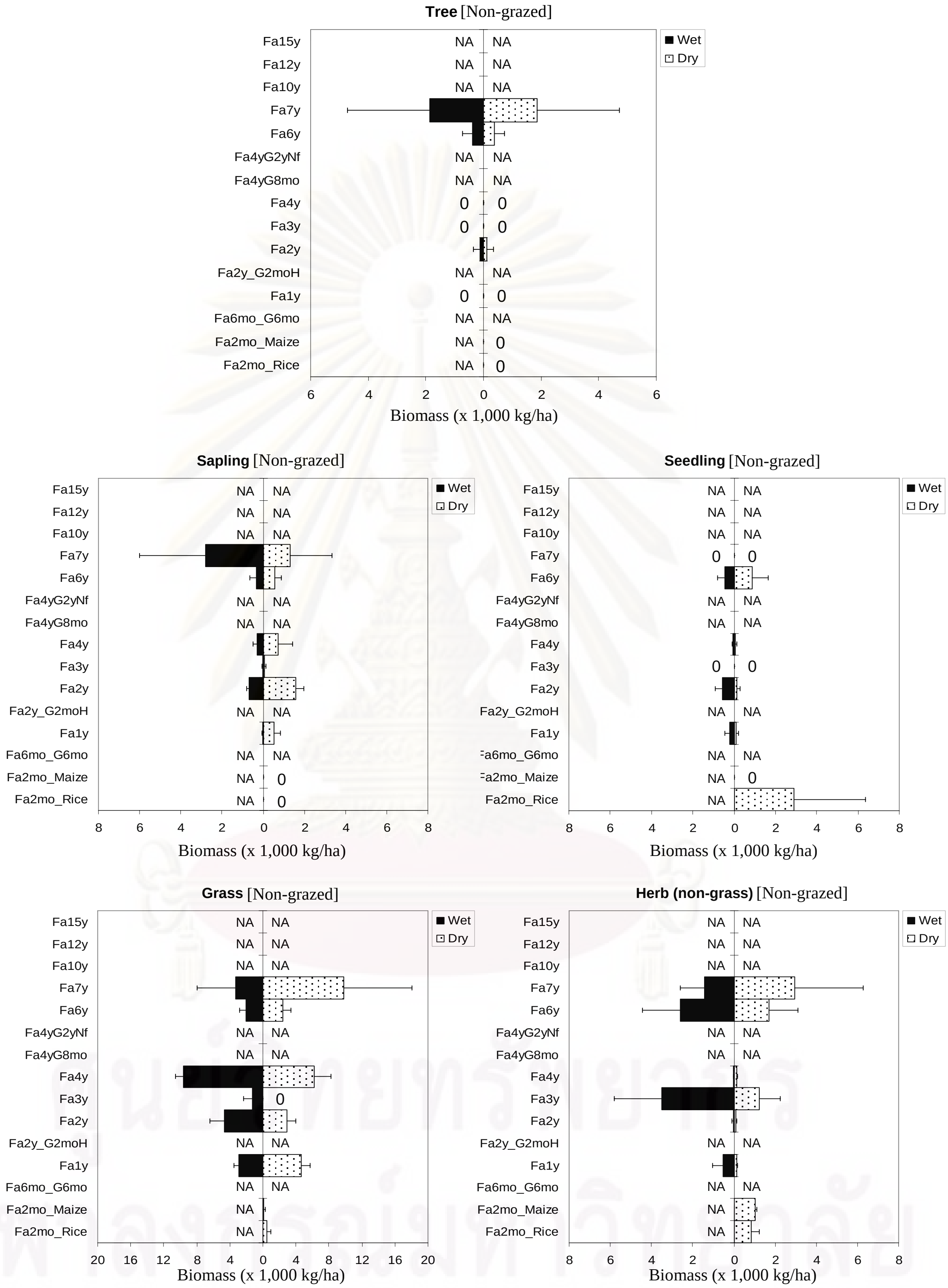
Figure 4.7. AGB observed in grazed fallows of different ages in Doi Tiew village, Nan Province, in 2007.

This value almost reaches the AGB of a secondary hill evergreen forest in Kaeng Krachan National Park (217,000 kg/ha) reported by Jampanin (2004), and is higher than the 140,600 kg/ha AGB reported for a dry evergreen forest in Thong Pha Phum National Forest in the Western forest complex of Thailand (Terakunpisut *et al.*, 2007). These observations tend to support the idea that cattle grazing can accelerate the forest regeneration.

The AGB of the sapling layer was found to be very variable and ranged from 77 ± 134 kg/ha at Fa6mo_G6mo to 15,627 ± 4,888 kg/ha at Fa4y_G2yNf, a plot never disturbed by fire. The AGB of the seedling layer ranged from 23 ± 40 kg/ha in Fa_G1y to 2,329 ± 291 kg/ha in Fa4y_G2yNf. The AGB of both the sapling and seedling layers decreased from the wet to the dry season in many sites, such as Fa2mo_G6mo, Fa_G2y and Fa_G3y. In these plots where some saplings and seedlings were damaged by cattle regeneration, the tree layer still occurred because some of these small plants could survive.

The AGB of the grass layer decreased between the wet and dry seasons in almost every plot, from 85.6 % in Fa_G2y to 18% in Fa2y_G2moH where the highest grazing intensity (1.37 LSU/ha) occurred. The AGB of the herb layer also increased in many plots where it dominated the grass layer. The highest increase was found in plot Fa2y_G2moH where it jumped from 229 ± 65 kg/ha in the dry season to 1,5840 ± 831 kg/ha in the wet season. This result shows the likely effect of a high cattle grazing pressure on the dynamics of accumulation of herbaceous plant biomass.

Figure 4.8 shows that the total AGB of the non-grazed fallows was very low, with a maximum value of just 1,874 ± 2,848 kg/ha in a seven-year-old field (Fa7y). Similar low figures for the AGB of sapling (0 to 2,810 ± 3,209 kg/ha in Fa7y) and seedling (0 to 2,900 ± 3,483 kg/ha in a two-month-old fallow after upland rice) layers were found.



Note: NA = Not available plot for measurement.

Figure 4.8. Above-ground biomass in fallows of different ages with no grazing in Doi Tiew village of Nan Province in 2007.

The establishment of seedlings were found as soon as the field was fallowed. In the two-month-old fallow, established from a former upland rice field, seedlings of legume species were colonizing the land rapidly. Nevertheless, the regeneration of trees, saplings and seedlings in non-grazed plots was very slow due to forest fire, especially in the Fa6y and Fa7y fallows where the land owner was absent and did not care. This slow growth was also linked to the dense cover of grass and herb layers in many of those plots, such as Fa3y, Fa6y and Fa7y.

The AGB of grass was highest in Fa4y (9,623 ± 935 kg/ha) at approximately three times higher than the maximum AGB of sapling (2,810 ± 3,209 kg/ha in Fa7y) and seedling (2,900 ± 3,483 kg/ha in Fa2mo_Rice) layers. No clear direction of change in AGB dynamics of the grass and herb layers between the wet and dry season could be identified. However, it was observed that Fa4y was disturbed by bush fire. This event damaged saplings and seedlings and the allowed the regeneration of grasses species.

4.3.1.4. AGB in litchi orchard

Figure 4.9 shows the AGB of vegetation layers found in litchi orchards. Sapling and seedling layers were not found in these plots. In the grazed ones, the total AGB in the wet season was about 14,200 kg/ha. The AGB of grass decreased by more than 80% from 916 kg/ha in the wet season to 139 kg/ha in the dry season, while the AGB of herb layers disappeared because of the continuous grazing and trampling.

Contrastingly, the AGB of herb layers were found to be far higher in the non-grazed plots with measured increases of 140% from 1,095 kg/ha in the wet season to 1,525 kg/ha in the dry season. Even if, recently, very few herders have been raising cattle in orchards, these data show that cattle grazing could be an effective technique to control weeds, especially the herbaceous species, in litchi orchards.

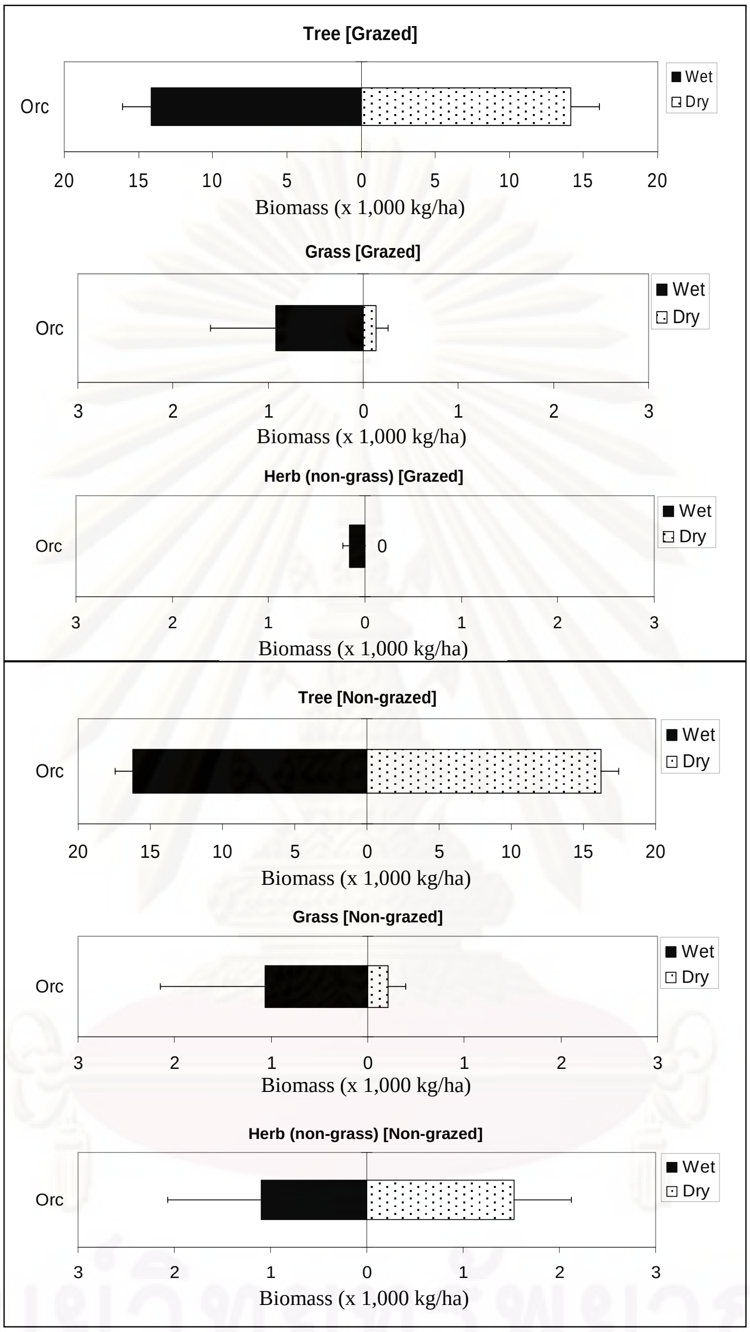


Figure 4.9. AGB in litchi orchards with or without cattle grazing in Doi Tiew village, Nan Province, in 2007.

4.3.1.5. Above-ground biomass in tree plantations of different age

Figure 4.10 displays the AGB of vegetation in tree plantation plots. Fewer trees found in the grazed plots compared to the non-grazed ones.

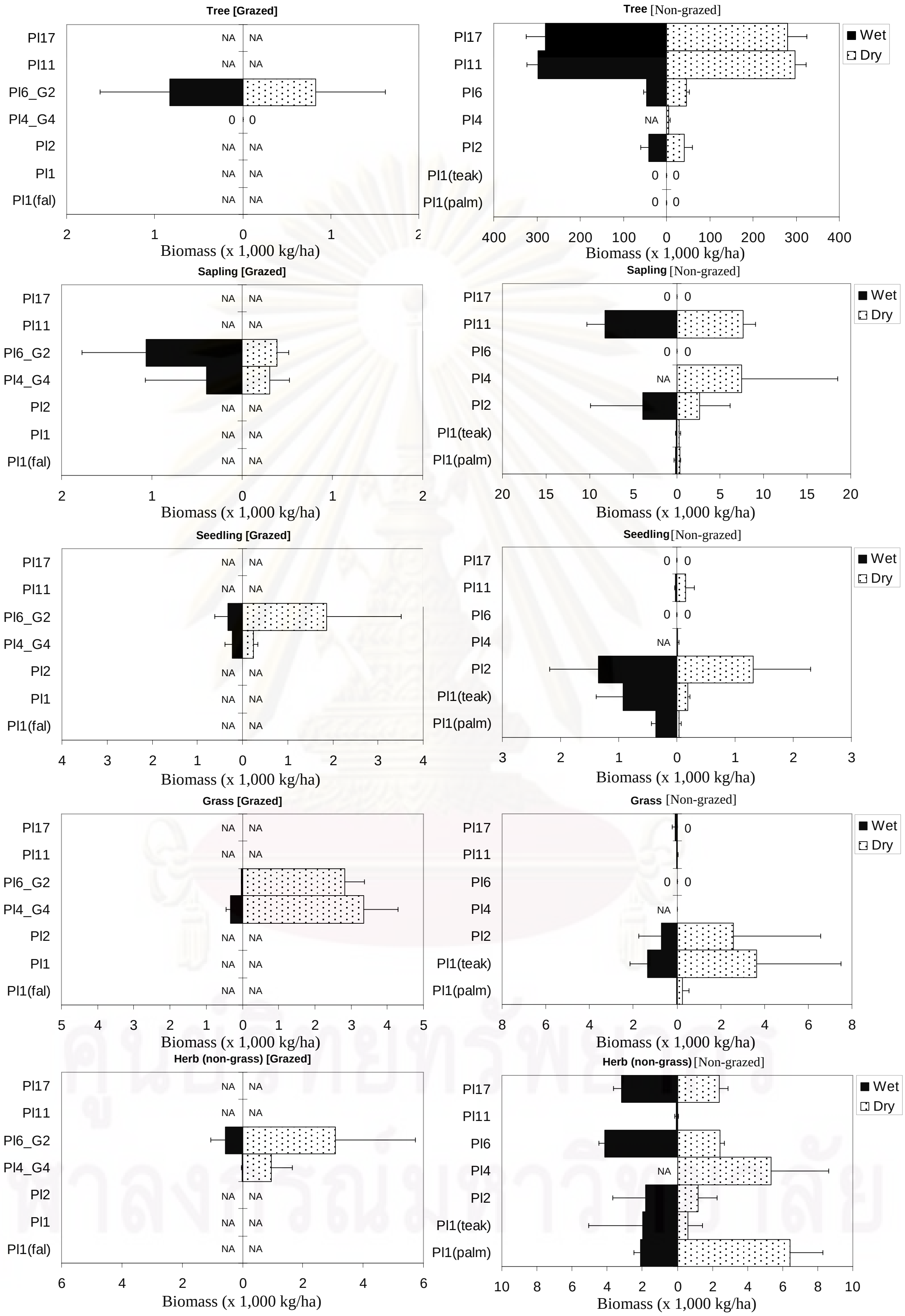


Figure 4.10. AGB in tree plantations of different ages in Doi Tiew village, Nan Province, in 2007.

For example, the total AGB in all plots of the tree, sapling and seedling layers was only 2,810 kg/ha compared with the 280,448 kg/ha in the 17-year-old in non-grazed area. The main cause was forest fires occurring every dry season. Re-plantation of missing young trees was carried out every wet season in the four-year-old plantation, followed by control of cattle grazing by foresters to allow a rapid growth of seedlings, grass and herb layers. As a result, the AGB of these three layers increased compared to the wet season. In the six-year-old plantation, grazing was stopped by foresters two years after planting and herders had to move their cattle to their fallows or sold their animals. Therefore, this plot had not been disturbed by cattle for four years. As a result, the AGB of the grass and herb layers increased as soon as the start of the wet season.

The AGB of non-grazed plots was far higher compared to the grazed ones because of the following two factors. The first one is planting density. In the 11-year-old stand planted at a 2 x 2 m interval the AGB of the tree layer increased up to 298,231 kg/ha. This value is similar to the 289,600 kg/ha recorded in a hill evergreen forest of Nam Yao and Nam Suad National Reserved Forest located close to Doi Tiew area (Pibumrung, 2007). The second factor is linked to the initial characteristics of the land before reforestation. For example, in the two-year-old plantation, the AGB reached 40,815 kg/ha, a figure approaching the 46,245 kg/ha observed in the six-year-old plantation established on more degraded land. But part of the measured AGB was coming from the pre-exiting stands in the two-year-old plot.

The AGB of the sapling layer did not vary much between the wet and dry seasons in every plot. But it was found that many seedlings died under the dense cover of grasses and weeds. The dynamics of the grass and herb layers in these reforestation plots were similar to the ones observed in fallows and orchards. For example, in the one-year-old plot planted to palms and the four-year-old plantation, the herb layer dominated and suppressed the growth of grass species in the dry season. But in the one-year-old teak plantation, the situation was the opposite as the grass grew rapidly and inhibited the development of other herbaceous plants.

4.3.1.6. AGB in natural forests

In natural forest plots, the AGB of saplings and seedlings layers were not significantly different between the wet and dry seasons as seen in Figure 4.11. No herb layer was found in these plots and the very few grasses observed in the wet season disappeared in the dry season. This is a very common characteristic of dense forest (Sahunalu, 1995).

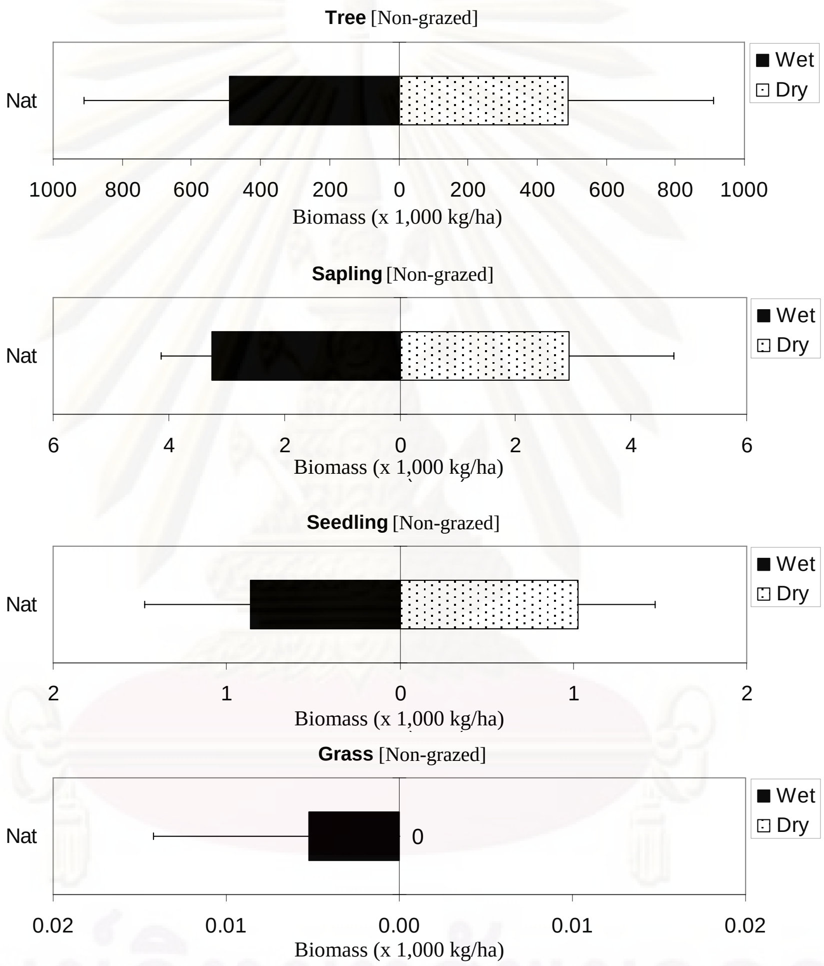


Figure 4.11. Above-ground biomass in natural forest at Doi Tiew village, Nan Province, in 2007.

4.3.2. Effects of cattle grazing and reforestation on forest regeneration

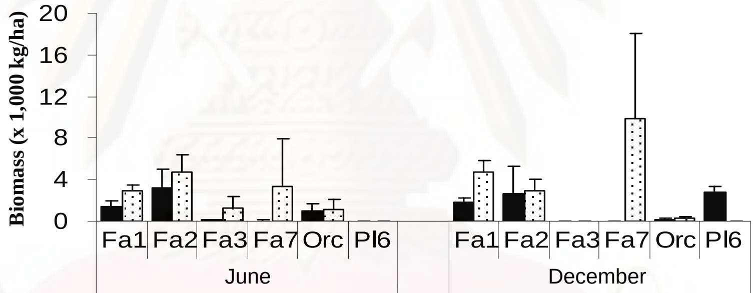
To make a statistical analysis of the effects of cattle grazing on the dynamics of different vegetation layers, six fallow, fruit tree and tree plantation plots for which complete data sets where available were selected. The results of this analysis are shown in Table 4.3.

Table 4.3. Statistical analysis of the differences in the AGB between grazed and non-grazed fallows, fruit tree and tree plantations in June and December 2007. *p*-values from the independent *t*-test.

	Vegetation layers in the wet season					Vegetation layers in the dry season				
Land use type	Tree	Sapling	Seedling	Grass	Herb (non - grass)	Tree	Sapling	Seedling	Grass	Herb (non - grass)
Fallow	0.03	0.12	0.20	0.05*	0.09	0.03	0.22	0.21	0.05*	0. 50
Fruit tree	0.20	-	-	0.86	0.24	0.20	-	-	0.61	0.01
Tree plantations	-	-	-	-	-	0.07	0.32	0.04	0.03*	0.09

*Note: * Significant at P < 0.05.*

These overall results show that cattle grazing had a significant effect on the grass AGB in fallows in both wet and dry conditions, and in the dry condition only in tree plantations. A more detailed plot by plot analysis shows that the effects of cattle grazing varied between sites as shown in Figure 4.12.



	June						December					
	Fa1	Fa2	Fa3	Fa7	Orc	Pl6	Fa1	Fa2	Fa3	Fa7	Orc	Pl6
Grazed	1.4	3.2	0.0	0.0	0.9	0.0	1.7	2.6	0.0	0.0	0.1	2.8
Non-grazed	2.8	4.6	1.2	3.2	1.0	0.0	4.6	2.9	0.0	9.8	0.2	0.0

Figure 4.12. Differences in the AGB of the grass layer between grazed and non-grazed plots of various land use types in Doi Tiew village, Nan Province, in 2007.

The data of Figure 4.12 support the notion that cattle grazing played an important role in reducing the grass layer in most plots. In plot Fa7, without cattle grazing, the grass AGB increased about ten times from the wet to the early dry season, compared to a very low 62 kg/ha for this layer in the grazed plot in the dry season. It is only in the six-year-old tree plantation that the grass AGB in the grazed plot was higher than in the non-grazed one. This was due to a slower establishment of the tree crowns in the grazed plot affected by bush fires, while better tree growth led to more shading inhibiting the growth of grass species in the non-grazed area (Figure 4.10).

Figure 4.13 displays the dynamics of the composition of the vegetation coverage depending on their age for grazed and non-grazed plots observed in fallows and tree plantations.

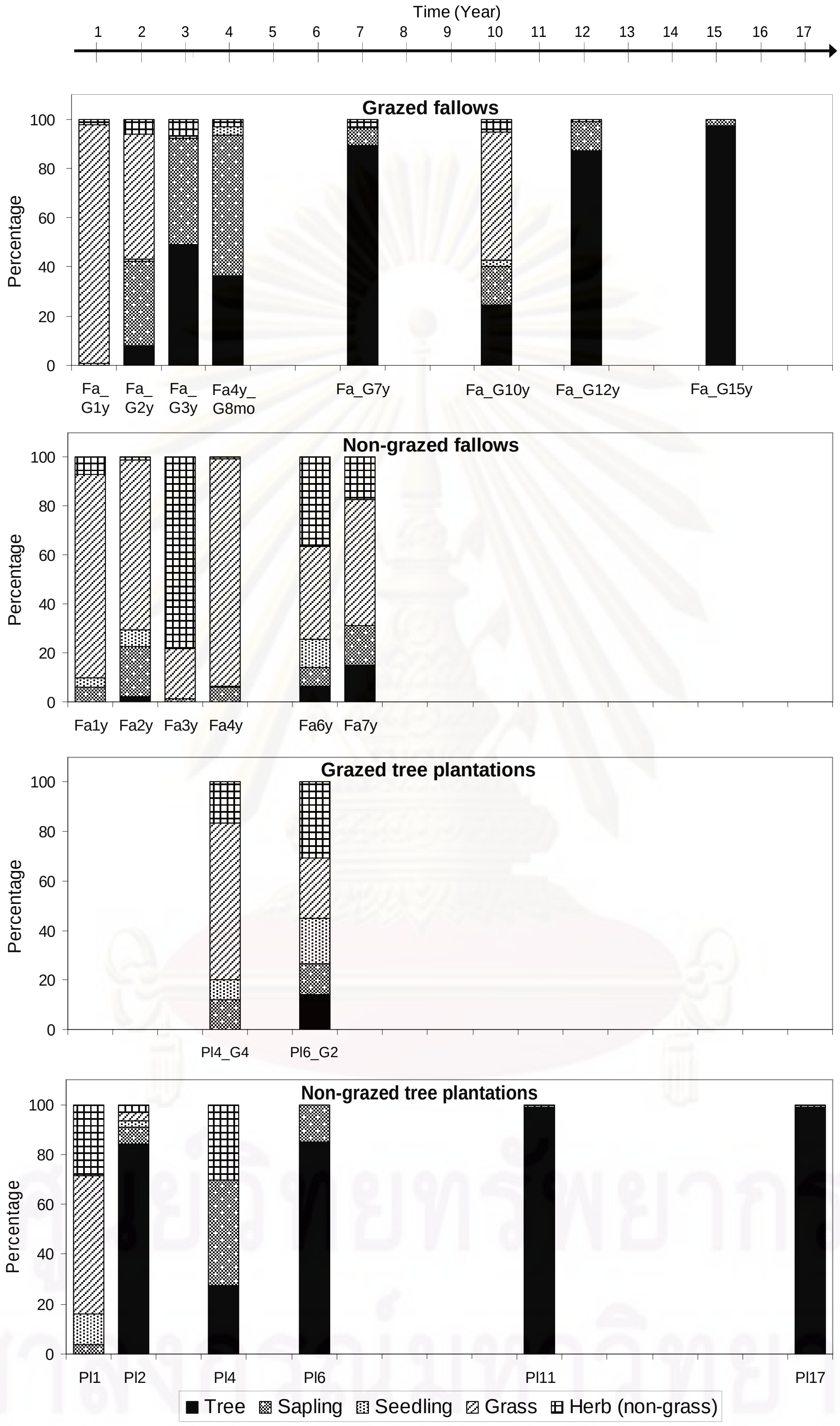


Figure 4.13. Changes in the composition of the vegetation coverage in grazed and non-grazed plots of fallows and tree plantations in Doi Tiew village, Nan Province.

4.3.4. Effects of reforestation on forest regeneration

Although the limited number of well-documented plots is not enough to display a full vegetative transition, Figure 4.13 illustrates the trends of forest successions in both land use types subjected or not to grazing. In fallows, following the grass dominated cover of the first two years, herbaceous plants, seedlings and saplings increase in the following years. A significant share of trees is observed earlier in grazed plots compared to non-grazed ones. In addition, albeit based on the limited dataset available, cattle grazing appears to allow the transition from an *Imperata sp.* grassland to a forest dominated by the tree layers (according to the NKU foresters and herders definition) in 15 years. This is in contrast to the situation of the non-grazed fallows where the tree layer increases very slowly compared with the grazed plots. Based on information collected during interviews with local stakeholders, this could be explained by the almost yearly occurrence of bush fires resulting in a long lasting domination of the grass and herb layers.

On the contrary to the situation observed in fallows, forest development in the grazed tree plantations was slow compared to the non-grazed reforestation plots. Again the yearly occurrence of bush fires in grazed plantations only explains this situation. Forest regeneration was faster in the non-grazed plantations, as clearly seen in the case of the six-year-old reforestation plot planted at a 2 x 2 m interval and displaying a total AGB of up to 46,244 kg/ha with crowns of young trees inhibiting the growth of grass and herbs in the non-grazed plot.

4.4. Discussion

4.4.1. Limitations of this survey

The implementation of this survey was constrained by many factors and conditions. The first one was the difficulty to find a complete set of comparable paired plots differing by only one major factor (grazed vs. non-grazed) across each set of other factors (fallow age, aspect, soil type, micro-climate and so on). This is partly due to the fact that plot selection had to be made in a limited area of farm land, in different topographical positions, and in a heterogeneous environment subjected to diverse farming practices. For example, usually grazed and non-grazed fallows of similar age are not close to each other and are commonly surrounded by other land use types, such as maize fields, orchards, or younger or older fallows. This problem was mitigated to some extent by the selection of non-adjacent plots but characterized by similar topographical conditions (Quesada *et al.*, 2009).

In addition it was difficult to document the land use history of each plot, yet this information is important in this kind of study (Toniato and Oliveira-Filho, 2004). The most difficult events to document were occurrences of disturbance due to past bush fires, including their severity and frequency, yet they play an important role on the dynamics of the vegetation coverage (Hoare, 2004). Consequently, many fallows were not available for selection and this contributed to the choice of an incomplete chronological set of plots for comparison.

Finally, the local cropping calendar forced us to make the AGB measurements in the early part of the dry season as farmers start to prepare the land for cropping as soon as late December. We could not take the risk to delay the observations by a month because many plots could have been burned before the gathering of AGB data in the dry season. Therefore, the data presented in this study could somewhat overestimate the values of AGB in the dry season compared to measurements made during the warmest months of February or March.

Nevertheless, despite these limitations, and in the absence of any other pre-existing data set on this subject, the results from this study are useful to document and partly quantify the effects of cattle grazing and tree planting on forest regeneration in this highland forest-farm land interface.

4.4.2. Processes affecting above-ground biomass dynamics in relation to forest regeneration

Forest regeneration is a result of complex processes in a composite vegetation system (Barnes *et al.*, 1997). Crk *et al.* (2009) state that, in recent times, forest recovery may depend more on anthropogenic activity than on bio-physical factors. This study found that two main human activities, cattle raising and tree planting, had positive effects on forest regeneration but in different ways. Nevertheless, we found that a key process by which these two activities facilitate plant growth was through the control of the grass and herb biomass. A dense vegetative cover dominated by grasses and herbs inhibits the establishment and growth of seedlings (Barnes *et al.*, 1997; Kimmins, 1987). Moreover, a dense ground cover by herbaceous plants increases the risk of fire hazard that would damage the seedlings and saplings, reducing their numbers and density and so maintain a dense cover by grass species such as *Imperata cylindrica* (Andrews, 1983; Falvey and Hengmichai, 1979; Gibson, 1983). Therefore, the control of the grass and herb biomass facilitated the early stages of establishment of a tree layer in the vegetation.

For example, in non-grazed fallows, high proportions of grass and herb biomass could accumulate, such as in plots Fa1y to Fa7y (Figure 4.13). In these fallows, frequent bush fires were an important factor controlling the vegetation succession (Fukushima *et al.*, 2008; Hoare, 2004). As a result, forest recovery takes a very long time to occur in such areas. On the contrary, in grazed fallows with a high grazing intensity (Fa2y_G2moH, LSU/ha = 1.37), the grass biomass was controlled very rapidly and replaced by annual herbs, such as *Chromolaena odorata*, that usually occupy the area for a short time before being dominated by seedlings and saplings (Kutintara, 1999). Unfortunately, we could not find another site to observe AGB dynamics and vegetation succession under a similarly high grazing pressure and we recognize that more observations on the effects of high grazing pressure on long term AGB dynamics are still needed. These investigations could also be conducted in ruzi pastures under a range of grazing pressures. But, because the purpose of ruzi cultivation at this study site is protection against the soil erosion, negotiation with the respective land owners would be necessary before being able to carry out this kind of on-farm research.

In fallows subjected to low grazing intensity, cattle grazing tended to maintain or decrease the grass biomass and as a result reduced the risk of bush fire. Consequently, the regeneration of a tree layer in such plots occurred faster than in non-grazed fallows.

The grazed reforestation areas were disturbed by yearly bush fires creating a dense cover of grass, and without fire control, the forest did not seem to recover. Finally, in the non-grazed tree plantations, although there were high proportions of grass and herb biomass in the young plots, the protection of the growth of seedlings and saplings led to enough shading to inhibit the growth of grass and herb species (Falvey and Hengmichai, 1979). As a result, in those plots a tree layers could recover in a few years (Figure 4.13).

4.4.3. Research findings and local stakeholders' points of view on the effects of cattle grazing and tree plantations on forest regeneration

This study was conducted to better understand the two contrasted perceptions of local herders and foresters on the effect of cattle grazing on forest regeneration in this forest-farm land interface, and for the research team to form their own point of view on these processes in the local conditions. The herders argue that cattle grazing can accelerate forest regeneration by reducing the risk of forest fire through the removal of grass biomass, while foresters say that grazing delays forest regeneration through tramping and browsing, and by killing saplings and seedlings, especially in young tree plantations.

The results presented above tend to suggest that the herders are right, at least under these conditions. Indeed we have seen that cattle grazing can reduce the grass biomass and reduce the amount of flammable materials in the dry season, as reported by Sathapornpong (1979). Moreover, cattle grazing can stimulate forest regeneration in fallows. The AGB measured in a seven-year-old grazed fallow (10,369 kg/ha) in this study was equal to the one observed in a six years undisturbed fallow of the Nam Yao and Nam Suad National Reserved Forest (Table 4.1) reported by Pibumrung (2007), whilst the AGB of a 12-year-old grazed fallow (55,891 kg/ha) was higher than the AGB of a 14-year-old teak plantation (43,500 kg/ha) or a 19-year-old *Gmelina arborea* plantation (23,900 kg/ha) in the same reserved forest (Pibumrung, 2007).

Regarding the foresters' argument, the results of this study in some grazed fallows, such as Fa_G2y, FaG3y, and a high grazing pressure in Fa2y_G2moH suggested that they too were true because the data showed the reduction in AGB of saplings and seedling from June to December. But, it was noted that the reduction of the sapling and seedling layers may not have a great affect on the forest regeneration rate as the tree layer could develop well as mentioned before. While in the tree plantations, this study could not conclude about the effects of cattle damages on saplings and seedlings by tramping because there was a confusion of effects with frequent bush fires that can also lead to the same kind of effect (Hoare, 2004; Kafle, 2006). In the literature, Andrews and Kwaengsopha (1979) reported that grazing at the rate of two heads of cattle/ha in one and two-year-old pine and eucalyptus stands had no effect on seedlings height or survival.

In summary, both the herders' and foresters' perceptions are correct but based on the specific state of vegetation that they are interested in. Herders talk about tree recovery by cattle, while foresters focus on saplings and seedlings that are very small and easy to damage. Therefore, both of them need to share these two perceptions by building a global vegetation dynamics based on different factors. Their perceptions could also be enriched by the reported research findings. This raises the question of how to share scientific findings on vegetation dynamics with them and how to confront them with the stakeholders' empirical knowledge?

4.4.4. Role of the on-farm researcher regarding the land use conflict and the need for co-management at the landscape level

Based on the results from this study and experiences from previous investigations carried out in similar vegetation animal rearing systems, several options could be proposed by researchers to improve the management of this forest-farm land frontier. For instance, the use of cattle grazing at low intensity in young tree plantations to control the grass biomass (Mayle, 1999; Riggs *et al.*, 2005; Vasilios, 2009), the plantation of native unpalatable species from grazed areas for reforestation in pure or mixed stands to mitigate the risk of damage by cattle (Smit *et al.*, 2006), or the introduction of a radically new cattle raising system based on the establishment of artificial pastures. But there is a high chance that the introduction of such techniques by outsiders would not mitigate the existing land use conflict and social tensions between herders and foresters. This is because they will not help them to better understand and trust each other, while this is necessary to support a mutual agreement on the characteristics of the desirable new land use system to be adopted.

Therefore, an urgent task for the on-farm researcher is to propose a way for the local stakeholders to better communicate, understand each other's opinions and interest, and be able to share their knowledge and perceptions on the effects of cattle grazing and tree plantation on forest regeneration. By making the new knowledge obtained from this ecological study available to the local herders and foresters, the researcher can enrich the exchanges and try to integrate their empirical knowledge with its scientific findings to establish a common agreement on the vegetation dynamics at work. Then, this common understanding could be used to look for mutually acceptable alternative ways to manage the local land system. Once desirable options are jointly identified, a negotiation process will take place to set up an action plan for the co-management of the land. Such a process can lead the researcher and local stakeholders to deal with different institutional levels that could contribute to the implementation of a more sustainable land management (Giller *et al.*, 2008).

In this research, we decided to test a collaborative modelling approach that seemed appropriate to the local context to set up such a process facilitating communication, joint learning and negotiation among stakeholders.

PART II: THE COLLABORATIVE MODELLING PROCESS

CHAPTER V

COLLABORATIVE LANDSCAPE MODELLING AND THE PROCESS IMPLEMENTED WITH LOCAL STAKEHOLDERS

Since the first United Nation's Earth Summit in Rio de Janeiro, Brazil in 1992, the Agenda 21 stimulated more and more discussion among scholars regarding the people's participation and respect for local knowledge in sustainable resource management. Participatory approaches have their origin in action research and have been used since 1930s. More recently and in the field of agricultural research, natural resource management and rural development, these approaches emerged more strongly as a response to top-down planning processes in rural development projects and to the failure of the linear transfer-of-technology model from the 1960s to the early 1980s (Neef, 2005). Participatory approaches aim at involving diverse types of stakeholders (e.g. local resource users, NGOs, policy makers, etc.) in all stages of research and/or development projects for shared learning and collective decision making (Reed, 2008). In past decades, the use of computer modelling[13] and simulation[14] has been integrated into participatory approaches because of their capacity for exploring scenarios that are difficult to test in reality. Models and simulation are alos used to support collective learning and decision making, and therefore are in full agreement with the main objective of participatory approaches (Epstein, 2008). Combining participatory processes and models when defining solutions to environmental problems, by aiming to increase both the efficiency and the legitimacy of environmental policies, is creating a new political context (Jonsson and Alkan-Olsson, 2005).

To account for the involvement of participants in the modelling process, different expressions are used with slight differences such as collaborative modelling (Renger *et al.*, 2008), participatory modelling (Hare *et al.*, 2003), mediated modelling

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[13] "Modelling" refers to the process of producing a model, which is an abstract representation of the structure and functions of a system of interest (Maria, 1997).

[14] The "simulation" refers to the operation of such a model (Maria, 1997). Simulation for scenario(s) exploration is used to explore directions of the system under study by changing conditions.

(Cole, 2007; Rauschmayer and Wittmer, 2006), group model building (Rouwette *et al.*, 1999), and cooperative modelling (Cockerill *et al.*, 2006).

In this chapter, following a brief presentation of the state-of-the-art in collaborative modelling, more details are provided on Companion Modelling (ComMod) approach selected in this research. The last section of the chapter provides an overview of the collaborative modelling process implemented with local stakeholders in Doi Tiew village of Nan Province.

5.1. Collaborative modelling approaches

Collaborative modelling approaches developed from the field of system dynamics since the late 1970s (Vennix, 1997). Frequently, modelling has primarily been used by scientists as means to capture and predicting aspects of complex systems. However, non-linear, complex and dynamic systems are unpredictable. In such a context, models should not be thought as expert systems designed for problem solving but rather as artefacts designed to gain a better understanding of the system through knowledge elicitation and sharing. Therefore, modellers started to involve experts and non-experts in the modelling process to create a holistic view of the system to be used to stimulate critical thinking. The term “collaborative” or “participatory” modelling refers to the group model building situations where model designers and/or users are actively involved in the process of co-design and/or use of models continuously along the modelling process (Rouwette *et al.*, 1999). However, some researchers narrow down this definition to the co-design stage only, to stress the critical importance of the joint creation of a shared representation of the system at the beginning of the modelling process to create common understanding of the system before moving to the simulation phase (Renger *et al.*, 2008).

Integrating knowledge from stakeholders in the research process is increasingly important in the analysis of complex issues dealing with a tangled web of related problems (multi-problem) across or at the intersection of many disciplines (multi-disciplinary), with the underlying processes interacting on various spatial and temporal scales (multi-scale) and involving different stakeholders (multi-actors) (van Asselt and Rijkens-Klomp, 2002).The frequently cited objectives of collaborative modelling approaches are as follows (Epstein, 2008; Mendoza and Prabhu, 2006; Neef *et al.*, 2006; Renger *et al.*, 2008):

i) to create mutual understanding of the system or problem by integrating mental models and knowledge from different types of stakeholders,

ii) to analyse the system under study, e.g. determine the critical elements or components influencing the system dynamics,

iii) to imagine how to operate the system and observe the dynamics of the system when some elements or components are added or changed (scenario analysis),

iv) to support communication, shared learning, and a negotiation process while improving the stakeholders' capacity for adaptive management along the modelling and simulation process,

v) to avoid the "black box" effect of a model (making it transparent to the users) and provide power balance among stakeholders, and

vi) to increase the capacity of potential users to use the model , i.e. the use of the model is not just limited to some experts in their laboratory.

In the field of natural resource management, collaborative modelling is attracting more and more attention because of the increasing uncertainty of the economic context, the heterogeneity of the stakeholders, and the rapidity of organisational change in social-ecological systems (Renger *et al.*, 2008). Most of the models developed to cope with issues related to natural resource management are spatially explicit. To input spatial information in the models, specific tools like Geographic Information Systems (GIS) are required. In landscape modelling, the spatial patterns emerging from land use change constitute a key feature to characterize the simulation results. The need to explicitly represent space and to define realistic virtual landscapes is strengthened when human activities (agriculture, hunting, forestry, etc.) are part of the system. It is also the case when the purpose of the model is to understand the interactions between natural and social dynamics to provide some insights about renewable resource management options explored through the simulation scenarios. The following section provides brief information about GIS-based and agent-based modelling and simulation approaches, because both are widely used in a collaborative way for integrated natural resource management (Gimblett, 2002; Parker, 2005; Ramsey, 2009).

5.2. GIS-based and agent-based collaborative modelling approaches

5.2.1. GIS-based models

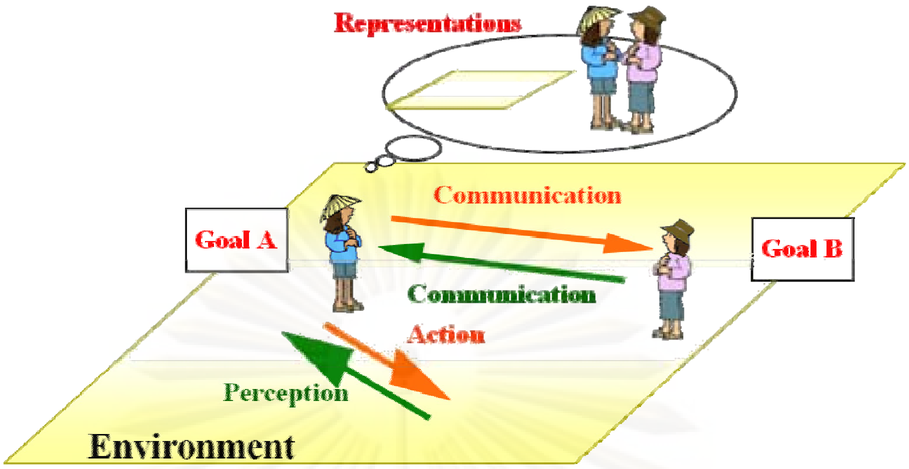
The use of Geographic Information Systems (GIS) for the construction of ecological or biophysical models is well-known (Ramsey, 2009) because it provides supporting tools for modelling, especially spatial data management, analysis and visualization and can be linked with other types of models through an interface managing the exchange of data (Mitasova and Mitas, 1998).

Many applications of GIS models were developed for natural resource management such as land use/landscape and urban planning, soil erosion management, watershed protection and biodiversity hotspot identification. These applications were carried out through several well-known collaborative GIS-based modelling approaches including GIS-based participatory mapping, participatory 3-dimentional (3D) modelling, participatory GIS, public participation with GIS and Mobile, Interactive GIS (Gonzalez, 2002; Krek, 2005; Rambaldi and Callosa-Tarr, 2002; Robiglio *et al.*, 2003). In recent years, GIS applications have moved towards developing dynamic maps to answer the criticism about GIS presenting only a "snapshot" of a situation at certain moment in time (Gimblett, 2002). An example is the 3D-Envisioning system (Beurden *et al.*, 2006; Lewis and Sheppard, 2006; Stock *et al.*, 2007).

However, it was found that GIS-based models could not easily represent stakeholders' decision-making processes and social interactions which are important to consider for collective decision-making (Gimblett, 2002).

5.2.2. Agent-based models (ABM)

ABM is an approach that has received increasing attention in the landscape modelling community in recent years because it offers a way to incorporate the influence of human decision-making in a mechanistic, formal, and spatially explicit way. ABM originated from the field of artificial intelligence, in parallel with Individual-Based Modelling in ecology in late 1980s (Huston *et al.*, 1988). ABM consists of a number of agents which interact both with each other and with their common environment, and can make decisions and change their action as a result of these interactions as shown in Figure 5.1 (Ferber, 1999)..



Source: modified from Ferber, 1999.

Figure 5.1. Schematic representation of a Multi-Agent System.

It is often considered that ABMs have particular advantages in a collaborative context because designing an ABM is quite "intuitive." It involves identifying the basic agents (active entities) who play a decisive role in managing the system, specifying their management entities and their degree of autonomy and stating how they interact with their environment and the other agents. These entities can be objects, items in the landscape, individuals or groups of individuals (farm, village, institutions, etc.) (Bousquet and Le Page, 2004). Stakeholders are therefore able to criticise the models or contribute to their design and improvement (Matthews *et al.*, 2007).

5.2.3. Combined use of GIS and ABM

In 2002, Gimblett edited a book on integrating GIS and ABM techniques for simulating social and ecological processes that reported pioneering applications. Nowadays, as reviewed by Matthews *et al* (2007) more and more modellers are following the same direction, see for instance Bone and Dragicevic (2009), Etienne *et al* (2003), and Guo *et al* (2008). At the same time, with the development of computer technology, several modelling platforms have included modules allowing integrating GIS and ABM (Nikolai and Madey, 2009; Parker, 2005). A loose linkage involves passing interchange files between the ABM and the GIS. This is for instance the case for the CORMAS platform that enables to integrate both raster and vector data to define realistic virtual landscapes (Bousquet *et al.*, 1998). The implementation of tightly coupled process-data models can be either ABM-centric or GIS-centric. The first one uses software libraries of GIS functions within ABMs. For example, the GeoTools Java library (http://www.geotools.org), which includes GIS data management and visualization functionality, is available for use by models developed with the RePast[15] ABM development platform. The second one would allow running interactively ABM functions within the graphical user interface of a GIS package. For example, an “Agent” analyst extension was developed to allow ArgGIS users to create agents and specify their behaviours and interactions, to schedule simulations, and to produce map with ArcGIS layers (North, 2004).

Because visual aspects are essential for users to follow the dynamic of the system under study and to interpret the simulation results, the next section focuses on the role of visualization in collaborative modelling.

5.3. Visualization in collaborative landscape modelling

As a collaborative process deals with diverse types of stakeholders, visualization of features and processes is important as a communication tool. Very often the modelling and simulation tools use visualization features allowing stakeholders to discuss the model components, architecture and its dynamics. Basically, writing and drawing (symbol or picture) on board or paper are frequently used to present the static structure and dynamic interactions of a system during the conceptual modelling phase. Some researchers rely on more advanced techniques to build conceptual models with stakeholders by using the Unified Modelling Language (UML), which is a universal language for object-oriented computer programming that can be easily linked to the subsequent phase of model implementation and coding (Fowler, 2004).

In model testing and use phases, particularly in the case of integrated socio-biophysical models, model visualization plays an important role to help stakeholders to observe the model behaviour, especially spatial dynamics. Socio-economic dynamics are usually observed through a set of indicators (e.g. income, production, stock of animals, etc.) displayed on graphs used to compare simulation results among different scenarios.

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15 http://repast.sourceforge.net/

Several types of visual features can be used with stakeholders for the spatial representation of the context of natural resource management. The choice of a given type of visualization also depends on the purpose of a model, the resources available, and needs to be adapted to the capacity of the users.

Landscape visualization needs to support the identification, communication and understanding of the important components and behaviour of the modelled phenomena (Kornhauser *et al.*, 2009). Visual representations in the model could be more or less abstract or realistic depending on the objectives of the model and its use (Burton and Obel, 1995; Lange, 2001). It is important for the relevant features of reality linked to the issue at stake to be clearly displayed and to allow the participants to distance themselves from real life in order to be creative when envisioning alternative options for landscape management (Dionnet *et al.*, 2008). In collaborative modelling and simulation processes, effective visuals presenting information should be clear and understandable by all types of potential users for models to have a chance to be usable and effectively used to support dialogue and decision-making. But, as Horlitz (2007) said, it is a "tightrope walk" between the demand for transparency (avoidance of the black box effect) on the one hand and the need to reduce complexity on the other hand.

To design effective landscape representations, Kornhauser et al. (2009) stressed the importance of "cognitive design and aesthetics aspects." Cognitively efficient visualizations help model users to detect rapidly important features on the model interface. But this is not easy to do when dealing with heterogeneous stakeholders (such as researchers, farmers, technicians, development workers, administrative officers, etc.) using different types of knowledge (scientific, empirical, expert, institutional, etc.) and experiences to frame and produce their own perceptions of the land and its dynamics. A suitable way to do it could be to co-design the landscape features with the main concerned stakeholders to discuss and select together the important features linked to the issue at stake to appear on the model interface, their spatial arrangement and possible evolution during a simulation. The aesthetic aspects of the visualization are also important to take into account as the visuals have to appeal to the users to highlight key messages and to increase memorization. This is particularly important when iterative gaming and simulation activities are used to facilitate the participatory comparison of successive versions of the same model (especially when they need to be validated by diverse users) or/and to carry out comparative analyses of results obtained from the simulation of different scenarios. The visual features should also stimulate communication among the participants in a collaborative modelling process and the emergence of new ideas and possible solutions to the problem under study through interactive exchanges and the creation of users own results (Horlitz 2007). This underlines the need for researchers to monitor and evaluate the practical use and influence of landscape visualizations with users along the collaborative modelling process (Sheppard, 2001).

Therefore, the emphasis is on how to create suitable visual representations of the landscape and its dynamics to stimulate the participation of diverse stakeholders in co-management of the land. The next section presents a comparative analysis of five case studies using different spatial representation features.

5.4. Comparison of collaborative modelling case studies with different visualization features

This section presents a comparative analysis of five collaborative modelling case studies in natural resource and landscape management. The analytical framework used to compare the case studies was modified from a proposed integrative methodological framework developed by the members of the “CGIAR Challenge Programme on Water and Food (CPWF) PN 25: Companion modelling for resilient water management” project in 2008. Beyond the comparison of the degree of stakeholders’ involvement in the modelling process and of the learning outcomes, the objective of the analysis presented in this section was to compare the advantages and disadvantages of different types of landscape’s visualization techniques used in collaborative modelling. The results were during the design of the visualization of the landscape to be used in the Doi Tiew case study.

5.4.1. Selection of case studies for comparison based on different visualization features

The visualization features of the selected case studies range from 2D and 3D schematic representations to 3D realistic images. Some of these features are computer-based. Table 5.1 provides a general description of the selected case studies.

The first case study dealt with a water sharing problem in Lingmuteychu watershed in Bhutan (Gurung *et al.*, 2006). This case study uses the most abstract spatial representation combining a 2D information board and 3D game board (Figure 5.2) used during Role-Playing Game (RPG) sessions organized with local farmers in order to facilitate the negotiation and to support collective action among groups of water users.

Figure 5.2. The visualization tools used in the case of water sharing in Bhutan (Gurung *et al.*, 2006).

The second case study used RPG and ABM presenting a pictogram-based visual representation of the reality (see Figure 5.3) (RPG-ABM) to participating Moroccan smallholders, aiming at accompanying the modernization of their irrigation system (Dionnet *et al.*, 2008).

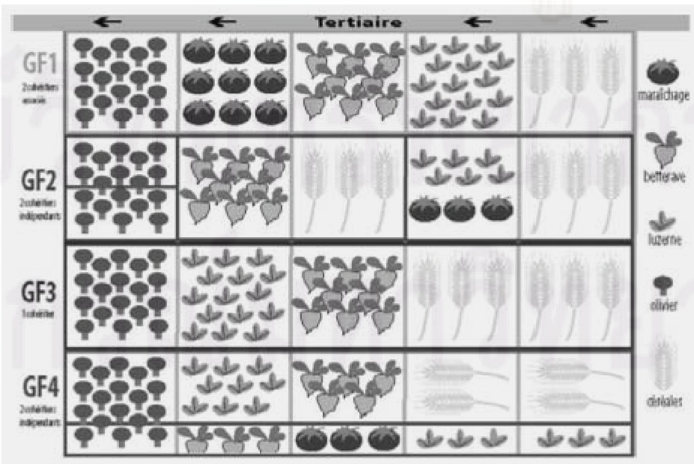

Figure 5.3. Pictogram-based representation of a farm land in a Moroccan irrigation system (Dionnet *et al.*, 2008).

The third case was related to the collaborative establishment of a conservation area using an approach based on Public Participation GIS (PPGIS) with a large number (approximately 2,900 persons) of stakeholders in Mexico (Vela´zquez *et al.*, 2009). This research aimed at taking the diversity of stakeholders' interests into account (see Figure 5.4). Three social groups were invited, including i) academics from relevant disciplines, ii) federal and provincial government employees from rural development, tourism, environment and communication institutions, and iii) local stakeholders such as NGOs, private landowners, presidents of municipalities and indigenous communities.

Figure 5.4. Two-dimension maps use in public participatory GIS in Mexico (Vela´zquez *et al.*, 2009).

The fourth case study describes the use of a GIS technique called "Participatory 3D modelling (P3DM)" with indigenous peoples in Kenya (Rambaldi *et al.*, 2007) by creating a 3D land use model (see Figure 5.5). It aimed to stimulate villagers' awareness on the biodiversity and natural resources loss.

The last case presented the 3D virtual envisioning system (ES) used in the Cudgewa Valley, Australia (Stock *et al.*, 2007), a region which development remains uncertain due to different factors such as cattle price fluctuation, popular tourism, and increasing land prices. Therefore, the research aimed to stimulate local stakeholders' awareness on possible landscape changes (see Figure 5.6) and how to nurture the sustainable management of the area.

Figure 5.5. Participatory 3-Dimentional Modelling with indigenous people in Kenya (Rambaldi *et al.*, 2007).

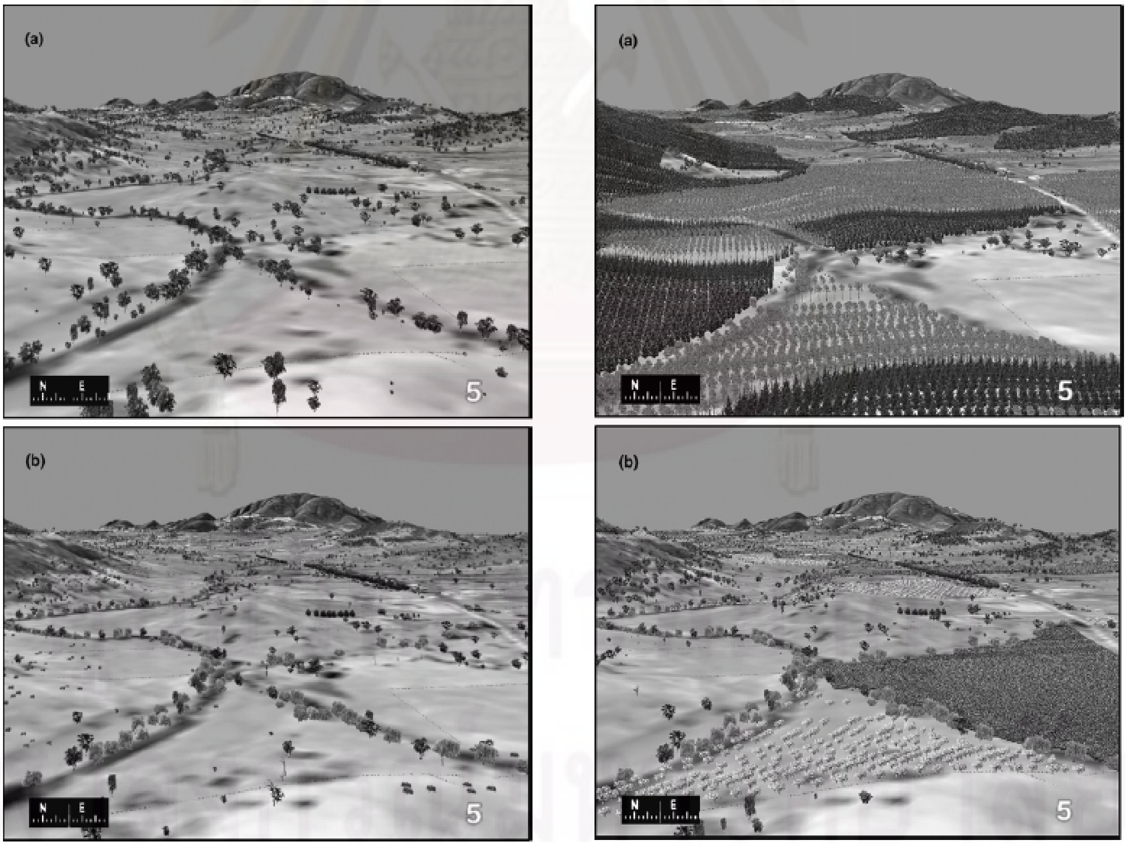

Figure 5.6. The virtual representation of the landscape in the 3D virtual envisioning system (Stock *et al.*, 2007).

Table 5.1. General description of five collaborative modelling case studies with different visualization features.

Method	Key resource management issue	Objective/ Goals	Structure of the modelling process			Mode of learning
			Tools and techniques	Sequence of methodological steps	Scenario exploration	
Role-Playing Game (RPG)	- Water management	- Set up a collective management between 2 villages	- 2 RPG workshops	- Field work for preliminary diagnosis to understand the system and problem - Conceptual modelling - Gaming and simulation sessions using RPG - Discussion	- 3 modes of communication (intravillage, intervillage (collective) and swapping roles))	- Learning via discussion, direct interactions among stakeholders during gaming sessions
RPG and Agent-Based Model (ABM)	- Modern irrigation technique to improve crops production	- Facilitate the shift toward a modern irrigation system	- RPG workshop - Policies analysis via ABM	- Diagnostic of situation with stakeholders - RPG to increase awareness of stakeholders - Scenario exploration via ABM adapted from RPG - Evaluation	- Individual and collective management	- Learning via discussion, direct interactions among stakeholders during gaming sessions
Public Participation-GIS	- Biodiversity protection	- Collaborative establishment for conservation area	- 2D based map - Cartographic material - GIS software - 9 workshops	- First phase: promote environmental awareness to stakeholders - Second phase: 9 workshops with total of 2,900 participants from 3 different social groups (academics, local stakeholders, indigenous communities). These 3 groups were involved separately. - Third sequence: final decision on conservation establishment (by overlaying the maps from the 3 groups)	- Different maps produced by different groups of stakeholders	- In the same social group, learning by discussion - Between social groups, learning through the different maps results
Participatory-3D modelling	- Land and natural resource loss	- Build 3D land use model	- Land use map - Contour map - GIS software - Tool to build 3D model and legends	- Establishment of working team - Consulting and mobilizing stakeholders - Choosing map scale - Generating contour map and based map - Producing 3D model	- Not available	- Learning via discussion and interactions during the 3D model building
Envisioning system (ES)	- Landscape planning	- Scenario exploration for sustainable development	- 2D, 1: 25,000 map - Envisioning system - Personal digital assistant (PDA)	- Two workshops with 20 participants of each workshop - Set up a system, generate 3D virtual landscape - Scenario exploration and discussion	- First workshop: alternative land management option proposed by researchers (annual and perennial pastures, forest regeneration and riparian alternatives) - Second workshop: conversion of farming to cropping	- Discussion on different scenarios

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5.4.2. Comparative analysis of case studies

Table 5.2 summarizes the advantages and limitations found in the selected case studies. A 3D spatial representation is more difficult to modify for scenario exploration compared to the spatial representations used in the other four cases. However, it has some advantage such as providing tangible features to stakeholders that are easier to refer to when discussing land use and planning issues.

All kinds of representation enabled a shared learning among stakeholders but each with a specific way to facilitate exchanges of perceptions. In the case of abstract representations used in the RPG and RPG-ABM tools, stakeholders shared their perceptions directly through the discussion during and after the gaming sessions. However, to allow direct interactions among participants, their number has to remain low. In comparison, PPGIS allows to involve much more stakeholders at the same time.

It was observed that the diverse groups of stakeholders can understand the 2D maps used in PPGIS, including indigenous people. They could argue where they need to set a protected area. Compared to the realistic representation provided by the 3D ES, it seems that the outcome of stakeholders understanding of the system was similar. In all cases (except for P3DM), stakeholders learned about the different future possibilities of landscape through observing the results from simulations. This analysis suggests that the visual representations of a socio-ecosystem on spatial interfaces provided by a model do not necessarily need a high degree of realism for the users to understand the features and the dynamics of landscapes. The representations just need to capture the key features and dynamics of the system related to the natural resource management problem being examined.

Table 5.3 synthesizes the technical aspects related to the use of the tools in the modelling process. It was found that in the case studies based on P3DM, PPGIS and ES, researchers had their own questions in mind before starting to use the modelling tools with the stakeholders.

Table 5.2. Evluation of different visualization features used in the five case studies.

Method	Spatial features used	Total number of participants	Advantage of features used	Limitations of features used
Role-Playing Game (RPG)	- 2D abstract representation of water system - Traditional game tiger and cattle board	12	- Simple but still meaningful features - Features used with RPG create an opportune atmosphere for communication and negotiation	- Time consuming activity
RPG and Agent-Based Model (ABM)	- 2D pictogram-based representation	12	- 2D pictograms are easily understood by players - Pictograms can be transferred into a ABM - ABM is a time efficient simulation tool	- Need computer programmer for coding the ABM
Public Participation-GIS	- 2D map with critical area for biodiversity conservation	2,900	- Available to use with diverse groups	- Different groups of stakeholders did not interact directly
Participatory-3D modelling	- 3D land use model - Colours based legends	156	- Tangible features - Can be used by stakeholders themselves and able to keep the model for a long time - Understandable by low formal education people - Many stakeholders can be involved in building the representation	- Difficult for scenario exploration
Envisioning system	- 3D virtual reality	20	- Attract stakeholders to participate in the workshop - Based on GIS interface: easy for participants to manipulate to select the (predefined) input to the model. - Can stimulate more than 10 scenarios (selected by participants) within a 2 hours workshop	- Some stakeholders attempt to compare the virtual image with reality, not discuss on the management issue. - High cost of the envision system and its related high-tech tools

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During the preliminary diagnostic phase, stakeholders involved in the ES case study had low interaction with the researchers, as the information was already stored in a GIS. In the case of PPGIS, some information from stakeholders was still needed to finalize the production of the map for endangered species. In the case of P3DM, stakeholders were requested to select areas and scale of the model, as well as the year corresponding to the situation to be represented, the of land use types, etc. to build the 3D model. So, the stakeholders using this technique are also designers of the model.

P3DM allowed stakeholders to build a model by themselves because it is not so complex, even if it can take a long time to meticulously finalize all the details that can be added to the block diagram. In the other cases, when the representation of space is computer-based, skills in computer programming (particularly in ABM and GIS software packages), are required. Therefore, stakeholders are excluded from the practical crafting of the tools.

Regarding the choices of scenarios to be simulated, all techniques allowed stakeholders to suggest which scenarios to explore with the modelling tool. In terms of outcomes of the modelling process, it was found that the case study based on PPGIS ended with a collective agreement on the area for park establishment.

Therefore, these different techniques have different capacities to involve stakeholders in the different stages of the modelling process. However, RPG and RPG-ABM are most suitable for stimulating interactions between conflicting parties in order to move towards a better mutual understanding.

Therefore, the Companion Modelling (ComMod) approach, based on the participatory use of RPG and ABM simulation tools, was selected in this study. It was implemented with the local stakeholders at Doi Tiew research site in order to i) facilitate dialogue, exchange perceptions, and co-learning among conflicting stakeholders, ii) build a shared representation of landscape dynamics and land management to explore alternative land use systems of their choice, and iii) facilitate negotiation leading to co-management of the land. The next section provides background information from the literature on the ComMod approach including its key concepts and theoretical references, its fundamental methodological principles, the phases of a ComMod process, and a presentation of the main tools used for its implementation.

Table 5.3. Participants and their degree of involvement at each modelling stage in five case studies with different visualization features.

Method	Type of participants	Degree of involvement in each stage						
		Problem identification	Preliminary diagnosis & data collection	First design of conceptual model	Model implemen-tation	Definition of scenarios	Scenario exploration	Decision on next steps
Role-Playing Game	Local farmer from 2 villages	2	1	2	0	4	5	4
RPG and Agent-Based Model	Local farmer	2	1	2	0	4	5	4
Participatory-3D modelling	Indigenous people	0	2	5	4	NA	NA	4
Public Participation-GIS	Diverse groups of stakeholders participating in the same activity	0	2	0	0	0	5	1
Envisioning system	Farmers, shopkeepers, councillors	0	0	0	0	4	5	4

Note: NA is not available.

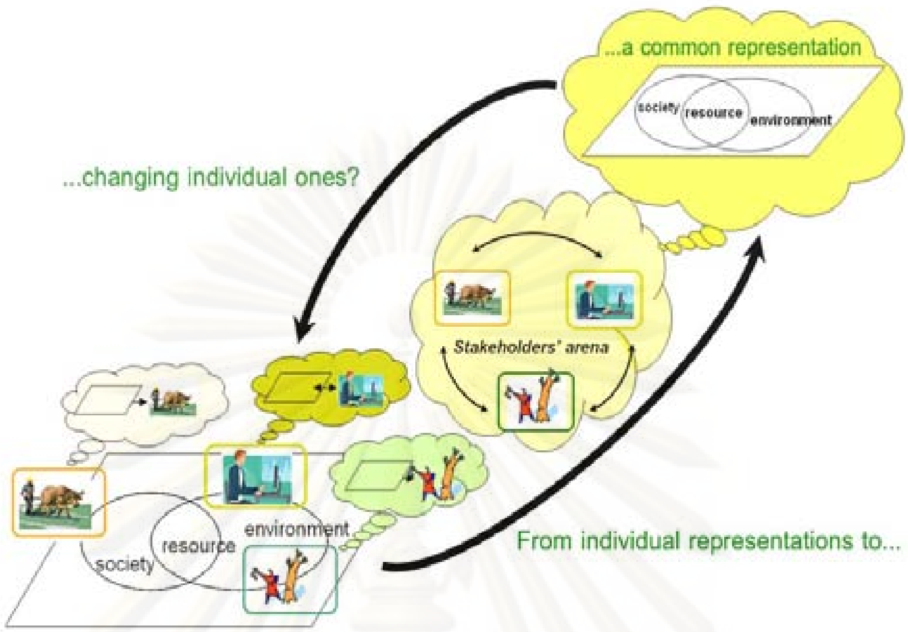
Degree of stakeholder involvement in modelling process: Bold character represents decision-controller. Arrow represents flow of information.
0 = No direct interaction
1 = Information [Stakeholder ⟵ **Modeller**]
2 = Consultation [Stakeholder ⟶ **Modeller**]
3 = Co-thinking [Stakeholder ⟷ **Modeller**]
4 = Co-designing [**Stakeholder** ⟷ **Modeller**]
5 = Total control [**Stakeholder** ⟷ Modeller]

5.5. Companion Modelling (ComMod) approach

The recent trend towards a more decentralised management of natural resources is inducing the involvement of an increased number and diversity of stakeholders having different perceptions and objectives regarding the use of local renewable resources. Moreover, there are also complex interactions between bio-physical, socio-economic, policy and cultural factors to be taken into account. To deal with such a context, innovative system-based and trans-disciplinary approaches are needed.

In 1993, a new approach called Companion Modelling (ComMod) dedicated to examine complex natural resource management issues was created by the GREEN (Gestion des ressources renouvelables et environnement: Management of Renewable Resources and Environment) research unit at CIRAD, France (Trébuil, 2008). ComMod main principles are to develop simulation models integrating various stakeholders' points of view and to facilitate dialogue, shared learning, support negotiation and collective decision making (Barreteau and Others, 2003). It emphasizes better understanding of interactions between ecological and socio-economic dynamics in a complex and uncertain system through iterative cycles alternating field observations and model implementations. ComMod considers that stakeholders' decision making processes need to be elicited to understand such interactions (Bousquet and Trébuil, 2005).

In ComMod, researchers are considered as one type of stakeholder in the arena because they bring into the arena their own point of view and knowledge and can influence other stakeholders' decisions since the start of the process. All points of view on the problem to be examined are considered as *a priori* legitimate ones. A communication platform integrating various stakeholders' points of view based on different kinds (e.g. empirical, indigenous, technical, expert, institutional, legal, and scientific) of knowledge and the contributions from different disciplines (e.g. social and ecological) is constructed and used through the ComMod process. A major step is the co-design of a common representation of the sub-system to be managed collectively as shown in Figure 5.7. During this phase communication and exchange of knowledge and points of view are facilitated and lead to changes in the stakeholders' perceptions of the common resource management problem at stake.



Source: http://www.ecole-commod.sc.chula.ac.th

Figure 5.7. Schematic representation of a Companion Modelling process based on co-designing a shared representation among stakeholders.

5.5.1. Key concepts and theoretical references

The ComMod approach was gradually built by relying on a bundle of theories and ways to look at the collective management of renewable resources.

5.5.1.1. The science of complexity

Complexity is usually referred to a condition of diverse components in a system with numerous forms of relationships. Complex systems tend to be high-dimensional, non-linear and hard to model (Holling, 2001). In a complex system, the properties at macro level emerge from interacting components at individual or micro level (Janssen, 2002). This paradigm supports the ComMod motivation to integrate various stakeholders' points of view to understand the complexity of the system. Moreover, the science of complexity underlines the fact that behaviour of a complex system is dynamic, uncertain, and unpredictable due to emergence and self-organization. These characteristics are important for the choice of modelling tools in ComMod that focuses on improving a better understanding of the system. Then, through simulations, stakeholders can interact and modify some components in the system to explore how to lead the system towards a more desired state.

5.5.1.2. Resilience and adaptive and management

Formerly, ecosystem resilience was defined as a measure of how far the system could be perturbed without shifting to a different regime (Holling, 1973). Recently, Carpenter *et al*. (2001) revised this definition of resilience applied to integrated human and nature systems (social-ecological systems) and is composed of three components: i) the amount of change the system can undergo and still retain the same controls on function and structure, ii) the degree to which the system is capable of self-organization, and iii) the ability to build and increase the capacity for learning and adaptation. Therefore, the resilience of such complex system can be enhanced by the increasing the adaptive capacity of the diverse stakeholders in the system (Walker *et al*., 2002). According to the concept of adaptive management (Holling, 1978), a complex ecosystem requires flexible, diverse, and redundant regulation, as well as monitoring procedures leading to corrective responses, and experimental probing of the ever changing reality. For the management to increase the adaptive capacity of the system to change, social processes influencing the state of the ecosystem need to be taken into account. This is because solutions to concrete collective resource management problems could emerge from interactions among stakeholders. Thus, the organization of platforms to stimulate interactions among stakeholders for the generation and exchange of knowledge is required (Trébuil, 2008). Therefore, such knowledge exchange can result in the integration of diverse points of views. Through the co-learning process, a proposed management model can be collectively agreed upon among multiple actors.

5.5.1.3. Collective management of multi-actor processes

ComMod relies on theories of collective action in social systems, especially the common-pool resources and public goods (Pretty, 2003). ComMod processes emphasis on coordination and negotiation among diverse types of stakeholder. Through a negotiation and collective learning processes within a social network, a set of agreed rules defined by the stakeholders themselves could improve the management of system as well as improve trust among the stakeholders.

5.5.1.4. Constructivist epistemology

From an epistemological point of view, constructivism proposes that people actively create their own sense of what is real based on their experiences (Kriz, 2008). Constructivism supports the learning process, and views all of knowledge as “constructed” (Röling and Wagmaker, 1998). ComMod realizes the importance of different stakeholders’ perceptions when looking at a natural resource management problem because these different perceptions often lead to a conflict. ComMod attempts to integrate knowledge from diverse disciplines and various points of views of local stakeholders into a shared representation regarding the problem at stake through a communication and social learning process. By creating a shared representation of the system among stakeholders, they could be better to seek for a collective management (or improve individual behaviour) to mitigate land use conflict based on their modified perceptions along the learning process.

5.5.1.5. Post-normal science

Post-normal science characterizes a methodology of inquiry that is appropriate for cases where “facts are uncertain, values in dispute, stakes high and decisions urgent” (Funtowicz and Ravetz, 1993). Post-normal science postulates that works (research, development of action plans, etc.) based exclusively on scientific knowledge under normal science cannot deal with conditions of high uncertainty. For example, recommendations proposed by hard science to manage a particular area may not be successful due to the final human actions and agreement in that area. As a consequence, the role of interdisciplinary teams, including natural and social scientists, is to understand and strengthen collective decision-making processes through a platform of interactions among stakeholders (Trébuil, 2008).

5.5.1.6. Patrimonial mediation

“Patrimonial” is defined by Ollagnon (1991) as “all the material and nonmaterial elements that work together to maintain and develop the identity and autonomy of their holder in time and space through adaptation in a changing environment.” Patrimonial mediation is an approach that contributes to the understanding and practice of co-management. Mediation is a negotiating method that brings in a neutral party in order to facilitate agreement among the different parties involved in the process. ComMod was borrowed the importance of a prospective analysis of the system evolution and in the search for possible future solutions to common problems.

5.5.2. Fundamental characteristics of companion modelling

5.5.2.1. The ComMod posture

ComMod is an action-oriented research approach that always involves multiple stakeholders throughout the process to ensure that the diverse perceptions of a natural resource management problem are included. In ComMod, a researcher becomes an actor of the system understudy and a facilitator of exchanges among participating stakeholders. The researcher perception and representation of the system is shared with other stakeholders and to be criticized and improved. Researchers play a dual role in ComMod: i) to generate new knowledge on a system or on the ComMod approach itself, and ii) being an actor of the system, to improve it through changes in the stakeholders' perceptions, interactions, and actions (Trébuil, 2008). Regarding the ethical issues related to such a posture, ComMod group developed a "charter" (Barreteau and others, 2003) to avoid the risk of manipulating local actors, or being manipulated by them. The ComMod charter recommends the systematic monitoring of the effects and impact of ComMod activities, and the hypotheses made in the ComMod process should be transparent and explicit to all participating stakeholders.

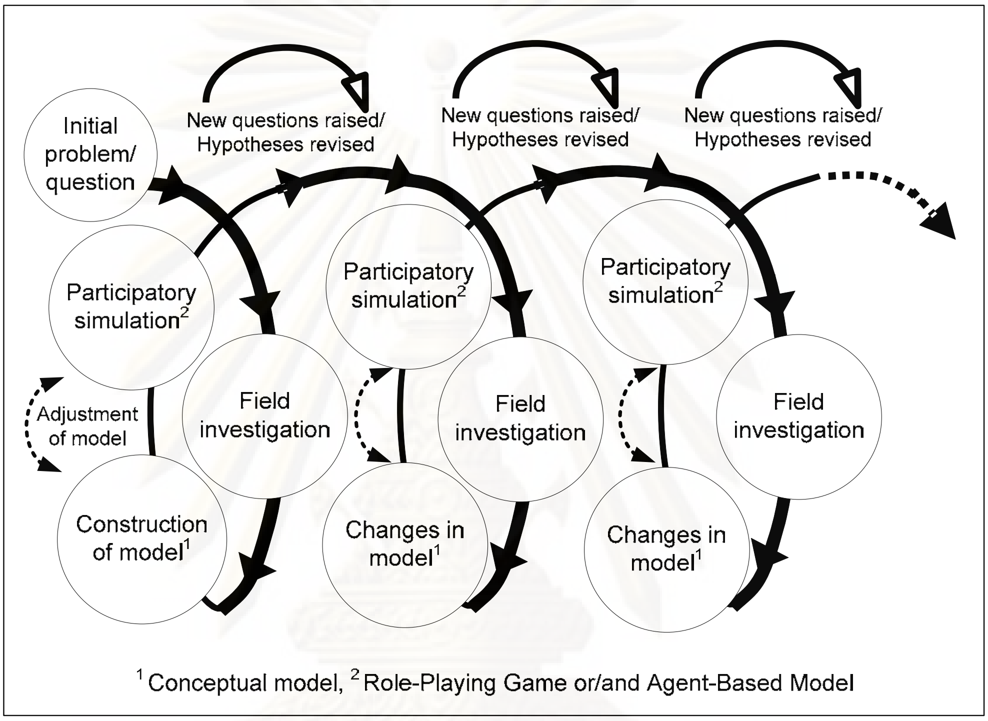
5.5.2.2. A back and forth iterative and evolving process between laboratory and field activities

A ComMod process is an iterative and continuous one, alternating laboratory and field activities (interviews, field/farm surveys, field workshop including gaming sessions and/or participatory modelling, etc.). At the end of each loop, the conceptual model representing the system under study is revised, and the consistency of the hypotheses is reassessed (Figure 5.8).

There are three main stages in a ComMod process that can be repeated as many times as needed (Bousquet and Trébuil, 2005).

1. Field investigations and a literature search supply information and help to generate explicit hypotheses for modelling by raising a set of initial key questions to be examined by using the model.

2. Modelling: the conversion of existing knowledge into a formal tool to be implemented as a simulator.
3. Simulations, conducted according to an experimental protocol, to challenge the former understanding of the system and to identify new key questions for new focused investigations in the field.



Source: Barnaud et al. (2006)

Figure 5.8. The iterative phases of a ComMod process.

5.5.2.3. Two main objectives of Companion modelling

Two different but related objectives are driving the implementation of a ComMod process: i) to develop simulation models integrating diverse stakeholders' points of view (including researchers' ones) to better understand the system under study, and ii) to facilitate collective learning, coordination and negotiation processes supporting the adaptive co-management of renewable resources (Barreteau and Others, 2003). Thus, ComMod can be used in two specific contexts i) to produce new knowledge and ii) to support collective decision making processes. While the first context deals with system research through a particular relationship between modelling and field activities, the second one involves methodological research to facilitate the concerted management of resources in a complex system (Trébuil, 2008).

5.5.3. The Companion modelling process

From a methodological point of view, there are five main phases in a ComMod process: i) initialization of the process, ii) co-construction and conceptualization of models with stakeholders, iii) implementation and validation of models, iv) scenario identification, exploration and assessment, and v) monitoring and evaluation of ComMod effects and impact. A more detailed description of a full ComMod sequence distinguishes 12 steps as shown in Table 5.4.

Table 5.4. The 12 steps of a full ComMod sequence.

	Steps	Comments
1	Sensitizing activities	Sensitizing activities: introduction of the ComMod approach to key stakeholders requesting to look into a given development question, and assessment of its suitability and possibility for use in the local context.
2	Definition of the key question	Definition of the key question to be examined, by the process leaders and, sometimes, other stakeholders as well.
3	Collection of information related to issue	Inventory of relevant scientific, expert, and indigenous knowledge available through literature review & complementary diagnostic surveys to fill the gaps.
4	Eliciting knowledge for modelling	Knowledge elicitation for modelling via surveys and interviews.
5	Conceptual model design	Co-design of the conceptual model with stakeholders concerned by the question being examined.
6	Model implementation	Choice of the tool (computer-based or not) and model implementation.
7	Model verification, calibration and validation	Model verification, validation and calibration with local stakeholders.
8	Identification and definition of scenarios	Identification and definition of scenarios with local stakeholders.
9	Exploratory simulations	Exploratory simulations with local stakeholders.
10	Dissemination of the outputs	Dissemination of the outputs to stakeholders who did not participate in the process.
11	Monitoring-evaluation of the effects of the ComMod process on participants	Monitoring-evaluation of the effects of the ComMod process on participants (awareness, knowledge, communication, behaviour, decision, practices, etc.).
12	Training of interested stakeholders	Training of interested stakeholders on using the tools produced during the collaborative modelling process.

However, there is a lot of flexibility in the approach and its key tools allowing for the adaptation of a ComMod sequence depending on the context of each case study and at a particular time, so it may happen that ComMod practitioners do not exactly follow these steps chronologically.

5.5.4. Complementary main tools and techniques used in Companion modelling

In the different steps of a ComMod process, several complementary tools and techniques can be used with stakeholders, such as in-depth interviews, focused group debates, cognitive mapping, Geographic Information System (GIS), Role-Playing Games (RPG) and Agent-Based Model (ABM). As already mentioned, the implementation of ComMod does not stick on a fixed protocol: tools and techniques used may vary from case to case. The different tools and techniques have to efficiently support the production and exchange of knowledge among stakeholders as well as the collective decision making processes on natural resource management issues. Some tools and techniques used in ComMod are presented below.

5.5.4.1. ARDI method for collaborative conceptual agent-based modelling

ARDI has been thought to facilitate the involvement of stakeholders in designing a conceptual agent-based model related to some natural resource management issues (Etienne *et al.*, 2008). ARDI is based on a sequence of stages meant to precise: (i) the **a**ctors whose practices directly impact the key resources and those acting to encourage the direct stakeholders to change their practices; (ii) the key **r**esources used in the socio-ecosystem; (iii) the **d**ynamics driving the evolution of the socio-ecosystem and (iv) the main **i**nteractions between the entities of the socio-ecosystem. For each of these stages, diagrams are collectively and progressively built according to protocols insuring that each participant will have an equal opportunity to make suggestions.

5.5.4.2. Synergistic use of RPG and ABM in gaming and simulation

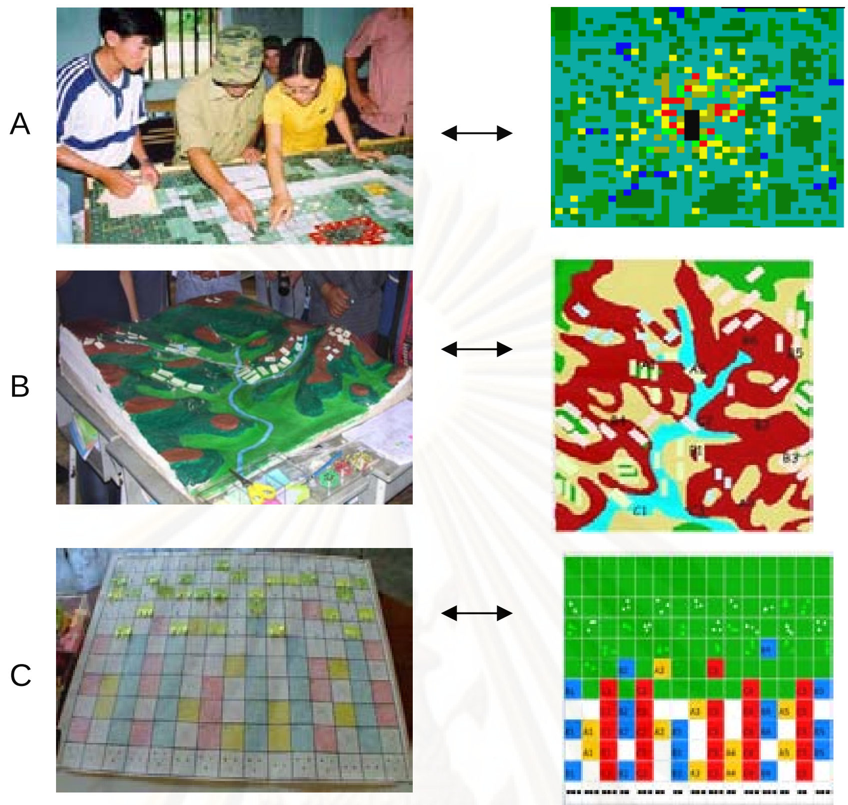
The implementation of a conceptual agent-based model results in the production of a concrete model (a simulator) that can be used to run some scenarios. An agent denoting here a conceptual “decision-making entity”, there are two possibilities to create a concrete instantiation (a particular entity of that kind): either to write (using a programming language) the decision-making algorithms as pieces of computer code, or to request a human being to play the corresponding “role”. Simulators based exclusively on human agents are commonly called role-playing games (RPGs) and the participants endorsing roles are called players. On the other hand, ABMs refer to simulation models based exclusively on computerised agents. A whole range of situations exists between these two extremes where some decisions are human and others are computer-specified. Frequently, ABMs and RPGs are used in combination during a ComMod process, such as Etienne *et al.* (2003), Castella *et al.* (2005), Barnaud *et al.* (2007). The similarities between RPGs and ABMs, stressed by Barreteau and others (2003), are presented in Table 5.5.

Table 5.5. Similarities between Role-Playing Game and Agent-Based Model.

Role-Playing Game	**Agent-Based Model**
Players	Agents
Roles	Rules
Game set	Interface
Game session	Simulation
Turn	Time step

Source: Adapted from Bousquet et al, 2002.

RPGs are very effective in stimulating exchanges among participants and collectively generating scenario proposals but far less so in exploring them. During a game session, producing a time step (game turn) in fact requires a great deal of time. Comparatively, getting close to the relevant simulation horizon in terms of the question asked requires a very short time with an ABM.



Note: A: based on a case study in North Vietnam (Castella et al., 2005)
B and C from a case study in North Thailand (Barnaud et al., 2007; Barnaud et al., 2008).

Figure 5.9. Synergistic use of between RPGs and ABMs.

Figure 5.9 displays the similarity of spatial representations used during some participatory simulation workshops relying on RPGs and ABMs interfaces (produced with the CORMAS platform). In RPGs, spatial representations can be simple and with a high degree of abstraction (e.g. 2D block diagram and 2D landscape) or can be more realistic (e.g. 3D topographical block model). In CORMAS, ABMs, 2D or 3D representations of spatial features are converted to 2D raster format.

5.5.4.3. Logbook for monitoring and evaluation of a ComMod process

In an attempt to help structuring the monitoring and evaluation while implementing a ComMod process, a group a researchers elaborated a tool called "logbook" (Figure 5.10). It is based on three types of documents: (i) an Excel file, providing a chronological account of all the activities related to the implementation of ComMod at a study site together with a listing to identify all the participants in the process; (ii) a set of activity reports, accessible from the master Excel file; (iii) a set of additional documents such as personal interviews, movies, etc. to be used in in-depth analyses. The logbook is filled regularly during the implementation of a ComMod process. Activity reports have to be written at completion of the activity and should include personal feelings about how the activity was carried out and its outcomes. The master Excel file provides macro functions allowing automatic statistical treatments.

a) Chronology sheet

Log book

Doi Tiew case study, Nan Province, Northern Thailand

ct persons: Mr. Pongchai Dumrongrojwatthana, Agricultural Technology Programme, Faculty of Science, Chulalongkorn University, and Deprtment of Geography, Paris-x University

ed on 39742.00

Date	Duration (hr)	Organizer	Participants	Moderator / leader	Language	Type of activity	Objective	Location	Supporting tools or equipment
22-28/12/2007	108.00	PD	PD, WT, KR	PD	Thai	Ecological study	To study the impact of cattle grazing on forest regeneration in dry season.	Doi Tiew area	Ecological field equipments
25/12/2007	1.00	PD	PD, ST	PD	Thai	Discussion and request	To investigate the cattle population in village level by providing a simple questionaire to primary school's childrens to interview their parent at home	Doi Tiew school	Questionaire
9-11/01/2008	24.00	MCC,CMU	PD, conference colleague	MCC,CMU	English	International conference	To present "Companion modelling to facilitate adaptive forest management in Nam Haen sub-watershed, Nan Province, Northern Thailand".	Sheraton Hotel, Chiang Mai, Thailand	Computer
16/01/2008	4.00	Agricultural Technology program	Ph.D. students in Biological sciences and Agricultural Technology program	Seminar course organiser	English	Seminar	Proposal defence	Room 221, Biology Dept. Science Fac. CU	Computer
27/02/2008	1.00	PD	PD, AS	PD	Thai	Interview	To interview NKU chief on cattle raising and current situation (to fill the gap)	Nam Khang headquarters	Guildline for interview
27/02/2008	1.00	PD	PD, KerrSH	PD	Thai	Interview	To interview more information regarding cattle raising and current situation (to fill the gap)	Doi Tiew village	Guildline for interview

b) Actor sheet

Identification	Name	Institution	Position	Type of Knowledge	Speciality
PA	Pacharin Apiwan	NNP	Officer	institutionnel	conservation
KK	Kanya Kongkheaw	NNP	Officer	institutionnel	conservation
ThP	Theves Prarom	NNP	Officer	institutionnel	conservation
KI	Komsan Insri	NNP	Officer	institutionnel	conservation
AS	Anucha Sehreerat	NKU	Head	technique	forestry
PK	Pichet Kampatan	NKU	Officer	technique	forestry
SR	Suttipong Rangsee	NKU	Officer	technique	forestry
KT	Kittisap Tippala	NKU	Officer	technique	forestry
RP	Rabaeb Paeng-ud	NKU	Officer	technique	forestry
TP	Thanwa Paeng-ud	NKU	Officer	technique	forestry
JU	Jaroon Upala	NKU	Officer	technique	forestry
MonT	Montri Tanakhwang	Healthcare	Head	technique	health
PachP	Pacharin Pano	SKRP	Head-Agriculture section	technique	agriculture
PrU	Prakob Ubprajak	SKRP	Officer	technique	agriculture
KS	Khwanchart Sirinya	SKRP	Officer	technique	agriculture
JN	Jak Namwong	SKRP	Officer	technique	agriculture
TunN	Tun Namwong	SKRP	Officer	technique	agriculture
TW	Tal Wongyai	SKRP	Officer	technique	agriculture
TN	Tawach Namwong	SKRP	Officer	technique	agriculture
SuP	Sujira Pano	SKRP	Officer	technique	agriculture
SK	Sakchai Korkerd	SKRP	Officer	technique	agriculture
US	Utid Srisitthipoj	LDD	Head	institutionnel	administration
SuK	Surapon Katewang	LDD	Officer	technique	administration
ST	Sanaoh Thepsen	School	Head	institutionnel	education
SB	Somjade Boontawee	School	Teacher	institutionnel	education

Figure 5.10. An part of the logbook used in in the Doi Tiew ComMod case study in Nan Province, Northern Thailand.

5.5.4.4. Social network analysis

Social network analysis investigates the relationships among actors (clans , village, work unit, etc.) in a social system (Wellman, 1983). Anthropologists introduced "network analysis" to visualize the relationships between actors (McGrath *et al.*, 2003). In socio-ecosystems, there is a diversity of interacting stakeholders. Moreover, in such adaptive complex systems, the interactions are dynamics so the social network can change over time. Therefore, it is interesting to monitor the evolution of the social network along a collaborative modelling process to assess its actual influence on the evolution of the relationships among stakeholders.

Information stored in the above-mentioned logbook (such as the number of activities, their duration, who participated in them, from what stakeholder categories, what kind of knowledge was shared, etc.) can be used to analyse the relationships among stakeholders and to depict knowledge exchange. The NetDraw Package[16] allows producing sets of diagrams[17] based on such information. To prepare a file in a format compatible with the NetDraw package, a set of Microsoft Excel add-ins was produced and provided by Etienne (2009) (personal communication).

5.6. Overview of the ComMod process implemented at Doi Tiew site

This section briefly presents the ComMod collaborative landscape modelling process implemented at the research site. Figure 5.11 illustrates the evolution of its objectives and of the tools used, while Table 5.6 recapitulates the process according to the 12 basic steps of a ComMod process (cf. Section 5.5.3).

A preliminary diagnostic analysis to identify the key resource management problem at the study site (See chapters III and IV) was carried out through the interviews of stakeholders, a farm survey and a field study at the plot level. Knowledge from these preliminary diagnostic activities was used by researchers to assemble, a first conceptual model of the vegetation dynamics by using the ARDI conceptual modelling method (cf. Section 5.5.4.1). Vegetation and cattle population dynamics, cattle management dynamics and interactions between actors and resources

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16 Available for free download at http://www.analytictech.com/

17 More details on the social network method and different types of diagrams are available at http://www.faculty.ucr.edu/~hanneman/nettext/index.html

were conceptualized through the production of a set of diagrams (see details in the next chapter).

The collaborative modelling process itself was executed into three successive sequences with diverse activities, the second and third ones building on the previous one. The simulation tool used during these three sequences was a computer-assisted role-playing game (cRPG) that progressively and collectively paved the way towards the production of a fully autonomous ABM allowing the simulation in the laboratory of land use scenarios related to different management strategies

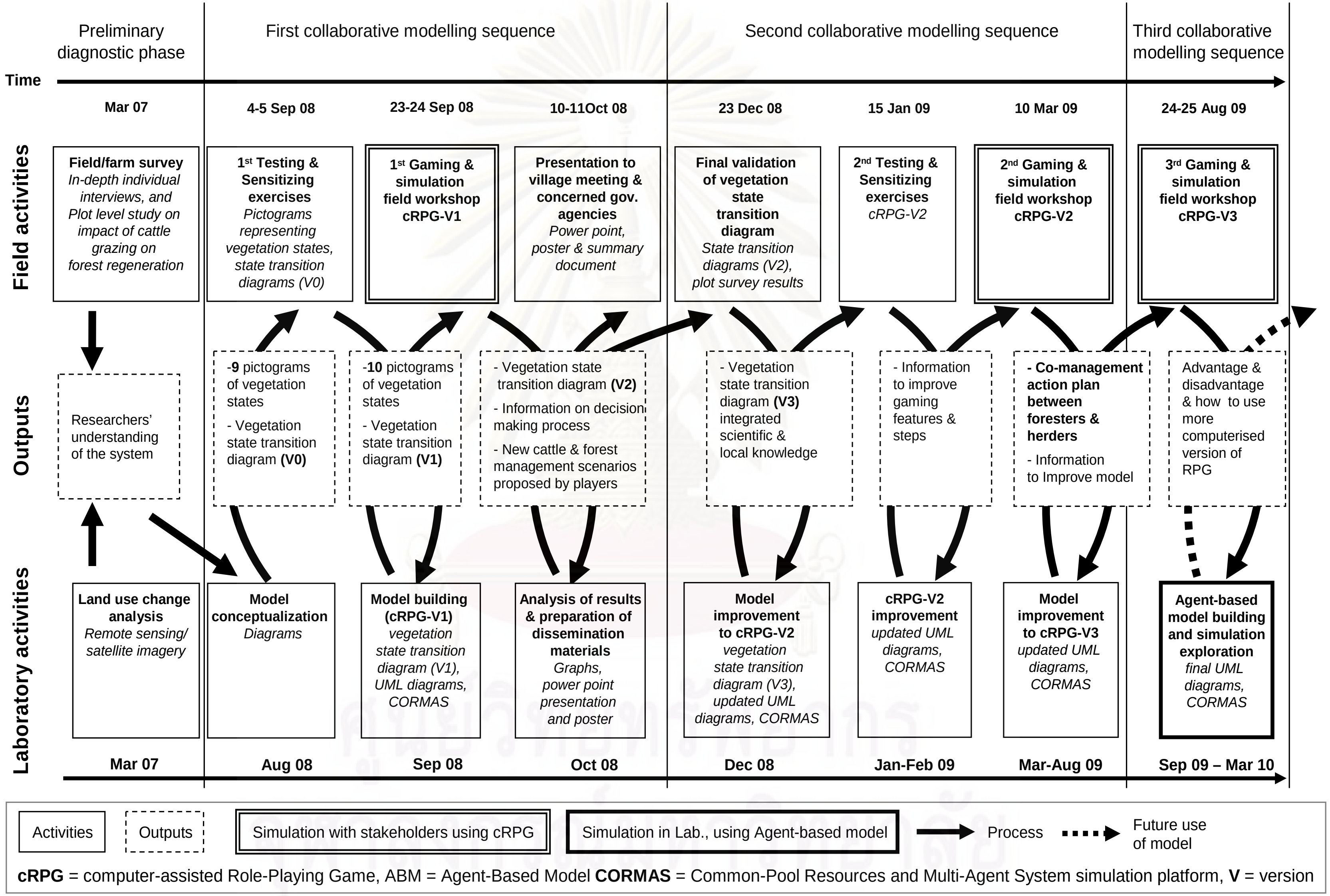
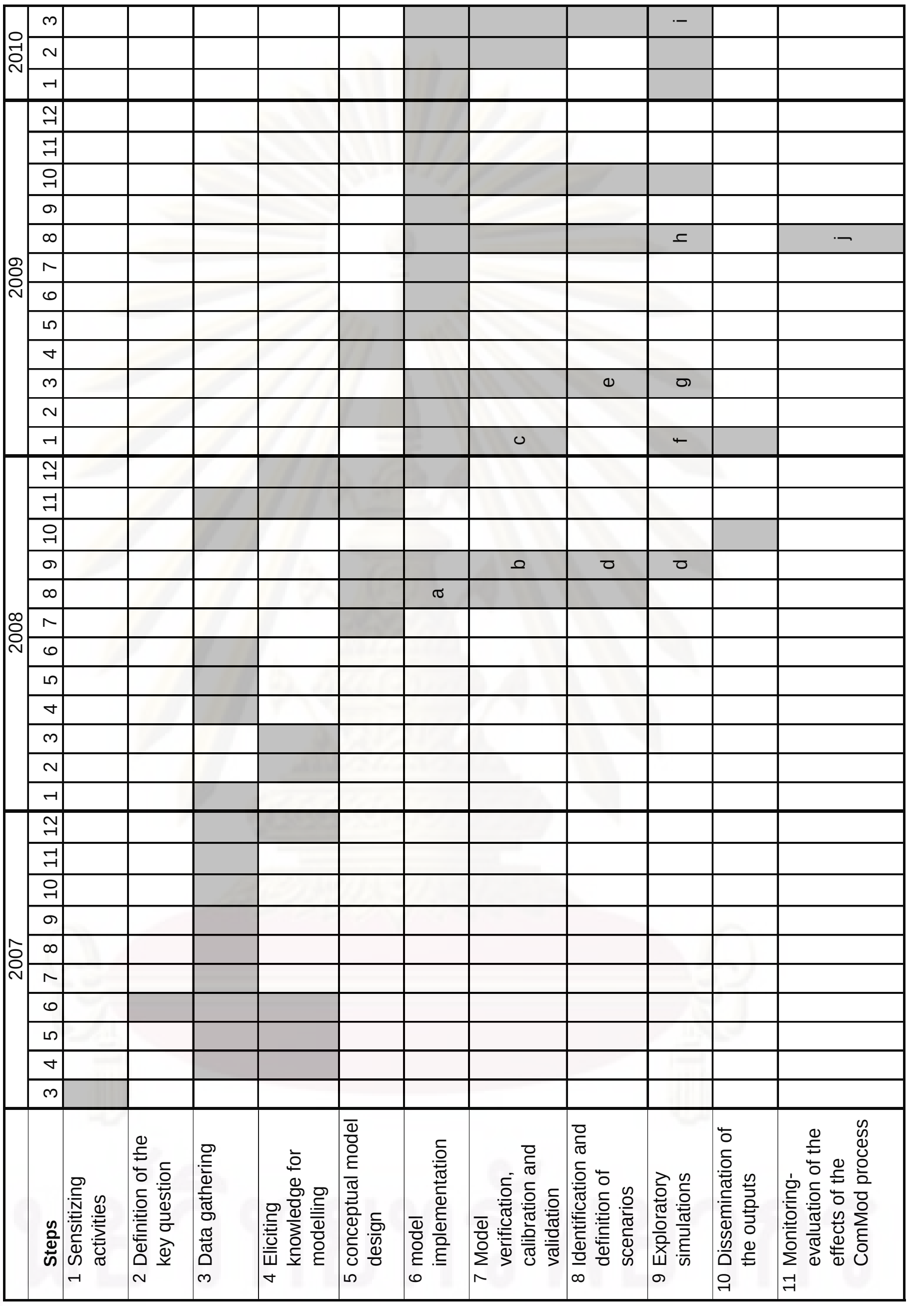


Figure 5.11. Successive phases of the ComMod process implemented in Doi Tiew village of Nan Province, Northern Thailand, 2007-2009.

Table 5.6. Timetable of the Companion modelling process implemented at Doi Tiew forest-farm land interface, Nan Province, Northern Thailand.



Note: a: Computer-assisted Role-Playing Game (cRPG).
b: Through testing exercises with stakeholders (4 reforestation foresters, 5 herders).
c: Through testing exercises with stakeholders (2 reforestation foresters, 5 National Park foresters).
d: Simulation with local stakeholder using cRPG-V1.
e: Addition scenarios were requested by players from the first RPG.
f: Testing addition scenarios.
g: Simulation with local stakeholder using cRPG-V2.
h: Simulation with local stakeholder using cRPG-V3.
i: Simulation in laboratory.
j: Evaluate from individual interview conducted by researcher.

5.6.1. First participatory modelling sequence

The ultimate goal of the first sequence was to build a representation shared by local herders and foresters of how forest regeneration is affected by cattle raising and reforestation (Figure 5.11). This sequence comprises four activities (see details in Chapter VI), i) the co-design with local stakeholders of vegetation states and its dynamics, ii) the construction of the gaming and simulation tool, and its test it with bachelor students, iii) a first gaming and simulation field workshop, and iv) dissemination activities to sensitize stakeholders who did not participate in the field workshop.

5.6.1.1. Co-design of vegetation dynamics and implementation of a gaming and simulation tool

The first version of vegetation state transitions proposed by the researchers was first validated with a small group of five herders and four foresters. Later on, a set of UML class and sequence diagrams was designed by the research team that allowed completing, adding on an updated version of the state transitions diagram, the first version of the conceptual model. Based on this conceptual model, a spatial representation and gaming rules of a Role-Playing Game were crafted. A computer-assisted RPG (cRPG) was preferred to an ABM for two reasons. Firstly, a RPG allowed stakeholders interacting together to share their points of view, learning and negotiating regarding the conflict. Secondly, it was more convenient to automatically compute the updating of the vegetation states. The CORMAS simulation platform was used for the encoding.

5.6.1.2. First gaming and simulation field workshop

The first version of the computer-assisted Role-Playing Game (CRPG-V1) was used in a two-day workshop. The first day of the workshop was carried out at Doi Tiew School with the herders only to provide them the opportunity to become confident with the simulation tool, overcoming their low formal education level. The day after, the participatory modelling and simulation activity was conducted between the herders and the foresters at Tha Wang Pha District located in the lowland because it was a neutral place for this two conflicting parties.

5.6.1.3. Dissemination of results from the first workshop

Due to the fact that the workshop allowed the participation of only few participants, it was important to communicate about what happened and to disseminate the lessons learned from this workshop to the non-participating stakeholders. For that purpose, a Power Point presentation and a summary document were presented to non-players during a village meeting, at Sob Khun Royal Project, in the District Livestock Development Office and in Nanthaburi National Park headquarters. Two A0 size posters showing the first gaming and simulation process and results were delivered to the village and to the NKU office to remind the players and to facilitate discussion with the non-players.

5.6.2. Second participatory modelling sequence

After the first workshop, the herders and the foresters requested to continue the process to mitigate the land use conflict. Therefore, the second sequence aimed to facilitate a co-management action plan among the local stakeholders was set up. This sequence included three activities (see details in Chapter VII), i) the final validation of vegetation state transition diagram, ii) game testing with NKU and NNP officers using improved tools, and iii) the second gaming and simulation field workshop.

The final validation of the state transition diagram was carried out by integrating knowledge from the herders, foresters and researchers after they understood better the interactions between cattle raising and forest regeneration through the first gaming session. Thereafter, the cRPG-V1 was improved based on suggestions from local stakeholders and further observations made by the research team. This new version (cRPG-V2) was designed to simulate new cattle and land management techniques proposed by stakeholders. It was used through a second gaming and simulation field workshop with more diverse participants (i.e. NNP and DLD officials) leading to a collectively agreed action plan.

5.6.3. Third participatory modelling sequence

Along the collaborative modelling process, some herders expressed their concern about the limited number of villagers who had been directly involved in the gaming and simulation activities. They also requested to modify the tool to allow simulation of cropping activities in the village. The third modelling sequence tried to accommodate these requests with the objective of the research team. At first, the cRPG-V2 evolved into a more autonomous version (cRPG-V3). It was then tested with former players (who participated in the first and/or the second workshop), and also with new herders who never participated to the ComMod process. At the same time, a decision about planting upland rice was integrated in the sequence of the model to partially take into account the herders' request (see details in Chapter VIII).

5.6.4. Implementation of a fully autonomous ABM to explore and compare scenarios

The last step consisted of building an autonomous version of the simulation tool (ABM) to enable in the future further participatory simulation activities with more participants (to be used for out- and up-scaling). This activity was carried out in the laboratory. Once the model was verified and tested, some scenarios have been explored (see details in Chapter IX).

CHAPTER VI

BUILDING A SHARED REPRESENTATION OF THE INTERACTIONS BETWEEN CATTLE RAISING AND REFORESTATION

This chapter presents the first sequence of the ComMod process about the land use conflict created by cattle raising and reforestation activities implemented with the concerned stakeholders at the study site. The goal of this first sequence was to build a shared representation of the interactions between cattle raising and reforestation activities on forest regeneration. A multi-step collaborative modelling process was initialised by the researchers[18] because at the beginning the herders and foresters mistrusted each other and did not want to communicate. Therefore, it was difficult to let them start such a collaborative process by themselves. In this chapter, a description of the methodology adopted to build a modelling and simulation tool is presented along with the results obtained from this first collaborative modelling sequence and the stakeholders' suggestions on how to further steer and improve the ComMod process.

6.1. Methodology

6.1.1. Preparation of the first conceptual model using PARDI methodology

Based on the knowledge provided by the comprehensive analysis of the context, issue and sub-system to be examined presented in part I, a first conceptual model was created. The ARDI[19] methodology (Etienne *et al.*, 2008) was used to characterize the Problem, Actors, Resources, Dynamics and Interactions to be represented in the first version of a gaming and simulation tool built as a computer-assisted Role-Playing Game (cRPG-V1). The construction of the conceptual model involved the preparation of several complementary diagrams, representing the ecological dynamics and human-resource interactions. Moreover, for a visual representation of vegetation states in the vegetation dynamics diagram, instead of

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[18] In a trans - disciplinary ComMod process at Doi Tiew site, a team of researchers including myself as ComMod practitioner and ComMod experts (a modeller and a geo - agronomist) worked closely to build the model.

[19] ARDI was initially developed as a collaborative methodology for co - designing a conceptual model. But it can also be used as a general framework to design (individually or collectively) a conceptual agent - based model.

using a classic colour-based legend frequently used in many landscape models, we decided to use more explicit pictograms with drawing (see pictogram in Figure 6.6).

6.1.2. Co-design of a shared representation of vegetation dynamics

The first representation of the vegetation dynamics, as understood by researchers, was shared and improved with four foresters and five herders during separate meetings held on the 4th and 5th September, 2008. Separate meetings were preferred because of the initial absence of trust between these two main categories of stakeholders. This activity also allowed the participating herders and foresters to share their own perceptions within these more homogeneous groups. During this activity, the herders and foresters were asked to comment upon and improve the range of proposed vegetation states and their corresponding pictograms, i.e. what states were missing or needed to be removed?. In a second step, they were asked to use these pictograms to build successions of vegetation states depending on natural regeneration and different human activities, including low (less than 1 LSU/ha) and high (more than 1 LSU/ha) cattle grazing pressure, reforestation and bush fire.

6.1.3. Design of a simplified landscape and its dynamics

A heterogeneous transect was selected from the 2003 land use map that was produced during the land use and land cover change analysis (see details in chapter III). The proportions of the main land cover types were calculated and their correspondence with the above-mentioned vegetation states verified. This transect was simplified to fit into a grid made of assembled pictograms representing the key features of the landscape heterogeneity and gradients. This simplified landscape was then converted into an environment file in the Common-pool Resource and Multi-Agent Systems (CORMAS) simulation platform (Le Page and Bommel, 2005). The vegetation dynamics were driven by the state transition diagram produced during the co-design step.

6.1.4. First gaming and simulation field workshop

6.1.4.1. Methodological principles and selection of the participants

A computer-assisted Role-Playing Game (cRPG) [20] was built and used as the main tool of this phase for two main reasons. Firstly, the preliminary activities implemented with the the herders and foresters showed that their time available to join in collaborative modelling activities was limited, while the ecological dynamics (i.e. succession of vegetation states) to be taken into account are quite complex. Therefore, such a hybrid simulator was suitable because of the automatic updating of vegetation states by the computer instead of series of time-consuming players' decisions to consider each transition that would have slowed the gaming and simulation too much to retain a playful atmosphere. Secondly, the RPG is a proven tool to create lively collective discussions among the participants as well as to elicit stakeholders' representations (Barreteau *et al.*, 2001; Bousquet *et al.*, 2002; Castella *et al.*, 2005; Dionnet *et al.*, 2008). Therefore, the choice of a cRPG tool in this context seemed appropriate at this initial stage of the participatory modelling process. The computer module in charge of updating vegetation states was programmed under the CORMAS simulation platform.

The objectives of this first field workshop were to use the cRPG as a communication tool to i) improve the understanding of vegetation dynamics by sharing different perceptions, ii) understand the herders' and foresters' decision making processes and practices regarding cattle and landscape management, and iii) to facilitate communication, exchange of perceptions and collective learning between the herders and foresters so as to improve their adaptive management capacity when faced with uncertainties (land availability for cattle raising or tree plantations, etc.) through gaming and simulation of different scenarios (baseline and possible future ones).

Type B, C and D herders (see section 3.3.2 for definition of types A-D), the NKU manager and two other officials were invited to take part in this workshop..

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[20] A computer - assisted Role Playing Game is a kind of model among four types of computer models. "Computer - directed" simulation couples high computer control with high computer - participant interaction, "computer - based" simulation couples high participant control with high computer - participant interaction, "computer - controlled" simulation couples high computer control with high participant - participant interaction, and "computer - assisted" simulation couples high participant control with high participant - participant interaction (Thavikulwat, 2009).

Moreover, officials from the Sob Khun Royal Project, the Doi Kard Headwater management unit, and the District Livestock Development (DLD) were invited to participate in this event as observers, because these government agencies had no conflict with the Doi Tiew herders but they could share their perceptions to mitigate the land use conflict.

The main characteristics and expected outputs of this first workshop are presented in Table 6.1, whilst the structure of the first version of the cRPG (cRPG-V1) is described in the following section. Before using this gaming and simulation tool with the local stakeholders, it was tested at Chulalongkorn University with under-graduate students. The objective was to train research assistants who will assist the researchers in the management of gaming sessions at the study site and to check time management in a gaming session.

6.1.4.2. Gaming and simulation process and the exploration of scenarios

The workshop comprised of two main progressive phases. Firstly on the first day the gaming and simulation with herders at Doi Tiew School was to test the herders' understanding of the game and to prepare them to play the game with the foresters. Secondly, on the following day the gaming and simulation between experienced herders and foresters at Tha Wang Pha District Office was to facilitate exchanges and share perceptions between them. The school and district office were considered as neutral places for these two conflicting parties.

At the beginning of the workshop, the facilitator (same as the main researcher) introduced the research team, the context of the land use conflict as known from preliminary diagnosis, and the objectives of the game. Then, the information on the bulletin board was explained slowly to players. The questions from them were then allowed to clarify. One session was to sensitize newcomers and four scenarios were conducted during the workshop.

Table 6.1. Description of the first participatory gaming and simulation field workshop implemented in Doi Tiew village of Nan Province, Northern Thailand.

Activity	First test	Gaming and simulation (G & S) workshop			
	4^{th}-5^{th} Sep 2008	23^{rd} Sep 2008		24^{th} Sep 2008	
		Day 1; am	Day 1; pm	Day 2; am	Day 2; pm
Location	District Office	Doi Tiew School		District Office	
Objectives	- To test a gaming tool based on the researchers' under-standing of vegeta-tion dynamics. - To understand the stakeholders' perceptions of these dynamics. - To sensitize a small group of stakeholders before participation in a G & S workshop.	- Introduction of the gaming tool to newcomers (similar activity to sensitizing exercise). - To explore with herders what needs to be modified in the researchers' representation of the system.	- To investigate the herders' decision-making process and interactions regarding cattle rearing and forest regeneration. - To prepare the herders to participate in G & S sessions with foresters by giving them more time to understand the G & S tool.	- To present day 1 (pm) results to the foresters and show them how the cRPG works. - To demonstrate how the cRPG works without entering players' decision on cattle raising and reforestation.	- To investigate the foresters' and herders' decision-making processes and interactions. - To stimulate communication, collective learning and sharing of knowledge and perceptions between herders and foresters.
Types and numbers of participants (in bracket)	- NKU foresters (4) - Herders (5) - Researcher (1) - Assistant (1)	- Herders (13) - Researchers (4) - Assistants (7)	- Herders (14) - Researchers (4) - Assistants (7)	- NKU foresters (3) - Herders (8) - Researchers (3) - Assistants (7)	
Main tool used	- Pictograms of possible vegetation states based on transition diagram proposed by researchers (V0)	- RPG using pictograms of vegetation states	- cRPG-V1	- Power point presentation of day-1 results - Simulation in cRPG-V1 (no human decision)	- cRPG-V1
Scenarios (number of rounds simulated) & activity	- Vegetation dynamics affected by different factors (cattle density, fire, etc.) - Discuss and agree on vegetation state transitions with foresters and herders, separately	- Herders indicate the next vegetation state based on given cattle number and paddock size.	- S1 (3 rounds): 2 groups of herders manage cattle, no reforestation plots. - S2 (1 round): 2 groups of herders manage cattle with reforestation plots of different ages located in landscape by researchers.	- S3 (10 time steps): demonstration of vegetation dynamics with reforestation plots and without cattle in the landscape.	- S4 (4 rounds): herders and foresters manage a common landscape, negotiation is allowed, and different age of reforestation plots set in landscape sheet by foresters.
Expected Outputs	- Vegetation state transition diagram produced by herders and foresters - Information to design the gaming and simulation tool and features	- Updated vegetation state transition diagram (V2) with larger group of participants	- Herders' understanding of the gaming tool and features - Improved communication among herders	- NKU foresters' understanding on how the G & S works and decisions	- A shared representation on forest regeneration - Improved communication among them - Suggestions on how to improve the process.

Note: cRPG is for "computer-assisted Role-Playing Game."

On the morning of first day, the first batch of trained players assisted the newcomers to understand the vegetation pictograms, which were used to build successions of vegetation states leading to forest recovery in a blank landscape sheet (Figure 6.1) with different given cattle grazing pressures (i.e. no, low or high cattle density in a fixed size of paddocks).

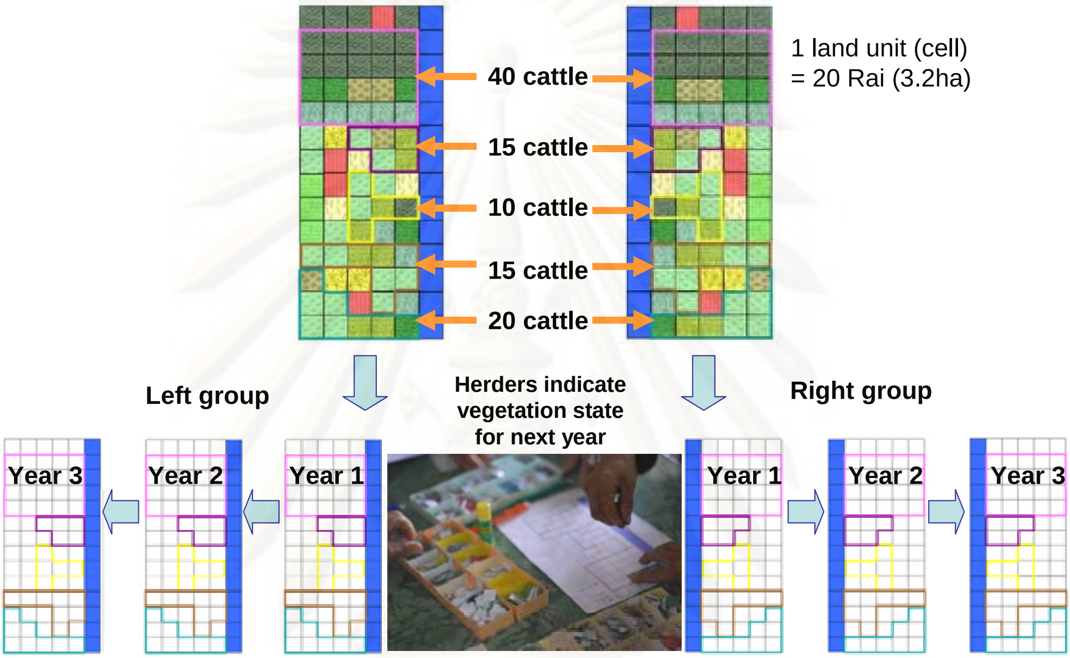

Figure 6.1. Two groups of herders simulated forest succession under different conditions (cattle density and size of paddocks) during sensitizing session of the first gaming and simulation workshop.

In the first half of the afternoon two groups of herder were asked to simulate the first scenario (S1), where they had to manage cattle grazing in the absence of reforestation plots in the landscape. In the second half of the afternoon, the second scenario (S2) was introduced in which reforestation plots of different ages were inserted in the landscape by the researchers, so the herders could get used to them before the gaming and simulation session with the foresters the following day. Due to time constraints, however, only one round could be played. The main steps are shown in Figure 6.2.

The morning session of the second day started with presentations of the S1[21] results by representative herders from each group. It was then followed by the demonstration of the computer simulation through the third scenario (S3), in which cattle grazing is not allowed in reforestation plots. In the afternoon, the fourth scenario "herders and foresters manage a common landscape" was played. Again, the main steps are displayed in Figure 6.2. At the end of each session, debriefing was carried out by asking general questions about how well the simulated game represented reality, the reality of results and their strategies during the gaming sessions. The ensuring discussions to share the different opinions or experiences were allowed and were observed by the research team. Finally, the summary of the gaming session and the possible next steps of the ComMod process were proposed to the participants.

Individual interviews with the participants were conducted in the village and at NKU (see interview guideline in Appendix D). The NKU manager was interviewed in Bangkok on the 7th October 2008, and the village headman was interviewed on the 10th October 2008, according to their available time.

6.1.5. Dissemination of results from the first gaming and simulation workshop

After three weeks of the workshop, the results and graphs showing indicators were presented at the village meeting on the 10th October 2008 and at the Sob Khun Royal Project Office on the 11th October 2008. A0 size poster and a slide show were prepared and delivered to the village and the NKU office to both refresh the minds of players and also to stimulate discussions between players and non-players.

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[21] S1 was selected for presentation because we needed to observe the herders' behaviour with and without foresters participating in the simulation.

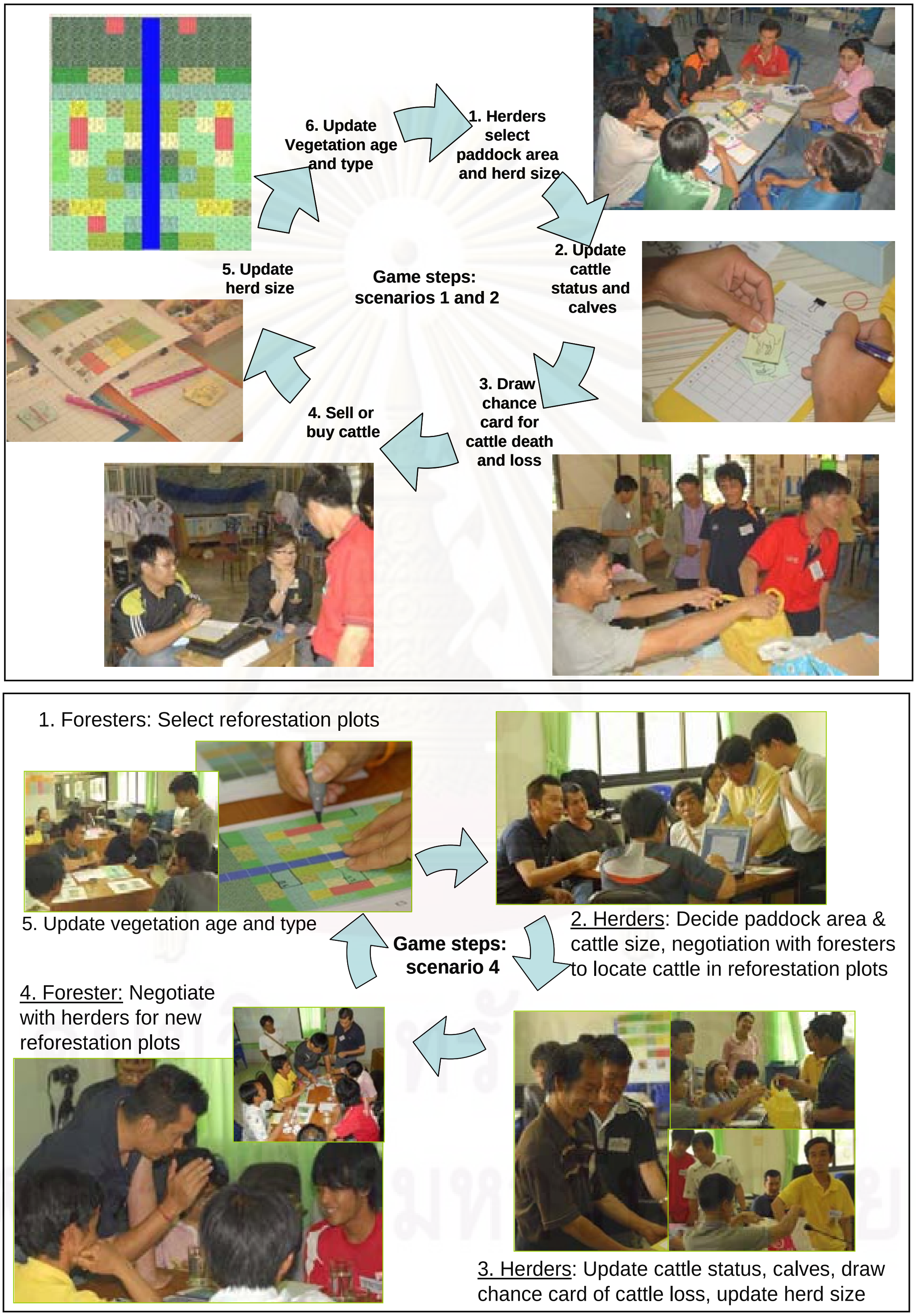


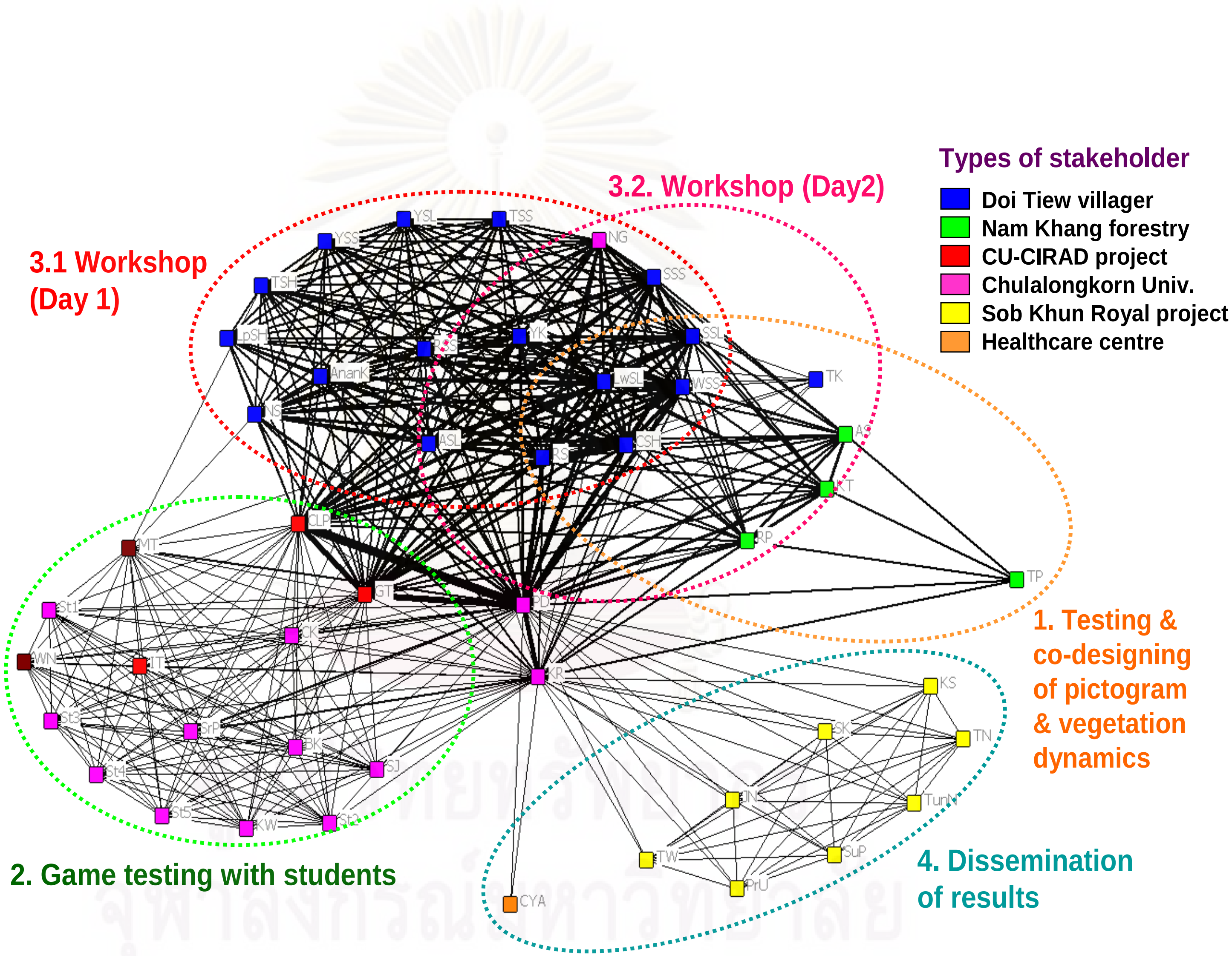
Figure 6.2. Main steps of scenarios 1, 2 (top), and 4 (bottom)
(scenario 3 was simulated in computer) in the first gaming and simulation workshop.

6.2. Results

6.2.1. Stakeholders' participation in successive activities

In this first modelling sequence, there were two main groups of local stakeholders, herders and NKU foresters, participating in different activities as illustrated by the social network diagram shown in Figure 6.3.

This diagram shows that the research team, which prepared the modelling tool and facilitated the preparation, implementation and evaluation of the gaming and simulation workshop, displayed the highest intensity of communication among its members and intensive exchanges with the two main parties, herders and foresters, involved in the land use conflict. Exchanges among the herders themselves were also intensive and a sub-group of herder who played in the second day had many exchanges with the NKU foresters. A shorter time was spent on dissemination activities with the Sob Khun Royal project and village healthcare officials.



Note: Line thickness is proportional to time spent interacting. Abbreviations denote the names of participants in each activity (See details in Appendix E)

Figure 6.3. Intensity of communication among different types of stakeholders and participants during the first sequence of the ComMod process in Doi Tiew village of Nan Province, Northern Thailand.

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6.2.2. The first conceptual model

Simple diagrams showing the key actors and resources, and the vegetation state transitions based on the researchers' point of view are presented in Figures 6.4 and 6.5, while more sophisticated Unified Modelling Language (UML) diagrams are presented below in the description of the cRPG-V1 tool. The idea was to submit this first conceptual model, based on the researchers' points of view, through its translation into a cRPG to be used with the local stakeholders so as to allow them to improve it with them along the ComMod process.

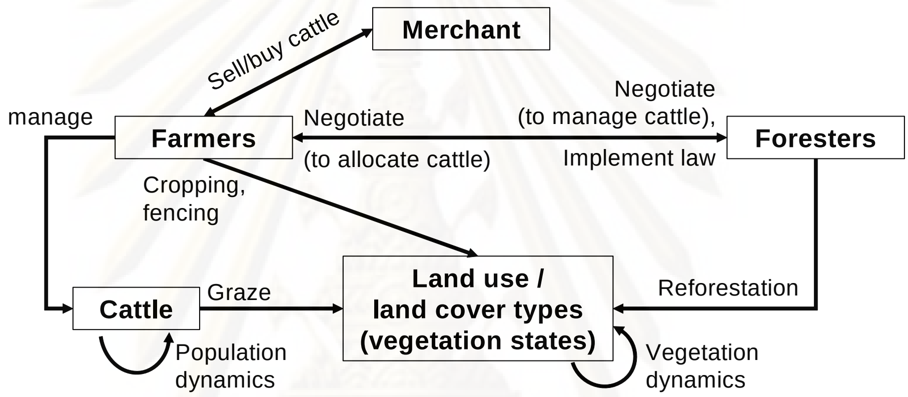
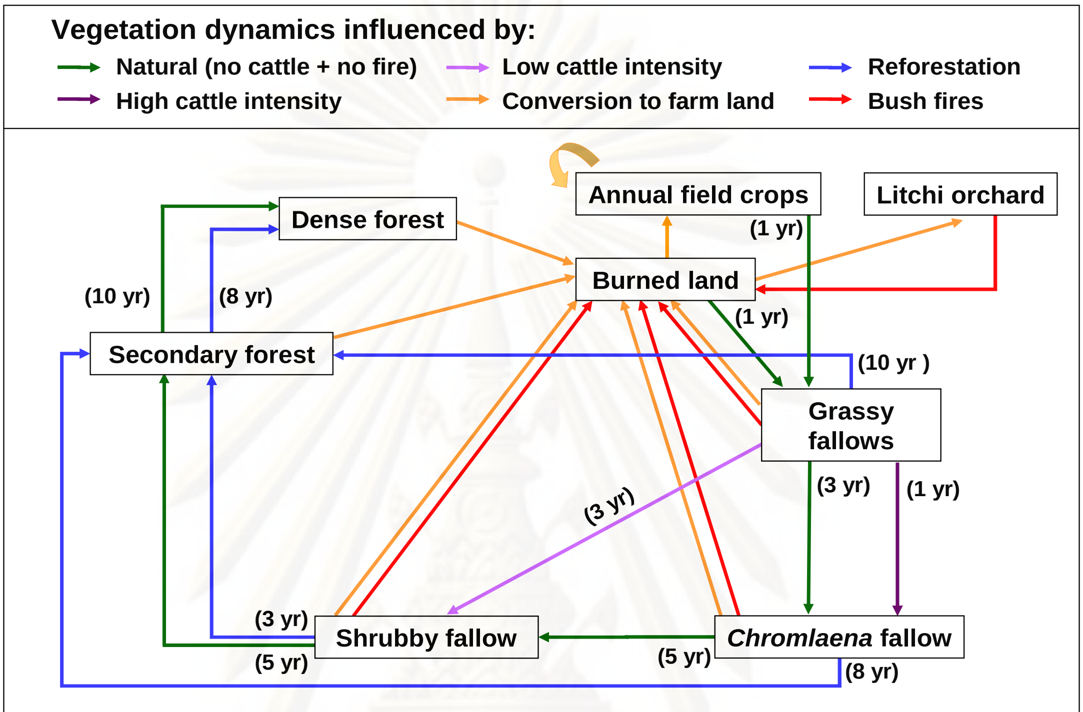


Figure 6.4. Conceptual model showing the interactions between key actors and resources.

Figure 6.4 shows three interacting actors, i.e. foresters, farmers (mainly herders) and cattle, making direct use of the land resources. "Farmers" are engaged in cropping, fencing and managing cattle activities based on their farm characteristics, cattle population and vegetation dynamics. "Foresters" refer to NKU officials who practice reforestation activities. "Farmers" and "Foresters" have to negotiate land use for cattle raising and reforestation activities. Another actor is the "Merchant" who buys cattle from the local herders or sells lowland breeds to the "Farmers."

The state transition diagram shown in Figure 6.5 shows the vegetation dynamics based on different factors selected by the researchers. Burned land was considered as a transition state. It can evolve to annual field crops (upland rice or maize) or litchi orchard or to a grassy fallow (*Imperata* and *Thysanolaena* mixed with *Imperata* fallows) based on the farmers' decisions. The vegetation succession from "burned land" to "dense forest" (dense crown cover) by natural process takes approximately 24 years. Such parameters of the vegetation succession were later improved with the local stakeholders, based on their input from their empirical experiences (see details in the following section).



Note: Based on interviewed information, high cattle intensity is greater than 1 livestock unit (equivalents of 250 kg of body weight) per ha. Numbers indicate the duration of succession in years. Arrow without a number means an immediate change or a short time is needed for that change from one state to the other.

Figure 6.5. Vegetation state transitions based on researchers' point of view at Doi Tiew forest-farm land interface, Nan Province, Northern Thailand.

The first set of nine pictograms (Figure 6.6), which corresponded to the main vegetation states and their respective forage biomass was prepared based on researchers' understanding of the local vegetation successions. Each pictogram was associated with a corresponding photograph of that typical vegetation taken in the local landscape (Figure 6.6). The choice of using the pictograms with the stakeholders was to facilitate the effective visual recognition of vegetation states, especially for those herders who have a little formal education levels, and to effect the association of their own empirical experiences and knowledge to them, and to easily link their real landscape features with these visual representations. This set of pictograms was then tested with the concerned herders and foresters.

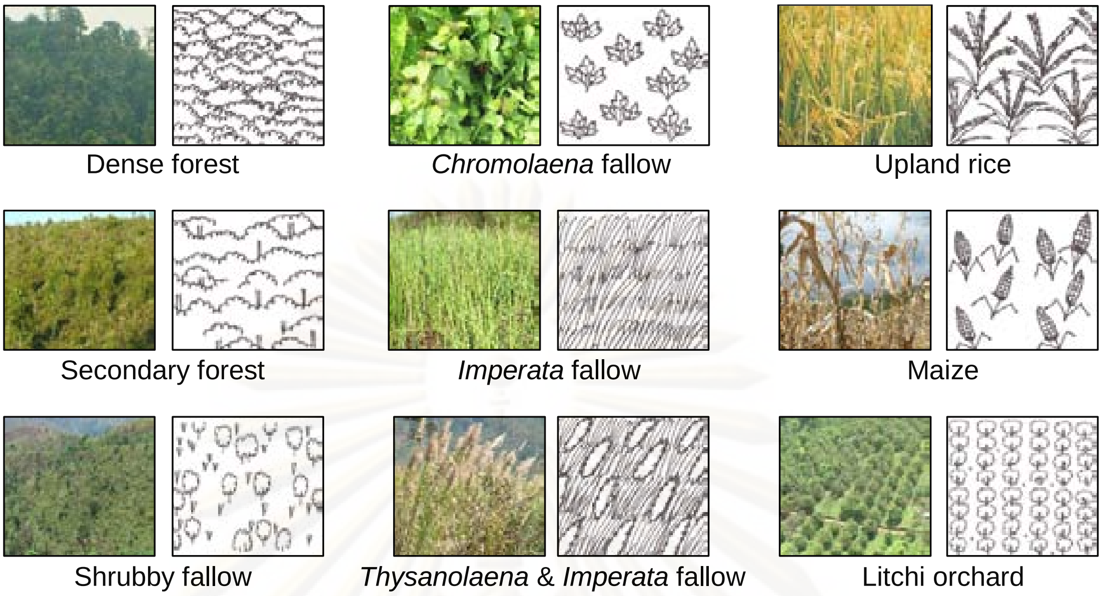


Figure 6.6. Pictograms representing the nine vegetation states and associated photographs used with Doi Tiew herders and foresters.

These nine pictograms depicted the main land use and land cover types encountered in the Doi Tiew agro-ecosystem during the ecological survey (see details above in chapter IV). There are three main crops (upland rice, maize and litchi), four types of fallows (*Chromolaena*, *Thysanolaena* and *Imperata*, *Imperata* and shrubby), and two (secondary and dense) types of forest. These pictograms were associated to the first vegetation state transition diagram, as shown in Figure 6.5.

6.2.3. New vegetation dynamics and state transition diagram produced by the herders and foresters

Two days of sensitizing activities before the workshop allowed some of the participants (five herders and four foresters) to share separately their understanding of forest regeneration. Based on the knowledge acquired from the preliminary diagnostic activities, the researchers proposed the nine pictograms (Figure 6.6) of the main vegetation states, that is to represent the most common kinds of vegetative cover. They were rapidly recognized by the participants. The group of foresters proposed to add a new type of vegetative cover called "*Chromolaena* mixed with *Imperata* fallow" in their diagram (see pictogram in Figure 6.8). They said that "this is an intermediate state before the appearance of other types of fallows. So, it is important to have it in the diagram." After adding this new pictogram, they were able to display and discuss their relationships in transition sequences and to manipulate these pictograms to represent vegetation succession.

At this stage, the researchers obtained two different diagrams representing vegetation dynamics. Interestingly, by producing the vegetation dynamics factor by factor, we obtained minor differences in the transition duration (in years) from one state to another (Table 6.2). The key factor that slows vegetation succession was "bush fire," not damage inflicted by cattle as indicated by foresters. We observed that both of them attempted to blame the other side. Foresters said that "according to the lack of fresh grass in the dry season, herders burn the dry grass to stimulate the regeneration of the young ones for their cattle." On the other hand, the herders said that "the foresters burn their reforestation plots because they can not find new land for reforesting. Then, they ask for the budget from the government to repair (reforest) that region." These kinds of sensitive opinions were difficult to objectively substantiate or weight, but it is important to take them into account for further activities because their debate might lead to the failure of collaboration between these two conflicting parties.

Table 6.2. Duration of each transition phase based on the herders' and foresters' points of view on different driving factors.

Initial state to final state		**Transition duration (year)**				
		Natural succession	**Low cattle and no fire**	**High cattle and no fire**	**Reforestation**	**Reforestation & low cattle**
ChroImpFal -DF	Foresters	21	15	NA	14	18
	Herders	18	11	8	16	16
	Difference	*3*	*4*		*2*	*2*
ImpFal - DF	Foresters	22	16	NA	15	19
	Herders	19	12	8	15	19
	Difference	*3*	*4*		*0*	*0*
ThylmpFal - DF	Foresters	18	15	NA	14	18
	Herders	16	11	8	14	18
	Difference	*2*	*4*		*0*	0
ChroFal - DF	Foresters	19	12	NA	14	17
	Herders	20	9	7	15	15
	Difference	*1*	*3*		*1*	*2*
Crops - DF	Foresters	22	-	-	-	-
	Herders	19	-	-	-	-
	Difference	*3*				

Note: ChroImpFal: Chromolaena and Imperata fallow, ImpFal: Imperata fallow, ThyImpFal: Thysanolaena and Imperata fallow, ChroFal: Chromolaena fallow, and DF: Dense forest.
NA: Not complete information because foresters had no experience on this condition.

At the end of the activity, the herders asked the researchers to improve the pictograms because the “secondary forest” and “dense forest” looked too similar to them. Therefore, we improved these pictograms by overlaying different colours (see details below). Finally, both foresters and herders were asked to join the coming gaming and simulation workshop to mitigate the land use conflict. They were interested to participate.

6.2.4. Simplified virtual landscape and vegetation dynamics

The set of ten pictograms representing the vegetation states validated by the herders and foresters was distributed in a total of 154 cells (grid made of 11 columns x 14 rows) to represent the landscape main structure and heterogeneity as shown in Figure 6.7. Each cell corresponds to 3.2 ha in reality and this virtual space was large enough to be used by 10-12 herders (managing a total of approximately 100 heads of cattle) and several foresters for displaying their land management decisions and practices in simulation gaming sessions based on the cRPG tool.

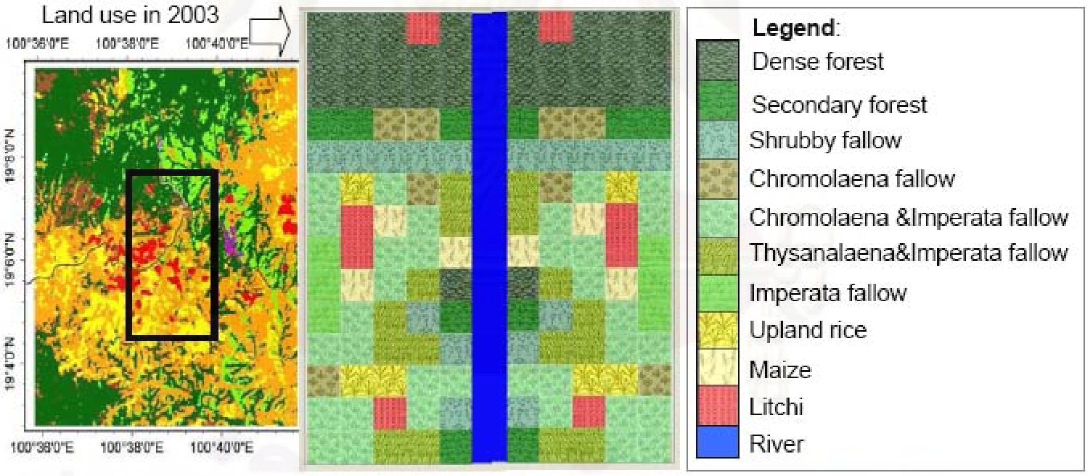


Figure 6.7. The spatial interface of the first version of the computer-assisted Role-Playing Game (green shade = forest, yellow shade = farm land).

The spatial grid was organized to be symmetric on both sides of a virtual river to allow two (one left and one right) groups of herders to play in parallel. Later on, the comparison of the emerged landscape patterns resulting from the different land management strategies adopted by each group was facilitated by this displaying of them on each side of the “river”. Based on their empirical experience, the local users were assumed to be able to relate this landscape to real circumstances, such as the forage biomass corresponding to each pictogram or the location of forest conservation zones, etc. This facilitated the comparison of landscape patterns resulting from the different land management strategies adopted by each group, such as individual vs. more collective herd management.

This virtual landscape was converted into a regular spatial grid in CORMAS. Regarding the vegetation dynamics for this virtual landscape, the two diagrams obtained from the previous step were merged into a new one (Figure 6.8) to be discussed in the first participatory gaming and simulation workshop.

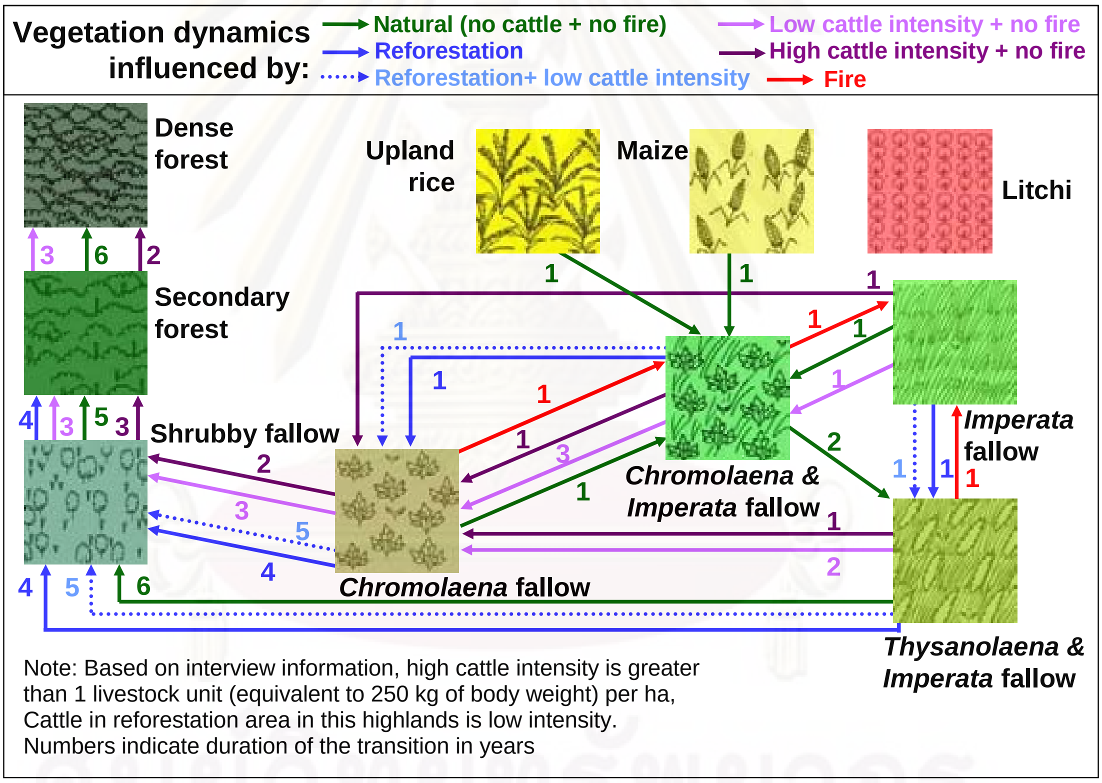


Figure 6.8. Vegetation state transition diagram used for programming the prototype agent-based model (cRPG-V1).

6.2.5. Description of the first version of the computer-assisted Role-Playing Game (cRPG-V1)

Describing the implementation of any ABM is often cumbersome: its structure, characterized by intertwined interactions and rule-based algorithms, is difficult to unfold. To help readers understand the structure of ABMs more easily, and enable them to re-implement such kinds of models, a protocol named "Overview-Design Concepts-Details (ODD)" developed by a group of modellers, has been proposed as a standard format for the description of both individual-based and agent-based models (Grimm *et al.*, 2006). The cRPG-V1 was developed based on the ABM concept; therefore, its description was based on ODD[22].

6.2.5.1. Overview of the cRPG-V1 tool

Purpose: This model was built to represent the researchers' understanding of vegetation dynamics in relation to cattle management and reforestation efforts. It was improved by using with the local stakeholders to facilitate communication among the herders and NKU foresters through the exploration of different land management scenarios. The stakeholders' interactions and decision-making during the gaming and simulation sessions were observed and analyzed, and this information was used later in the construction of an autonomous ABM.

An overview of the model static structure is illustrated in Figure 6.9 in the form of a UML class diagram (see details below in sub-models section).

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[22] Three blocks of elements within the protocol were defined: Overviews, Design concepts and Details. **"Overviews"** provide information about the model to reader to be able to re - implement the skeleton of the model. First, the "purpose" of the model is to inform readers what is to be done with the model. The "state variables and scales" outline the structure of the model. The spatial and temporal scales used in the model are also covered in the Overviews. The "process and scheduling" is described by listing all the processes that occur in the model and how they are scheduled (Polhill *et al.*, 2008). **"Design concepts"** deals with a wide range of high - level concepts related to the field of complex adaptive systems such as emergence, adaptation, stochasticity, and observation, etc. **"Details"** block aims to describe key entities, process and scheduling in detail so that the model can be completely re - produced. The "initialization" deals with how the environment and the individuals are created at the start of a simulation run. "Inputs" refers to environmental and economic conditions that influence all entities in the model. Finally, "sub-models" representing the processes listed above in the Process overview and scheduling are presented and explained in detail.

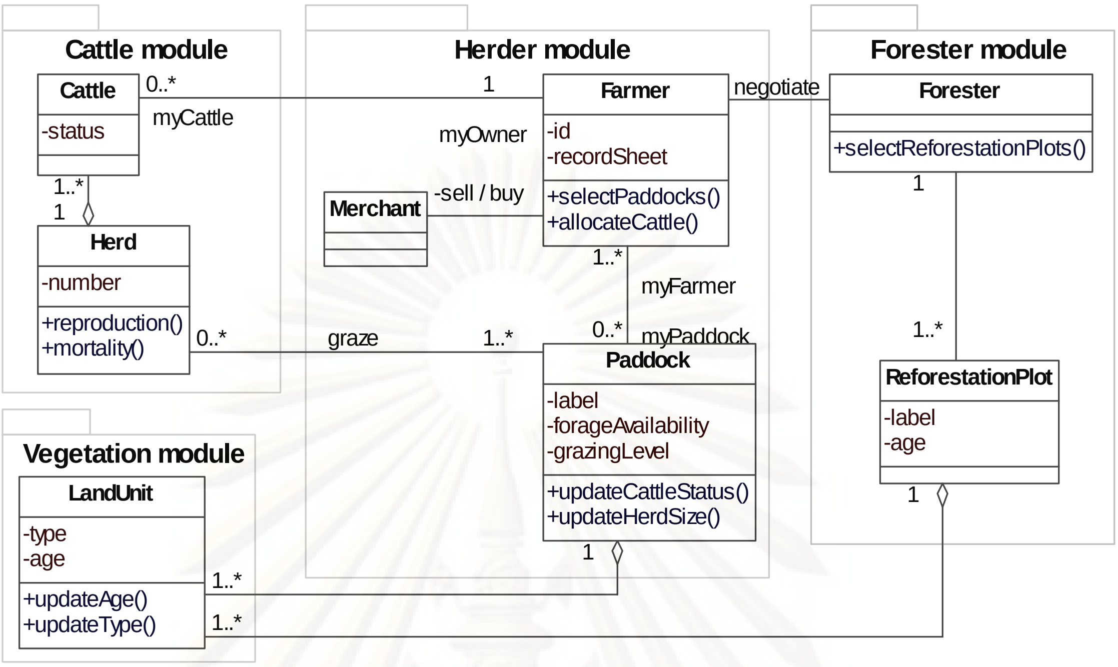
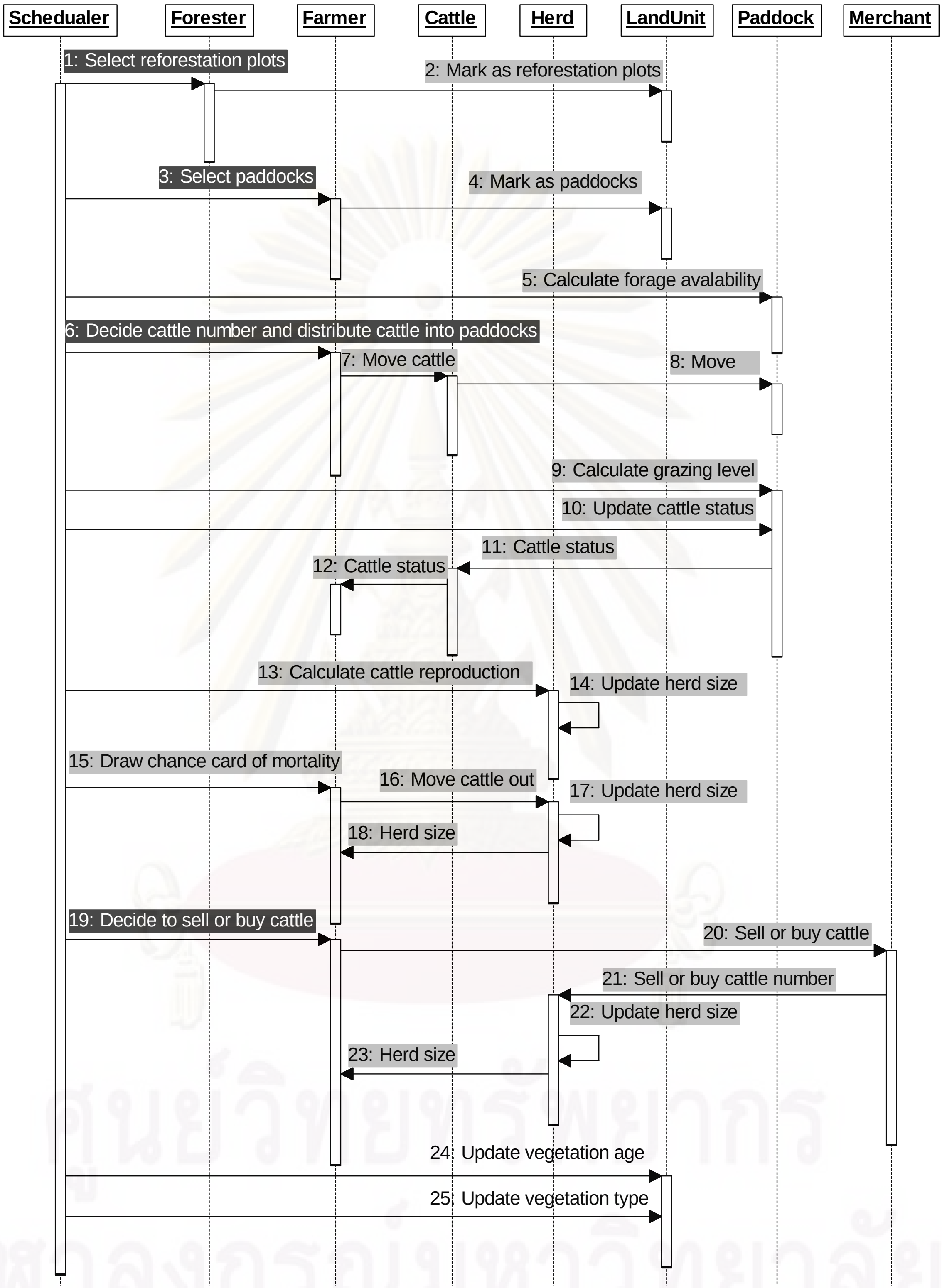


Figure 6.9. Initial conceptual model of the first version of the computer-assisted Role-Playing Game showing attributes and interactions between actors and resources.

Process overview: The model proceeded in annual time steps, each round of play corresponding to one calendar year. This model was used with human agents, therefore, some steps were computed and others decided by players as shown in the UML sequence diagram in Figure 6.10.

The sequence of the game depended on the scenario played (details about the four scenarios that were played are provided in the next section). However, seven main successive steps can be described in the following order: i) the foresters decide the location of new reforestation plots, ii) the herders decide and locate herds in preferred paddocks and choose their size, iii) the ABM update the cattle status and calculate the number of newborn, iv) draw a chance card to indicate the death and loss of cattle herd, v) the ABM updates the herd size, vi) the herders decide to sell or buy cattle, and vii) the facilitator input decisions on reforestation and paddocks in the computer to update vegetation age and type. The management decisions through different scenarios allowed the herders and foresters to observe each other's behaviour and constraints. At the same time, the researchers could observe the ongoing decision-making processes to improve their own understanding of the land management system.



Note: Activities with a black background correspond to decisions made by the participants, whereas those with a grey colour were monitored by research assistants, and other activities were driven by the computer.

Figure 6.10. The successive decisions made and actions taken by each model entity in the first version of the computer-assisted Role-Playing Game.

6.2.5.2. Design concepts of the cRPG-V1 tool

Individual or collective management and adaptation: The model allowed the players to discuss and adapt their landscape management strategies on an individual or collective basis. For example, the herders could pool their herds together to graze in a single large paddock in order to increase the availability of forage (food).

Interaction: Decisions made by one player may affect other players. During the gaming sessions, the floor was permanently open for discussion. For example, if a herder wanted to raise a large herd, he had to discuss with other herders about paddock availability, size and location to avoid a land use conflict. The herders and foresters also negotiated about the sharing of land for grazing and tree plantations as well as about the possibility for the cattle to graze in young plantations.

Stochasticity: There is a high risk of cattle mortality ("death" due to predators or diseases, and "loss" from the flock due to accidents such as falling down in a steep areas). Variability of the cattle birth rate in such extensive cattle raising system with minimal animal care is also high. Therefore, chance cards for birth rate and mortality risk were introduced in the game.

Observation: Figures showing step by step the evolution of the landscape (snapshots of the spatial grid by a function provided by CORMAS), individual herd sizes and cattle status were the indicators used to observe the results of players' decisions during the simulation of each scenario. Short debriefings between scenario explorations were carried out for the players to deliberate and adapt their decision making processes.

6.2.5.3. Details of the cRPG-V1 tool

Initialization: In agreement with the size of the virtual landscape, the number of players in a cRPG session was limited to 10 to 12 herders (managing approximately 100 heads) plus a group of several foresters. The virtual landscape used in the tool was explained beforehand.

Input: This model has no input.

Sub-models: There were four main modules in this model.

a) Vegetation dynamics module: This is represented in Figure 6.8, showing the succession of vegetation states based on different land management activities. Five factors influencing the vegetation dynamics were implemented in the CORMAS, but the dynamics based on bush fire were not represented in the cRPG-V1. This choice was made to avoid a direct hot debate on “who creates the bush fires?” between the herders and foresters, as observed in the sensitising activity, that may lead to the failure of communication at the beginning of the participatory process. Nevertheless, bush fires could be introduced into the model if requested by players.

b) Cattle dynamics module: Manages the updating of cattle status, reproduction, and mortality. In this sub-model, cattle dynamics change according to simple rules that are established based on the findings from the preliminary farm survey (Table 6.3).

Table 6.3. Rules used in the cattle dynamics module of the cRPG-V1.

Method in UML diagram	**Conditions**			**Cattle status**
	Grazing level	Paddock size (cells)	Number of suitable cells (“*ImpFal*,” “*ThyImpFal*,” “*ChroImFal*”)*	
Update cattle status	Low (cattle density < = 2.4 head/cell)	> 10	5 - 6	fat
		> 10	3 - 4	normal
		< = 10	3 - 4	normal
		< = 10	1 - 2	thin
	High (cattle density > 2.4 head/cell)			thin
	Herd size		Cattle Status	**Number of newborn/year**
Reproduction	5 - 14		Fat/normal	3
			Thin	2
	15 - 25		Fat/normal	4
			Thin	3
	> 25		Fat/normal	8**
			Thin	5
	Herd size	**Proportion of chance card used (total = 10)*** (Number of cattle lost , number of cards)		
Mortality	< = 25	0,2 – 1,4 – 2,4		
	> 25	2,2 – 3,4 – 4,4		

Note: * *ImpFal: Imperata fallow, ThyImpFal: Thysanolaena and Imperata fallow, ChroImpFal: Chromolaena and Imperata fallow*

*** The proportion of female animals is higher in large herds in this extensive cattle raising system. Consequently, the number of newborns was set to reflect this fact.*

**** A small herd has a lower risk of mortality compared with a large one.*

These rules can be adjusted by the players if requested. It was assumed that the herders could know the number of male and female animals and their age because in reality they maintain their herd size by preferentially selling male cattle because of their more aggressive behaviour. Therefore, when the number of cattle was declared, they could associate a composition of the herd to it. Moreover, the cattle dynamics module was kept simple to provide more time for herders to communicate with foresters: the focus had to be set on communication with foresters rather than on cattle biology.

c) Forester module: Deals with forest management. In the first step of each round, the foresters had to select two cells to become new reforestation plots. They could negotiate with the herders to convert farm land. When these cells were marked as reforestation plots, their vegetation dynamics changed accordingly based on the state transition diagram.

d) Herder module: Focuses on cattle raising. At each round of play, the herders had to decide the paddocks' number, size and location. A herder could manage more than one paddock and send his cattle to graze at different places. The herders could negotiate with the foresters to use already established reforestation plots as grazing areas. At the end of a round of play, the herders could decide to sell or to buy cattle to adjust their herd size. Sales and purchases were recorded in individual herders' record sheets.

6.2.6. Herders and foresters shared their perceptions through the first gaming and simulation field workshop

A total of 16 herders from three types of farmers (B, C and D) and three NKU foresters participated in the workshop, while invited observers from Sob Khun Royal Project, Doi Kard Headwater management unit, and District Livestock Development did not show up due to having to attend an urgent meeting elsewhere at Nan Provincial Administrative Office.

6.2.6.1. Findings from the successive gaming sessions

First day sessions with the herders only: in the morning session, two groups of herders were set up and the already trained players assisted newcomers to understand the vegetation pictograms and how to use them to build successions of vegetation states leading to dense forest recovery. Because of their different empirical experiences in cattle raising (different herd sizes, management techniques, and locations of grazing land), the two groups produced different outputs regarding the duration of steps in vegetation transitions. They were also different from the one programmed in the prototype ABM in CORMAS (Figure 6.11).

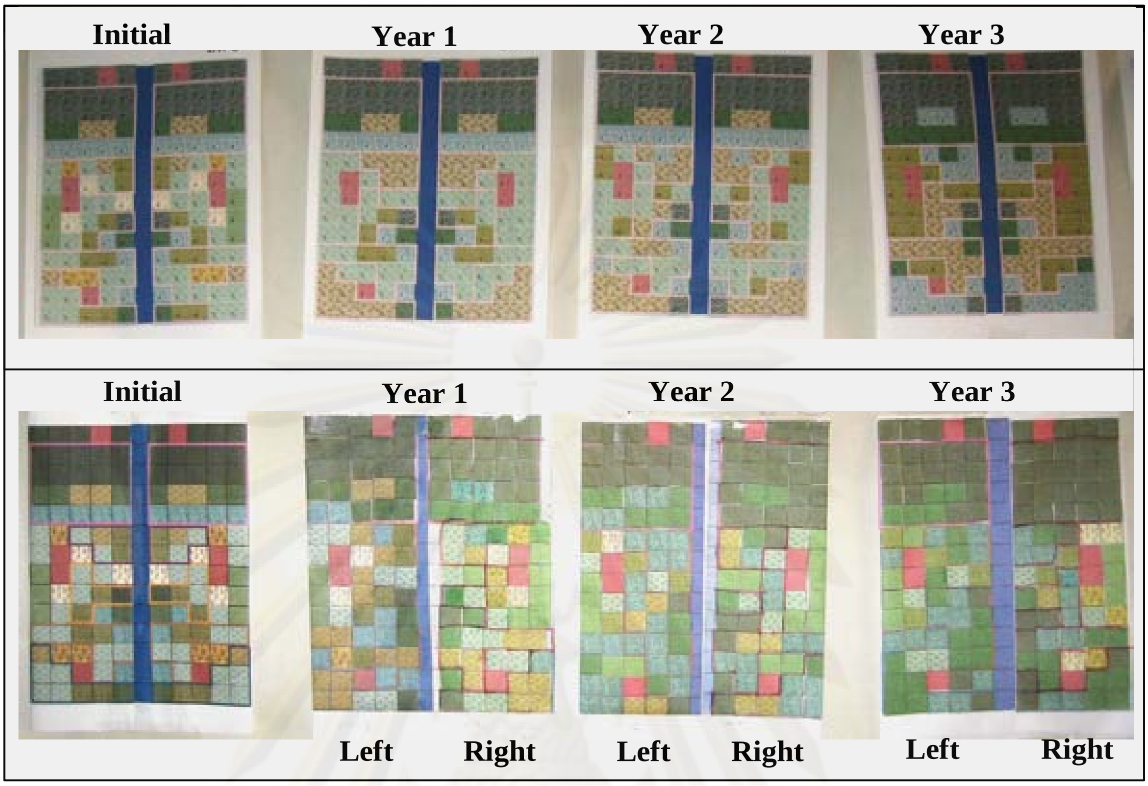


Figure 6.11. Comparison of simulation results between CORMAS simulation (top row) and two groups of herders' decisions (bottom row) regarding vegetation dynamics at the landscape level in the first gaming and simulation workshop.

In the debriefing, the herders were asked to exchange their points of view regarding these differences (Figure 6.11) and to agree on a common vegetation state transition diagram. The participants learnt and understood the role of the computer as a tool able to automatically update the vegetation types based on a set of rules instead of completing the update by hand.

In the first half of the afternoon, after the researchers made the necessary modifications of the vegetation transitions rules in the computer according to the latest proposition from the herders, the two groups of herders were asked to simulate a first scenario in which they had to manage cattle grazing in the absence of reforestation plots in the landscape. It was found that most of the herders understood how the gaming and simulation exercise worked after playing a first round. But several herders who never received any formal education needed more explanations in Hmong language from others.

The dynamics of the landscapes managed by the two groups over four successive years are shown in two different ways in Figure 6.12. It was found that in the first round of play the herders use different management strategies to manage their cattle. The herders in the left sub-group decided the herd size based on their needs. For example, one of the herders decided to test the management of a herd of 100 cattle, which is larger than their actual real life herd. A type D player chose 40 heads. The large holder selected the paddock size and location before the others. While in the other sub-group (right side of the river in figure 6.11), the herders attempted to share out equally the paddock size by counting the number of cells and dividing this by the number of players. As a result, individual herd sizes in this sub-group were similar, although they have different farm types from A to D. Moreover, we observed that individual decisions were also important in managing the cattle population in the landscape after this first round of play.

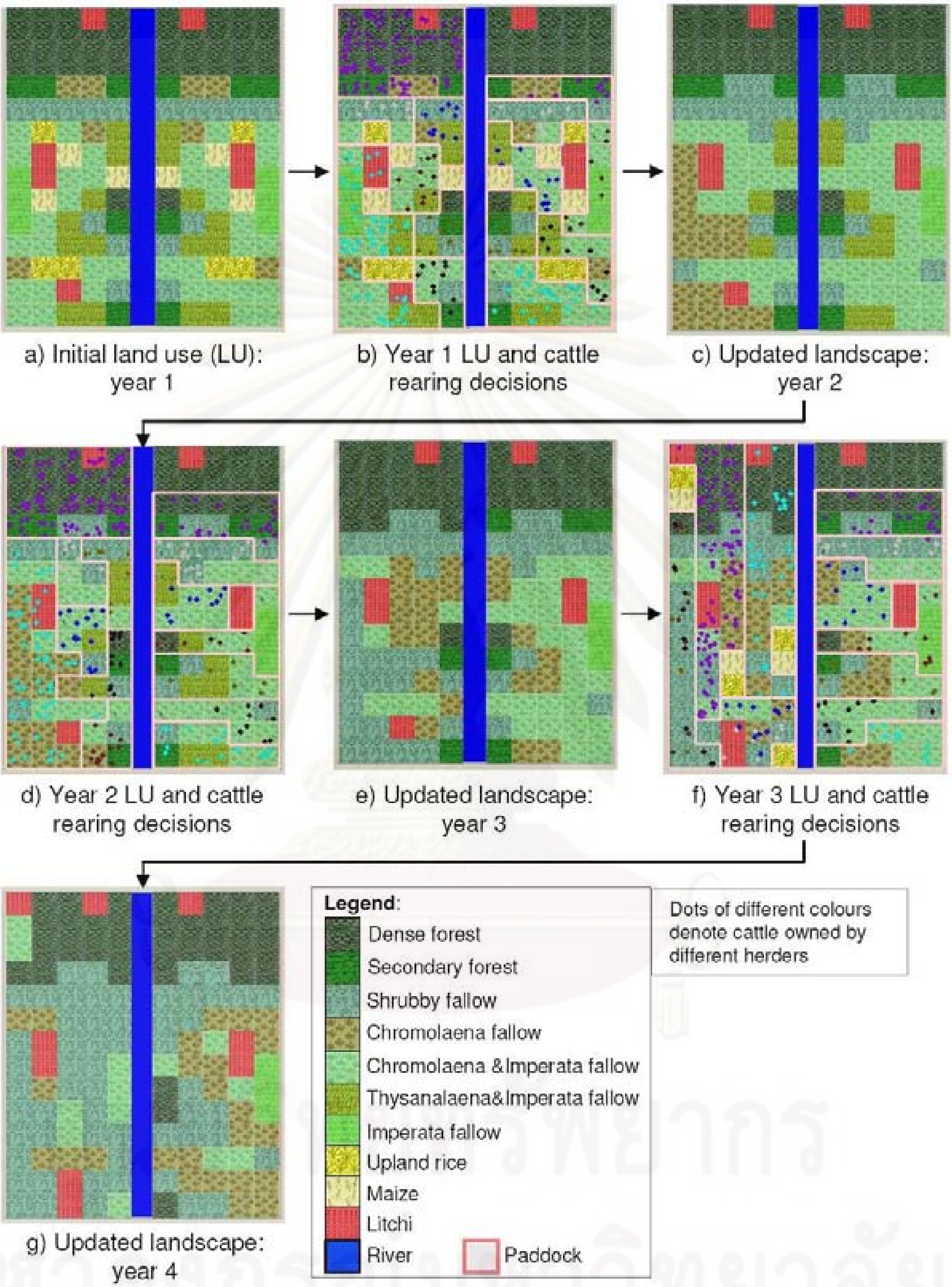
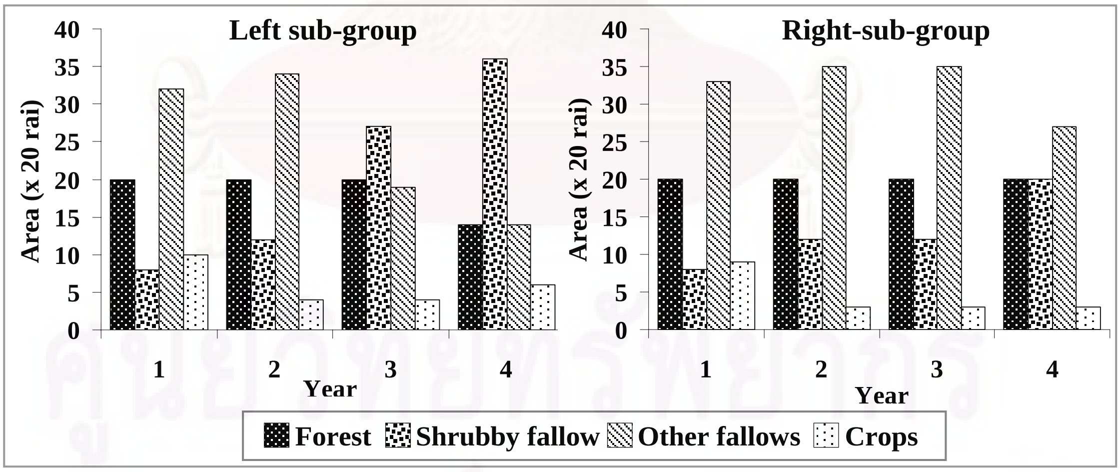


Figure 6.12. Landscape, paddocks, and cattle grazing dynamics for two groups of herders (left and right) simulating cattle management without reforestation plots (scenario 1) in the first gaming and simulation workshop.

In the second and third rounds of play, the herders took the landscape dynamics and their herd size into account before making decisions on the location of their grazing land with the objective of improving cattle fattening. Many techniques were implemented by the herders to meet their objective: i) to enlarge paddocks to increase the volume of forage available (Figure 6.12d), ii) to sell their cattle to reduce grazing pressure, iii) to pool their individual herds into a collective herd with 2-3 owners (Figure 6.12f), and iv) to open a new plot to plant annual crops and an orchard inside the forest area (Figure 6.12f) with the interesting reason mentioned by the herder who did it: "I sold some cattle last year and this year I have to grow crops to get more income. But the land was occupied by other players so I decided to convert forest cells in my paddock."

Figure 6.13 shows the different land use by area, based on the virtual landscape (Figure 6.12). It shows that the left sub-group who raised more cattle than the right one allowed shrubby fallows to cover more land year by year, while the right sub-group maintained a domination of the grassy and *Chromolaena* fallows in the landscape. This is in agreement with the vegetation state transition rules agreed by the players.



Note: Forest = Dense forest + secondary forest cells; Crops = Upland rice + Maize + Litchi cells.

Figure 6.13. Vegetation dynamics in the simulation of cattle management without reforestation plots in the landscape (scenario 1) by two groups of herders in the first gaming and simulation workshop.

Differences between the two groups of herders, in term of the key monitoring indicators of cattle population dynamics, are provided in Figure 6.14. In the first year, there were a total of 200 and 77 heads in the left and right sub-group, respectively. After two years of grazing, the grassy fallows were limited (Figure 6.13) and the herders saw that the quality of grazing lands (paddocks containing fewer grassy cells) was decreasing. As a result, the herders had to sell their herds in order to improve their cattle status. This was clearly observed in herders B2 and D1 in the left sub-group who had large stocks. This result proved that herders play the game seriously to achieve the good cattle status.

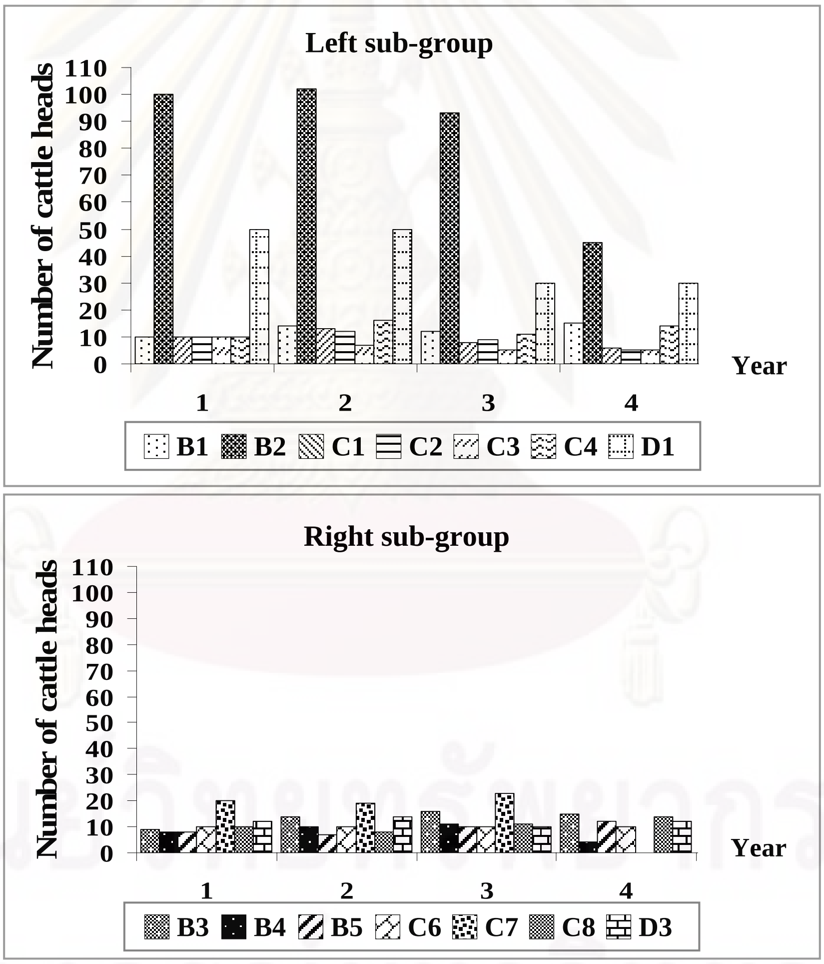


Figure 6.14. Dynamics of cattle herd size during the simulation of cattle management without reforestation plots (scenario 1) between two groups of herders in the first gaming and simulation workshop.

Figure 6.15 displays the dynamics of cattle status (fat, normal or thin) of each indicated herder. The grazing pressure was higher in the left sub-group that raised more cattle and as a result the cattle status of many herders in this sub-group was not good compared with those raised by herders in the right sub-group, especially in the second round of play where the cattle population increased limiting the amount of forage available. But after some members of the left sub-group sold cattle in the second and third rounds of play, their cattle status improved. The right sub-group clearly illustrates the fact that a low grazing pressure leads to a good cattle status. However, as the quality and quantity of grazing land in landscape decreased in years 3 and 4, cattle status also degraded as fewer herders had fat herds.

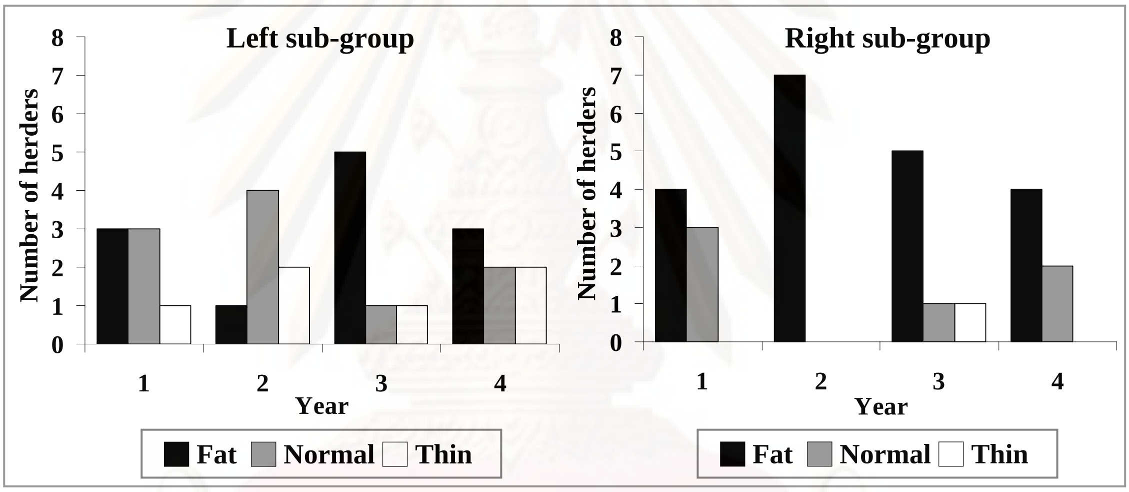


Figure 6.15. Dynamics of cattle status in the simulation of cattle management without reforestation plots (scenario 1) by two groups of herders during the first gaming and simulation workshop.

During a short plenary discussion, representatives of each group were invited to explain the individual and group strategies selected to manage cattle under this first scenario and to interpret their effects on the landscape features. They provided rapid explanations, without hesitation, and demonstrated their understanding of both the gaming features and rules, and of the simulated dynamics. In particular, they were at ease with the use of pictograms to depict landscape dynamics and it was not difficult for them to relate them to real vegetation cover. As already observed by previous ComMod users in this region (Barnaud *et al.*, 2007), members of each of the two groups displayed a strong relationships between their decisions and behaviour in the gaming sessions and in actual circumstances. To them, “the game is not difficult to understand and to follow because it is like what we do in reality. The game is fun but we think seriously how to manage the land. The game is an opportunity to discuss and share experience on cattle rearing and cropping activities.”

In the second half of the afternoon session, the second scenario was introduced in which reforestation plots of different ages were introduced in the landscape for the herders to prepare themselves before the gaming and simulation sessions with the foresters planned for the following day. But due to time constraints, as expected, only one round could be played in which both sub-groups of players decided to locate their herds in every reforestation plots. The reason they offered was that “we have been rearing cattle in this area before the foresters arrived. So, whether there are reforestation plots or not, we have the right to let our cattle graze everywhere.”

At the end of this first day, the importance of cattle rearing in this village and the herders’ wish to continue this activity were confirmed. But to be able to do so, the need to negotiate access to grazing land with the foresters and other government agencies to mitigate the current land use conflict was also very obvious.

Second day sessions with herders and NKU foresters: There was 50% (eight out of sixteen) of the herders from the first day participated in the second day gaming and simulation sessions. This number is low because the workshop was conducted at Tha Wang Pha District Office[23] located in the lowlands, which was not convenient for the herders to get to. However, those representatives that did attend, comprised of the village headman (type D), a TAO representative (type C), and two type B, three type C and one type D herders, covered the necessary groups to enable discussion and negotiation with the foresters (one manager and two officials) regarding the current land use conflict, despite the low representative sample size of each group.

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[23] This place was considered as a neutral work place to conduct a work between these two conflicting parties.

The morning session started with presentations by representatives from each sub-group of herders of the results of the previous day's simulation of the first scenario (S1-A[24]). This was done to introduce the gaming and simulation tools, their features, rules, and the outcomes of a session to the group of foresters. It was also a way for them to learn more about the herders' perceptions of the issue at stake.

Thereafter, a third scenario (S3) with "reforestation without cattle grazing in the landscape" was introduced and autonomously simulated with the computer to let the foresters learn about how to run and use the computer simulation. At the same time, they could observe changes in the vegetation dynamics in the absence of any cattle rearing activity. Following these two activities, the foresters were ready to join the herders in a full gaming and simulation session, which took place in the afternoon and was based on a fourth scenario (S4) in which the herders and foresters manage a common landscape. The dynamics of the landscape managed by the two sub-groups of herders and the foresters establishing their reforestation plots over four successive years are shown in Figure 6.16.

Foresters appeared to understand very well the representation of different landscapes and how to play the game. Theses were confirmed by the results that they requested to have different ages for their tree plantations in the landscape (0 for a new plot, and 2, 5 and 10-year-old plots) to make it more realistic. They related the age of the reforestation stand with vegetation types (e.g. a 10-year-old tree plantation looking like a *"Dense forest"* according to them). Their new tree plantations were located next to the youngest ones because in their own words "we do like this in reality" to gradually expand the forest cover.

They also announced that they would allow the herders to let their herds graze in reforestation plots that are at least five-year-old and the herders accepted this rule. This announcement showed that the foresters wanted to compromise with the herders, at least in this gaming and simulation session. Later on, when the foresters faced difficulties in finding suitable land units to establish a new reforestation plot in the right side of landscape (Figure 6.16d, f), their leader walked to the herders' tables to negotiate access to a parcel of land for reforestation. This confirmed that the foresters need to talk with the herders.

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[24] S1 - A was selected for presentation because we needed to observe the herders' behaviour with and without foresters participating in the simulation.

Surprisingly, the left sub-group of the herders used this simulation exercise to present their idea about using a small number of cattle for forest regeneration. They pooled their 40 heads of cattle together and started grazing in the upper part of the landscape, next to the forest area. After three years, they moved their herd to the lower part of the landscape where abundant grassy cells were available (Figure 6.16c-i). Thus the herders from this sub-group also understood well how the gaming and simulation worked because they could integrate their own knowledge on vegetation dynamics into the gaming session through this cattle management strategy.

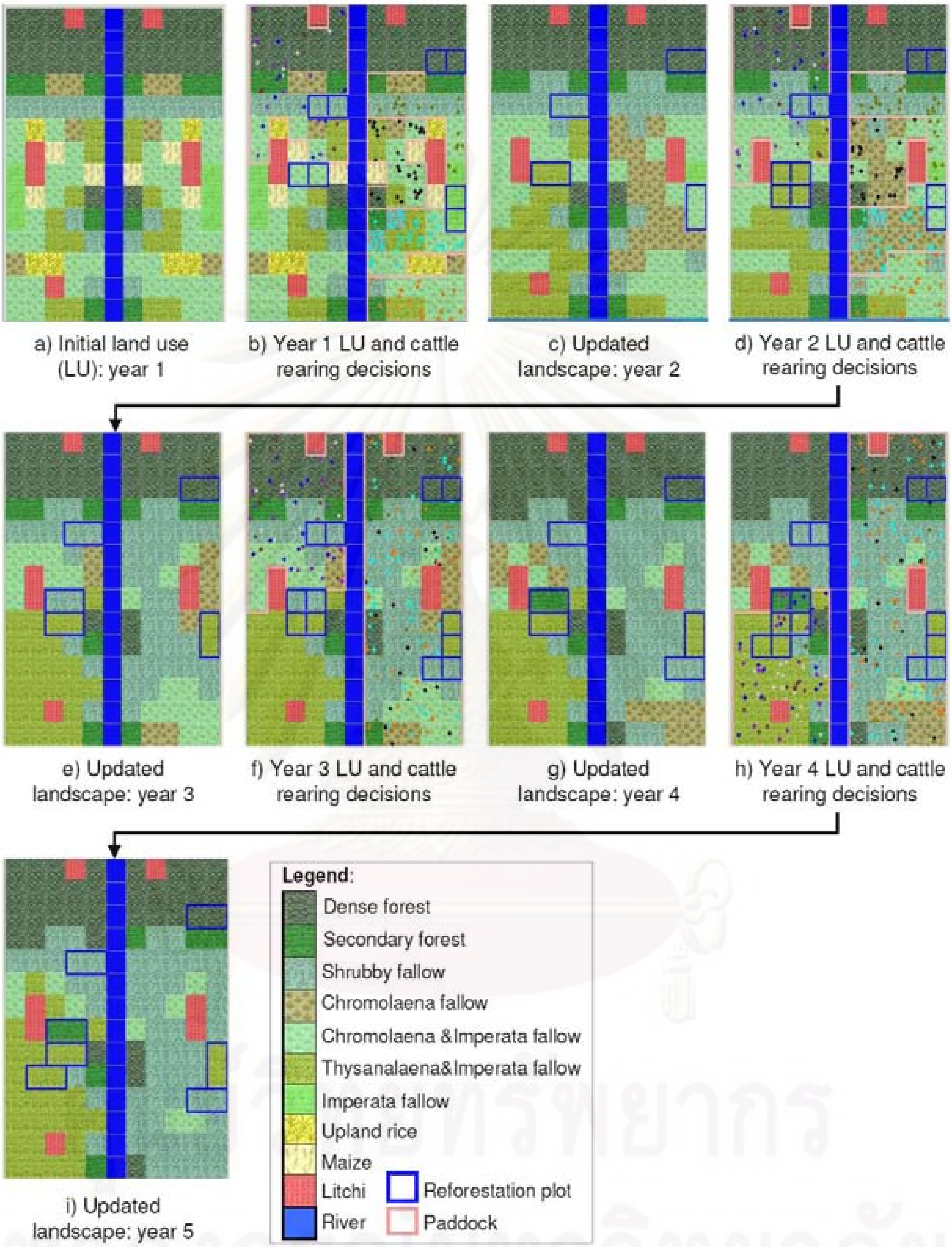
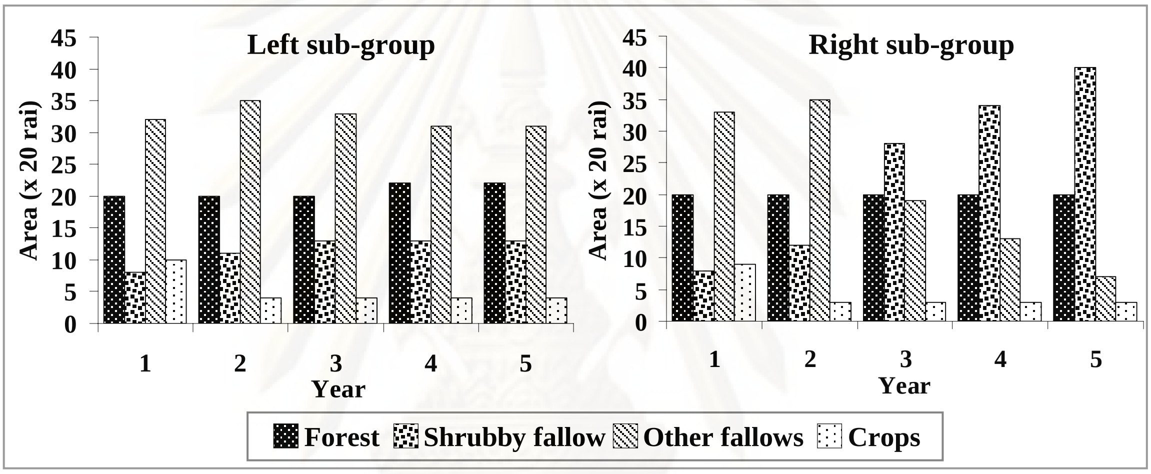


Figure 6.16. Landscape, paddocks, reforestation plots and cattle dynamics in the simulation of two groups of herders and one group of foresters managing the same landscape (scenario 4) in the first gaming and simulation workshop.

The right sub-group of herders decided to raise a large herd made up of 120 cattle. They managed their herds individually in the first two years. But when facing a lack of productive grazing land in the third year, they decided to pool their cattle in order to improve their status. The duration of the steps towards forest recovery in the part of the landscape managed by this sub-group was shorter than in the other one (Figure 6.17). All of them understood that this shorter succession time was due to the effect of high cattle grazing by herders D3 (40 heads) and C6 (30 heads) and related to the agreed vegetation dynamics from the previous day.

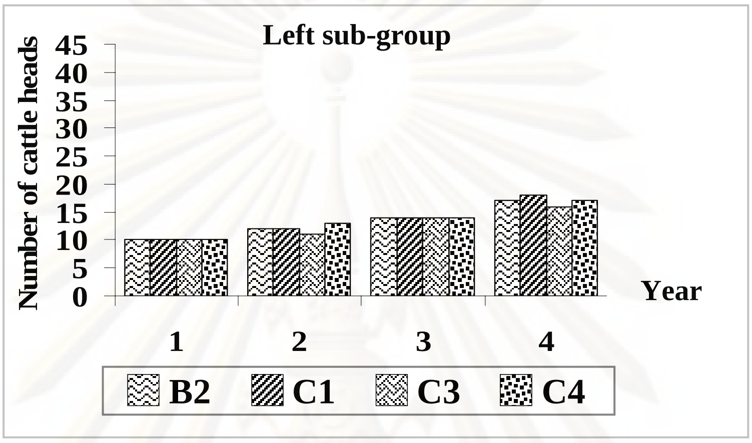


Note: Forest = Dense forest + secondary forest cells; Crops = Upland rice + Maize + Litchi cells

Figure 6.17. Vegetation dynamics during the simulation of a scenario with two groups of herders and one group of foresters managing the same landscape (scenario 4) in the first gaming and simulation workshop.

Interestingly, compared with the simulation of S2 in the afternoon of day-1, the two sub-groups of herders acted differently. They did not encroach on the forest (Figure 6.13) and in this scenario and these settings they accepted the foresters' rule regarding grazing in young tree plantations, showing that in these simulations the villagers could also accept and follow agreed upon rules. Moreover, the herders declared that they wanted to negotiate with the foresters.

Differences between the two sub-groups regarding key monitoring indicators of cattle population dynamics is summarized in Figure 6.18. The left sub-group chose small herds and a corresponding low grazing pressure. They located their cattle together in the northern part of the landscape during the first three years of the simulation before moving their herds to the southern part in the fourth year because there was still plenty of grassy cells to graze due to the absent of grazing in the previous year and, therefore, a slow vegetation succession in this part of the landscape. Therefore, the cattle population increased continuously year after year.



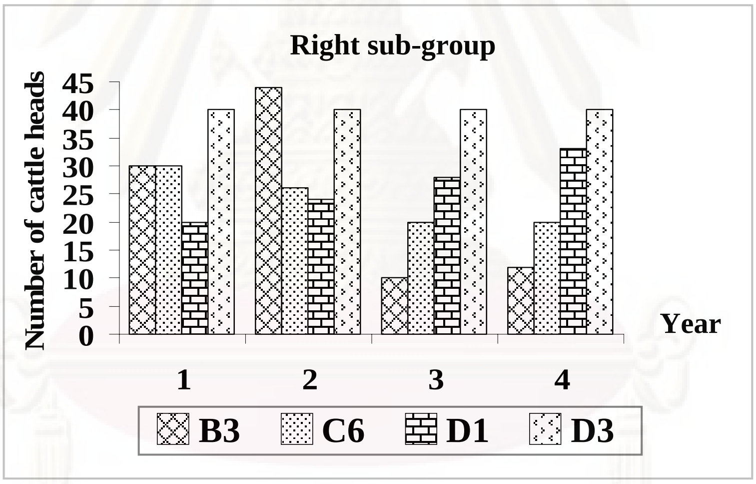


Figure 6.18. Dynamics of cattle herd size in the simulation with two sub-groups of herders and one group of foresters managing the same landscape (scenario 4) in the first gaming and simulation workshop.

Individual decisions played an important role in cattle management in the right sub-group, especially in the decision of whether to sell cattle. Different strategies were observed, for example, B3 decided to sell a lot of cattle at the end of the third round because of his words that “I need money to buy a car, so I sell 40 heads”, C6 sold cattle every year and D3 decided to maintain his herd size at the same size as he started with. Moreover, D1 had a low herd size of 20 individual cattle, which was different from the previous day when he played with his actual herd size (50 cattle) and he decided not to sell his cattle because he believed that there was enough forage for his cattle.

Figure 6.19 shows the dynamics of the cattle status (in terms of fat, normal or thin) in both sub-groups of herders. Because of the low grazing pressure, due to their small cattle population (40-80 heads during four years), the left sub-group could maintain a better cattle status than the right sub-group that choose to rear larger herds.

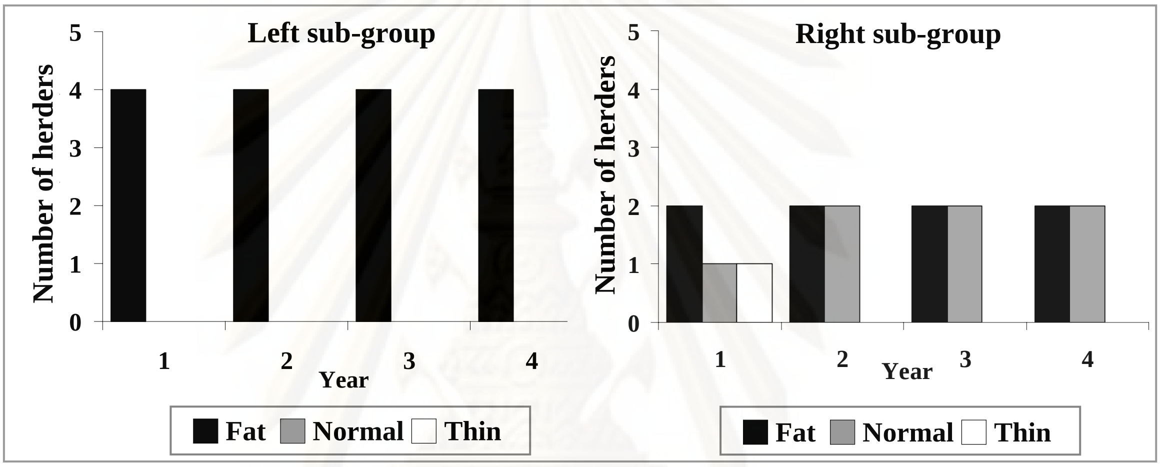


Figure 6.19. Dynamics of cattle status in the simulation of the management of the same landscape by two sub-groups of herders and one group of foresters (scenario 4) during the first gaming and simulation workshop.

In the final plenary discussion that took place after the simulation, the herders explained with confidentially the positive effects of cattle grazing on forest regeneration in front of the foresters. But they also made the point that they did not know what the herders in the village would do if the most of the area becomes covered by dense forest. The results from this second day of gaming and simulation activities showed that they were efficient in facilitating the communication and sharing of perceptions between foresters and herders, and a dialogue between the two parties was established.

6.2.6.2. Requests from the players regarding the next phase of the ComMod process

At the end of this first sequence of ComMod activities in which the herders and foresters started to talk and to understand each other, they also saw more clearly the urgent need to improve cattle and land management in this area and requested researchers to continue the process by focusing the activities on their topics of interest. The herders wanted to use the ComMod tools to test new cattle raising techniques discussed in the plenary discussion at the end of the first workshop. They were dealing with the introduction of paddock rotation and artificial pastures established with “Ruzi” grass in the landscape. On the other side, the foresters said they wanted to help herders moving into that direction and were ready to provide them with a piece of land to experiment with such new cattle rearing practices.

Both parties suggested inviting new participants to take part in the gaming and simulation process. NKU foresters thought that the head of NNP should participate because of his official authority over the park area, while the herders requested the presence of representatives from the District Administrative Office and District Livestock Development Office because their trust in NKU foresters, and that they really would help them to achieve their goal was still limited. It was decided that the next workshop could be carried out at Doi Tiew village school because it is easy to get there for herders, NKU and NNP officials. Herders, who insisted to invite the District officials, suggested that “the District officials from Tha Wang Pha lowlands could come to the workshop location with the research team.”

6.2.7. Dissemination activities

Because only a few herders participated in this field workshop, the main results were presented in front of about 100 villagers with the support of a PowerPoint presentation and a A0 size poster during a village meeting (Figure 6.20 and Appendix F). The explanations were provided by the researcher and three herder-players who had a good understanding of the gaming tool and the results of the sessions. At the end of the presentation, some members of the audience said that they did not believe that the foresters will help the villagers to improve the cattle raising system. Moreover, we found that some students were interested in the different management strategies during the gaming and simulation sessions. They were interested to let their parents play the game to learn these diverse cattle management strategies to improve cattle raising system in the village.

Figure 6.20. Presentation of the gaming and simulation workshop during a Doi Tiew village meeting.

A similar presentation was made and a document distributed to Sob Khun Royal Project officials and a meeting organized with District Livestock Development officials. Both organizations seemed interested to participate in the subsequent ComMod activities. Moreover, the poster was permanently displayed at the village healthcare centre and NKU headquarters where the former players are working for them to use this visual support to present and discuss the gaming and simulation workshop activities and results with visiting villagers who were interested.

6.3. Lessons learned from this first ComMod sequence

6.3.1. Improved understanding of the system

The first and second objectives of the workshop aimed at a better understanding of the vegetation dynamics and of the decision-making by the herders and foresters. This was achieved as follows:

Vegetation dynamics: Through the co-design, testing, and use of the simulation tool in the gaming and simulation field workshop, vegetation states and their dynamics were validated with the local stakeholders. Both villagers and herders found that the results of the gaming sessions relying on the vegetation state transition diagram were realistic. In particular, several herders were confident enough to explain the results from the afternoon's gaming sessions of the first and second day to the foresters and later to the whole village. On the other side, the NKU head said that "this model is enough to be used for communication and learning for the villagers and there is no need for more precise ecological data as this would make the negotiation more difficult."

Cattle dynamics: The herders understood the game without having to insert a complex module dealing with cattle age classes. The simplicity of this model was appropriate to stir communication between the herders and foresters. Nevertheless, the herders managing large herds pointed to the fact that in reality, cattle deaths and losses were higher than in the game and that this needed to be corrected before further use of the simulation tool.

Decision-making processes and practices regarding cattle and land management: Several dimensions were observed during the gaming and simulation sessions. In the preliminary diagnosis, some participant seemed to see no future for herders in the area. However, the ComMod activities confirmed that cattle raising was still an important farming activity as villagers still want to raise livestock as long as grazing land is available. Interactions among villagers during collective decision-making processes were very much improved because this kind of exchanges amongst them had never been observed before. We observed that the communication broke the barriers between clans and between different farm types, and the herder-players assisted each other when they had to act together, i.e. they shared their land resources for cattle raising. In another example, one herder still relying on the local breed of cattle did not want to pool his herd with the other players' ones because he was afraid that his animals would decrease the cattle quality of the others. Regarding the foresters' decision-making processes on reforestation, it was observed that they use a strategy based on the gradual expansion of young tree plantations by selecting new plots adjacent to the recently planted ones. The knowledge of these behaviours dealing with cattle rearing and reforestation were useful for programming the subsequent autonomous ABM.

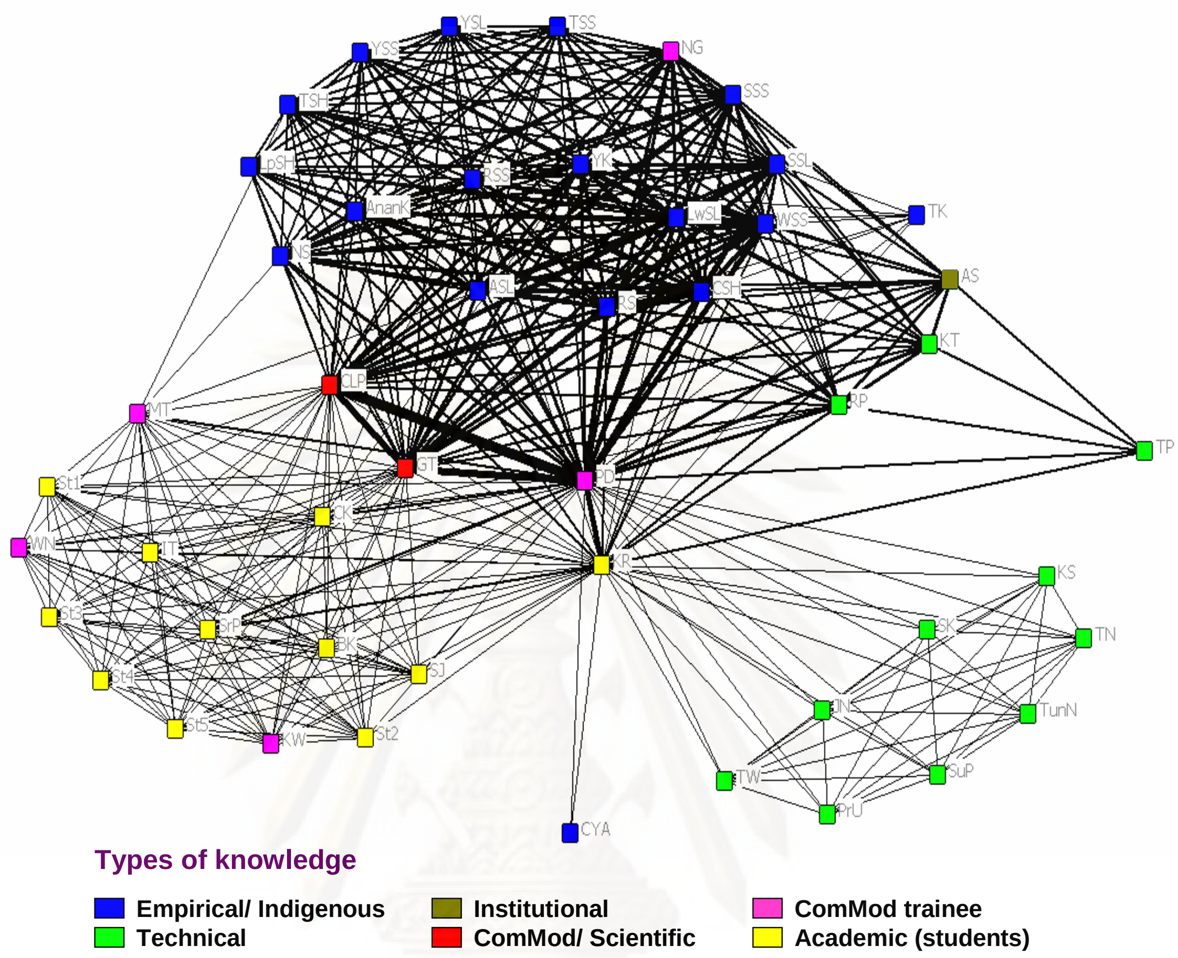
6.3.2. Improved communication and trust between the two main interest groups

In relation to the third objective of the workshop, the gaming and simulation activities were useful to improve communication and trust between herders and foresters. During the simulation of the fourth scenario on the second day of the workshop, the herders used the gaming session to present their ideas on reforestation by "using cattle" in front of the foresters. At the same time, discussion and negotiation between foresters and herders about land to be allocated to reforestation allowed both parties to listen to each other, exchange perceptions and improve their mutual understanding of their respective objectives and perceptions regarding forest recovery and land resources. The herders realized more clearly the urgent need for them to better manage grazing land, and the foresters declared that they were ready to help. This showed that some trust between herders and foresters was emerging by the end of this first ComMod sequence. However, it was found that the level of herders' trust in the foresters was still low when they requested to involve a representative from the District office to participate in further activities as a mediator.

Nevertheless, based on their better understanding of the situation, all the players agreed to continue the ComMod process by using the game to explore new cattle management techniques (rotations and artificial pastures) by inserting small plots in the landscape as proposed by the foresters. Therefore, the researchers decided to improve the ABM part in the cRPG-V1 to accommodate the new technical options proposed by the players and to use this new simulation tool with both the former and new interested stakeholders for collective decision support.

6.3.3. Knowledge and perceptions sharing among stakeholders

This first sequence of ComMod activities also allowed the sharing and integration of diverse types of knowledge among stakeholders as shown in Figure 6.21.



Note: Line thickness is proportional to time spent interacting.

Figure 6.21. Exchange of different types of knowledge among the participants in the first sequence of the ComMod process.

Most of these exchanges occurred during the field workshop where the intensity of communication was high. Exchange of perceptions and shared learning between herders and foresters were achieved through the co-design and the use of the cRPG. Among local stakeholders, empirical knowledge from individual herders was transferred to their neighbours through discussions and the observation of players' behaviour. Technical and institutional knowledge from foresters was shared as it was integrated in the representation of vegetation successions. Based on their increased awareness on the issue to be solved collectively, the herders and foresters realized that they need to adapt their management strategies and start thinking about how to improve the actual situation.

6.3.4. Possible methodological and technical improvements

Based on the information gathered during the players' interviews after the workshop and the observations of the research team during the proceedings, some possible methodological improvements could be suggested:

Debriefing: Only chronological series per scenario of pictures of the virtual landscape were presented to players on paper and with power point presentations (see. Figure 6.12 and Figure 6.16), and no time was available to show graphs of indicators (like in Figure 6.14, 6.15, 6.17, 6.18 and 6.19) to them. They only observed from their own record sheet. Therefore, these graphs could be useful, especially for the herders who have a low formal education, to improve their understanding on the effects of their decisions made on cattle and vegetation dynamics. Another point to be improved was related to the language barrier. We observed that whilst some players could follow the power point presentation with the facilitator's explanations, some of them did not understand clearly what was being shown. In the sub-groups of herders, explanations in Hmong language by people who understood the game better than others were noticed and this was observed to be the most efficient way to train newcomers. Therefore, it was necessary to keep experienced players for further activities.

Timing: In this first workshop, there were many time consuming steps which needed many research assistants to complete, such as updating the herd size. However, after the first workshop finished, we found that players understood the gaming sessions and how the computer worked. Therefore, the cRPG could be improved by programming those steps that need research assistants to complete into CORMAS. By doing this, it could save time.

Forester's attendance: In this first field workshop, they came late and had to leave early. Therefore, their role and interactions with villagers in the game were not as intensive and long as expected. We planned to play more rounds to observe their decisions, but it was not feasible. This problem deserved special attention in the preparation of the following workshop requested by both herders and foresters.

6.4. Conclusion and next steps

The implementation of a first ComMod sequence at this site demonstrated that complex ecological and social dynamics related to cattle grazing and forest regeneration in montane Northern Thailand could be modelled with stakeholders after simplifying the system by selecting only key interactions between resources and different users. The resulting tool is a shared representation that can be used to simulate and collectively discuss scenarios.

This experiment also confirmed that such a simplified model with a 2-dimensional visual representation can be used by on-farm researchers to improve communication and to support co-learning among stakeholders concerned by this land use conflict. Differences in formal education levels were not a serious obstacle to the use of the proposed tools and the expression of their own opinion by the players was satisfactory in the non-threatening gaming environment created by the use of the CRPG-V1 tool. The interactive and visual features of the simulation tool helped to manage the lack of confidence in public speaking and the local language barrier.

The ComMod activities implemented so far have allowed the exploration of interactions and decision making processes related to cattle grazing and forest regeneration in a dynamic, inclusive and very interactive way. The simulation results showed that human decisions regarding cattle management are an important driving force of the system behaviour at the landscape level. Beyond the current conflict of interests, they also provided the local stakeholders with convincing illustrations of the importance of resource users' coordination mechanisms if a sustainable management of the complex agro-ecosystem has to be achieved.

But in the search for acceptable collective management strategies, more concerned stakeholders, such as the NNP and District Livestock Development managers should be involved in the process and be able to discuss alternative land management options to be simulated and collectively assessed. Based on the progress made, the second sequence of ComMod activities was planned to further support collective decision making among the stakeholders by making use of an updated simulator better tailored to the stakeholders' needs at this stage. The cRPG-V1 was improved and used to explore land use scenarios based on new cattle management techniques (paddock rotation and ruzi artificial pastures) as requested by the the herders and foresters.

CHAPTER VII
SETTING UP AN ACTION PLAN FOR COLLECTIVE MANAGEMENT OF THE LAND BY LOCAL STAKEHOLDERS

7.1. From stakeholders' requests to the role game for decision support

At the end of the first gaming and simulation field workshop, herders and foresters requested the research team to modify the tools to be able to test the new cattle and land management techniques they had suggested in the second workshop. Moreover, they requested to be able to invite new participants from the NNP and DLD into the process to share opinions, particularly on the technical feasibility of their propositions, and to set up a concrete action plan for the collective management of the land to be implemented in reality in order to mitigate the land use conflict.

To do so, the second sequence of the ComMod process was organized in four main chronological activities including: i) the final validation of the vegetation state transition diagram by integrating scientific knowledge from the plot study reported in chapter IV and empirical knowledge from the herders and foresters, ii) the conception of a second gaming and simulation field workshop based on the use of an improved version of the gaming and simulation tool allowing the participants to test their proposed technical innovations, iii) sensitizing and testing activities with this new version of the tool with NNP officials (newcomers in the process) and NKU foresters, and iv) implementation of a second gaming and simulation field workshop to set up a co-management action plan with local stakeholders. Detailed presentations of these activities, their respective results and the lessons learned during this second sequence are provided in this chapter.

7.2. Methodology

7.2.1. Final validation of the vegetation state transition diagram

As the foresters and herders understood each other better and were ready to communicate after the first field workshop, the researchers decided to conduct a collaborative activity focusing on the final validation of the vegetation state transitions. Therefore, a half day session involving researchers, foresters and herders was dedicated to this activity in December 2008. Two foresters and two herders who were interested to discuss with foresters about the vegetation dynamics were invited to participate. The session started with a presentation of the main results from the plot study in different types of land use. Then, researchers explained the interdependence between events. For example, fire risk was an important cause of reforestation failure, while cattle grazing could reduce the volume of dry materials and therefore reduce the risk of bush fire. A discussion and exchanges of opinions were organized before to finalize the diagram. This final version of the diagram was used to update the vegetation dynamics module of the cRPG-V1. At the end of the session, a detailed plan for a second gaming and simulation field workshop was also discussed (e.g. size of plots proposed by foresters to be inserted in the virtual landscape, new pictogram of ruzi pasture to be used, date, location, etc.).

7.2.2. Conception of the second field workshop and improvement of the gaming and simulation tool

This second field workshop aimed to set up a co-management action plan among the local stakeholders by taking into account the suggestions made by the herders and foresters at the end of the first workshop. Therefore, more participants were invited, including the heads and officials from NNP and DLD. As more participants were to attend the workshop, it would likely be difficult to control the process. To avoid this, the number of participating herders was reduced to six persons to make the discussions more effective. These herders were selected to cover three farm types (B, C and D).

7.2.3. Sensitizing and testing activities with new concerned stakeholders

A full day of sensitizing and testing activities was conducted at Doi Tiew School in January 2009[25] with five NNP officials and two NKU foresters. The main objectives were to sensitize new officials from NNP, to test the use of the cRPG-V2 and to identify possible improvements. The session started with the presentation of these objectives followed by the results from the first workshop. Then, the

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[25] In fact, the plan of the research team was to conduct the second field workshop on that date. But due to price fluctuations of maize, one of the local villagers' main economic crops at that time, all the invited herders decided to go to the market to sell their products in the lowlands and did not show up at the school.

participants were divided into three main roles. One NKU forester and four NNP rangers were asked to play the role of herders, whilst another NKU forester and one NNP official played their own roles.

The following two scenarios were played: i) the herders manage cattle on an individual basis by using the paddock rotation technique (morning session), and ii) the herders manage cattle collectively by using the paddock rotation and/or ruzi pasture techniques (afternoon session). Two and three rounds were played for each scenario, respectively. The five main successive phases of a round of play in the game are shown in Figure 7.1.

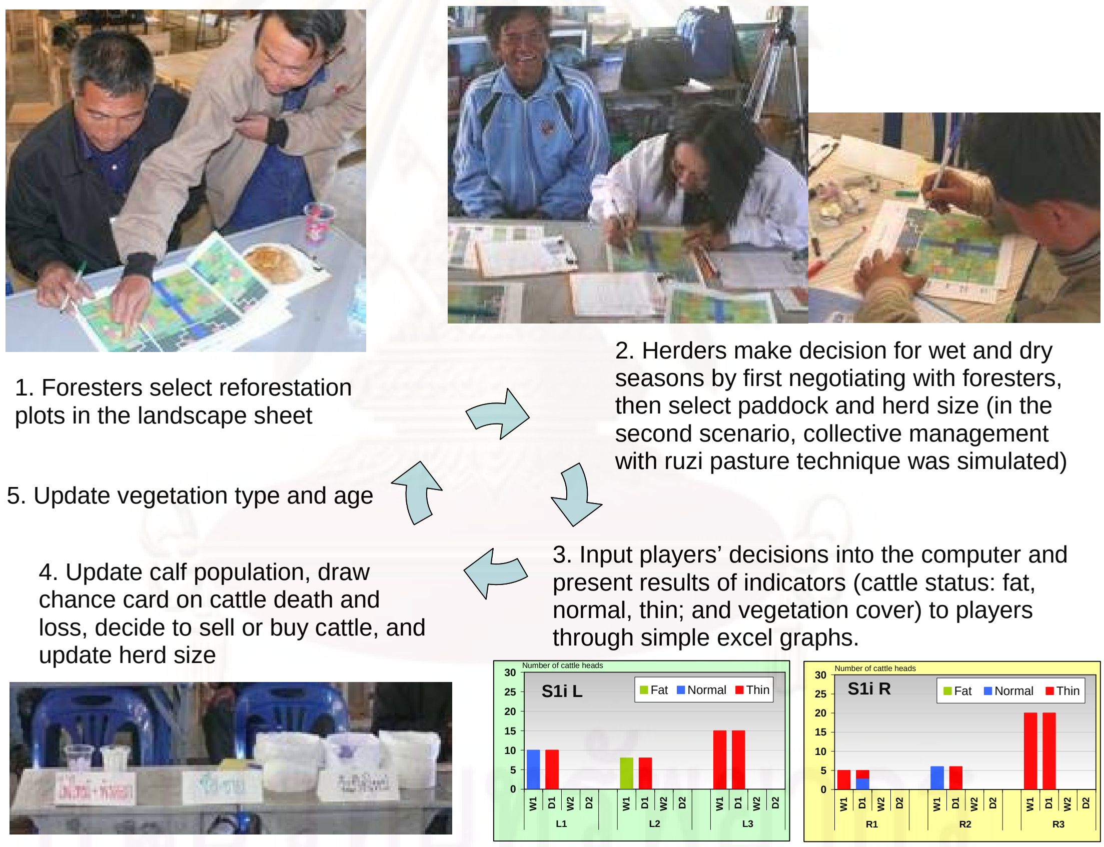


Figure 7.1. Main successive phases of a round of play in the second gaming and simulation field workshop.

At the end of the day, a plenary discussion was held on the following topics: difficulties in the gaming and simulation sessions, the gaming tool features and their relation with reality, players' decision making and learning during the sessions, the feasibility of implementing the new cattle management techniques in reality, and suggestions on how to further improve the cRPG-V2 tool.

7.2.4. Second gaming and simulation field workshop

The second gaming and simulation field workshop was carried out in March 2009. The objectives of this field workshop were to use the cRPG-V2 as a decision support tool to i) investigate the local stakeholders' decision-making processes regarding the new cattle and land management techniques, ii) facilitate the discussion of results from gaming and simulation sessions leading to the design of a collective action plan among local stakeholders, and iii) understand local stakeholders' needs for further tailoring and adaptation of the ComMod process. Table 7.1 presents the main characteristics and expected outputs of this second field workshop.

Table 7.1. Description of the second participatory gaming and simulation field workshop at Doi Tiew village of Nan Province, Northern Thailand.

Activity	Sessions in gaming and simulation (G & S) workshop		
	Morning G & S session	Afternoon G & S session	Plenary discussion
Objectives	- To take stock of the evolution of the process and explain the new gaming tool (cRPG -V2) and the objectives of G & S. - To facilitate communication and discussion and to improve trust among stakeholders. - To explore herders' individual decision making regarding the new cattle and land management techniques	- To facilitate communication and discussion and to improve trust among stakeholders. - To explore herders' collective decision making regarding the new cattle and land management techniques	- To facilitate the co-management of the land and set up a joint action plan among stakeholders.
Types of participants (number)	- Herders (5) - Nam Khang Unit foresters (2) - Nanthaburi National Park officials (3) - District Livestock Development official (1) - Researchers (1) and assistants (6)	- Herders (5) - NKU foresters (2) - NNP officials (3) - Researchers (1) and assistants (6)	
Scenarios (number of rounds simulated)	- S1 (3 rounds): herders manage cattle individually & facilitator assigned the order of play among herders	- S2 (4 rounds): herders manage cattle collectively	-
Expected Outputs	- Improved understanding on local stakeholders' decision making processes regarding the new cattle and forest management techniques. - Improved communication and trust among stakeholders.		- A collective action plan to be actually implemented.

Note: cRPG is for "computer-assisted Role-Playing Game."

The day before conducting the gaming and simulation sessions, the researcher organized a one hour exercise with six herders to make them familiar with the new features and rules of the simulation tool. On the day of the workshop, two scenarios with different modes of decision-making (individual and collective cattle management) were simulated. The objectives were to explore the advantages and disadvantages of these two modes of decision-making and to stimulate co-learning among the local stakeholders. To make sure that the herders' perception of the paddock rotation technique was discerned, it was compulsory for the herders to use the paddock rotation technique in the first round of play and for each scenario. Then, in the following rounds, herders were free to choose their preferred cattle management techniques based on their interest and objectives. Individual interviews with the participants were conducted the day after the gaming sessions.

The main phases of a round of play in the game were a little bit modified from the sensitizing and testing activities in January, so as to obtain a more effective time management. During the sessions, herders and foresters could discuss and negotiate to manage the same landscape following the main phases presented in Figure 7.2.

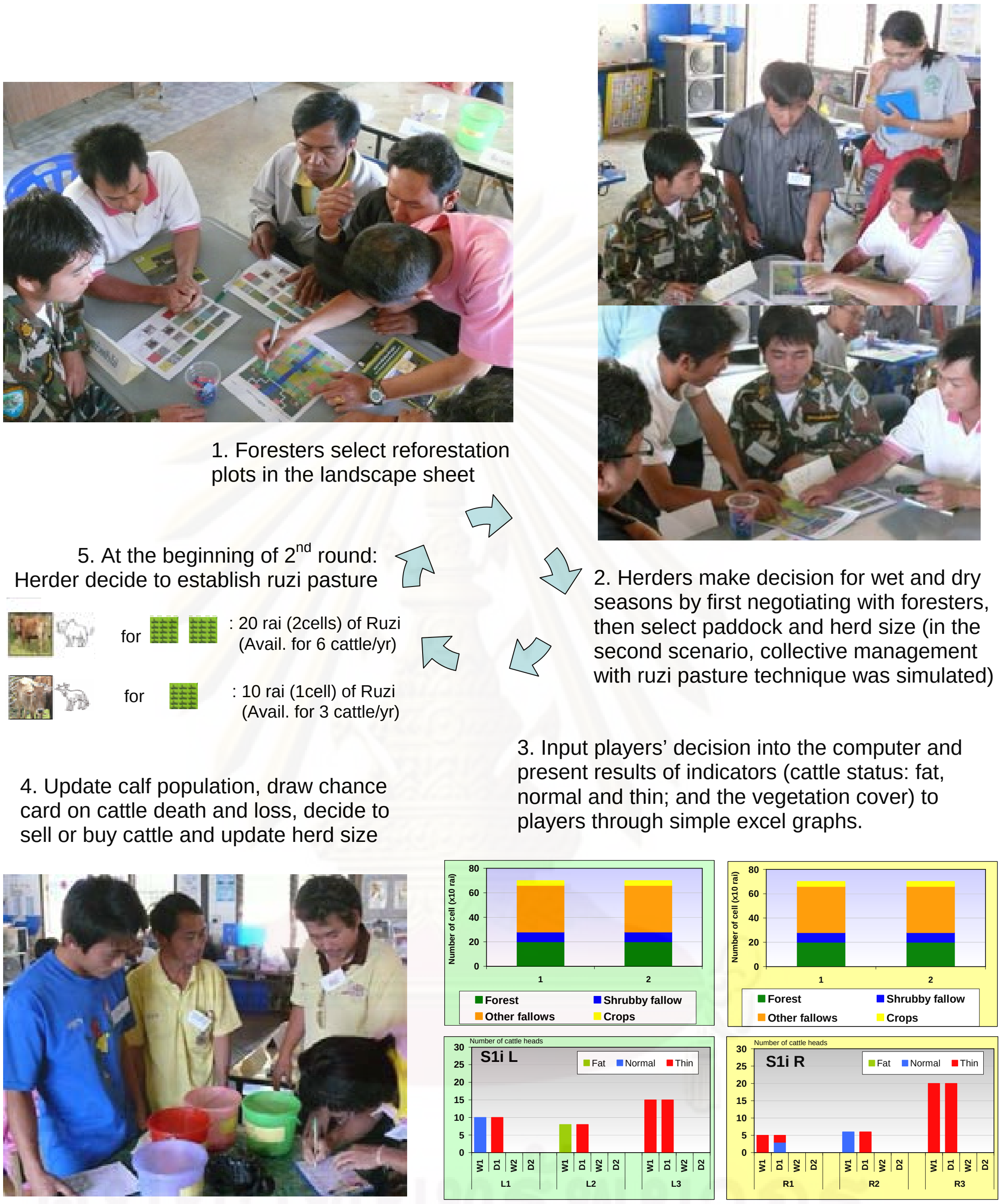


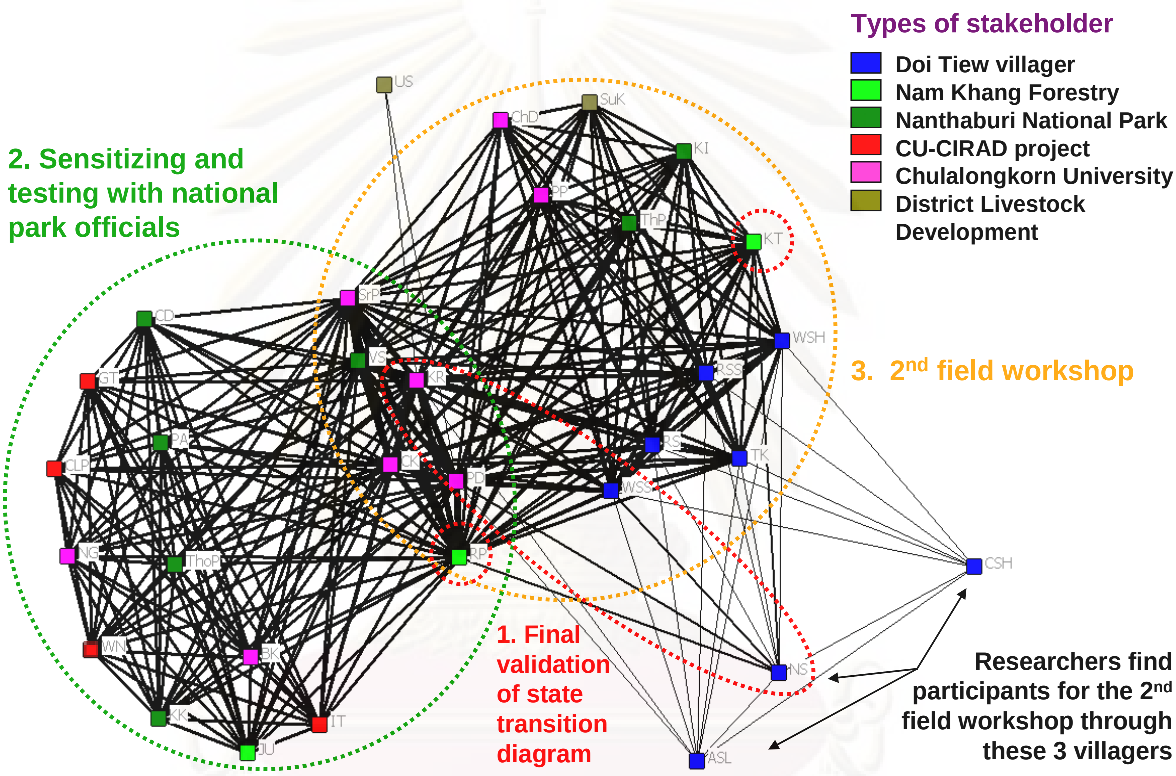
Figure 7.2. Main successive phases of a round of play in the simulation of scenarios during the second gaming and simulation field workshop.

More details about the phases of a gaming session are provided in the description of the cRPG-V2 simulation tool in the results section below.

7.3. Results

7.3.1. Stakeholders’ participation in successive activities

A greater diversity of stakeholders participated in the different activities of this second sequence of the ComMod process (Figure 7.3) compared with the first sequence one as shown in Figure 6.3.



Note: Line thickness is proportional to time spent interacting.

Figure 7.3. Diversity of stakeholders and their social interactions in the second sequence of the ComMod process, Doi Tiew village, Nan Province, northern Thailand.

From this diagram we assessed that each participant from the main category of stakeholders (NKU, NNP and herders) was able to communicate with the others in all activities along this second sequence. Therefore, the highest intensity of communication (thickest line) can be seen between those persons who spent several hours together. The workshop facilitator spent some time with three herders[26] to identify and select participants in the second field workshop. We found that they preferred to decide by themselves which of the herders would be participating in the second workshop. This showed their interest in the ComMod process.

7.3.2. Final diagram on vegetation dynamics validated by herders and foresters

In the first activity of the second sequence, a final version of the vegetation state transition diagram was obtained (Figure 7.4), through sharing of scientific findings from our ecological survey and empirical knowledge from the herders and foresters.

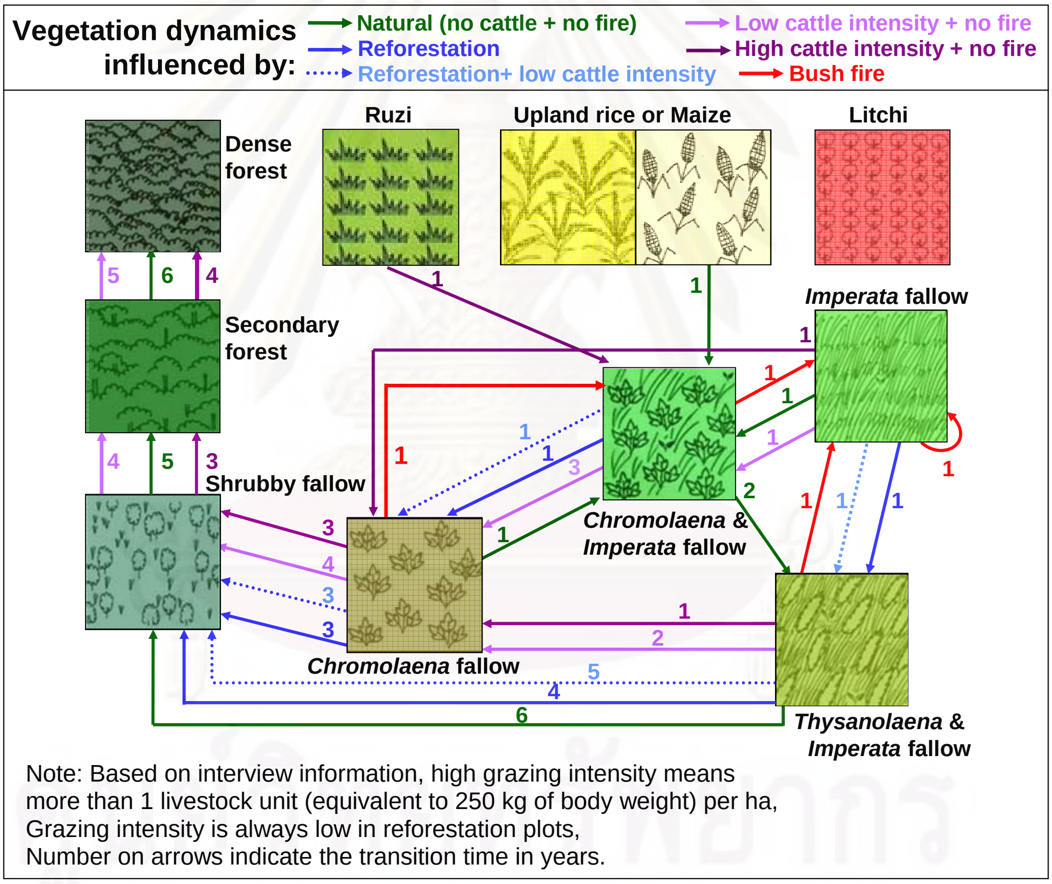


Figure 7.4. Final version of the vegetation state transition diagram integrating scientific knowledge from plot level study and empirical knowledge from herders and foresters of Doi Tiew village in Nan Province, Northern Thailand.

[26] "CSH" stands for the village headman, "NS" for a herder who participated in all ComMod activities since the beginning, and "ASL" for a former player who participated in the first workshop for two days and planned to join the second workshop as a player again, but on the actual workshop date, he did not come due to his urgent duty in the lowlands.

A new pictogram for "ruzi pasture" was added into the diagram and is always associated with high grazing intensity. The herders declared that, based on their information heard from DLD, if the grazing intensity is well-managed, a ruzi pasture can be used for several years. The herders' information on this topic seems similar to research results published by Cheva-isarakul and Cheva-isarakul (1990) that the pasture could be used up to five years before improvement of the plot.

Regarding the interdependence between vegetation states and bush fire, the foresters agreed that cattle grazing reduces the volume of grass and leads to a reduction in the risk of bush fire. However, the analysis of the causes of these fires was a serious point of contention in their discussion as the stakeholders were blaming each other. The ComMod facilitator had to re-orient the discussion to go back to the importance of collective management. Later on, the effects of bush fire on vegetation dynamics could be discussed and were found to affect four types of herbaceous fallow: *Chromolaena*, *Imperata*, *Chromolaena* mixed with *Imperata* and *Thysanolaena* mixed with *Imperata*. Both foresters and herders agreed that other types of vegetation cover were very difficult to burn due to the low volume of dry materials on their ground surface. This final version of the vegetation succession diagram was coded into the updated simulation tool.

7.3.3. New version of the computer-assisted Role-Playing Game

The existing gaming and simulation tool was improved called "cRPG-V2" version used in the second field workshop. The modifications made are explained in details below by using the format of the ODD protocol.

7.3.3.1. Overview of the cRPG-V2 tool

Purpose: The major purpose of the cRPG-V2 was to be a collective decision-support tool[27] to improve cattle and forest management between local stakeholders. By using this version of the model, the players should be able to compare the results obtained after implementing different land and cattle management strategies including seasonal rotation of paddocks and establishment of ruzi pastures, within or outside of the pilot testing plot proposed by the foresters. The players should then be able to

[27] This refers to the second objective of the ComMod approach.

discuss them with other participants and, particularly, to assess their feasibility in actual circumstances.

The model static structure did not change compared to the previous version, except that a new management unit, “National park” (an aggregation of “LandUnit”) was added.

The model spatial interface was modified according to the players’ requests, particularly to allow the simulation of possible future scenarios of interest to them, and is displayed in Figure 7.5. A new pictogram for “ruzi pasture” was added to the legend to represent their preferred forage species. National park boundaries, reforestation plots of different ages and pilot experimental plots proposed by foresters were also inserted on each side of the simplified virtual landscape to reflect the multiple use of land. The scale of a cell was also changed from 3.2 ha to 1.6 ha to adjust the gaming tool to a lower number of participating herders.

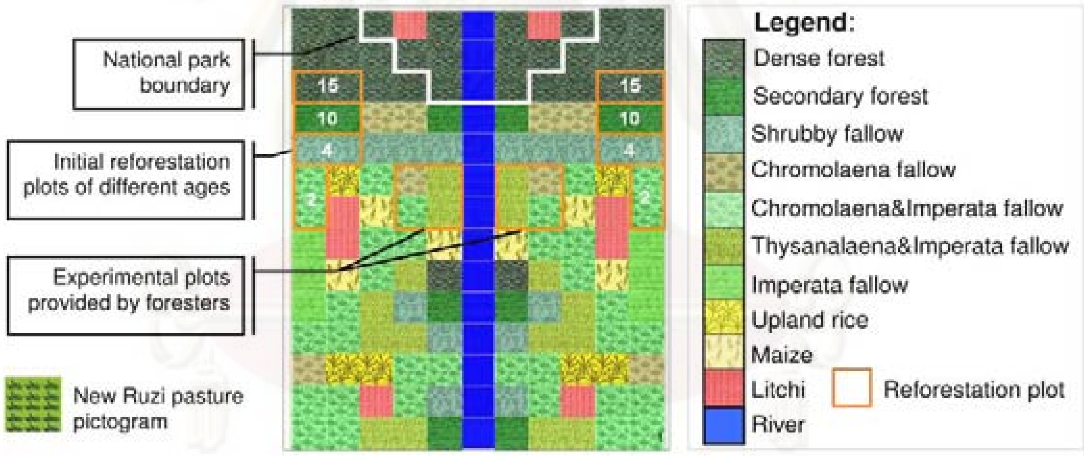


Figure 7.5. Modified spatial interface used in the second version of computer-assisted Role-Playing Game.

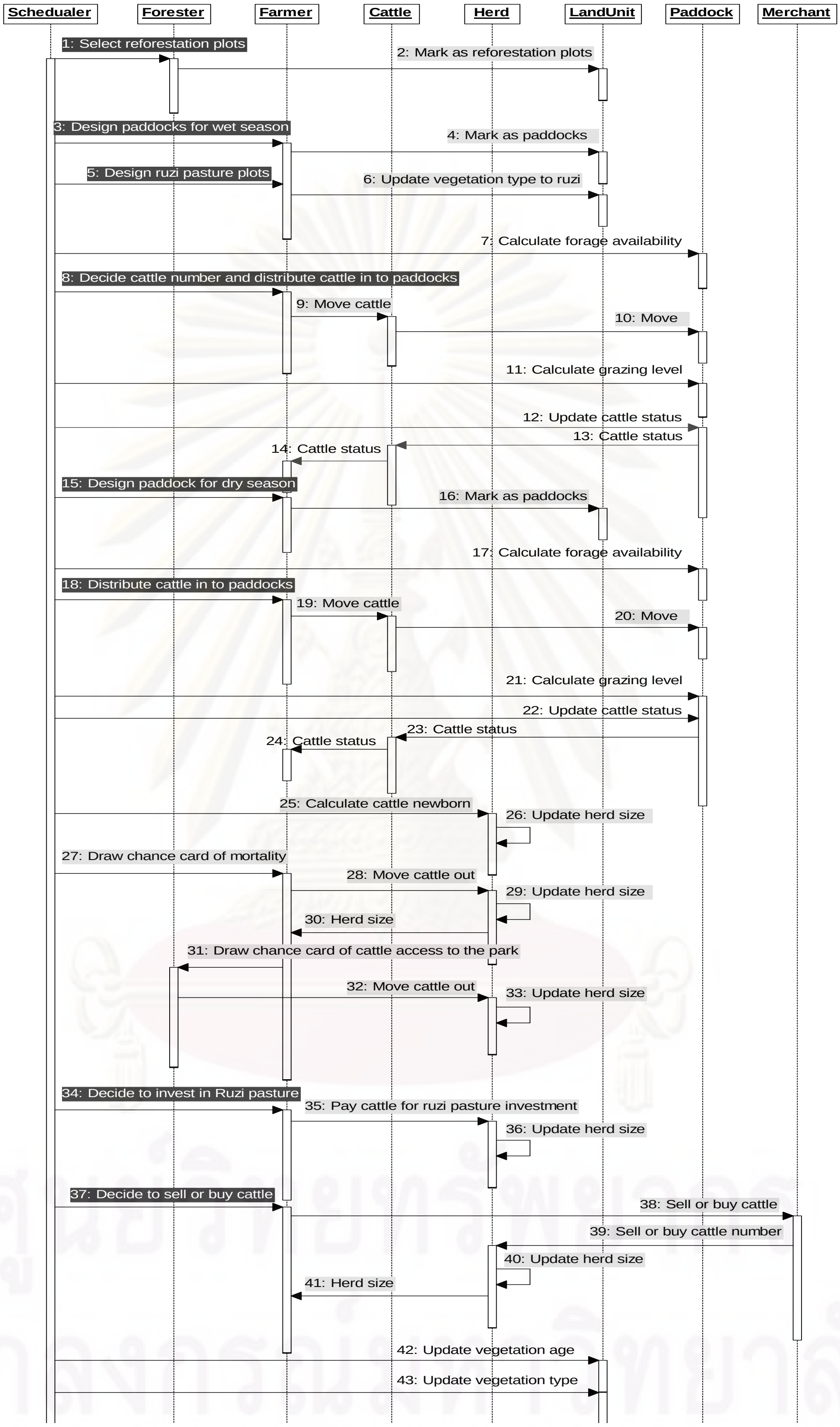
Process overview: the cRPG-V2 proceeded in seasonal time steps, with a first wet season at initiation followed by a dry season before the next wet period. This change was requested by the herders because they want to test seasonal paddock rotation technique. Moreover, the reforestation plots and the ruzi pastures can only be established during the wet season in reality, while cattle are usually sold during the dry season, when the lowland market demand is driven by the New Year festival.

However, one round of play in a gaming session corresponded to one full year because many decisions such as the selection of the location of reforestation plots, sales and purchases of cattle, and updating vegetation states in the computer were still made once a year. The successive phases in each round of play were similar to the ones already described for cRPG-V1. Only the “select paddock” and “ruzi pasture plots” steps were added (see details in the description of the herder sub-module below). The gaming scheduling is shown in the UML sequence diagram in Figure 7.6.

7.3.3.2. Design concepts of the cRPG-V2 tool

Like in the previous version, individual or collective management of herds, adaptation and interaction, and stochasticity concepts still exist in this second version.

Observation: Maps showing the changes of the virtual landscape on a year by year basis were made available to the players, individual herd size and cattle status were the indicators used to observe the results of players’ decisions during the simulation of each scenario. During the gaming and simulation sessions, two graphs produced with the Microsoft Excel package dynamically linked to the CORMAS were presented to players to observe the development of the cattle status and the vegetation cover in the landscape.



Note: Activities with black background are decisions made by the players. Those with grey background colour are completed by research assistants, and the other ones are managed by the computer.

Figure 7.6. Diagram showing the successive decisions made and actions taken by each model entity in the second version of the computer-assisted Role-Playing Game.

7.3.3.3. Details of the cRPG-V2 tool

Initialization: The number of players was calibrated for six herders or lesser (managing a total of approximately 60 heads of cattle). The national park occupied 15 cells at the top of the virtual landscape. Reforestation plots of 15, 10, 4 and 2 years age were also initially demarcated in the virtual landscape, as shown in Figure 7.5.

Input: This version has no input.

Sub-models: The four main modules still exist in this version of the model.

a) Vegetation dynamics module: This was improved by allocating forage availability values in the wet and dry seasons to each land unit and using this information to update the cattle status in CORMAS. A set of forage regeneration rules was attributed to each type of vegetation (see the full list of parameters in the description of the final ABM below in chapter IX).Forage dynamics related to seasonal variation (forage in wet season is higher than in dry season) and present and past grazing level (method to record grazing pressure was coded in CORMAS). It was simplified and posted on a figure displayed on a bulletin board in the gaming room and explained to the participants before the first gaming session. As mentioned above, the ruzi pasture state was introduced in this model as presented in the state transition diagram (Figure 7.4). Information on forage availability in the wet and dry seasons was calibrated based on the results from our plot level ecological study, and the literature (Phaikaew *et al.*, 2003; Phaikaew *et al.*, 1996).

b) Cattle dynamics module: This was improved based on the players' suggestions from the first workshop. Changed rules and functions used in cRPG-V2 are shown in Table 7.2. Cattle reproduction function was coded in CORMAS based on the status (fat, normal or thin) of the reproductive animal. Research assistants still needed to update the herd size and cattle mortality (deaths and losses) because of the added step of "drawing a chance card for cattle trespassing into the park" for herders rearing cattle close (distance of two cells or less to the park boundary) to the park boundary (Figure 7.5). This step was added following a request made by the new NNP players in the sensitizing and testing activities. As trespassers were allowed to negotiate the punishment with the NNP rangers, this step offered an opportunity for the herders to communicate and share their opinion with NNP officials.

c) Forester module: No major change was made from the previous version. In the first step of each round, the foresters selected two cells to establish new reforestation plots.

Table 7.2 Rules and functions used in the implementation of the cattle dynamics module in the second version of the computer-assisted Role-Playing Game.

Methods	Cattle Status	Function
Reproduction	Fat/normal	$y = 0.0014x^2 + 0.3643x$
	Thin	$y = 0.0027x^2 + 0.1665x$
	Herd size	**Proportion of chance card used (total = 10) *** (Number of cattle lost , number of cards)
Mortality (without ruzi grass)	< = 25	0,2 - 1,4 -2,4
	26 - 40	2,2 - 3,4 - 4,4
	> 40	2,1 - 3,4 - 4,5
Mortality (with ruzi grass)	All	0,4 - 1, 2 **
Loss due to the National Park fine ***	All	0,4 - 1,2

Note: ** A small herd has a lower risk of mortality compared to a large one, and the risk of* mortality (death and loss) in large herds was improved based on players' suggestion.
*** Mortality in ruzi pasture was set to be low because cattle do not need to walk far away to find forage. This reduces the possibility to encounter predators or to fall down on steep slopes.*
**** Only herders having paddock close to the park boundary had to draw this card. Herders were allowed to negotiate with park officials to avoid loosing cattle trespassing into the park.*

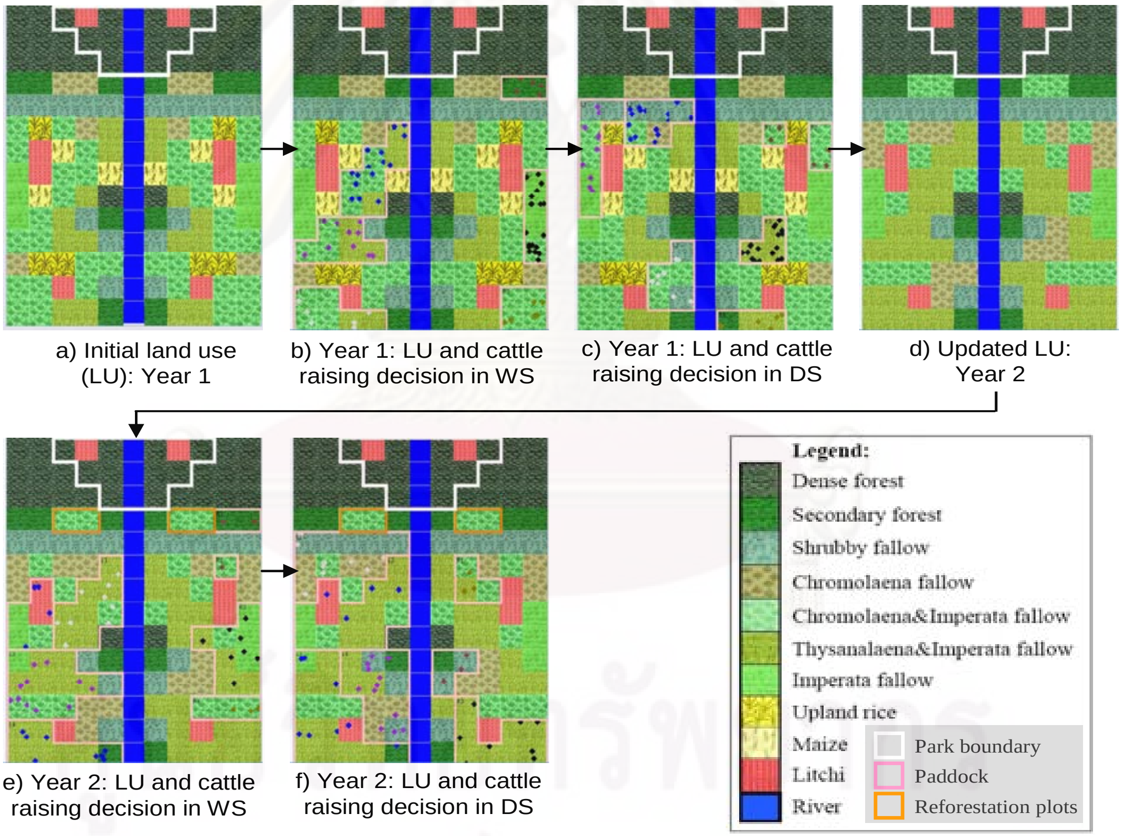
d) Herder module: The general concepts, such as individual or collective management, and negotiation with foresters, were similar to those implemented in the cRPG-V1. However, more herders' activities were added in this new version as follows. The selection of preferred paddocks had now had to be planned for two successive seasons (wet then dry) of a whole year. They also had to decide whether to rotate paddocks between the two seasons or not. If yes, blue and red markers were used to delineate the paddock used in the wet and dry seasons respectively. The wet and dry season paddocks could overlap if the herders considered that there was enough forage to cover their cattle needs in both seasons. If they decided not to rotate paddocks, a black marker was used instead of the blue and red ones.

Before deciding to sell or to buy cattle, the herders had to decide whether they needed to establish a ruzi pasture in the next year or not. In the gaming sessions, the cost of investing in a single 1 cell (10 rai = 1.6 ha) ruzi pasture was calibrated based on cattle price recorded in the farm survey. The herders needed to exchange one card of cattle with fat or normal status against two cells of ruzi pasture, and one card of a thin status animal for a one-cell ruzi pasture. Blue, red and black markers were also used to indicate the use of ruzi pasture for cattle grazing in different seasons.

7.3.4. Key findings from sensitizing and testing activities

7.3.4.1. What happened during the gaming sessions?

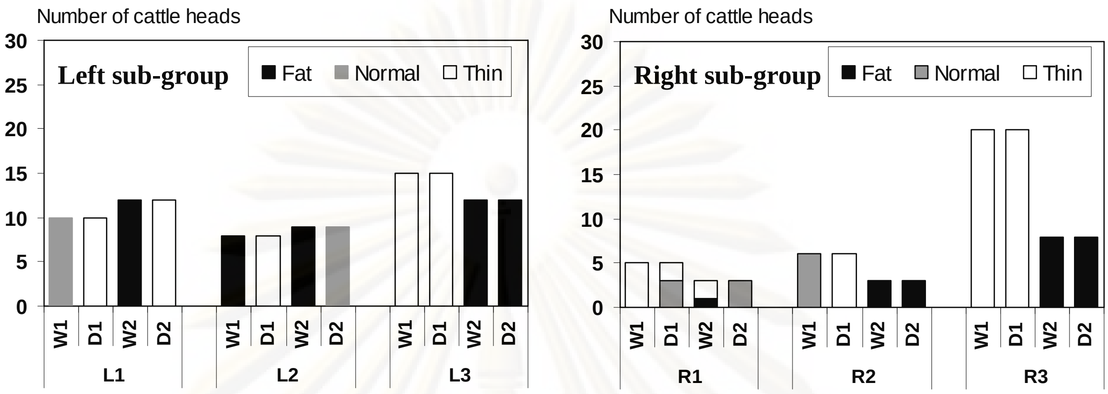
Because the NNP and NKU foresters were assigned to play the role of herders, the foresters faced difficulties to select suitable sizes of paddocks and appropriate land unit types to locate the paddock at the beginning of the first scenario and gaming session. For example, some of them selected a small paddock occupying only four cells but decided to have it grazed by 20 cattle which could not get enough forage to cover their needs. This demonstrated their lack of knowledge and experience regarding cattle raising (Figure 7.7b and c). But it was also a way for them to become more aware of the herders knowledge and decision making rules.



Note: Dots of different colours denote cattle owned by different herders.
WS: Wet season, DS: Dry season.

Figure 7.7. Dynamics of the virtual landscape based on the decisions (paddock location and size, size of herd per paddock) made by the two groups of foresters playing the role of herders under scenario one (Herders manage cattle individually with paddock rotation technique) before the second field workshop.

From the second round of play, the foresters had a better understanding of the gaming rules, especially the updating of cattle status. Therefore, all of them enlarged their paddocks to increase the forage availability (Figure 7.7e and f).

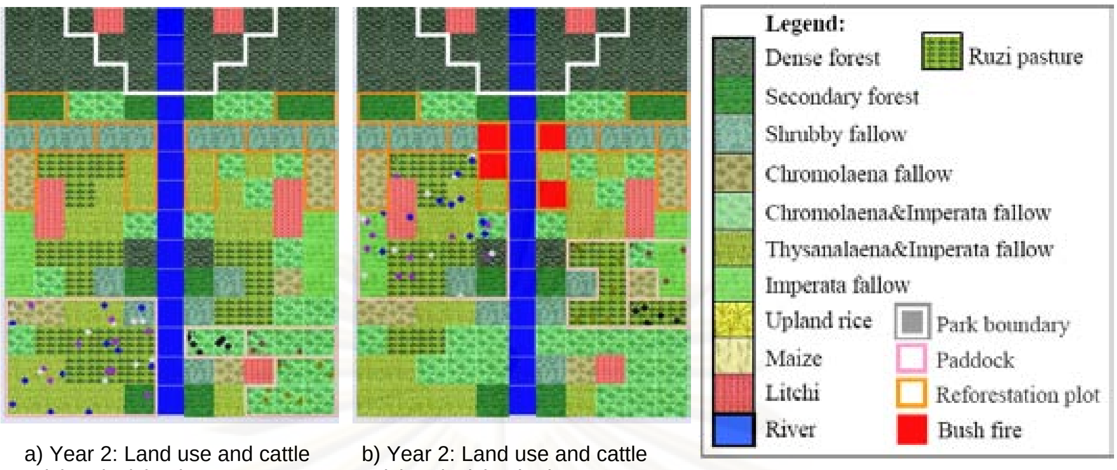


Note: L1, L2, L3, R1, R2 and R3 correspond to sixdifferent players, W = wet season, D = dry season.

Figure 7.8. Dynamics of cattle herd size and status based on the decisions (paddock location and size, size of herd per paddock) made by the two groups of foresters playing the role of herders during a testing activity based on scenario one (Herders manage cattle individually with paddock rotation technique) before the second field workshop.

Figure 7.8 shows the dynamics of cattle herd size and status during the simulation of the first scenario by two groups of three players each. In the first round cattle management was rather poor with a high proportion of normal or thin animals, especially in dry season. However, in the second round of play, cattle status improved significantly due to the larger size of paddocks.

In the afternoon session, three rounds of the second scenario in which “herders manage cattle with ruzi pasture and/or paddock rotation techniques” were simulated (Figure 7.9). We observed that all the foresters who played the role of herders showed interest in establishing ruzi pastures. They declared that by relying on ruzi pastures they may be able to reduce the size of their paddocks. Under this collective management scenario, the left sub-group decided to pool their cattle in a single paddock (Figure 7.9a), while the right sub-group discussed together but preferred to split their herds in different paddocks (Figure 7.9b).



a) Year 2: Land use and cattle raising decision in wet season

b) Year 2: Land use and cattle raising decision in dry season

Note: Dots of different colours denote cattle owned by different herders.

Figure 7.9. Example of the virtual landscape with paddocks, cattle herds and ruzi pastures assigned by the two groups (left and right of river) of foresters playing the role of herders under scenario two (Herders manage cattle collectively with ruzi pasture and/or paddock rotation techniques).

The occurrence of bush fire was also tested with these stakeholders, as shown by the red cells in Figure 7.9. The next vegetation state of these cells after fire was *Chromolaena* mixed with *Imperata* fallow and it was accepted by the new players from NNP. The vegetation dynamics over the whole landscape were difficult to observe through the three rounds of play. But the NKU foresters gave explanations to the new players during the gaming sessions so that the NNP officials understood the principles of vegetation change based on different factors.

At the end of the third round, it was found that the players from the left sub-group had a better understanding of the game features and rules as displayed by the animal status indicator in Figure 7.10. This was probably related to the individual performance of players because one of the players in the right sub-group was an old man (see on Figure 7.1, the man who wears the light blue jacket), and we found out that elders have more difficulties to catch the game dynamics.

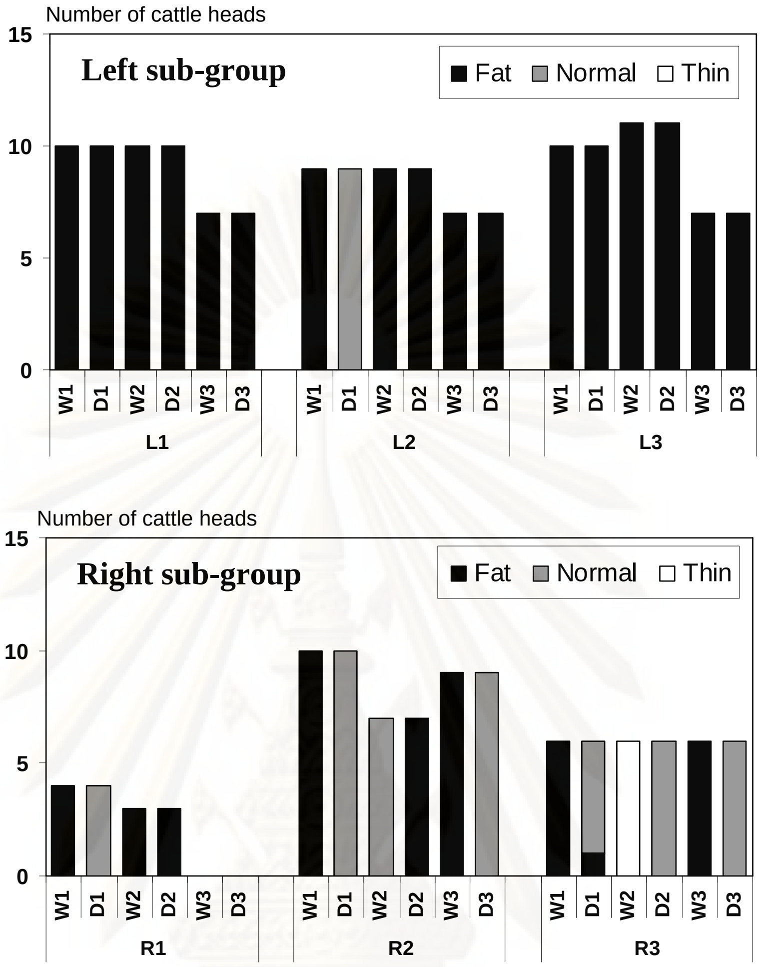


Figure 7.10. Dynamics of cattle herd size and animal status between two groups of foresters playing the role of herders with different management strategies under scenario two (Herders manage cattle collectively with ruzi pasture and/or paddock rotation techniques).

The players assigned to the roles of reforestation and national park ranger did not face any difficulty because of their knowledge and previous experience from the first workshop. No serious discussion occurred between the “herders” and “foresters” (all were actually government officials) during the gaming sessions. Moreover, no critical event, such as a lack of land, occurred during the gaming sessions that could have triggered a land use conflict between the “herders” and “foresters”. But the main objectives of these activities (to test the new version of the gaming and simulation tool and to sensitize the new NNP stakeholder) were achieved.

7.3.4.2. Outcomes from the plenary discussion

Five points were pointed to the participants during the plenary discussion. The first one was about the difficulty of the game. All the new comers from NNP said that it was not difficult to play but they needed one to two rounds of play first to understand how the gaming and simulation tool worked. The second point was the representation of the key features of the actual system to be managed in the gaming and simulation tool. All of them agreed that the simulation tool was already complex enough to represent the landscape heterogeneity and the cattle raising activity.

The third point was dealing with the players' decisions and learning during the gaming sessions. It was found that NNP officials played the game by following the rules and conditions explained by the facilitator. But they learned from the game because they had never actually practiced cattle rearing and so they acquired a better understanding of the difficulty of the herder's work. At the end, they mentioned the need to improve cattle rearing by establishing ruzi pastures for an efficient use of the limited amount of land and also to improve the quality of cattle carcasses. This observation was directly linked to the fourth point of discussion on the feasibility of implementing these new techniques in reality. NNP participants said that "it is impossible to establish pastures in the national park area. If the herders are interested they have to find available land by themselves." They also pointed to the fact that herders may not be interested in the ruzi pasture and paddock rotation techniques because they had been practicing an extensive cattle raising system for a long time. On their side, NKU foresters said that "their unit manager has a plan to find a piece of land managed by NKU to set up a pilot experiment with herders if they show interest."

Finally, the participants were asked to suggest some improvements in the organization and implementation of the gaming sessions before the coming second workshop with Doi Tiew herders. All of them suggested that new players should be allowed to practice for one or two rounds of play before starting the simulation of a scenario to familiarize themselves with the gaming features and rules. Moreover, NNP players asked to add a step of punishment for cattle trespassing beyond the park boundary as this actually occurs regularly in reality. If they can catch the cattle, the owner has to buy it back from them, otherwise the park will keep it.

7.3.4.3. Technical improvement for the second workshop

Beyond the suggestions made by the players, the game management team also observed the weak points of the proceedings during this full day's activity, especially that of time management. It was found that in each round of play, the time spent by herders to make decisions and the time needed to enter the players' decisions into the computer was too long to enable playing enough rounds of each scenario. It appeared necessary to introduce a regulation limiting the time allocated to players to make their decisions. Moreover, a longer explanation of vegetation state transition rules for the new comers was needed to ensure the same level of understanding of the vegetation dynamics.

7.3.5. Key findings from the second gaming and simulation field workshop

Eleven local participants showed up on the first day of the workshop. Only five herders (two type B and three type C farmers) were present because another invited type D herder had an urgent duty in Tha Wang Pha lowlands. To compensate for his absence, one herder was asked to manage two farms in parallel. Among these five herders, two were new participants in the ComMod process who were interested to join. The other six participants were government officials comprised of two NKU foresters, three NNP rangers and one DLD official.

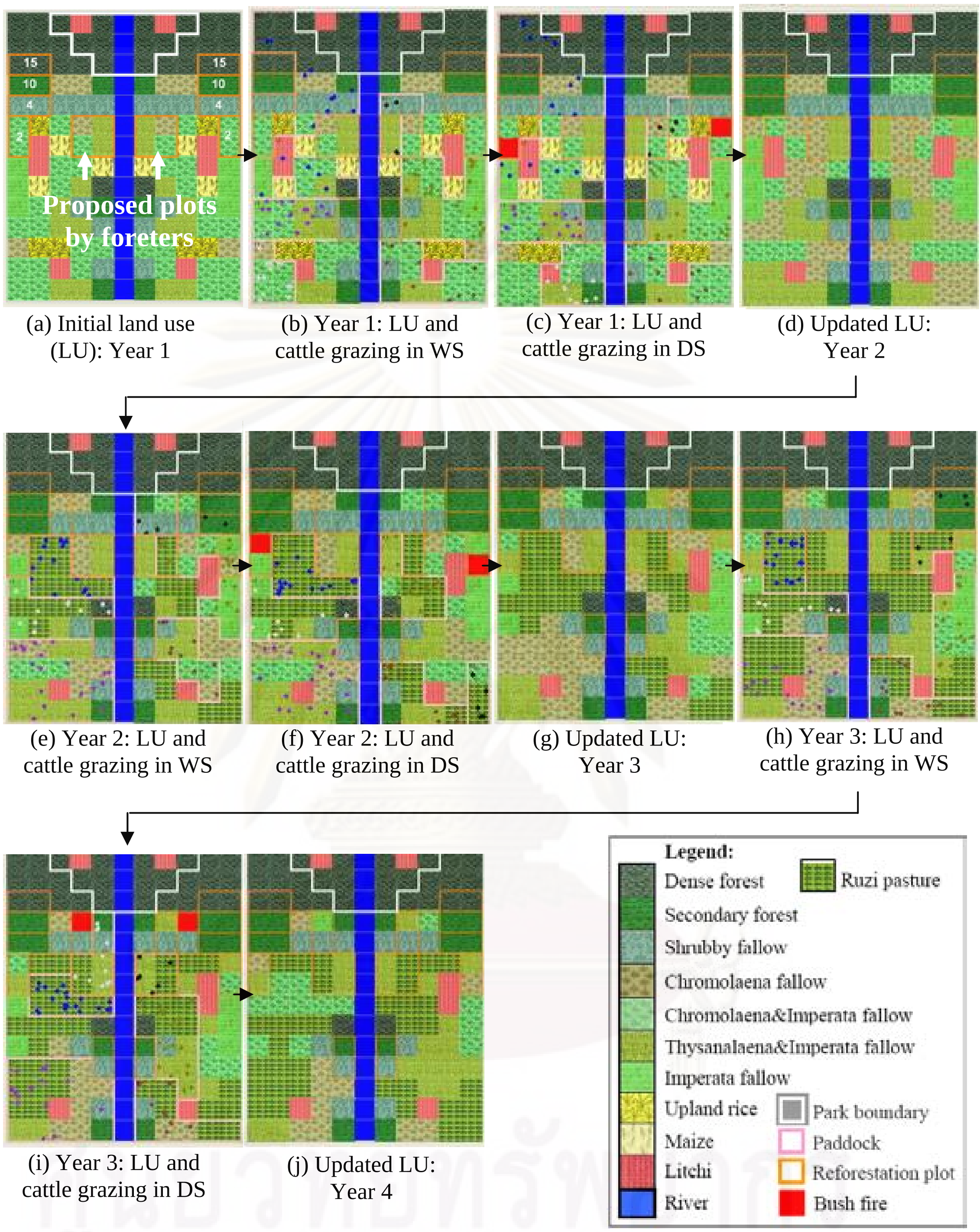
7.3.5.1. Herders interested in ruzi pastures and the plot proposed by the foresters

Three and four rounds of the two scenarios based on individual and collective management of the land and cattle were played respectively. In both scenarios, the herders and foresters could manage their herds and reforestation plots although the size of the landscape was reduced form the first workshop. It was observed that former players helped the newcomers play the game by giving explanations in Hmong language.

The herders in the left sub-group decided to set up initial herd sizes in the game according to the number of animals they rear in reality. Members of the right sub-group selected their herd size based on their wishes and one of them was assigned to manage two farms. These initial herd sizes were used in both scenarios so as to be able to compare their results. Like in the first workshop and in reality, the foresters selected new reforestation plots adjacent to the previous (especially young) ones. We found that, in both scenarios, the herders were more interested in the use of ruzi pastures in rotation than only paddock rotation. They also showed their interest in using the experimental plot proposed by the foresters.

Figure 7.11 shows the dynamics of landscape under the first scenario based on the herders' individual management of their herds. Right from the beginning of the gaming session, the herders discussed with NKU foresters on how to use the proposed piece of land as a paddock (Figure 7.11b, c). The foresters said to the herders that both "paddock rotation or ruzi pasture with rotation were allowed in the wet and dry seasons." They added that "if you rotate your paddock, you will have grass for two seasons as when you moved from one place to another, grass will recover and small seedlings and saplings will have more opportunity to survive." This conversation defined the management strategy to be used on the proposed experimental plot provided by the foresters. The herders accepted the foresters' request because they could have access to more grazing land.

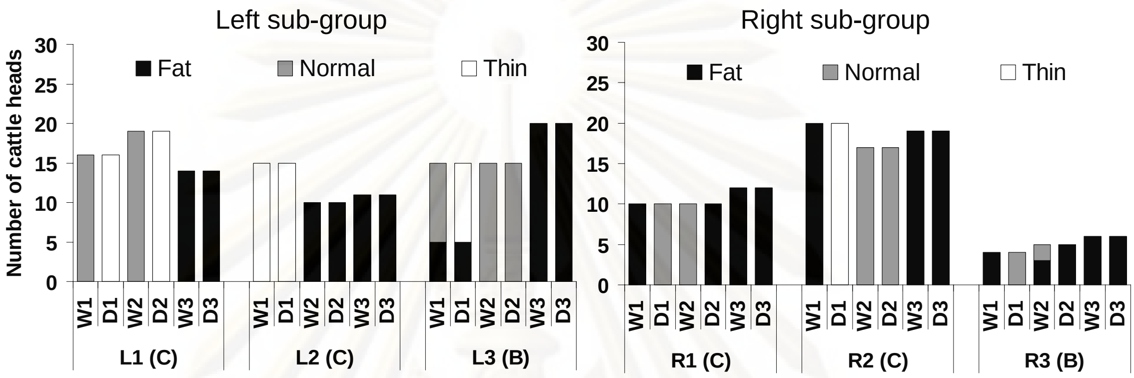
In the second round, four out of five herders started to establish ruzi pastures and used them alternatively between the wet and dry seasons (Figure 7.11e, f). They believed that this could improve the cattle status within small paddocks. The type C herder who did not establish any ruzi pasture in this round said that he thought that there was enough grass in his paddock to satisfy his herd needs (Figure 7.11d). However, he decided to establish a ruzi pasture in the third round (Figure 7.11h, i) due to the domination of a *Chromolaena* based fallow in his paddock (Figure 7.11g). From these results we can identify two reasons leading to the decision to establish a ruzi pasture: i) when herders need to graze a limited area and ii) when forage availability on the land is degrading. We observed in the sessions that the *Chromolaena* fallow was seen as the preferable vegetation type to be converted into a ruzi pasture.



Note: Dots of different colours denote cattle owned by different herders.
WS: Wet season, DS: Dry season.

Figure 7.11. Landscape, paddocks, cattle grazing and vegetation dynamics between two groups of herders (left and right) during the simulation of scenario one (Herders manage cattle individually and a common landscape with foresters) in the second field workshop.

Differences between the cattle status of the two sub-groups are illustrated in Figure 7.12. In this workshop, this indicator was presented to the players at the end of each year for them to better understand its relationship with their decisions and practices. The total cattle population of the left and right sub-group were 45 and 34 heads, respectively.



Note: W = wet season D = dry season, Numbers after "W" and "D" indicate round (year) of play, "L" and "R" indicate herders playing in the left or right sub-groups with their farm type in brackets.

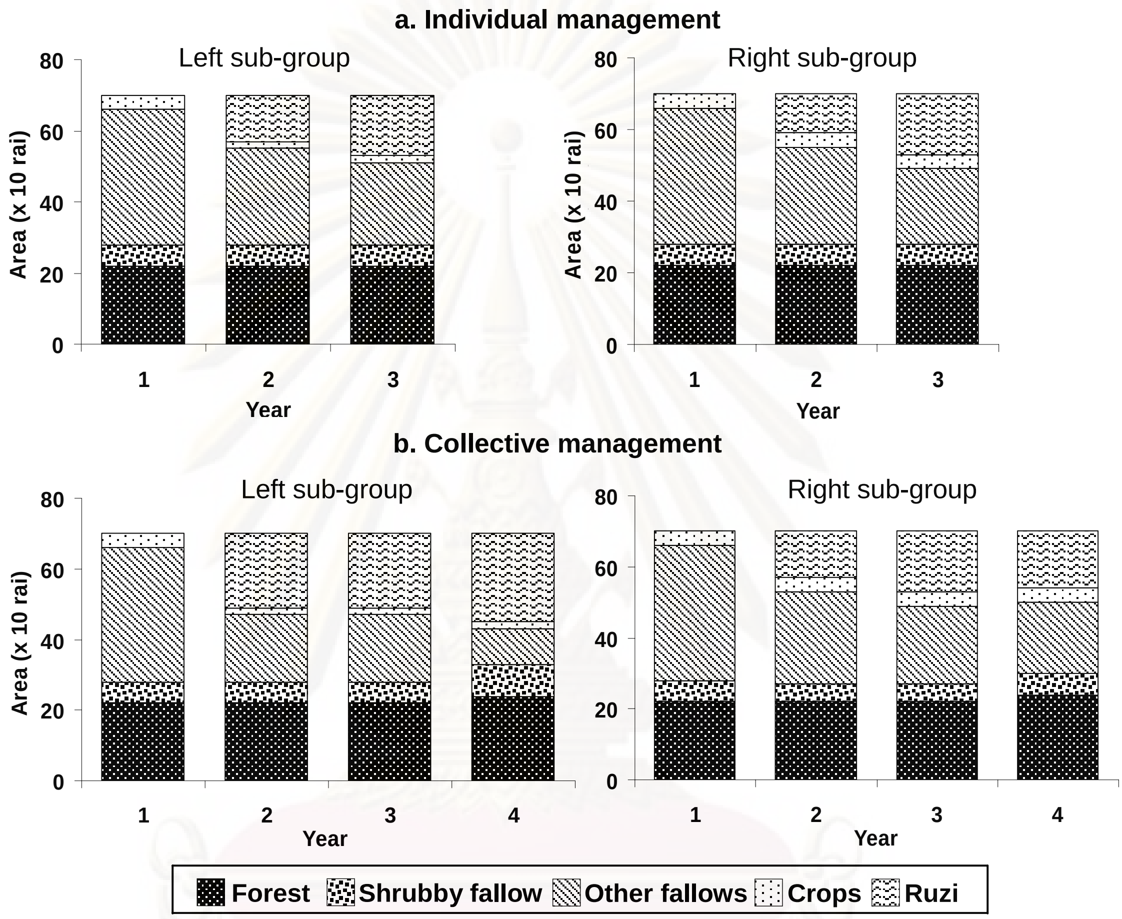
Figure 7.12. Dynamics of cattle herd size during the simulation of scenario one (Herders manage cattle individually and a common landscape with foresters) between two groups of herders in the second gaming and simulation workshop.

In the first dry season the status of many animals were thin or normal because the forage availability was lower. Herders said that it looked like the situation in reality as cattle usually loose weight in the dry seasons. The year after, herders (excepted L1) invested in ruzi grass production to increase the forage availability. As a result, the status of these herders' animals improved to normal and fat categories since there was enough forage in the dry season.

7.3.5.2. Advantages of collective management of the grazing land

In the second scenario, herders could discuss within their sub-groups. When the left sub-group decided to pool their cattle, the right one decided to distribute their herds separately in the landscape. Their arguments were that "we raise different breeds of cattle and therefore we do not want to pool them." This showed that, beyond the game rules explained by the facilitator, the herders imported more cattle management aspects based on their own real experiences.

After simulating the different modes of communication among them, the herders learned that the collective management of cattle allowed a more extensive establishment of ruzi pastures as seen in Figure 7.13.



Note: Forest = Dense forest + secondary forest cells; Crops = Upland rice + Maize + Litchi cells.

Figure 7.13. Land use dynamics according to two modes of communication among herders simulated by two groups of herders in the second field workshop.

Figure 7.13 shows the land use dynamics based on the two scenarios. In the collective management mode, the left sub-group established a large area of ruzi pasture as soon as it was allowed in the second year of the simulation by sharing the cost with their cattle to invest in forage production. On the other hand, fewer plots of ruzi pasture were observed in the second year in the right sub-group due to the separation of paddocks. It made the herders hesittate to barter their own cattle cards for ruzi.

7.3.5.3. Interactions among diverse type of participants

The herders communicated with the NKU foresters to use the proposed experimental piece of land, but they also negotiated with the NNP players during the step of drawing chance card for cattle trespassing into to the park. But that negotiation was not successful as NNP officials took possession of an animal from the herders when the "cattle trespass into the park card" was drawn. As observed in reality, this confirmed the willingness of NNP officials to implement the law without flexibility. In order to avoid having to pay this fine, the herders avoided locating their paddocks close to the park boundary in the further rounds of play as shown in Figure 7.11e.

Regarding the communication between DLD representative and herders, the DLD representative was seen walking to the tables of both sub-groups of herders during the gaming sessions to observe how they made their decisions and to share his knowledge about the cattle market with them. He also encouraged the herders to continue to raise cattle with the following argument: "cattle raising is a profitable activity to save money, the market demand in the lowlands is increasing as well as government support to this activity." He also said to them that "extensive cattle raising is not suitable in the current situation because this village is surrounded by several conservation areas. New techniques such as cut and carry forage and artificial pasture are important." At the end of the gaming sessions, he said that if herders needed ruzi seeds, a group of 4-5 herders could write a note to his DLD office to explain their needs for forage seed and he would provide the seeds for free. This kind of discussion showed that in this workshop as in reality, the DLD official wanted to play a technical role with the herders. This DLD official also talked to NKU and NNP players about collective management of the land saying that "the villagers need help from government officials to improve their livelihood, therefore the law may not be enforced strictly; although this area is being protected, in many areas, cattle help to reduce forest fires." He also declared that "negotiation with villagers to manage the land is important." NNP officials answered that the final decision depended on the park manager, but that the rangers have to enforce the park law. The NKU forester said that his manager already attempts to help villagers and it could be good if the DLD office could help in term of technical support. Based on these inputs from the

DLD official, we could see that he was an important indirect stakeholder to be further involved in the implementation of the collective action plan after the workshop.

7.3.5.4. Co-design of an action plan during the plenary discussion

The proceedings of this second round of gaming sessions supported the stakeholders to share their opinions on how to demonstrate and actually practice the proposed new cattle raising techniques. In the final plenary discussion, several topics were discussed and negotiated to set up a co-management action plan as follows:

Co-management action plan: Central to this plan was the decision to set up a 10 ha pilot plot of ruzi pasture to be grazed, on a rotation basis on a piece of land provided by the NKU foresters.

Location: A NKU player who participated in several ComMod activities said that the "NKU manager has already decided the location but he still needs to discuss with herders whether it is suitable or not. If not, a new location will be provided." The rigid NNP players reminded him to "make sure the plot is outside of the park boundary to avoid the problem with the park law."

Forage seeds: Ruzi seeds will be provided by DLD, but a formal letter was required to justify the request. After that, it would take two to three months to get the seeds.

Budget related to this activity: NKU foresters said that their unit will use a budget from NKU to buy the barbed wire to build the fence. However, if it is too costly, bamboo will be used. Moreover, NKU will support land preparation by heavy machinery.

Labour: The herders will provide labour to build the fence and for land preparation.

Cattle: cattle from two herders will be available for grazing this pasture when it is ready. As this is a pilot plot, different densities of cattle will be tested for co-learning of the effects by herders and foresters, with technical support from the DLD.

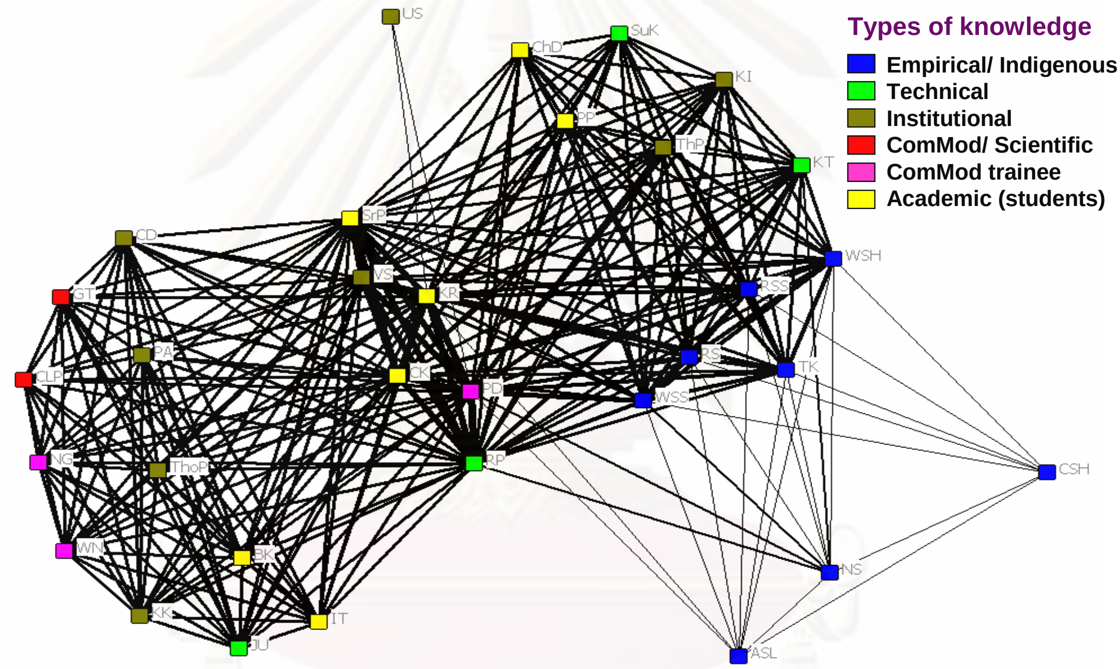
Water supply: the maintenance of the pasture may need a large amount of water. NKU forester said that this topic, linked to the location of the plot, still needs to be discussed with the NKU manager.

Facilitator: The participants requested the research team to pursue the facilitation of the process as this is a first co-management project between foresters and herders following years of land use conflict. Therefore, it is still difficult for them to completely trust each other. This is why, for both herders and foresters, the involvement of researchers is important and this request was taken into account when planning the continuation of the ComMod process at this site.

7.4. Lessons learned from the second ComMod sequence

7.4.1. Knowledge and perceptions sharing among stakeholders

This second sequence of ComMod activities allowed sharing and integration of diverse types of knowledge among stakeholders as shown in Figure 7.14.



Note: Line thickness is proportional to time spent interacting.

Figure 7.14. Exchange of different types of knowledge among the participants in the second sequence of the ComMod process.

Most of these exchanges occurred during the field workshop where the intensity of communication was high. Exchanges of perceptions and improved coordination among local stakeholders, particularly herders and foresters, were achieved through the gaming sessions and plenary discussion. Among local stakeholders, empirical knowledge of individual herders was transferred to their neighbours through discussions and the observation of players' behaviour, especially in the collective management scenario when they shared cattle to cover the cost of establishing a common ruzi pasture. Technical knowledge on the pasture from the DLD official and institutional knowledge from the NNP representatives (even if it was limited in this latter case due to the rigidity of the rangers' behaviour) were shared. Based on each stakeholders' awareness of the urgency to improve cattle raising and land management techniques, and the results from the gaming and simulation sessions showing the benefit of ruzi pastures, they could move on to negotiate a practical co-management action plan to be implemented in reality.

7.4.2. Improved understanding of the system

This second sequence also allowed an improve ment in the representation of vegetation dynamics and decision making of local stakeholders as follows:

Vegetation dynamics: A final version of the vegetation state transition diagram was achieved through *ad hoc* validation by the herders and foresters and was used to improve the simulation tool. During the second field workshop, we observed that participants no longer had any questions on the vegetation dynamics. However, the interviews performed after the workshop showed that the herders were not confident in the dynamics of the ruzi pasture because of their limited empirical knowledge on this grass species. Thus, acquisition of the knowledge on ruzi pasture was required for the herders and this, particularly the technical aspects, could be obtained from experts, such as the DLD, whilst the future experimental plot in reality will help them to improve their experience and hands on knowledge.

Decision-making processes and practices regarding new cattle and land management: Although the new cRPG-V2 gaming and simulation tool was more complex than the tool used in the first workshop, new participants, such as the NNP official and two new herders, could still play and use it while improving their knowledge on cattle raising. Based on the results from the second workshop, it seems that the future trend of cattle management in this village could go into the direction of establishing artificial pastures to compensate for the limited access to grazing land because this looks acceptable to all the participants. The herders perceived that the rotation technique by itself could not provide enough forage for their cattle as new reforestation plots (two cells/round) and the risk of losing trespassing cattle to the park would increasingly constrain their rearing activity. Therefore, by investing in ruzi pastures they could use a smaller but more productive amount of land to fatten their cattle. The methods used to decide on the number of ruzi cells were also observed. We found that herders attempted to associate their stock with the forage production capacity of a single cell of ruzi pasture. Then, they tried to calculate the number of cells needed and the cost of investment. Many herders faced difficulty in calculating this due to their low level of formal education and so they requested the research assistants to help them. Others decided the number of ruzi cells by looking at the available stock to be exchanged to cover the investment cost. If they had very few cattle, they just exchanged one cattle card to maintain their stock. These observations provided new knowledge to the research team about the herders' behaviours and decision making rules that was later used to improve the autonomous ABM.

7.4.3. Local stakeholders' perceptions regarding the researchers' role

Since the start of the ComMod process at the Doi Tiew site, the final output of the second workshop created a better understanding of the role of researchers in the study area. Since the preliminary diagnostic survey and especially the initial individual interviews, many herders thought that the research team (including foreign researchers) may provide some funding to them, some cattle or introduce and promote new cattle raising techniques. This kind of perceptions could be found in many remote areas across Thailand where several externally driven development projects have been implemented and provided funding from outsiders for local activities. From the foresters' perspective, they thought that researchers just came to interview them and may work on an ecological study before going back to university to write the report and maybe provide some recommendations to them at the end. But at the end of the first field workshop, some herders and foresters understood that the researchers were attempting to make them talk to each other. While, after the second field workshop, both sides said that now they understood better why researchers came to work in this area. Foresters changed their previous perception to a new one described as "the researchers using a new tool for them to understand each other and to support communication and decision-making by helping them think about possible choices together." On the herders' side, some of them said that the researchers attempted to stimulate them to think and discuss problem together s as to find ways to improve the existing cattle system by themselves. Some of them said that the researchers helped them to mitigate the conflict with foresters.

This clearly showed that it was not easy for the research team to get the full trust from the local stakeholders because of their own strong initial perconceptions based on their previous experiences. In this case, two workshops were needed for the local stakeholders to better understand why researchers worked with them. This may be seen as a relatively high transaction cost, but it would be very difficult to reduce it.

7.4.4. Herders' requests regarding the continuation of the ComMod process

The herders saw the importance of communication, shared learning and gained other benefits from the use of the gaming and simulation tool[28]. Therefore, they requested researchers to conduct a third workshop with new players. There were two lines of requests. First, some herder-players wanted other herders to play the game and learn by themselves saying that, thereafter, it would be easier to create new collective management action at the village level if all the herders acquired the same understanding of cattle rearing and awareness of the importance and urgency to improve cattle raising techniques. They said that they had already attempted to explain to non-players what they had learned from the gaming and simulation sessions but those persons did not believe them. These former players said that "other herders should come to play the game. Then, they can learn by themselves about the difficulty to manage cattle in the near future as the forest is expanding, and to discuss with other persons to get new ideas. Then they will understand by themselves and so it will be easy to discuss this together to find a collective solution." The other request was about the inserting cropping and economic modules in the gaming and simulation tool,where they wanted to use it to learn how to better manage land planted with crops with other villagers. Researchers took their requests into account as necessary in an evolving ComMod process. However, as this stage was the end of the second year of my research, we needed to balance the research objectives and the herders' requests in the short term.

7.4.5. Possible technical improvements

Although the cRPG-V2 was improved and successfully used with local stakeholders to set up a co-management action plan, time was still needed for further improvement leading to a fully autonomous ABM. It was observed that steps like the

[28] More details regarding individual and collective learning along the ComMod process are provided in chapter 10.

input of players' decisions into the computer and those managed by research assistants, such as drawing chance cards and updating the herd size, were still time consuming. Therefore, we decided to further improve the cRPG-V2 tool towards a more automagted computerized version to be used with the herders in a third sequence of the ComMod process built on their requests.

7.5. Conclusion and next steps

The implementation of the second ComMod sequence demonstrated that the collaborative modelling process could improve the interactions among stakeholders leading to the design of a collective co-management action plan to mitigate the local land use conflict.

The type of gaming and simulation tool (cRPG) used in the process was adapted to respond to requests from local stakeholders to explore new cattle management techniques (paddock rotation and ruzi pasture) before experimenting with them in actual circumstances. The cRPG was flexible enough to be used with a different size of the virtual landscape and number of players. Moreover, it was not difficult to understand and use although herders' decisions were now made on a seasonal basis.

The results from the exploration of the different scenarios made during this second gaming and simulation field workshop led to the decision to establish a 10 ha pilot plot of ruzi pasture at the end of a plenary discussion involving diverse groups of stakeholders. However, the important role played by the research team as facilitator of the process was recognized by the local stakeholders and became clear to them. Even better, was that trust between foresters and herders may occur following the implementation of their concrete action plan.

Regarding further steps, the out-scaling of the ComMod process to new herders was requested by former players. They aimed to improve the non-players awareness of the urgent need to improve cattle raising by involving them directly in the ComMod activities. Therefore, the research team planned to improve the gaming and simulation tool in CORMAS toward a more computerized version to facilitate such an out-scaling phase.

CHAPTER VIII
FACILITATING MORE INTERACTIONS AMONG HERDERS AND INTRODUCING THE USE OF A COMPUTER SIMULATOR

8.1. Balancing herders' requests and research objectives

After the two previous ComMod sequences, the researchers were trusted to a higher extent by the herders than at the start of the process, and their interest was to use the gaming and simulation tool for sharing what they learned with their neighbours. As should happen in a ComMod process (Barnaud *et al.*, 2007), these requests from local stakeholders were taken into account but this time they needed to be balanced with our research objectives as time available for field work was coming to an end.

As mentioned before, improvements of the simulation tool were still needed, particularly to make its use more time efficient. But its focus was the representation on the interactions between cattle and forest management. Integrating a crop management module might significantly increase the complexity of the model, making its use more difficult to newcomers during out-scaling activities, and may also shift the focus towards other agricultural development issues. Therefore, to keep the model simple and easy to use, just one new step, called "growing upland rice", was added in the gaming sequence of the simulation tool. Upland rice was selected because it is still an important crop for home consumption in every household. Although this choice was only partially meeting the herders' requests, this new step may influence cattle rearing because more land will need to be shared to grow upland rice in the same landscape. The conversion of a piece of land to upland rice field may affect the farmer's decision regarding the paddock size.

This chapter describes the use of a new and more computerised tool in a third ComMod sequence of gaming and simulation activities. The main improvements of the tool are described. The new cattle and land management technique that emerged from its use is illustrated by the evolution of the simplified virtual landscape use in the gaming and simulation sessions. At the end of this chapter, the lessons learned during this phase of the ComMod process, including the advantages and disadvantages of this kind of tool, are discussed and the next steps of the process at this study site are finally presented.

8.2. Methodology

8.2.1. Adjustment of the gaming and simulation tool

The cRPG-V3 version was improved to be a more autonomous one by adding a cattle mortality function in the code under CORMAS. More details about cattle dynamics were added in the Excel table recording the computer simulation results. This table was used with the players during the gaming sessions to support their decision-making. However, two other steps were not coded into the computer. The first one was the “drawing of a chance card for cattle trespassing into the park” because its result (one head of cattle removed from the herd by NNP) affected only a few herders in the model. The second was “sell cattle to invest in ruzi pasture” because we assumed that the cost of seeds will be supported by DLD as agreed at the end of the second sequence. Another modification was the addition of a new “select upland rice fields” step after the foresters’ managed “select reforestation plots.”

8.2.2. Third gaming and simulation field workshop

Another two day field workshop was conducted with the herders only with two main activities: gaming and simulation sessions in the first day and plenary discussion among the players in the following day.

8.2.2.1. Gaming and simulation sessions

A three-hour session was conducted in the evening in late August 2009 when the herders were available after their daily farming duties. There were nine participants in the gaming sessions. Five of them were new comers.

The objectives of the workshop accommodated the need of both researchers and herders needs and were as follows: i) to use the cRPG-V3 model as a communication tool to facilitate shared learning, collective discussion and adaptive management capacity between former players and new comers, ii) to sensitize the herders to the use of a more autonomous version of cRPG, iii) to assess the use of the cRPG-V3 model with two groups of herders, comprise of former players and new comers, and iv) to investigate how to further adjust it to match the needs related to its future use.

The session was implemented in four main phases. In the first phase the new comers were briefly interviewed to assess their farm type based on their stock of cattle only. The second phase was a presentation of the vegetation state transition diagram and of the outcomes from previous activities, particularly from the two gaming and simulation workshops. Former players assisted the process facilitator to explain the vegetation dynamics in Hmong language. Then, the gaming features, rules and scenarios were introduced to the participants. Important information on how to play the game was provided to the new comers. The third phase was the gaming and simulation sessions themselves. The same two scenarios (individual and collective modes of cattle management) used in the second field workshop were planned to be explored with the herders. In each scenario, the first two rounds were simulated according to the baseline conditions (no technical innovation). Then, in the third round of play, the new ruzi pasture technique was introduced and the players were allowed to use it in the landscape. Finally, a plenary discussion was organized to assess the herders' perceptions of the simulation sessions and their wishes regarding the future of the ComMod process. Individual interviews of the players were carried out the day after to assess the learning points, difficulties met in using the simulation tool and to record users' suggestions on how to improve it.

8.2.2.2. Plenary discussion regarding the future of the village in day 2

At the end of the third gaming and simulation session, the herders preferred to conduct a debate among villagers who understood and acknowledged the importance of improving the current cattle raising system. They asked the researcher cum process facilitator to prepare a presentation of the results from the third gaming and simulation sessions for them to use it in the collective discussion. The research team accepted to facilitate this phase to observe progress made in their adaptive management capacity.

8.3. Results

8.3.1. Third version of the computer-assisted Role-Playing Game (cRPG-V3)

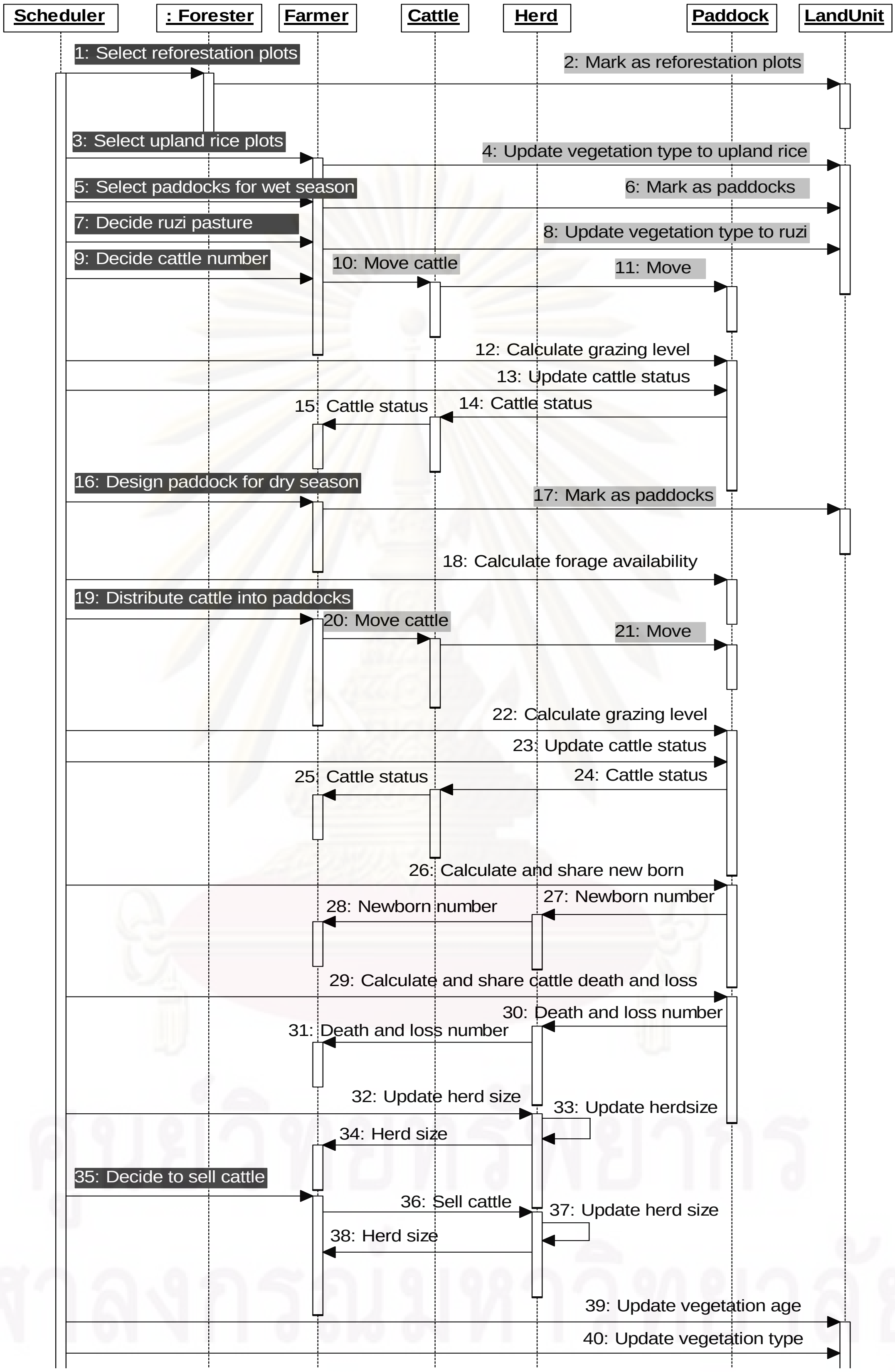
The modifications made in the simulation tool are explained in details below according to the structure of the ODD protocol.

8.3.1.1. Overview of the CRPG-V3 tool

Purpose: The cRPG-V3 was used as a communication tool for the collective learning and to improve the adaptive management capacity of the players. It was also used as a sensitizing tool to make herders familiar with autonomous computer simulations.

Modifications made in each module are provided in the section below. The spatial resolution in this version could be switched from one cell equal to 3.2 ha or 1.6 ha depending on the number of players. As nine herders participated in these sessions, the one cell was set to 3.2 ha was and this was explained to the players before starting the first gaming and simulation session.

Process overview: The cRPG-V3 operated according to seasonal time steps like the previous version. However, the “drawing a chance card for cattle trespassing into the park” and “sell cattle card to invest in ruzi pasture” were both removed and a “herders select upland rice fields” was added as explained above. The scheduling of a simulation run is shown in the UML sequence diagram in Figure 8.1.



Note: Activities with black background correspond to decisions made by real players. Activities with grey colour were implemented by research assistants, and other activities were driven by the computer.

Figure 8.1. Successive decisions made and actions taken by each model entity in the third version of the computer-assisted Role-Playing Game.

8.3.1.2. Design concepts of the cRPG-V3 tool

The cRPG-V3 tool shared similar concepts with the previous versions, cRPG-V1 and V2 tools.However, in this third version, the level of abstraction was higher during the gaming and simulation sessions because many of the activities that were formerly carried out by real players and research assistants were now coded in the computer.

Observation: Similar indicators of vegetation and cattle dynamics to those used in cRPG-V2 were used to observe the results of players' decisions during the simulation of each scenario. During a simulation, the table showing the dynamics of herd size, number of newborn, cattle deaths and losses and sales of cattle, as well as two graphs showing the evolution of cattle status and vegetation cover in the landscape were produced with the Microsoft Excel package dynamically linked to CORMAS. These tables and graphs were presented to the players to allow them to monitor the results of their decisions.

8.3.1.3. Details of the cRPG-V3 tool

Initialization: This version used the same initial landscape as the cRPG-V2. The number of players was set to 10 herders.

Sub-models: Among the four main modules in the cRPG-V3 model, the following two were improved from the cRPG-V2 to make more autonomous.

I) Cattle dynamics module: This mortality function was programmed in CORMAS (Table 8.1). This function was calibrated based on the results of the use of the chance card during the second field workshop as they were accepted by the players. Cattle mortality (deaths and losses) in the case of "without ruzi pasture" was decided at random between the lowest and highest rate of loss. These minimum and maximum rates were equal to 0.09 and 0.15 multiplied by the herd size, respectively. In contrast, under the "with ruzi pasture" situation, cattle mortality was set to a very low level due to the assumption that as there was enough forage in a fenced grass field, so that the cattle did not have to move to risky areas.

Table 8.1. Cattle mortality function used in the implementation of the cattle dynamics module in the cRPG-V3.

Method	Condition	Function *
Mortality	Without ruzi pasture	From minimum chance: y = 0.09x, to maximum chance: y = 0.15x
	With Ruzi pasture	y = 0.03x

Note: * y = number of dead and lost cattle, x = total number of heads in the herd.

II) Herder module: it was modified by coding the methods for sharing newborns and sharing death and loss of cattle among herders who pool their cattle in the same paddock. The proportion of each individual herd size in the pooled herd was taken into account for these estimations. The decision to sell cattle was also implemented in CORMAS (see the decision rule used in the final ABM below in chapter IX). The method to purchase cattle was not implemented in CORMAS because, based on the results from previous field workshops, it was not an important activity for herders in this extensive cattle raising system. Moreover, at the beginning of the second round of play, the herders were now asked to select upland rice fields before the selection of their preferred paddock and the decision about the herd size. The number of cells allocated to upland rice production and to ruzi, and their respective locations were freely decided by the herders based on their needs to satisfy household consumption.

8.3.2. Stakeholders' participation in the successive activities

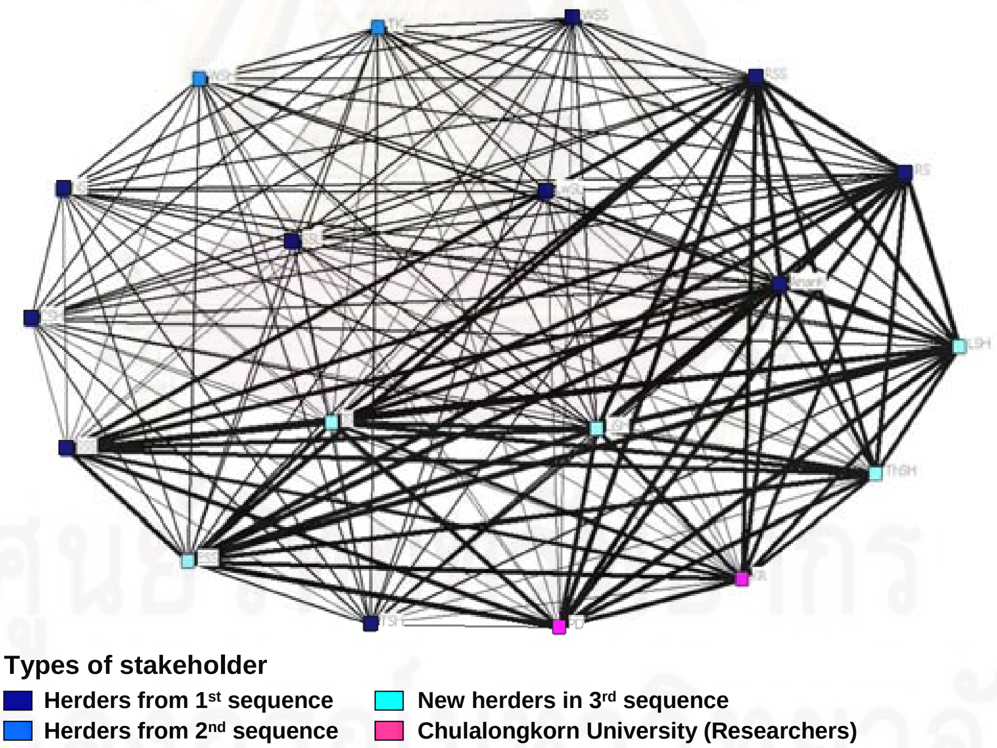
Although the third participatory modelling sequence was conducted with only the herders, there was a mixture of herders who had participated in the previous field workshops and new comers (Table 8.2). Five of the herders had never participated in any ComMod activity. Among the others who had participated in gaming sessions before, some came to play the game again because they wanted to learn more about cattle management from this simulation tool, while others were mostly interested to discuss about the future of the village in the second day, during the debate prepared by the herders who participated in the first day sessions. This diversity of participants supported the notion that the ComMod activities implemented so far provided some advantages for the herders, especially the former players who still showed interest to participate to the third ComMod sequence.

All together, a total of 17 herders participated in some activities of the third ComMod sequence. The intensity of the communication among them is presented in Figure 8.2.

Table 8.2. Number of herders in the third sequence with different levels of participation in the previous ComMod activities at Doi Tiew site of Nan Province, Northern Thailand.

Herders participation in the ComMod process	Third field workshop	
	Third gaming and simulation sessions (Day1)	**Collective discussion (Day2)**
No experience (new comers)	5	3
1st and 2nd sequence	2	3
Only 2nd sequence	-	2
Only 1st sequence	2	6
Total	**9**	**14**

Note: 17 and 5 herders participated in the first and second field workshops, respectively.



Note: Line thickness proportional to time spent interacting.

Figure 8.2. Intensity of communication among different types of stakeholders during the third sequence of the ComMod process in Doi Tiew village of Nan Province, Northern Thailand.

The highest intensity of communication in this sequence was between new comers and former players. They established the communication directly among themselves unlike during the first and second sequences when the research team played the role of middle man to conduct the activities. In this third sequence, new comers were very much active as shown by the high intensity of communication (Figure 8.2).

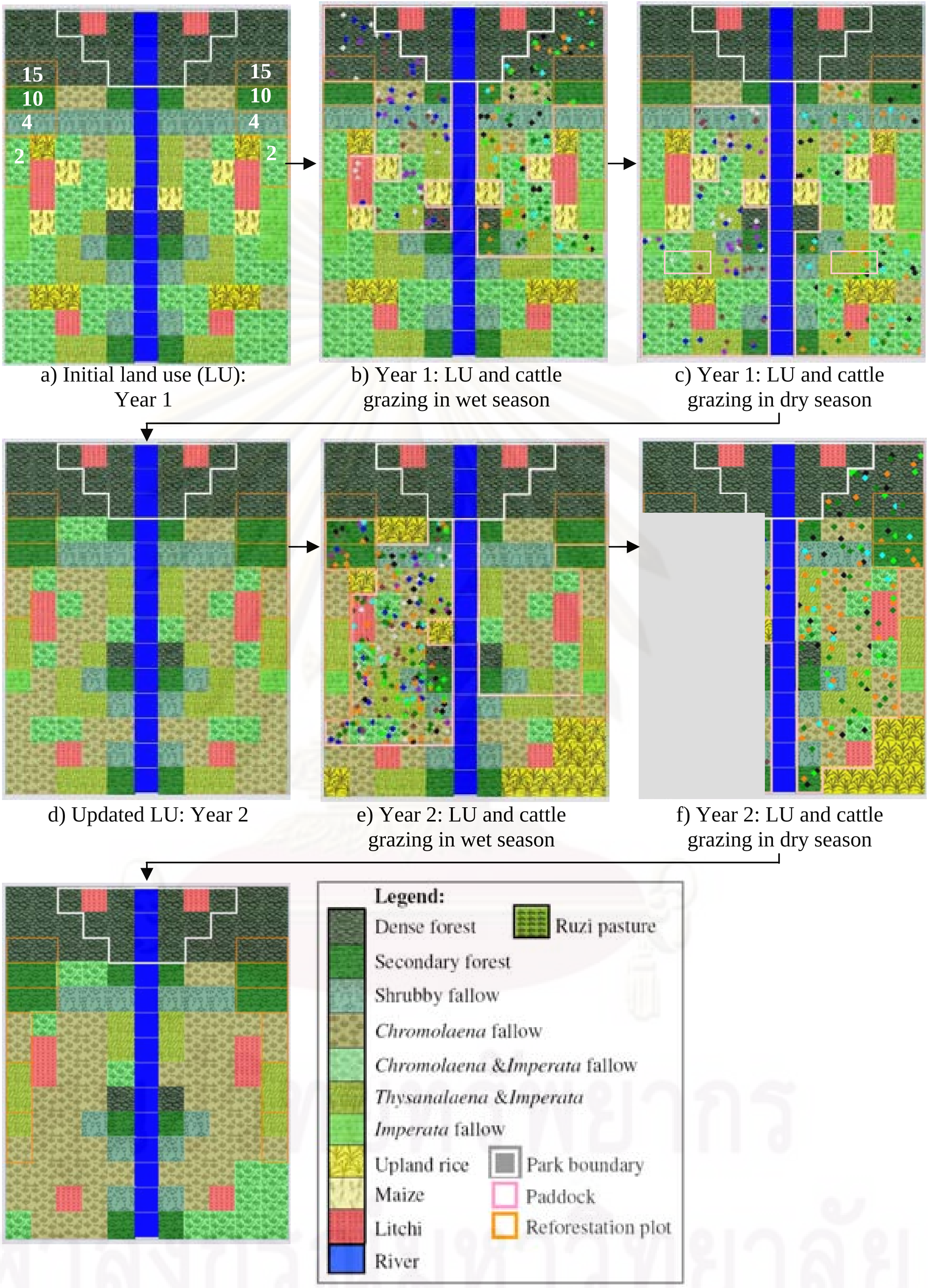
8.3.3. Findings from the third gaming and simulation field workshop

The third series of gaming and simulation sessions involved nine herders each with different experiences. Herders were divided into two groups, each comprised of comprising a mixture of different farm types, and with four and five herders in the left and right groups, respectively.

In the first scenario, the former players of each sub-group assisted the new comers to understand the gaming features, especially the representation of vegetation types and their dynamics, and how the computer worked. However, only two rounds of this scenario were played because the herders' interest in it was low. All the players discussed in Hmong language and a representative (a former player in the first and second workshops) declared: "Now the new comers understand the game. But the individual management scenario is not interesting to play. It looks like what they practice in reality and we know the constraints. So, we want to play the collective management scenario to discuss together." Then, they asked the facilitator to start the second scenario.

8.3.3.1. New emerging technique for cattle and land management

The landscape dynamics in the first two rounds (corresponding to four seasons) of play are presented in Figure 8.3. There were a total of 67 and 95 heads of cattle in the left and the right groups respectively. The individual herd sizes adopted by the participants during the gaming session were matching their actual herd sizes. Each group pooled their herds in a single paddock which was easier for them to manage.



Note: Dots of different colours denote cattle owned by different herders. In e) and f) show the mistake during the gaming and simulation session (see details in section 8.3.3.2).

Figure 8.3. Landscape, paddocks, and cattle grazing dynamics of two groups of herders (left and right) managing the land collectively in the third field workshop.

Interestingly, at the “selecting upland rice fields” step in the second round of play, the right group of players implemented a new land use technique by grouping the upland rice fields at the bottom of the virtual landscape because it was easier for them to create a paddock this way compared to a configuration based on scattered upland rice fields. They could also relate the size of the fields (number of cells) with their actual needs. Three of them selected two cells of upland rice saying that “we have many members in our households and one cell will not produce enough.” While in the left group, although they pooled their herds, they selected the location of their upland rice fields individually because at that moment they did not think that they could group upland rice field together.

8.3.3.2. Mistakes observed during the gaming session

In the second round of play, some disadvantages of using a computer simulation were observed. It was easy to miss inputs, especially to distribute the cattle in the paddocks, and a computer freezing problem occurred. In the wet season of the second round of play, the facilitator made a mistake by pooling cattle of all players into the single paddock belonging to the left group (Figure 8.3e). As a consequence, in the following dry season, the computer was frozen for several minutes before recovering. Finally, the capture of the landscape by the model was incomplete (Figure 8.3f).

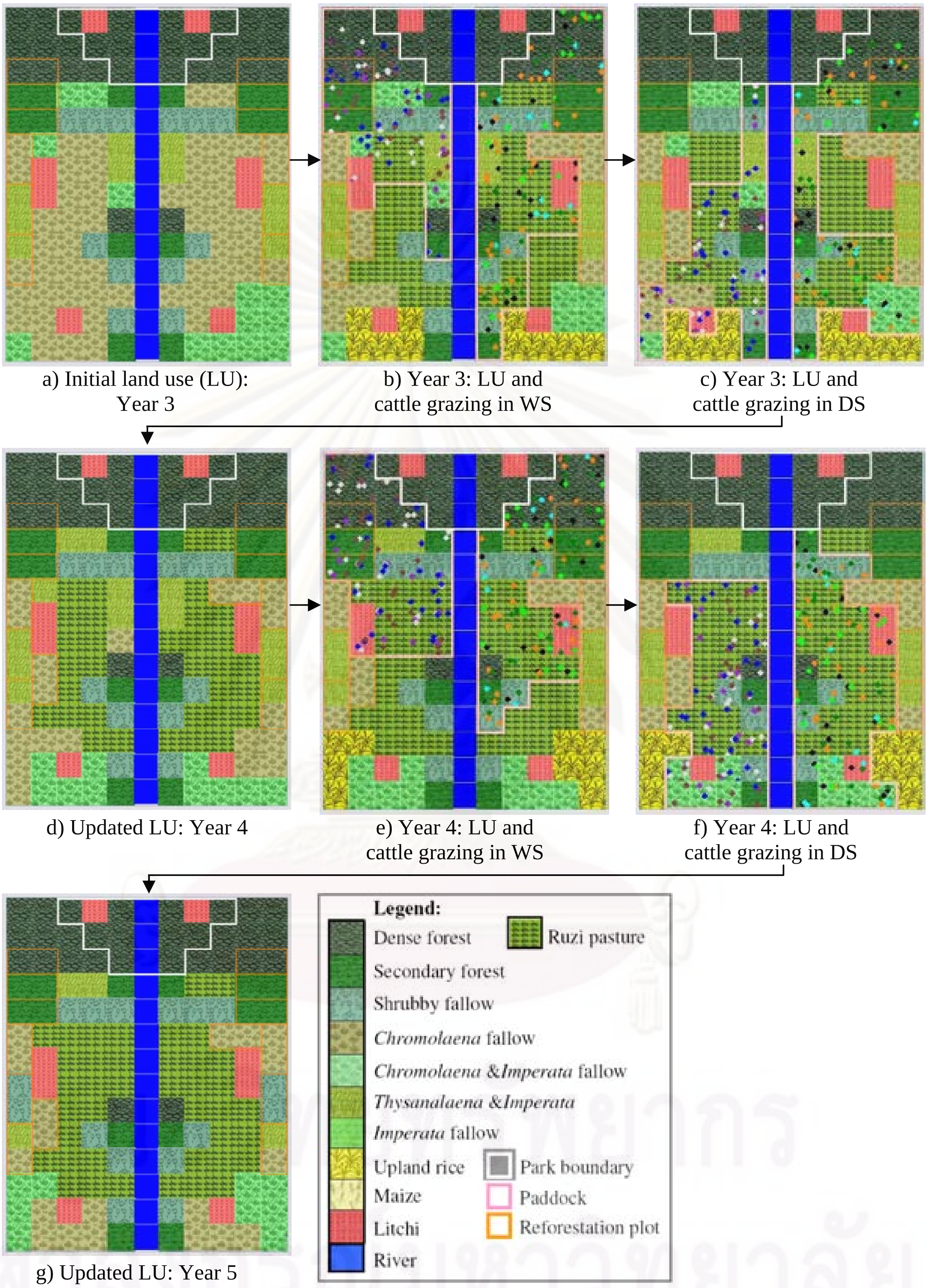
Regarding the first mistake, high cattle pressure occurred in the left group. As a result, the landscape became dominated by the *Chromolaena* fallow. However, this mistake allowed the facilitator to demonstrate the effect of high grazing pressure to the new comers and they agreed on the results. Then, the gaming and simulation continued by allowing players to establish ruzi pastures if they were interested to do so.

8.3.3.3. Herders became interested in ruzi pasture and upland rice zoning

Figure 8.4 displays the dynamics of the virtual landscape and the locations of cattle in the third and fourth rounds of play. The two groups adopted the ruzi pasture technique with rotation between the wet and dry seasons. However, there were minor differences between the two groups due to their different points’ of view: while the left group converted some *Chromolaena* cells to ruzi pastures because they took the labour requirements to establish pastures into account, the right group converted all the available *Chromolaena* cells to ruzi cells to secure enough forage and obtain good cattle status. These different decisions were discussed among them: the herders from the left group suggested to estimate the forage production capacity of a pasture before expanding it to secure good cattle status, and, by doing so, the paddock will be smaller. But the herders from the right group thought that they had a lot of cattle and that it was better to build a large paddock. As a result, each group decided to continue to apply their own strategies in the next round of play.

During the selection of upland rice fields, some imitation was observed as the left group also located its rice fields at the bottom of landscape like the other group. While in the right group, the herders reduced the total number of upland rice fields from eight to five cells (one cell per herder), herders who used to cultivate two cells of rice in the previous year said that “there is some rice production left from the previous year.” This showed again their capacity to relate land use in the virtual landscape of the gaming session with that of reality.

An even more interesting decision related to upland rice practices occurred in the fourth round of play. Both groups integrated their actual practice into the game by rotating their upland rice areas. They said that: “The land had already been used for growing rice for two years, so the soil fertility is reduced. Therefore, we have to find new areas that are more fertile.” This confirmed that, beyond the rules of the game explained by the facilitator, farmer-players integrated their actual farming knowledge and conditions related to both cattle and crop management into the gaming and simulation session. Unfortunately, the limited time available did not allow the facilitator to conduct more than four rounds. Therefore, this time, long term management of the landscape by herders could not be observed.



Note: Dots of different colours denote cattle owned by different herders.

Figure 8.4. Landscape, paddocks, and cattle grazing dynamics of two groups of herders (left and right) in the third and fourth rounds of simulation of their collective management of the land during the third field workshop.

8.3.3.4. Perceptions shared among participants during the plenary discussion

Several topics were discussed in the plenary discussion after the gaming sessions. The three key findings are as follows:

a) Assessment of a more abstract simulation and gaming tool: Because many steps were no longer directly handled by the players or the assistants as they were now coded in CORMAS, the game was a bit difficult to the new comers because they did not understand how the computer programme operated. They needed some explanations by the former players. After they were able to better understand and follow the simulation, and then the participants said they preferred to play with this new simulation tool because it allowed them to discuss, share opinions and learn new knowledge to manage their farming activities within shorter time. They also mentioned that most of the Hmong people do not want to participate in a very long activity, especially during the cropping season.

b) Herders' request to conduct a collective discussion with other former players: During the gaming sessions, we found that the herders were interested in the new idea of upland rice zoning. A type C herder who had participated in all three workshops said that it might be possible to implement this in reality. He suggested conducting a short meeting with former players who did not participate to this last workshop to present the results obtained and to discuss the possibility to put this new idea in practice. The players agreed and invited the former players the day after. They also asked the game facilitator to prepare the landscape maps obtained from the second scenario for their use in the discussion.

c) Ranking of suitable vegetation types for paddock and ruzi pasture: This is belonged to the research objective of preparing the tool to become an autonomous ABM. Herders were asked to rank the suitability of vegetation types for the establishment of paddocks and for ruzi pastures. To select a paddock, from the most suitable to the least suitable one they enumerated the vegetation types as follows: ruzi, *Imperata* fallow, *Thysanolaena* mixed with *Imperata* fallow, *Chromolaena* mixed with *Imperata* fallow, Litchi, shrubby fallow, *Chromolaena* fallow, secondary forest and dense forest. To establish a ruzi pasture, they considered that the most suitable vegetation type was *Chromolaena*, followed by *Chromolaena* mixed with *Imperata*, *Imperata*, *Thysanolaena* mixed with *Imperata* fallow and finally shrubby fallow.

According to them, the other types were too difficult to convert. This information was used to code the selection of paddock and the location of ruzi pastures in the version of the autonomous ABM.

8.3.4. Herders increased awareness of the need for collective management of farming activities

From the first workshop to the third one, a total of 24 herders (60% of the households rearing cattle in 2008 in this village) participated in the gaming and simulation sessions. Fourteen herders showed up to attend this final collective discussion. Some of them did not participate because they stayed overnight in their fields or had an urgent appointment. The four key findings from the debate were the following:

a) Implementation of ruzi pasture: Many herders suggested monitoring the experimental plot provided by the foresters so as to acquire information on the management of such pastures. Others suggested to test this technique in another area, such as the large piece of land managed by the village headman because it was big enough. Some of them suggested talking to the Royal Project to seek additional available land. Some technical points were also raised, especially the water supply, but they could not find a solution. Therefore, the facilitator suggested consulting the DLD expert on this topic.

b) Zoning of upland rice fields: Two main suggestions were made. First, some herders suggested inviting the non-herders to play the game to improve their understanding on the need for zoning. Then, the topic should be addressed again at the village level. Another suggestion was for herders having adjacent cattle grazing areas to discuss and test this technique.

c) Key persons to continue the process: The facilitator asked them to discuss about who in their village could become a facilitator, because it is important to think about the sustainability of the process. The herders agreed that the village headman, TAO representatives, and the village committee members should take the responsibility to continue the process because they have the authority to set up meetings and to contact government agencies if needed. The village headman and a committee member in the meeting said that they would accept this task. Regarding this, the monitoring by the researcher of what will happen is still needed.

d) Future use of the game: The facilitator allocated time to discuss the future use of the game with the herders. Beyond the use of the existing game with new participants, a type C herder suggested to build a similar game for maize management. He said that several villagers tended to grow maize but as the price was fluctuating, some smallholders were facing debt. Such a game could help them to learn more about maize agriculture in theory (*in silico*), before actually investing in planting large fields of maize in reality. He also explained that "if one fails in the (maize) game, like the ones with "thin cattle" that we have played, then they may deliberate more in reality."

In summary, topics discussed along the meeting proved that the ComMod process could increase the herders' awareness on the cattle and land resource management issue and make them learn about the importance of collective discussion and sharing perceptions. Nevertheless, the maintenance of this kind of communication among them was important to plan and to monitor.

8.4. Lessons learned from the third ComMod sequence

8.4.1. Improved understanding of the system

No suggestions to improve the vegetation and cattle dynamics in the tool were made in the third gaming and simulation field workshop. Regarding the decision-making processes and practices on cattle and land management, it allowed researchers to obtain the preferences of vegetation types for paddock and ruzi pasture establishment. Moreover, decision-making on cattle sales were verified. Although the herders pooled their cattle in a single paddock, they did not consult each other when selling animal to manage the whole population. Therefore, decision-making in the final ABM will be individual-based to reflect this observation.

8.4.2. Advantages and disadvantages of playing in front of the computer

The gaming sessions allowed the researchers to assess the cPPG-V3 tool:

Advantages: The cRPG-V3 supported serious discussions among the participants in a time-efficient way. It was also very promising for the future out-scaling of the process. By inserting a new step to "select upland rice fields" in the tool, a new land management technique, zoning of upland rice production, emerged and the players were eager to share it with non-players.

Disadvantages: During the gaming sessions, human mistakes and computer problems occurred. The interface used to input players' decisions should be improved with computer experts to limit the risk of error when inputing data. For example, the "undo" function would be important to insert in the model. Another problem that could happen in such remote areas is power cuts. During the stay of the research team in the village before conducting the third field workshop, there was no electricity for two days because of heavy rains and thunder storms. Therefore, the plan for field activities should be adapted to this constraint.

8.4.3. Possible methodological and technical improvements

Although the cRPG-V3 properwas enough to represent the cattle raising activity and useful to support collective discussion among participants, suggestions were made to further improve it as follows:

Time used to understand the gaming and simulation objectives and features by the participants: According to the herders' points of view, the full day Role-Playing Game sessions with more activities for them to interact and to decide provided a deep understanding of the simulation and allowed them more time for discussion between the two rounds of play. Therefore, the use of the game with new participants who never participated in the co-construction of the representation of vegetation dynamics is necessary to make them understand the transitions and successions of vegetation cover. This could be done by setting up a session for new participants to construct their own vegetation dynamics, like that which was successfully performed at the beginning of this ComMod process. Then, the different vegetation states could be compared with the validated version used in the model before conducting scenario explorations in front of the computer.

C*onstruction and use of an autonomous computer ABM*: Some 40 minutes were needed to simulate the second scenario in the third workshop. Therefore, it is still necessary to improve the tool toward an autonomous version to simulate several scenarios in a shorter time. By doing this, participants will have more time to compare and discuss the results like different landscapes produced by different land management strategies. Moreover, this ABM could also be used with other types of stakeholders, such as administrators or policy-makers who have only a limited time to play the long gaming and simulation sessions organized with villagers, or with different ethnic groups living near similar conservation areas and facing the same kind of land use conflict.

8.5. Conclusion and next steps

The third ComMod sequence demonstrated that the more autonomous computer tool could be used with herders characterized by a low level of formal education and partly served their request regarding the addition of crop management in the model. The continued participation of former herder-players from previous ComMod activities in successive simulation sessions and collective discussions (even around one year after the first workshop) showed that they were still interested in the ComMod process and wanted to use the simulation tool with more villagers. Toward such an end, an autonomous computer ABM representing the key decision making processes regarding cattle and reforestation management strategies was developed to be used for out-scaling this pilot study in the future.

PART III: FINAL SIMULATOR AND DISCUSSION

CHAPTER IX
THE FINAL VERSION OF THE DOI TIEW COMPUTER AGENT-BASED MODEL

This chapter presents the final version of the Doi Tiew simulator, which is a fully autonomous agent-based model, hereafter called DT-ABM. The DT-ABM simulation tool was completed by the researchers in the laboratory on the basis of feedback received from the participants and the insights gained by the research team during three field workshops using the many successive versions of the computer-assisted role-playing game. An autonomous ABM is more appropriate and efficient means to explore in a systematic and cost and time efficient manner to identify the management options and to allow the participants to refine (and so potentially optimise) these during a series of c-RPG workshops. The DT-ABM remains a simple model, including basic strategies for cattle management by the herders and tree plantation by the foresters. It allows the comparison of the results of four defined scenarios to investigate the effects on the viability of cattle raising and forest regeneration of the different possible combinations of two critical factors stressed by the participants: the use of artificial pasture (ruzi) and the collective vs. individual mode of cattle management. These scenarios were run for 10 years, a period long enough to observe the progression and succession of the tree-based vegetation cover, but not too long to require a module managing the inheritance of farms from one generation to the next. The implementation of the conceptual model was achieved with the use of the CORMAS simulation platform.

In this chapter, the final DT-ABM tool is first described by following the ODD protocol proposed by Grimm *et al.* (2006). The use of this model to run simulation experiments is then introduced by checking the coherence and consistency of the results obtained from two “constant (fixed) paddock scenarios.” The simulation of the four main scenarios derived from the local stakeholders’ main interest is then presented. An extra scenario is added to illustrate how new ideas are allowed to refine scenarios and may infuse into the DT-ABM simulator when used in an exploratory way. This is the kind of collaborative simulation process that could be carried out and further refined with the stakeholders in the near future.

9.1. Description of the Doi Tiew Agent-Based Model

9.1.1. Overview

9.1.1.1. Purpose

The DT-ABM simulator was designed for use as a communication and learning support tool between the researchers and local stakeholders, particularly the foresters and herders. However, at this stage of the collaborative research, and because of a lack of time, the DT-ABM was only used to explore those scenarios derived from the local stakeholders' propositions in the laboratory. The model incorporates the local stakeholders' and scientific knowledge obtained from the three sequences of the collaborative modelling process.

9.1.1.2. Variables and scales

The DT-ABM static structure, shown as a UML class diagram in Figure 9.1, is similar to the structure of the several versions of the c-RPG, except that to enable the representation of collective cattle management, a specific decision-making entity -"FarmersGroup"- was introduced. In collective scenarios, paddocks are managed at the group level: individual farmers only manage their cattle and all of them share the same paddocks whose selection is decided by the group.

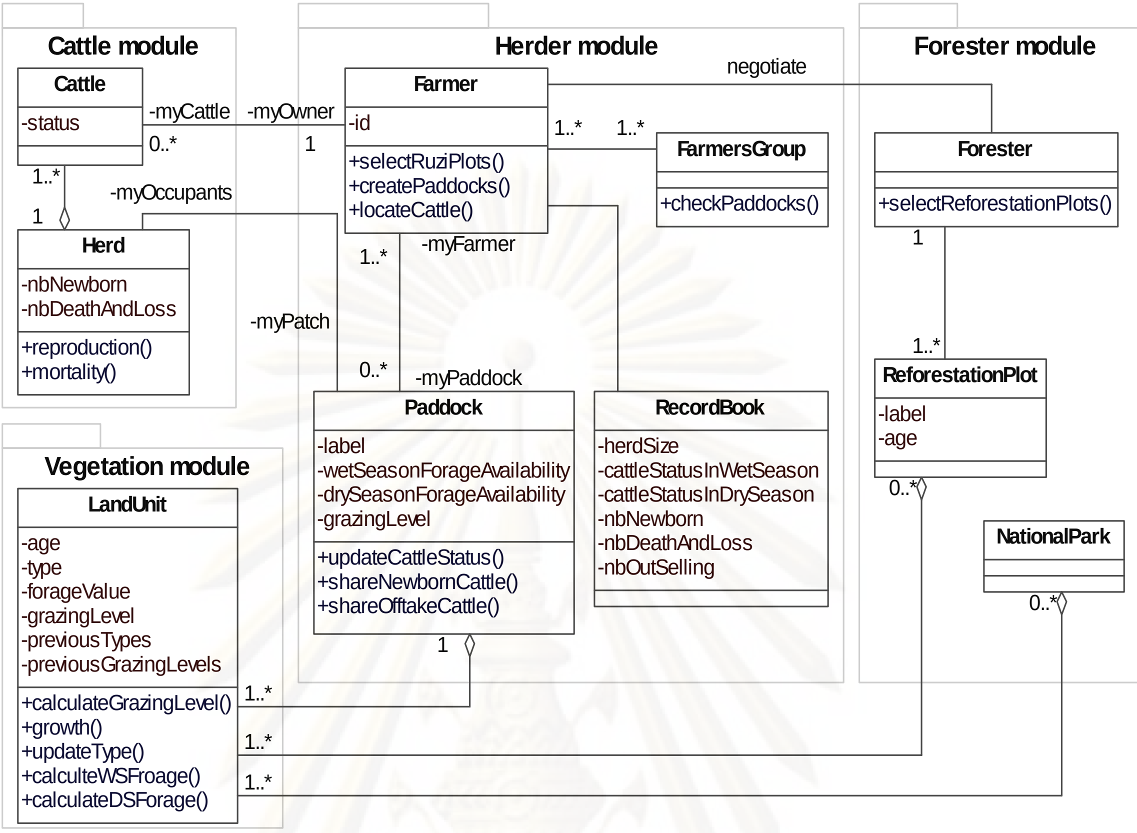


Figure 9.1. UML class diagram of the autonomous Doi Tiew ABM.

Table 9.1 provides details on all the parameters used in the DT-ABM. Some of them were calibrated based on the results of the field study conducted at the plot level, while other parameters, such as forage availability, cattle mortality and reproduction were derived from the literature. The duration of the transitions from a vegetation state to another one were all discussed and validated with the local herders and foresters.

Table 9.1. List and default values of parameters in the Doi Tiew Agent-Based Model.

Entity	Parameter	Default value	Unit	Source and main tool used
Land unit	Area (1 cell)	3.2	Ha	Author's survey
	Forage basic need of cattle	2	Forage unit/ season	
	Forage value for dense forest (DF)	2.4	Unit	Calibrated based on results of the author's plot survey, Phaikaew *et al* (1996)
	Forage value for secondary forest (SecF)	2.4	Unit	
	Forage value for shrubby fallow (ShFal)	4.8	Unit	
	Forage value for *Chromolaena* fallow (ChFal)	3.2	Unit	
	Forage value for *Ch-Imperata* fallow (ChImFal)	6.4	Unit	
	Forage value for *Thysanolaen-Imperata fallow* (ThyImFal)	7.2	Unit	

Entity	Parameter	Default value	Unit	Source and main tool used
Land unit	Forage value for *Imperata* fallow (ImFal)	8	Unit	Calibrated based on results of the author's plot survey
	Forage value for upland rice fallow (UpR)	16	Unit	
	Forage value for maize	16	Unit	
	Forage value for litchi	8.8	Unit	
	Forage value for ruzi	16	Unit	
	Wet season forage factor when no grazing	1		
	Wet season forage factor if low cattle density in previous season	0.95		
	Wet season forage factor if high cattle density	0.8		
	Dry season forage factor from normal forage value	0.8		
	Dry season forage factor if low cattle density	0.75		
	Dry season forage factor if high cattle density	0.7		
	Transition time from ImFal to ThyImFal by RF	1	Year	Validated among foresters, herders, and researcher
	Transition time from ImFal to ThyImFal by RFC	1	Year	
	Transition time from ImFal to ThyImFal by NC	3	Year	
	Transition time from ImFal to ChImFal by LC	3	Year	
	Transition time from ImFal to ChFal by HC	1	Year	
	Transition time from SecF to DF by NC	6	Year	
	Transition time from SecF to DF by LC	5	Year	
	Transition time from SecF to DF by HC	4	Year	
	Transition time from ShFal to SecF by NC	5	Year	
	Transition time from ShFal to SecF by LC	4	Year	
	Transition time from ShFal to SecF by HC	3	Year	
	Transition time from ChFal to ShFal by RF	3	Year	
	Transition time from ChFal to ShFal by RFC	3	Year	
	Transition time from ChFal to ChImFal by NC	1	Year	
	Transition time from ChFal to ShFal by LC	4	Year	
	Transition time from ChFal to ShFal by HC	3	Year	
	Transition time from ChFal to ImFal by Fire	1	Year	
	Transition time from ChImFal to ChFal by RF	1	Year	
	Transition time from ChImFal to ChFal by RFC	1	Year	
	Transition time from ChImFal to ChFal by LC	1	Year	
	Transition time from ChImFal to ChFal by HC	1	Year	
	Transition time from ChImFal to ThyImFal by NC	1	Year	
	Transition time from ChImFal to ImFal by Fire	1	Year	
	Transition time from ThyImFal to ShFal by RF	4	Year	
	Transition time from ThyImFal to ShFal by RFC	5	Year	
	Transition time from ThyImFal to ShFal by NC	6	Year	
	Transition time from ThyImFal to ChFal by LC	2	Year	
	Transition time from ThyImFal to ChFal by HC	1	Year	
	Transition time from ThyImFal to ImFal by Fire	1	Year	
	Transition time from ImFal to ThyImFal by RF	1	Year	
	Transition time from ImFal to ThyImFal by RFC	1	Year	
	Transition time from ImFal to ChImFal by NC	3	Year	
	Transition time from ImFal to ChImFal by LC	3	Year	
	Transition time from ImFal to ChFal by HC	1	Year	
	Transition time from ImFal to ImFal by Fire	1	Year	
	Transition time from UpR to ChImFal by RF	1	Year	
	Transition time from maize to ChImFal by RFC	1	Year	
	Transition time from ruzi to ChImFal by LC	4	Year	
	Transition time from ruzi to ChImFal by HC	1	Year	
	Transition time from ruzi to ruzi by NC	4	Year	
	Reforestation plot: Minimum age to allow cattle grazing	5	Year	Validated with stakeholders during the 2nd field workshop.
Herd	Minimum mortality rate	9	%	Validated with herders in the first field workshop
	Maximum mortality rate	15	%	
	Mortality rate with ruzi pasture	3	%	Estimated by researcher

Note: NC = No cattle, LC = Low cattle density, HC = High cattle density, RF = Reforestation.

The spatial resolution of the DT-ABM was selected for one land unit (a cell of the spatial grid) to represent an area of 3.2 ha (20 rai) in the reality. The grid is a rectangular matrix made of 14 x 11 cells and this virtual landscape corresponds approximately to 2.5 km^2. The DT-ABM is a discrete time-step model. A seasonal time-step was chosen similar to the one used with the cRPG-V3 tool. The time horizon was set to 10 years, which, although not excessive, is a reasonably long period to assess the different management strategies.

9.1.1.3. Process overview and scheduling

The key successive activities and processes activated during a simulation are; i) in the wet season only, foresters select the area for reforestation, ii) land units update the quantity of available forage according to the previous grazing pressure and to the current season, iii) herders decide the location of the paddocks and ruzi pastures (depending on the scenario being run) and locate their cattle, iv) the status of cattle is updated according to the volume of forage they got compared to their needs, v) in the dry season only, newborn, deaths and losses of cattle are calculated at the paddock level and then the herds' size are adjusted accordingly, vi) in the dry season only, herders may decide to sell cattle, and vii) by the end of the dry season only, the vegetation state of each land unit is updated. Figure 9.2 shows this sequence throughout a year in detail.

9.1.2. Design concepts

The DT-ABM simulator includes some randomness in the biological functions of the cattle population (mortality and reproduction) and also in the algorithm used by the herder agents when deciding to sell cattle (details are provided in the next section). On the other hand, the functions to select suitable land units for reforestation plots, paddocks and ruzi pastures are purely deterministic.

The production of visual outputs by the DT-ABM is achieved through a dynamic connexion with the Excel package, the same as for cRPG-V3. Bar charts showing the cattle population dynamics and vegetation changes were used to compare the simulation results.

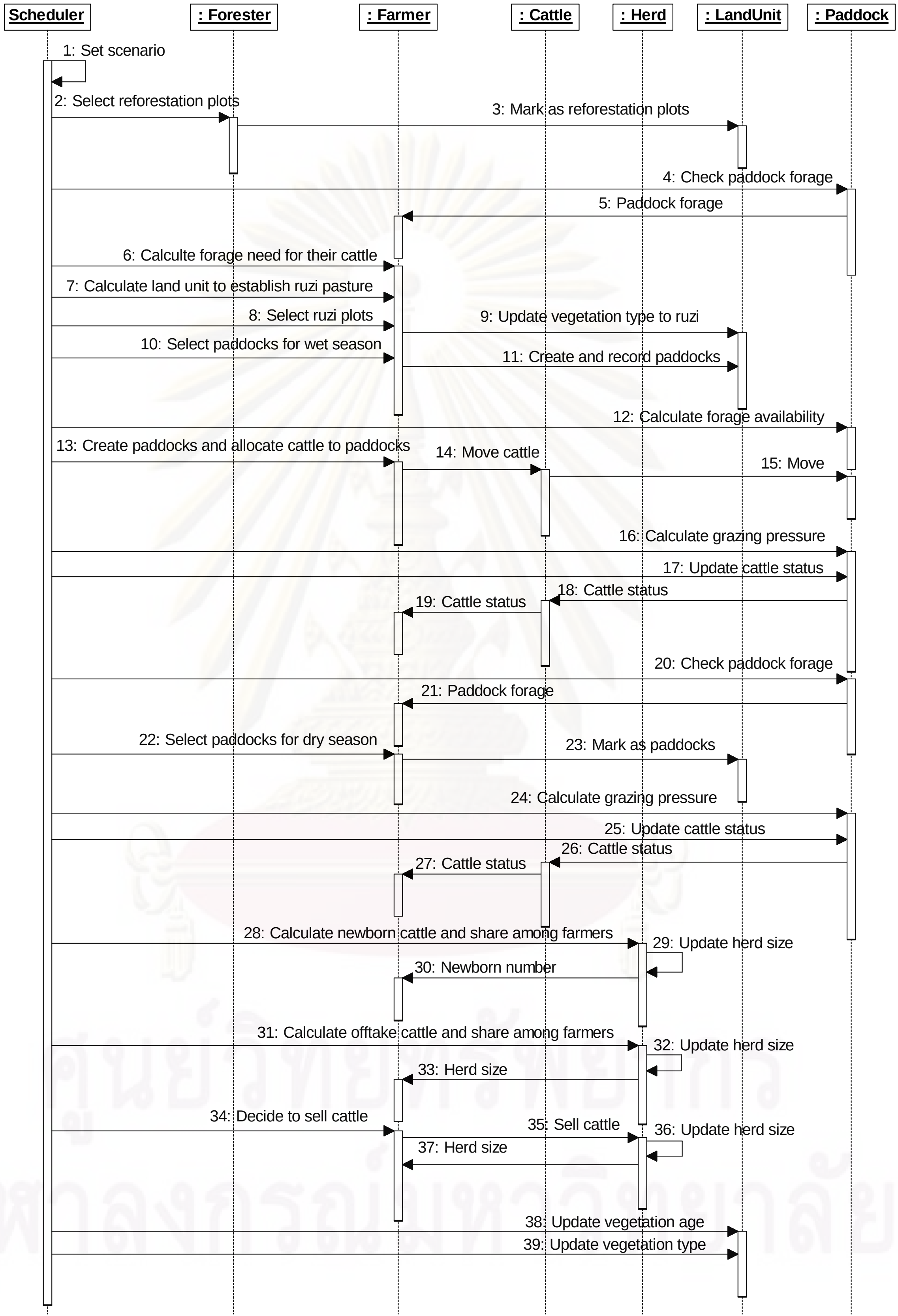
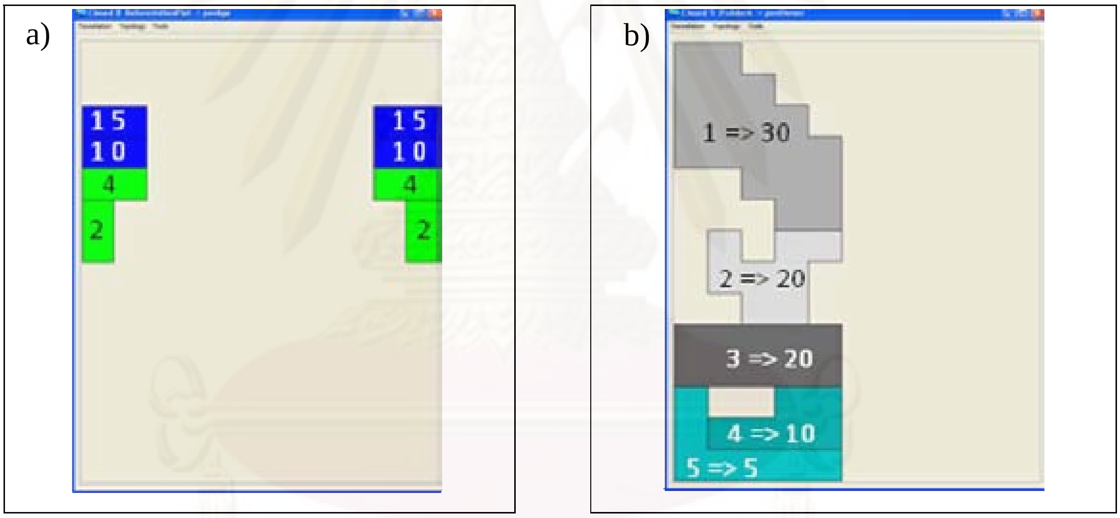


Figure 9.2. UML sequence diagram of cRPG-V3 illustrating activities in the Doi Tiew Agent-Based Model.

9.1.3. Details

9.1.3.1. Initialization

The initial virtual landscape of the DT-ABM tool is similar to the one used with the cRPG-V3 model. Four reforestations plots pre-exist on each side of the landscape, as shown in Figure 9.3a., and their age(s) are indicated. Less than five year old reforestation plots unauthorized for grazing are displayed in green whereas reforestation plots authorized for grazing are shown in blue. Five herders with different herd size (30, 20, 20, 10 and 5 heads respectively) are initialized on the left side of the landscape. The right side is not grazed at all to assess the impact of grazing at first glance. For individual scenarios, each Herder agent is assigned a predefined paddock as shown in Figure 9.3b.



Note: i = > n written inside a polygon of a given colour means that herder i has an initial herd size of n cattle to be located inside this polygon (an aggregate of land units) corresponding to the paddock assigned to herder i. on the paddock which extent corresponds to the polygon.

Figure 9.3. Initial reforestation plots with different ages (a) and initial five paddocks with number of cattle (b).

Figure 9.3 shows that the largest paddock on top of the virtual landscape overlaps with two old reforestation plots. In collective scenarios, the five paddocks are aggregated into a single one and the five Herder agents are grouped together in a collective entity.

9.1.3.2. Input

The DT-ABM does not require any input.

9.1.3.3. Sub-models

The algorithms corresponding to the key activities of the rule-based entities implemented in the DT-ABM simulator are described in this section. The translation of these algorithms into a source code enabling the running of the simulations with a computer was performed with the Smalltalk object-oriented programming language. The full listing of the code can be downloaded from the CORMAS website[29].

a) *Vegetation dynamics module*: The vegetation is represented through different cover types, each one being characterized by a potential forage availability (see Table 9.1). Two aspects related to the vegetation dynamics have been implemented: the transitions between two vegetation states and the related estimation of the actual forage volume provided by a land unit covered by a given type of cover according to the season (forage volume being 20% less in the dry season), and the intensity of grazing (calculated at the paddock level, as described in the cattle dynamics module below) in recent seasons. There are two levels of negative impact and the minor one is applied only when the intensity of grazing remained low during the last two seasons (see Table 9.1). These parameters were included to account for the impact of overgrazing on the forage availability, but their values still need to be better assessed.

The specifications of the transitions between vegetation states are exhaustively listed in Table 9.1. A transition between two vegetation types is affected by several factors related to human activities: reforestation, cattle rearing with low or high intensity and fire. All these parameters were discussed with the local stakeholders at several stages of the collaborative modelling process through different activities as reported in the second part of this dissertation.

b) *Cattle dynamics module*: Individual cattle are all characterized by the same basic forage need (Note: to keep the model simple, neither sex nor age were considered) set as being equal to two units of forage per season. Their health status ("fat", "normal" or "thin") is automatically adjusted at the end of each season

[29] http://cormas.cirad.fr/logiciel/DT_state01.zip

depending on whether they found enough forage or not in the paddock selected by their herder to cover their needs. The total amount of forage available in a paddock is equally distributed among the animals located in it. An animal retains its ‘normal’ status unless it gets less than 80% of its basic needs (it will then become “thin”) or more than 120% of its needs (then it becomes “fat”). The grazing intensity in a paddock is based on the ratio between the total quantity of forage available and the total number of cattle. When this ratio is greater than the cattle basic forage need, the intensity of grazing is considered to be “low”, otherwise it is considered to be “high.”

Table 9.2. Foresters’ preferred vegetation states when selecting new reforestation polts in Doi Tiew Agent-Based Model.

Preference	Vegetation state
Most preferred	*Chromolaena* fallow
	Chromolaena mixed with *Imperata* fallow
↓	*Imperata* fallow
	Thysanolaena mixed with *Imperata* fallow
Less preferred	Shrubby fallow

d) *Herder module*: Based on the observations made during the gaming sessions, the discussions during the debriefings and the personal interviews of the participants, the DT-ABM includes the possibility for each herder to sell cattle once a year at the end of the dry season. The rules depend on the herd size. Herders with more than 15 animals consider selling animals only when the size of their herd increases due to natural growth. Most of the time (probability 0.8), they sell exactly the number of animals provided by the natural growth of their herd, but sometimes (probability 0.2) they sell 1 to 3 extra animals on the top of this number. On the other hand, small herders managing between 8 and 15 animals do not consider the natural growth of their herd to decide whether or not to sell animals. To make money, they decide to sell either 1 (with probability 0.8) or 2 (with probability 0.2) animals every year. However, very small herders having less than 8 animals sell 1 head in each dry season with a probability of 0.2 only.

To provide enough forage for their cattle, herders can manage their paddocks in two different ways. In scenarios without the possibility to establish any “ruzi” artificial pasture, a herder facing a lack of forage tries to expand their initial paddock by adding some surrounding land units, as long as the quantity of forage available does not match his herd's needs. But surrounding land units belonging to the national park or to reforestation plots established less than five years ago cannot be considered, whereas parts of the paddocks used in the previous season by other herders can. The surrounding land units that can be used to expand a paddock are sorted according to the quantity of forage available, the best units being selected first. Herders are activated one after the other, starting from the herder managing the largest herd down to the one raising the smallest herd. This asynchronous mode of operation increases initial inequalities as the first herder expanding his paddock could encroach on his neighbours' paddocks. If a herder cannot secure any paddock, he sells all his land and stops raising cattle. In scenarios allowing the establishment of artificial pasture, the lack of forage is addressed by converting a share of a paddock into ruzi grassland. In this situation, the paddock boundary does not change.

9.2. Scenarios exploration in the laboratory

A total of seven scenarios were explored in the laboratory with the DT-ABM simulator. The first two scenarios were defined to check the consistency of the model implementation by verifying that simulation outputs were consistent with the algorithms presented in the previous section. The first scenario refers to the actual situation in that region before government conservation agencies started to operate. It is obtained by disabling the reforestation module. In this first scenario (denoted NRf), which serves as a reference, there is no possibility for the herders to improve their paddocks, neither by expanding them nor by introducing artificial pasture. In the second scenario, called "Reforestation without negotiation" (Rf), the foresters establish tree plantations on both sides of the spatial landscape as specified in the previous section. The aim of simulating these two scenarios was mainly to verify whether the DT-ABM tool was able to produce reliable results or not.

Then a set of four scenarios to be simulated with this new tool was defined by referring to the scenarios played with the local stakeholders during the first and second field workshops (see Table 9.3). These scenarios combine two levels of decision-making regarding paddock management (individual vs. collective) and two modes of increasing the availability of forage (paddock enlargement vs. introduction of the innovative ruzi pasture). The results of the simulations suggested refinements of the collective management scenario with this technical innovation. Therefore, a fifth scenario was simulated and its results added in the comparative analysis.

Table 9.3. Five scenarios to be compared using the Doi Tiew Agent-Based Model.

Technical innovation	**Mode of communication and cattle management**	
	Individual (One herder, one paddock)	Collective (All herders, one paddock)
Without ruzi	I	C
With ruzi	IR	CR
With ruzi and small paddock	-	CRS

9.3. Simulation results

Because the DT-ABM includes some randomness (for instance in functions related to the number of cattle), a rigorous comparison of scenarios would require to replicate n times each simulation and to compute basic statistics. However, the purpose of this model is not to define any recommendation but to be used as a mean to build on the suggestions made by the participating stakeholders during the gaming sessions. Therefore, some insights gained through the observation of the different above-mentioned scenarios are presented below.

Figure 9.4 illustrates the landscape dynamics observed between the start and the completion of the simulation of the seven scenarios (the spatial dynamics for the whole 20 time steps of each simulated scenario are displayed in Appendix G). A comparison on the simulation results is provided below.

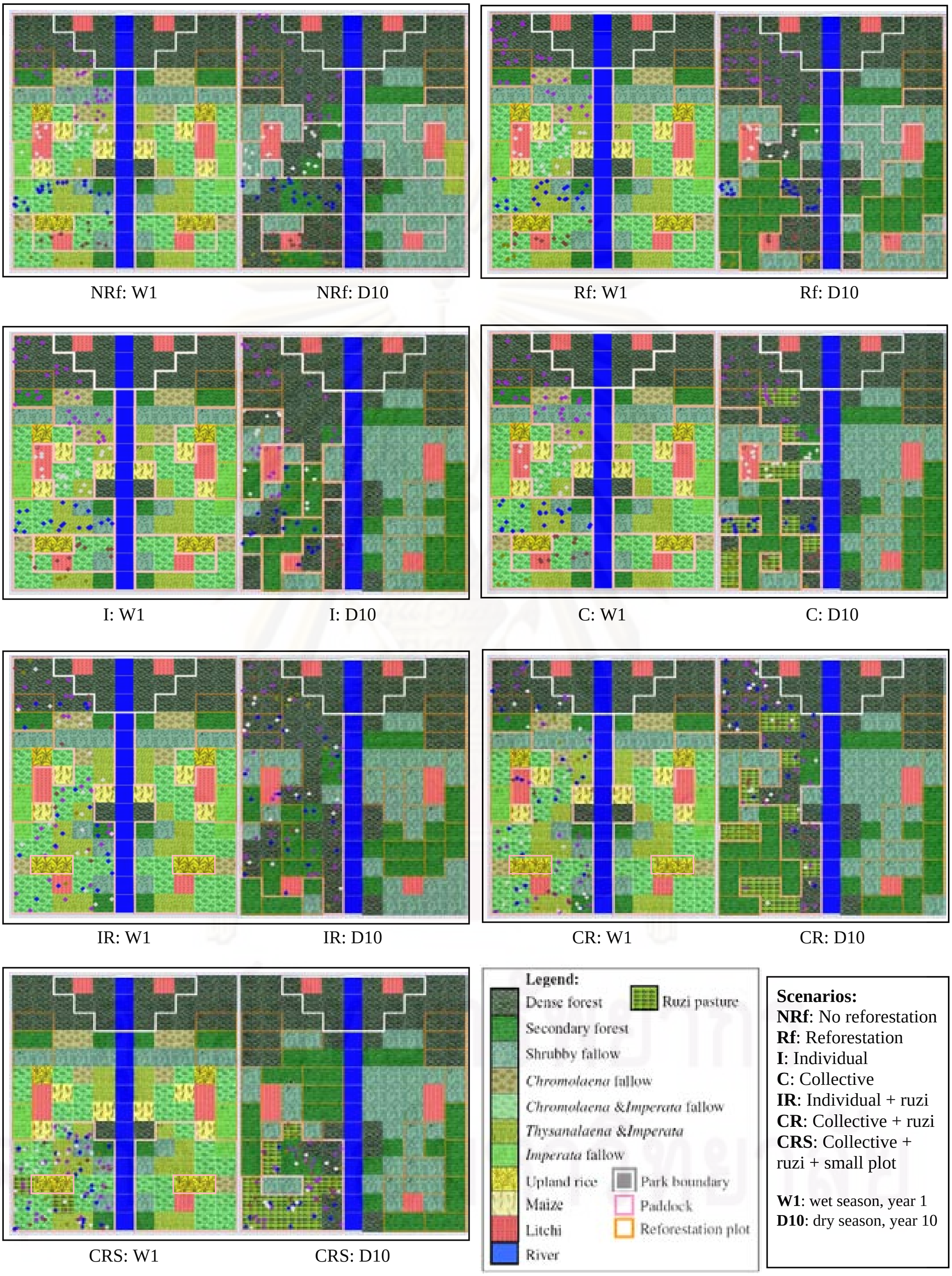
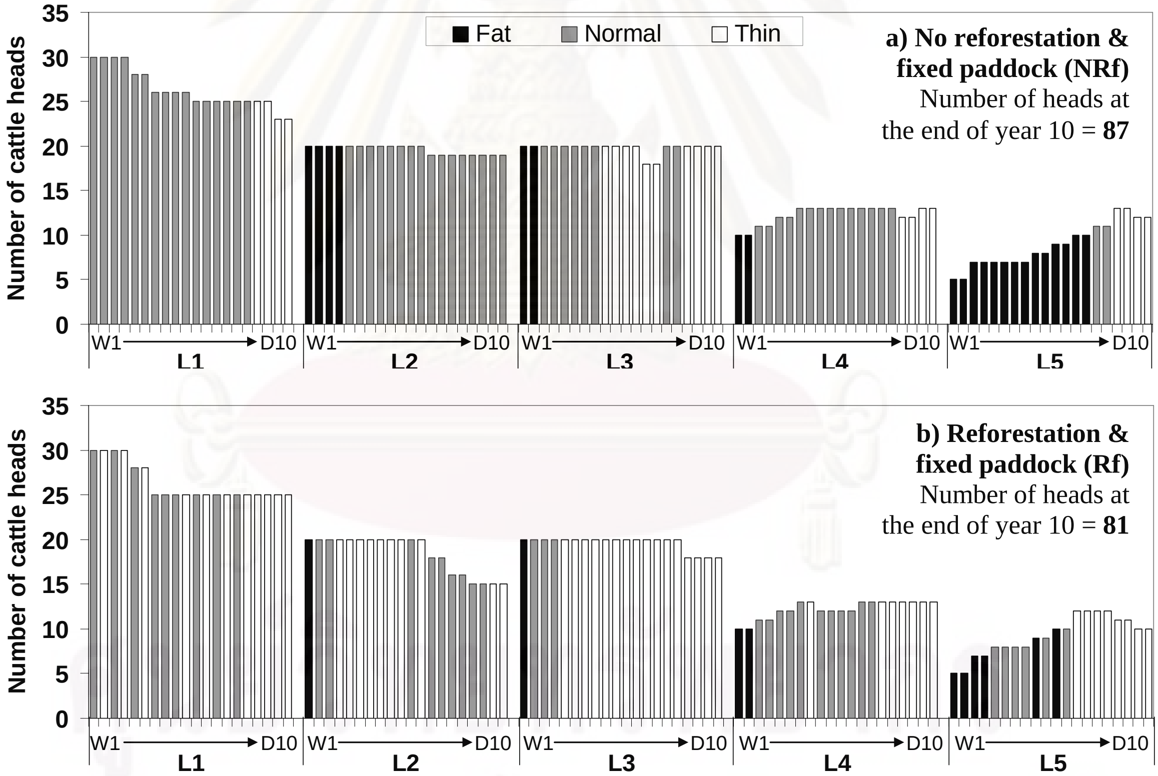


Figure 9.4. Landscape, paddocks and reforestation plots during the first wet season (W1) and at the end of the simulation in year 10 (D10) in seven scenarios.

9.3.1. In the fixed paddock strategy

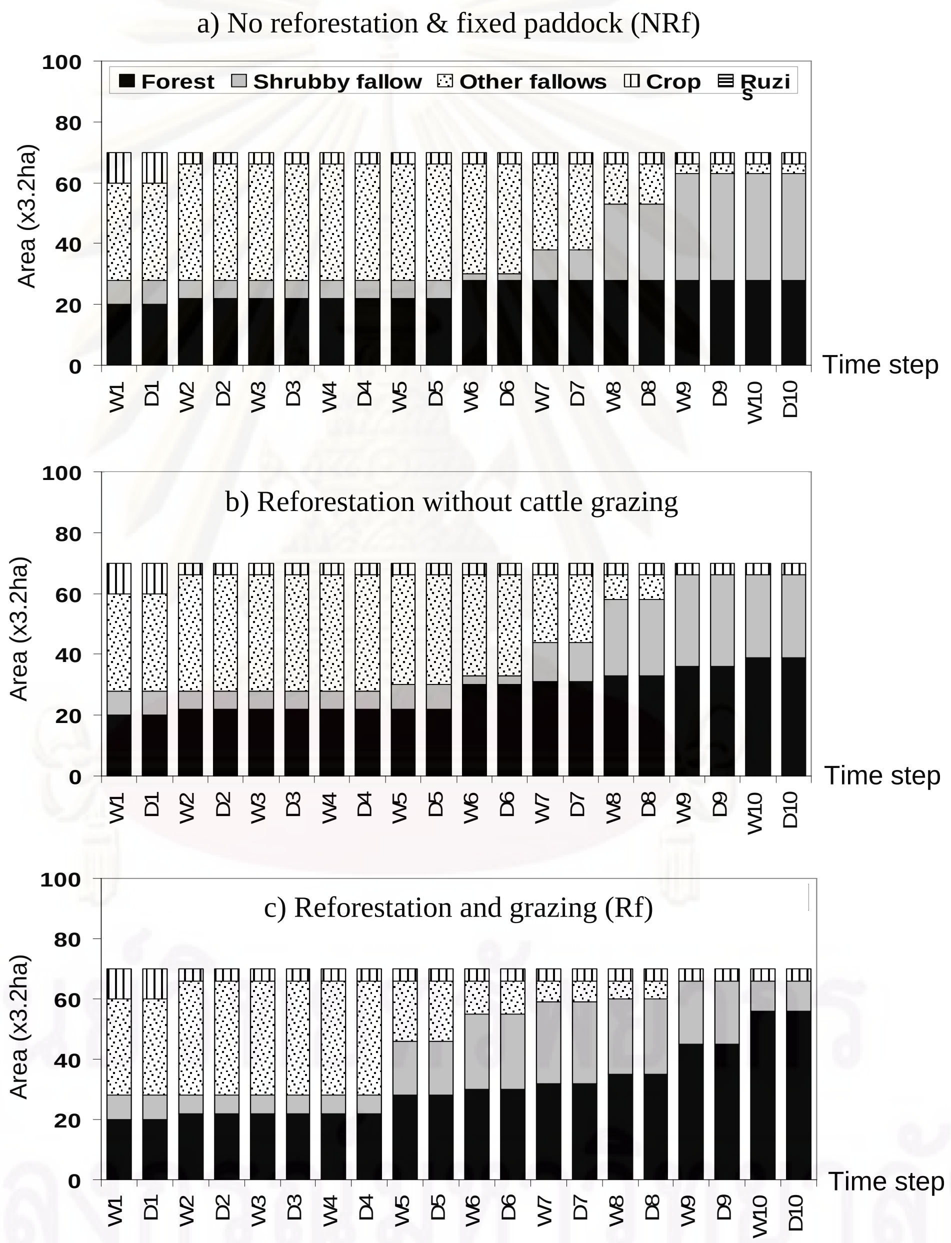
Figure 9.5a shows the simulation results for the cattle status and number when the paddocks remain the same and in the absence of reforestation efforts. In the fifth year, the proportion of “thin” animals increased for herder L3 due to the domination of forest cover, and in the last two years of the simulation ofr most of the other herders (Figure 9.5a). With reforestation taking place in the landscape (Figure 9.5b), cattle are becoming “thin” faster and after 10 years, all herds are in a bad shape, even for herders (like L2) adjusting their number of animals. This is worse than what was observed in the previous scenario because of the encroachment of reforestation plots on land use for paddocks.



Note: Simulation run for 20 seasonal time steps (equivalent to 10 years), starting from the wet season in year 1 (W1) to the dry season in year 1 (D1), up to the wet season in year 10 (W10) and the dry season in year 10 (D10). L1 to L5 denote the five herders operating on the left side of the virtual landscape.

Figure 9.5. Dynamics of herd size and status of cattle for each herder under NRf and Rf scenarios.

Figure 9.6 shows that the forest cover regenerates faster with reforestation plots than without. Moreover, the simulation results show that low grazing pressure stimulates forest regeneration. The rule excluding cattle from young reforestation plots is producing a *de facto* kind of rotational grazing where the reforestation plots are open for grazing again five years after their establishment.



Note: Simulation run for 20 seasonal time steps (equivalent to 10 years), starting from the wet season in year1 (W1) up to the dry season in year 10 (D10).

Figure 9.6. Vegetation dynamics under different land management strategies in the simulation of the NRf and Rf scenarios.

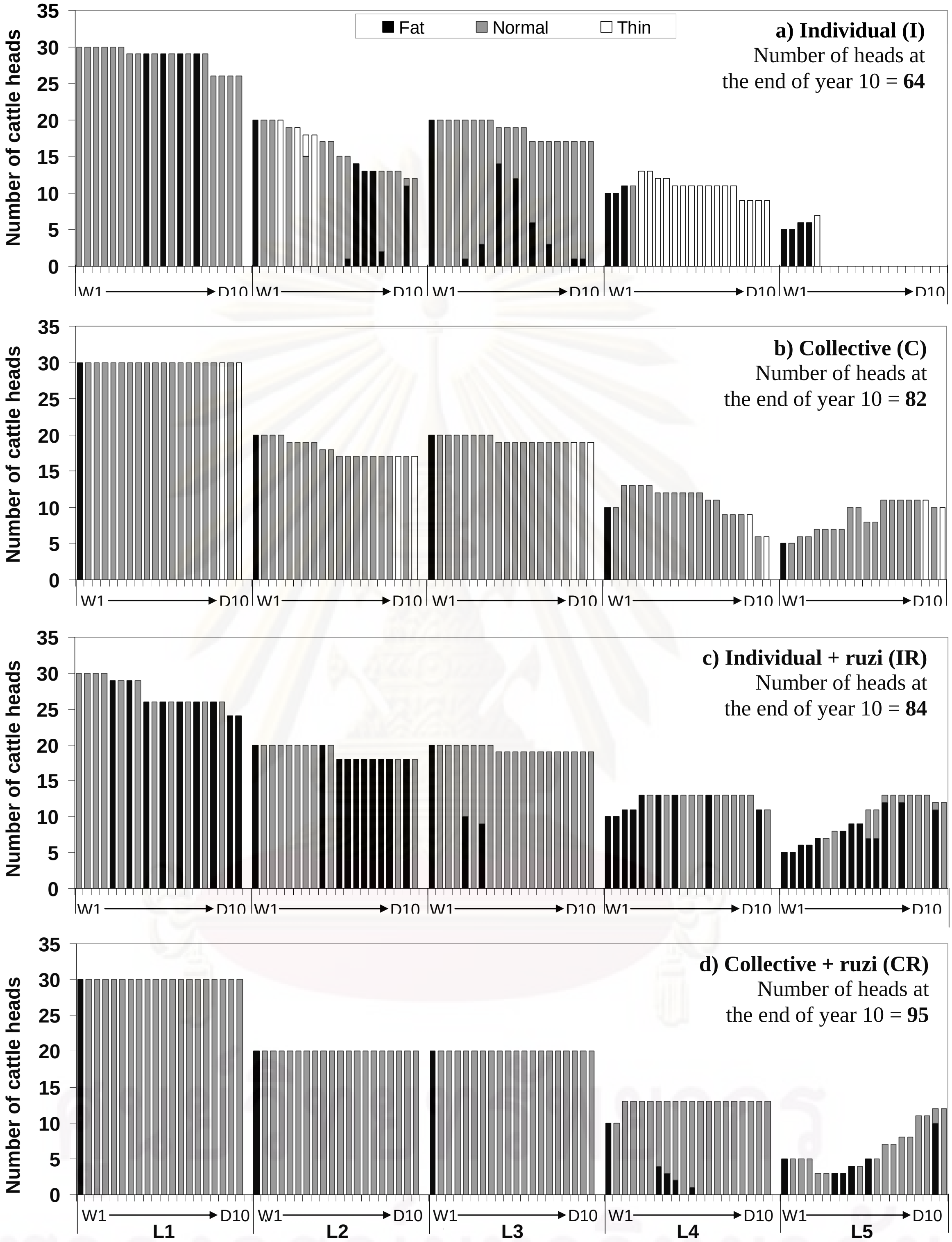
9.3.2. Effects of different modes of communication and technical innovation

9.3.2.1. Effects on cattle dynamics

Figure 9.7 shows how the different cattle management strategies affect the number and status of cattle. In the individual management (I) scenario, only farmers managing large herds could maintain their cattle population because they could select the most suitable land units for their paddock to meet their cattle needs. In the DT-ABM, if no more land is available to build a paddock, there is no other option for a herder than to sell his herd and to quit cattle rearing; this is what happened to herder L5 (Figure 9.7a). This inequitable way to manage paddocks is obviously unsuitable to smallholders.

Compared to that seen in scenario I, the quality and quantity of cattle in the collective management (C) scenario improved for all the herders when they pooled their cattle into a single paddock, as shown in Figure 9.7c. Nevertheless, in the dry season at the end of the fifth year, the simulated landscape was not suitable anymore to sustain all the cattle because of the forest recovery and by that time, all the animals had become "thin." This unsatisfactory situation was also experienced during the gaming sessions, and it paved the way towards the introduction of the technical innovation based on ruzi grass pastures.

Both individual and collective management with ruzi pasture provided better results than the corresponding (I and C) scenarios based on expansion of the paddocks only. In scenario IR, all the animals were fat due to the increase in forage availability in each individual paddock, while in scenario CR, the cattle status remained just normal. This apparent disadvantage of scenario CR needs to be balanced by the fact that for these particular simulations, the virtual landscape supported more cattle in scenario CR (95 heads by the end of the simulation) than in IR (84 heads by the end of simulation).



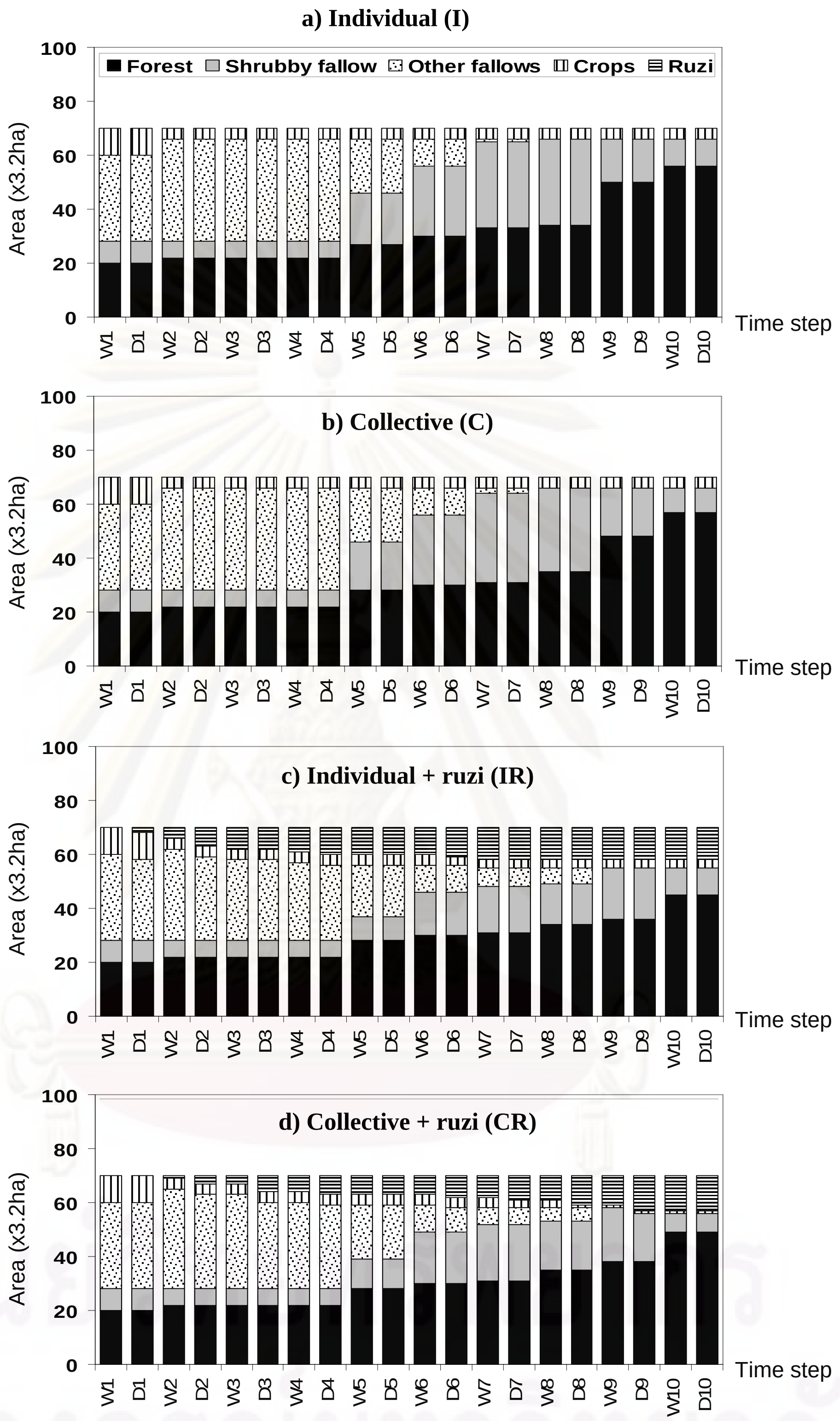
Note: Simulation run for 20 seasonal time steps (equivalent to 10 years), starting from the wet season in year 1 (W1) to the dry season in year 1 (D1), up to the wet season in year 10 (W10) and the dry season in year 10 (D10). L1 to L5 denote the five herders operating on the left side of the virtual landscape.

Figure 9.7. Simulated evolution of cattle number and status under four scenarios with individual or collective cattle management, and with or without technical innovation.

The effect of reforestation on cattle rearing was observed during the simulation of these four scenarios. In the (I and C) scenarios with expansion of the paddocks, the reforestation induced the split of some initial paddocks into separate and smaller paddocks. As a result, the herders had to allocate their cattle to different paddocks having different forage availabilities, which could result in heterogeneous cattle status (see for instance L3 from year 3 to year 8 in Figure 9.7a, L5 from year 2 to year 3 in Figure 9.7c and L4 from year 4 to year 5 in Figure 9.7d). On the top of the already mentioned differences between collective and individual management scenarios, such observations, if shown to the local stakeholders, could reinforce their motivation to achieve a better coordination among them in order to avoid this more problematic management of numerous small paddocks.

9.3.2.2. Effect on forest regeneration

Figure 9.8 illustrates that of the four scenarios modeled here (I, C, IR and CR), the forest regeneration was faster and more important in scenarios I (56 land units) and C (57 land units) compared to scenarios IR (45 land units) and CR (49 land units). This is due to the fact that when a land unit was converted to a ruzi pasture it was not possible for foresters to reforest it later on. Therefore, scenarios IR and CR seem to benefit the herders more than the foresters. Such simulated results illustrate the likely requirement for a balanced compromise between forest conservation and the social acceptance of land use by the residential villagers.



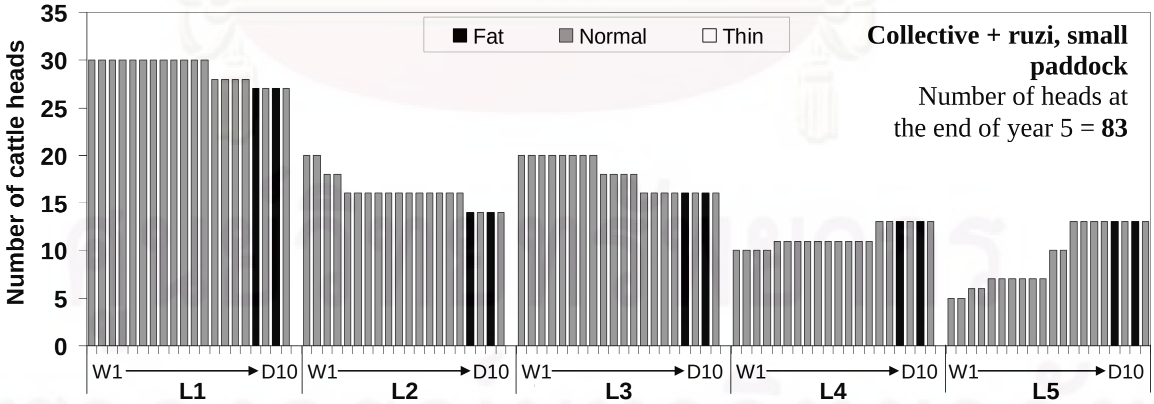
Note: Simulation run for 20 seasonal time steps (equivalent to 10 years), starting from the wet season in year1 (W1) up to the dry season in year 10 (D10).

Figure 9.8. Simulated vegetation dynamics under four scenarios based on individual or collective cattle management and with or without technical innovation.

9.3.3. Additional scenario to assess the impact of assigning a smaller initial paddock to a group of herders adopting the ruzi pasture innovation

While analysing the simulation results of these scenarios proposed by the stakeholders in the laboratory, an additional scenario appeared to be worth investigating. This is illustrative of the creative effect of performing exploratory simulations. The same kind of stimulation could also occur if the DT-ABM tool was to be used with the local stakeholders who actively participated in its design. In this new scenario called “CRS” (for collective management with ruzi pasture and a small initial paddock), the researchers proposed to use a smaller initial paddock composed of only 27 land units compared to the 62 land units used to delimit the collective paddock in scenario CR.

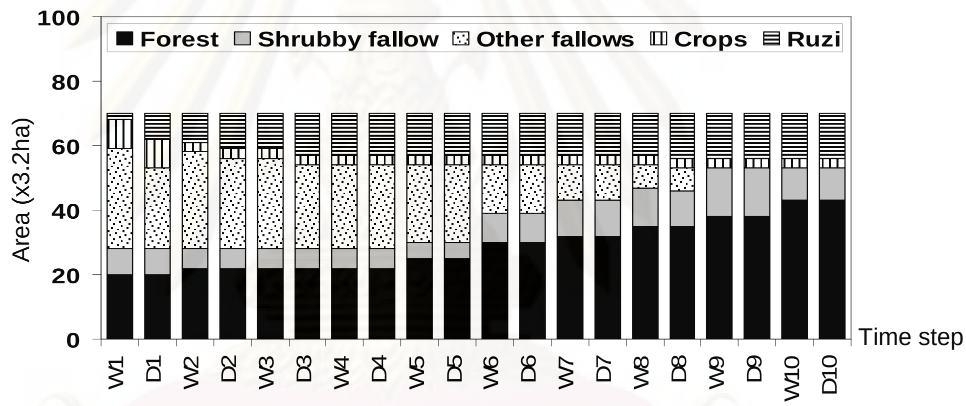
Figure 9.9 presents the simulated development of cattle status and number with time under this new CRS scenario. The results obtained for cattle status and numbers were broadly similar to those recorded under the IR and CR scenarios (Figure 9.7c, d). Moreover, after 10 years of simulation the paddock was made of only 22 land units because some of them were converted to reforestation plots in the meantime. Nevertheless this small paddock was still enough to feed 83 heads as no “thin” animals were observed. It also seems to be able to provide for cattle grazing for a longer period at this herd size.



Note Simulation run for 20 seasonal time steps (equivalent to 10 years), starting from the wet season in year 1 (W1) to the dry season in year 1 (D1), up to the wet season in year 10 (W10) and the dry season in year 10 (D10). L1 to L5 denote the five herders operating on the left side of the virtual landscape.

Figure 9.9. Simulated evolution of herd size and cattle status under scenario CRS.

This last CSR scenario led to the slowest forest regeneration with only 43 land units under forest on the virtual landscape after 10 years of simulation with a significant proportion of fallows up to year 8 as shown in Figure 9.10. This is due to the fact that ruzi pasture was not possible for reforestation. Moreover, the reforestation without cattle grazing tended to show a slower regeneration speed, similar to what was observed in Figure 9.6b (only 39 land units under forest in the virtual landscape), because the land was still dominated by fallows. Figure 9.11 illustrates that from year 7 the *Thysanolaena* fallow covered the upper left and middle parts of the landscape (above the paddock) where no cattle grazing occurred. While in contrast, in all the other scenarios the landscape was dominated by shrubby fallows at the same time period.



Note: Simulation run for 20 seasonal time steps (equivalent to 10 years), starting from the wet season in year1 (W1) up to the dry season in year 10 (D10).

Figure 9.10. Vegetation dynamics resulted from the small paddock strategy (CRS scenario).

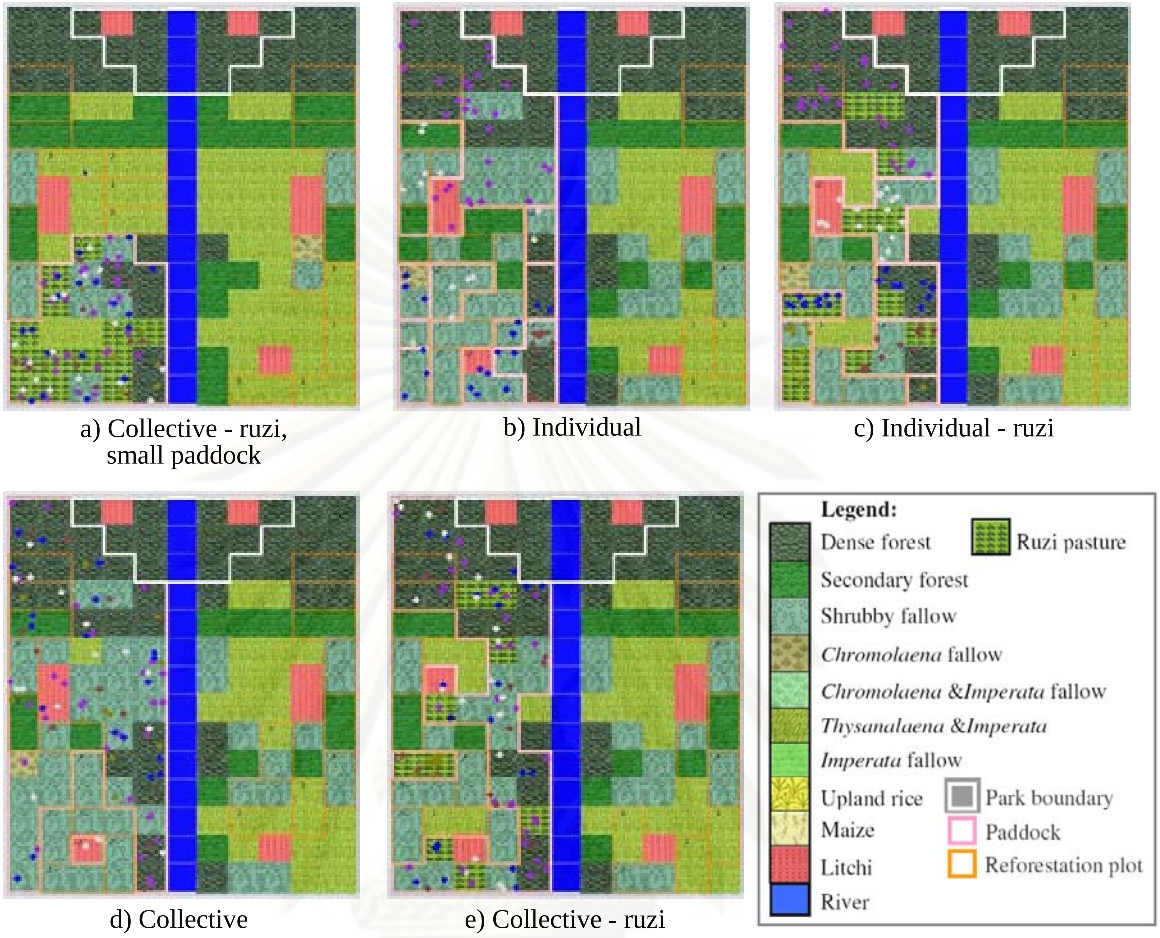


Figure 9.11. Vegetation covers in the dry season of the seventh year to compare CRS scenario (a) to the other four scenarios.

9.4. Discussion

9.4.1. Advantages and disadvantages of each scenario on cattle raising and reforestation activities

Table 9.4 summarises the outputs from the simulations of the different scenarios. In general, the rearing of cattle in this system is improved through collective herd management combined with the adoption of the artificial pasture technique.

The total number of land units converted to ruzi artificial pastures and the number of reforestation plots were similar under these seven scenarios. Differences among the scenarios are related to the process of forest regeneration and the evolution of cattle status and number.

Table 9.4. Summary of the simulation results obtained with the seven scenarios.

Scenario			Nat.*	NRf	Rf	I	C	IR	CR	CRS
Cattle status	Fat		-	-	-	-	-	24	-	-
	Normal (85 heads)**		-	19	-	55	-	60	95	83
	Thin		-	68	81	9	82	-	-	-
Total			-	**87**	**81**	**64**	**82**	**84**	**95**	**83**
Paddock dynamics	Paddock numbers	Initial	-	5	5	5	1	5	1	1
		End	**-**	**5**	**7**	**11**	**1**	**8**	**2**	**1**
	Paddock size (cells)	Initial	-	62	62	62	62	62	62	27
		End	**-**	**52**	**37**	**45**	**55**	**38**	**39**	**22**
	Average size	Initial	-	12.4	12.4	12.4	62	12.4	62	27
		End	**-**	**10**	**5**	**4**	**55**	**5**	**20**	**22**
Vegetation dynamics	Forest (20 cells)		**39**	**54**	**56**	**56**	**57**	**45**	**49**	**43**
	Shubby fallow (8 cells)		27	12	10	10	9	10	7	10
	Other fallows (32 cells)		0	0	0	0	0	0	0	0
	Crops (10 cells)		4	4	4	4	4	3	1	3
	Ruzi (0 cells)		-	0	0	0	0	12	13	14
Reforestation size (cells)			-	**8**	**28**	**27**	**27**	**27**	**26**	**25**

*Note: * Natural succession (no cattle and no reforestation in landscape.*
*** Numbers in bracket in this column refer to the initial situation, 1 cell equal to 3.2 ha in reality.*

From the researcher's point of view, the data shown in this table tend to identify the CR scenario as the most suitable one (followed by the CRS, IR and C ones) to balance the outcomes between cattle raising and reforestation.

Although the CR strategy requires a large paddock, it seems to be the most valuable one because it allows the herders to use cattle to reduce the dry biomass on the ground and to stimulate forest regeneration. Moreover, this strategy could also stimulate herders and foresters to negotiate a co-management of the land, leading to an improved relationship and trust between these two parties. The second most interesting strategy was the CRS one because of its effective land use and ease in managing pasture and reforestation plots. However, under the CRS scenario herders and foresters tend to manage the landscape separately and so its drawback is that it may not stimulate an agreement on co-management of the land or develop trust between the two parties. Scenario IR was ranked third: although it supported a high cattle population, the average size of paddocks was the worst (Table 9.4), meaning that herders would need to manage their cattle in many small and fragmented paddocks. The collective management without any technical innovation scenario was found to be even less promising because it seems unsustainable in the medium term: there was not enough forage left to feed the cattle after year 5, so the herders would need to decrease their herd size.

Nevertheless, it would be much more interesting to use this computer model in a prospective way with the local stakeholders themselves to explore more options of interest to them and to support collective discussions about possible future management of their land.

9.4.2. Future use of this model

We clearly state that the DT-ABM simulator is a model that could not be used to make predictions[30]. To account for some unpredictable events regarding the natural cycle of cattle and also the way herders may decide to sell several animals when facing urgent financial needs, some randomness has been included in it. Moreover, the processes influencing availability of forage at any time period have been extremely simplified. Therefore, in the future, the DT-ABM tool should be carefully presented to the stakeholders and used for the purpose of stimulating the exploration of existing and new scenarios only.

The seven scenarios explored in the laboratory could be simulated step by step and discussed with both the participating villagers, who contributed to its creation by participating in the gaming workshops and related activities, and also subsequently with other villagers at this site and elsewhere. The use of this tool in this manner would partially alleviate the restrictions related to the short period of time explored in gaming sessions (usually only 3 - 4 rounds of play or crop years in a single session). The simulations conducted with the DT-ABM over 10 years would thus allow the participants to envision trends and more long term consequences of different

[30] Several models have been developed for predictive purpose such as "Dynmod" (Lesnoff, 2007) developed under Microsoft Excel and used for the projection of cattle population in low-intensified farming systems in Tropical areas; "ForClim" (Weber *et al.*, 2008) that applied the forest gap model to simulate the dynamics of vegetation cover in response to grazing; "WOODPAM" (Gillet, 2008) a model used to predict the long term dynamics of a pasture-woodland landscape. Vavra *et al.* (2007) developed a complicated state transition model to project the vegetation cover for the next 200 years.

management strategies dealing with forest regeneration and cattle raising in a far more cost (time and cash) efficient way. Moreover, the use of the seven scenarios presented above could encourage the participants to identify new ones that meet their interests and explore these together as well. Because the DT-ABM tool is flexible enough to be easily modified, these suggestions could be tested “on the spot”, based simply on the stakeholders’ demands.

The modelling of more scenarios, and assessments of each one, could also help the local stakeholders to further improve their perceptions and understanding of the system to be managed, particularly the causal effects between cattle raising and reforestation activities. It could also help herders and foresters to think about new possibilities to manage this particular forest-farm land interface together. For example, a negotiation over the minimum age of reforestation plots to authorize grazing (set to 5 years in the model) could be supported by the observation of new simulations. It would also be interesting to discuss what to do in the situations when there is either insufficient, or else no more, suitable areas for the establishment of ruzi pastures.

Importantly, the debriefing and discussion of the simulations results should focus on the stakeholders’ understanding (Kriz, 2008). For an effective use of the DT-ABM with herders, it would be better to have the former player(s) who participated in its design explain the simulation results in the Hmong (native) language to others.

To up-scale the ComMod process, the DT-ABM simulator could be used as a communication tool with local herders and other government agencies, e.g. District and Provincial officials who although they have the mandate to support decentralised natural resource management, they have a limited time to participate in any meetings. By visioning the results of the simulated scenarios, these officials could easily understand the villagers’ perceptions, needs and propositions regarding land management. Moreover, this model could be tested at other sites where similar land use conflicts are occurring.

9.4.3. Possible modifications of the model

Several possibilities can be suggested to further improve this model. The first one would be to modify the DT-ABM to obtain a hybrid[31] version that would allow real players and computer agents to co-exist and to simulate a scenario. This hybrid version could be used to support more interactive simulations and therefore lead to a better understanding of the model among local stakeholders. This broad type of hybrid simulation has already been successfully implemented at a neighbouring site and on another topic by Barnaud *et al.* (2008), and so this could serve as an initial basis for the construction of an interactive interface that will receive the players' decisions made in the previous versions of the model (c-RPGs) to be used by the virtual agents acting as artefacts of human players only. This could help to further avoid the "black-box effect" of using computer tools, especially with new comers who were not involved in the co-design of the model through the gaming and simulation features. It is well known that such an early involvement greatly helps to understand how the simulation works (Druckman and Ebner, 2008).

Another potential improvement would be to include a cropping module in the model. It would make it more comprehensive, more flexible to accommodate a variety of new scenarios (including those based on switching from animal rearing to crop production) and more interesting for out-scaling the process. However, as the model becomes more and more complex with diverse topics available for discussion, it may also become more difficult to understand for the villagers and it could dilute their interest.

A third direction to improve the model would consist of getting more accurate values for some parameters, especially the ones related to the dynamics of ruzi pastures in this highland environment. This could be attempted in the near future thanks to the stakeholders' plan to work together on an experimental plot where a ruzi pasture will be co-established and co-managed by foresters and herders to produce more information.

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[31] An hybrid model is here defined as a model combining virtual and real players in a simulation.

9.5. Discussion

Using the DT-ABM simulator in the laboratory to compare the different scenarios was mainly useful to verify the consistency of this tool with the knowledge that was integrated to implement it. The main contributors to the production of this knowledge, namely the local stakeholders represented in the model, should now also be involved in this scenario exploration phase. Within the limited scope of this research, it was not possible to start this activity, but it will be attempted in the near future. The model is still a rough representation of the complex socio-ecosystem, but, hopefully, will be shared by the local stakeholders who participated in the early phases of the modelling process.

CHAPTER X
DISCUSSION

The ComMod experimental process, outlined in the previous chapters, was conducted in a forest-farm land interface in a highland area of Nan Province to help mediate a land use conflict between the local herders and government foresters. We chose to co-design the modelling process with all principal sides, representatives of the main concerned stakeholders, so as to develop a system that would be jointly managed by all sides. By doing so, we aimed at improving the communication, and sharing their differing perceptions of the interactions, between those factions interested in cattle rearing and those in reforestation so as to reach a better mutual understanding among the different stakeholders. Three successive sequences of collaborative modelling activities were implemented with these representative stakeholders. This relied on a family of simulation tools composed of three versions of a computer-assisted Role-Playing Game (cRPG), used mainly as a tool to enhance communication and knowledge sharing, and lead to the construction of a computer autonomous simulator called Doi Tiew Agent-Based Model (DT-ABM) used for scenario exploration through simulations in the laboratory so far.

In this chapter, we reflect on the adaptive use of the gaming and simulation techniques and tools used with this ComMod process. We also analyse the dynamics of the stakeholders' participation and the learning effects of the collaborative modelling activities on the management of this forest-farmland frontier. Finally, the strengths and limitations of this ComMod process are discussed to identify possible approaches to improve this model for future implementation in a similar context.

10.1. Importance of the preliminary diagnostic analysis

Barnaud *et al.* (2008) demonstrated the usefulness of the initial agrarian and institutional diagnostic activities prior to the launch of a participatory modelling process for integrated natural resource management in northern Thailand. In this study reported here, the preliminary diagnostic phase was more comprehensive and combined a literature review, an analysis of the land use and cover change in relation to recent agrarian transformations at the landscape level, a farm survey to produce a typology of the local herders, a stakeholder and institutional analysis (Chapter III), and finally a plot level ecological survey on the effects of cattle grazing and forest regeneration on vegetation dynamics (Chapter IV). These initial diagnostic activities were essential for the researcher to understand the key components of the land system and its agro-ecological as well as social dynamics. They reinforced the first two hypotheses of this research (Chapter I), as presented in detail below.

Performing the land use and land cover change analysis coupled with stakeholders' interviews verified the first hypothesis, which states that "the negative effects of forest management on the agrarian system at this site are at the origin of the current land use conflict between the local people and the forest conservation agencies, whilst forest management activities have accelerated the deforestation in this area." Forest management policies, particularly the establishment of the NNP and the prohibition of cattle rearing in the forest area, negatively affected the livelihood of the Doi Tiew villagers. Many households, especially the most economically vulnerable farms, had to sell their cattle and could no longer access the forest to harvest timber and non-timer forest products, losing an important source of food and extra cash income. The land use map produced in this diagnostic phase (Figure 3.3) confirmed that the forest degradation occurred very fast after the establishment of the NNP, since the farmers converted part of the remaining forestland outside of the park to fields to secure land rights. This development reinforced the latent land use conflict and encouraged the launch of a process to nurture an appropriate co-management of the land between the foresters and villagers.

Another important diagnostic activity was the ecological study on the effects of cattle grazing and reforestation on the forest regeneration. At the beginning of the research, the herders and foresters had different perceptions regarding the effects of cattle grazing on forest regeneration[32], while the researchers, as outsiders of the system, had no prior knowledge or opinion regarding the effects of cattle grazing on forest regeneration in this area. Without this ecological study, it was difficult for the researchers to conduct a collaborative process with the herders and foresters because there was no objective evidence to validate or to deny the diverging statements made by the stakeholders. Although the comparative analysis between plots remained

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[32] Herders said that cattle accelerate forest regeneration, while foresters said that cattle damage sapling and seedling. More details are presented in Chapter IV.

incomplete, the results from this study, at least partly, confirmed the second hypothesis: "not only reforestation, but also cattle grazing have positive effects on forest regeneration through the acceleration of the proportion of the woody above-ground biomass." Furthermore, results from this ecological survey at the plot level allowed the researchers to propose the first representation of the vegetation dynamics by selecting key vegetation states to produce a state transition diagram based on different factors, including cattle grazing and reforestation activities. Following minor improvements suggested by the field collaborators, this diagram was collectively validated with the two conflicting parties and became a key module in the series of simulation tools used with them to mitigate the land use conflict.

These preliminary diagnostic activities were also important to prepare the initialization of the subsequent collaborative modelling phase. In particular, they helped to identify the relevant stakeholders that needed to be involved (Reed, 2008). In this case study, the legitimacy of the research team to propose the ComMod process originated from a request made by the Nanthaburi National Park (NNP) manager. However, the stakeholder analysis showed that the government agency most impacted by the land use conflict was the Nam Khang Headwater Conservation and Development Unit (NKU), not the NNP, because rambling cattle could damage seedlings and saplings planted by NKU, while the impact of cattle on the park was very low. Therefore, key actors like NKU were made explicit thanks to the stakeholder analysis conducted in the diagnostic phase.

The preliminary analysis was also helpful for the selection of participants in the collaborative modelling phase, especially the herders. The farmer typology allowed the researcher to select representatives of different categories of herders having different amounts of assets, cattle and farmland management strategies to participate in the gaming and simulation field workshops. This mode of selection also introduced social equity in the process as small and large stockholders were able to express their needs and to share their perceptions regarding the conflict (Reed, 2008).

Nevertheless, the implementation of this set of preliminary diagnostic activities took more than one year due to several constraints. The most important one was the villagers' initial lack of trust (even suspicion) in the research team. This is because this remote village is known to be a base for amphetamine drug trafficking between the Lao PDR and Thailand and, from time to time, very unexpected (and sometimes violent) local events linked to this illicit trade impeded our research activities. To improve this difficult situation, at the very start of the fieldwork, we suggested working closely with a key villager, trusted by the other residents, for him to assist the research team.

10.2. The family of simulation models used in Doi Tiew

ComMod processes are iterative and evolving (Bousquet and Trébuil, 2005). In this research, the stakeholders' perceptions were changed thanks to a combination of both individual and collective learning processes along the successive sequences. Therefore, the simulation tools co-developed to meet the changing needs and objectives proposed by the stakeholders. This section discusses the development, roles[33], advantages and limitations of the simulation tools produced and used along the ComMod process implemented in this study.

10.2.1. Evolution of the tools used

Like in other similar ComMod processes, the simulation tools used in this case study were designed to keep the model simple but to still be relevant and able enough to represent the heterogeneity of the land and stakeholders, and the key interactions among them and with the land, of the land system. Table 10.1 summarises the development of the simulation tools used, from the cRPG-V1 to the final DT-ABM. All these different versions shared a common main purpose: to facilitate communication and exchanges, learning, decision support, or scenario exploration in the laboratory. According to the typology proposed by Sterk (2009), the roles of cRPG-V1 to V3 were mainly heuristic and relational: they were used to improve understanding of the system, to foster communication, to share knowledge and points of view, and to stimulate coordination among the key stakeholders.

Initially, the key relevant actors, resources and dynamics were identified and used to build the first version of the cRPG-V1 gaming and simulation tool. Because the starting point was the existing land use conflict, we focused at that stage on the representation of the vegetation dynamics aspects related to cattle grazing and reforestation activities and we spent approximately four months working with the

[33] Several potential roles for modelling tools in multi-stakeholder situations have been identified, such as: a heuristic role to improve understanding; a symbolic role to help put an issue on the political agenda; or a relational role to enhance network building and coordination (Sterk *et al.*, 2009).

herders and foresters to co-construct and validate the vegetation state transition diagram. Along this process, the herders and foresters perceptions were gradually exchanged and integrated into the model. Other biophysical factors, such as the topography, nutrient cycles, rainfall, etc., were not considered because they were not necessary to examine the land use conflict. Moreover, their integration into the model, to make it more realistic for example, would have led to a sophisticated tool that would be too difficult to understand by the local users. To minimize the complexity of the first version of the tool, we omitted complex cattle dynamics, such as sex ratio, age class and density dependent parasite/pathogen loads, from the model. The objective was to keep the model as simple as possible, but still relevant, so as to facilitate communication between the two conflicting parties. The integration of a sophisticated cattle module would have incited the herders to pay more attention to the management of their herds instead of communicating and negotiating with the foresters. The other significant simplification of the simulation tool is related to the spatial representation and the choice of a 2D virtual landscape with pictograms. We found that the herders and foresters accepted this simplification because they could still recognize the main actual spatial heterogeneities of their land system in this virtual landscape. This allowed them to bring their actual circumstances and experiences into the gaming and simulation sessions and to use the simulation tool to discuss the improvement of this forest-farm land interface familiar to them.

The cRPG-V1 was changed to the cRPG-V2 following requests from the foresters and herders interested to test new cattle and land management strategies, such as seasonal paddock rotation and artificial pasture. As a consequence, the degree of abstraction of the visual representation and the topics of the scenarios to be explored with the new tool changed to become somewhat more realistic. A new pictogram for the ruzi pasture and initial reforestation plots were introduced into the cRPG-V2 model. Furthermore, the time step of the simulation changed from yearly to seasonal, following the suggestions of the end users of this tool. The participants in the process in fact requested most of these changes. This then illustrates that they understood the new version of the simulation tool and saw the benefits of using it to support decision-making.

To achieve the transformation from the successive versions of the computer-assisted role-playing games up to the autonomous agent-based computer simulator

(DT-ABM), the activities completed in the sessions by the research assistants and the players had to be formalized and coded into CORMAS. To design the final version of the simulation tool, specific decisions made by the players were simplified to a set of rule-based commands. The collective debriefings and the individual interviews organized after each gaming session helped to collect the required information to design such an empirically-based ABM (Janssen and Ostrom, 2006).

Table 10.1. Characteristics and changes made in the simulation tools along the ComMod process implemented in Doi Tiew case study, Nan Province, Northern Thailand.

Character	cRPG-V1	cRPG-V2	cRPG-V3	DT-ABM
Main objective	Collective learning	Decision support	Collective learning	Scenario exploration
Role	Heuristic and relational roles	Heuristic and relational roles	Heuristic and relational roles (among herders)	Heuristic (to be used later with local stakeholders)
Degree of abstraction of tool (1: less abstract to 4 more abstract)	1: All decisions made by real players with help from research assistants	2: Reduction of some steps (see change made below) implemented in CORMAS	3: Only decisions on the selection of paddocks size and locations, & selection reforestation areas are made by players	4: All decision- making steps coded in CORMAS
Degree of abstraction of visual representation	Abstract 2D pictogram-based landscape	A somewhat more realistic visualization due to the additional pictogram for ruzi pasture, the boundary of the national park and the availability of reforestation plots in spatial landscape at initialization		
Change made to the tools				
Time step	Yearly	Seasonal: start from wet season followed by dry season		
Spatial representation	- Simplified landscape based on the 2003land use map - 1 cell = 3.2 ha	- Made more realistic by inserting the park boundary existing reforestation plots at initialization - Reduced scale of landscape from V1 to 1 cell = 1.6 ha	- 1 cell = 3.2 ha	- 1 cell = 3.2 ha
Number of players allowed to play	10-12	6	10	5, by default (could be adjusted up to 12 players)
Vegetation dynamics module	- 10 vegetation states	- New vegetation state transition rules integrating herders, foresters and researcher knowledge - Insert “ruzi pasture” pictogram and its dynamics - Assign forage value for each vegetation type and dynamics between wet and dry seasons implemented in CORMAS	- No change	- No change
Cattle dynamics module	- Assistants helped herders to draw chance cards for cattle mortality and to update herd size	- Reproduction function improved based on herders’ suggestions are implemented in CORMAS - Assistants helped herders to draw chance cards for cattle trespassing into the park	- Mortality function with and without ruzi, and decision rules to sell cattle implemented in CORMAS. - Remove “decide to buy cattle” step	- No change
Herders module	- Players decide initial cattle population & sell/ buy cattle	- Methods to share newborn and death of cattle are implemented in CORMAS	- Decide “upland rice area”	-Method to sell cattle, expand paddocks, select paddocks’ components to be converted in ruzi implemented in CORMAS
Forester module	- Players select 2 cells for reforestation	- Players select 2 cells for reforestation	- Played by researcher during the workshop	- Method to select area for reforestation implemented in CORMAS

10.2.2. Advantages and limitations of these tools

Several advantages and limitations of the cRPGs and DT-ABM simulation tools were found during this research.

10.2.2.1. Advantages

Transparency and contribution to improved trust between researchers and end users: By allowing the stakeholders to co-design and to modify the initial researchers' representation of the system based on their perceptions, empirical experiences and requests (i.e. addition of vegetation types, integration of local indigenous and scientific knowledge in the vegetation state diagram, and initialization of different ages of reforestation plots by the foresters), such iterative and collaborative modelling and simulating process leads to the production of more transparent tools which are easier to use, and to stronger trustworthy relationships between the research team and the engaged local model users.

Easy to perceive and not difficult to understand: A key advantage of such simple and accessible models lies in the fact that not only plain information making sense to the users is offered, but the consequences of their different decisions (e.g., land and cattle management options here) are also made visible along the modelling process (Horlitz, 2007). Each pictogram used in this case study embedded a potential forage biomass linked to the proportion of grass and this was easy to understand compared to the range of shades or plain colours used in many GIS model. This allowed the model users, especially those with a low level of formal education, to make use of their own experiences when using these tools. Moreover, the visualization of the effects of each group of players' decisions on the land cover on both sides of the symmetric landscape and the comparison of these results during several gaming and simulation sessions allowed the users to observe and comment on the changing patterns resulting from different individual or collective management strategies. This also stimulated their reflection on how to better adapt to an expanding forest cover and improve their forest-farm land management strategies (more details on learning effects are provided below).

Flexibility: This is a crucial characteristic in collaborative modelling and we have seen that new types of vegetative cover, scales and time step could be requested by the model users along the three sequence of modelling process. Moreover, the DT-ABM simulator will allow users to modify the initial paddocks and herd size before simulation. This flexibility is also important for the re-use of models with more diverse types of stakeholders who could request new changes.

Support collective learning and participation in gaming and simulation sessions: Such sessions have been established as being of beneficial use in learning (Barreteau, 2003; Crookall and Thorngate, 2009; Kriz, 2008; Wilson *et al.*, 2009). In this case study, the herders and foresters did not communicate or listen to each other at the beginning of the research. One reason was the language barrier between Hmong and central Thai, especially the administrative terms used in legal matters that led to communication failure. The simulation tools gradually developed along the collaborative process from their inputs and requests helped the local actors to share their knowledge and exchange their perceptions, strategies and needs. It was found that, during gaming and simulation sessions, they could test their proposed scenarios in a non-threatening context (e.g. herders converted the secondary forest in gaming sessions based on the first scenario) and learn by observing the subsequent development of the landscape patterns that resulted from their own and other stakeholders' behaviour and decision-making. Three workshops implemented in this case study were enough to allow the conflicting parties to design a first agreed upon concrete action plan, that may be a first step towards the adoption of a more negotiated and decentralized management strategy of the land in this area.

Support concrete decision-making without having to use a more realistic landscape representation: Some studies have shown that models for decision-support need a relatively higher degree of realism than the ones used to facilitate learning (Appleton and Lovett, 2003; Dionnet *et al.*, 2008). However, other studies have found the opposite trend (Hoogerwerf and Lammeren, 2005; Von Haaren and Warren-Kretzschmar, 2006). In this case, we found that a much more realistic visual representation was not necessary to accommodate the insertion of the new cattle raising techniques requested by the herders. Only the nature of the scenarios simulated and explored in the first and second workshops evolved toward more realistic ones.

The "human interface": One needs to recognize the key role played by the "human interface" that is the process facilitator who helps the participants to make use of the tools and models, tailoring them to their changing needs along the learning process by modelling and simulating process (Castella, 2009; Horlitz, 2007). In this study, we found that in the first and second field workshops the first batch of herders were able to train the newcomers in their own words and in a time efficient way for them to quickly understand the meaning of the pictograms and their use in displaying and managing landscape heterogeneity.

10.2.2.2. Limitations

Need for a more user friendly tool: The final DT-ABM simulator was developed for future use to improve the "processing speed [that is a] determining factor for success if the model is used in participatory and exploratory exercises involving stakeholders" (Engelen, 2000, cited in Horlitz, 2007). However, all versions of the models produced in this study are difficult for the local users to handle by themselves because these tools rely on the computer to update the vegetation states and to produce the refreshed landscape after each round of play or simulation time step. Along the three field workshops, we found that herders were interested in using the gaming and simulation tool with their neighbours but nobody was able to use these ones. Therefore, the development of a user-friendlier version would be needed for them to be able to continue the sharing and joint learning process on their own. Table 10.2 lists the specific advantages and limitations of the different versions of the gaming and simulation tool used in this research.

It was found that the cRPG-V1 supported interactions among participants in a more efficient way because they were able to easily relate the decisions to be made during the gaming sessions to their actual decisions, while the cRPG-V3 was more difficult for newcomers to use than the cRPG-V1 version. Both the assistance from former players and more time to provide detailed explanations were required. The DT-ABM computer simulator still needs to be tested with the stakeholders (with both former players in the previous workshops and newcomers to ComMod activities) to assess its inherent limitations.

Table 10.2. Advantages and limitations of the simulation tools used in the ComMod process implemented iat Doi Tiew village, Nan Province, Northern Thailand.

Tool	Advantage	Limitation
cRPG-V1	- Provided an in-depth understanding of the situation and increased awareness of the conflicting issue - Provided a high level of interactions among participants - Useful to elicit decision-making processes and social interactions among stakeholders to be incorporated into the autonomous Agent-Based Model - Suitable for learning by acting (Crookall and Thorngate, 2009) and observing other players' behaviours	- Costly and time consuming, requested several assistants to implement many complementary tasks, not suitable when participants have another activity the same day of the workshop - Number of players in a gaming session was limited
cRPG-V2	- Supported more scenarios exploration than cRPG-V1	- Became complicated for participants who never participated in the gaming sessions
cRPG-V3	- Adjusted to participants' needs: additional step on "decide upland rice" - Better time management than cRPG-V1 and V2	- Inputing information via the model interface was mistake-prone - More difficult for new comers compared with cRPG-V2 and V1
DT-ABM	- Reduced risk of human mistakes while manipulating - Time & cost efficient simulation - Suitable for learning through discussion of simulation results from diverse scenarios	- Need for a "human interface" to explain the model features, especially vegetation dynamics - Need programming skills to allow the modification of the model upon request.

10.2.3. Suggestions for future use of these models

Different kinds of modelling tools can be used with different types of stakeholders (Castella, 2009; Von Haaren and Warren-Kretzschmar, 2006). According to their specific degree of abstraction, the simulation tools produced in the Doi Tiew case study could be useful in different situations. The three first versions of the model could be used to support collective learning with local stakeholders. The cRPG-V1 would mainly be useful at the beginning of a process implemented at a new site, where similar problems are occurring, in order to improve the knowledge on the structure and behaviour of the system. The cRPG-V2 and cRPG-V3 tools could be used with experienced players to improve their individual thinking capacities, to promote shared learning and to pave the way towards more coordination among actors when managing the land. The DT-ABM version could be used with stakeholders who have limited time to participate in long gaming and simulation workshops, especially the government officers and policy makers. The presentation of the outputs from different scenarios through rapid simulations could allow them to better envisage the effects of various land management options on the landscape, but also on the different segments of the local population. Moreover, both the c-RPG-V3 and DT-ABM tools could be used for educational purposes by allowing students to play different roles during a gaming session[34], and to discover an alternative way to learn about interacting constraints in natural resource management, particularly the ones related to the ecological and social aspects of the co-existence of forest conservation and cattle raising in the highlands.

10.3. Evolution of stakeholders' participation

10.3.1. Dynamics of participants

Figure 10.1 illustrates the dynamics of the stakeholders' participation along the ComMod process implemented at this study site. Because the land use conflict is a sensitive issue, the researchers facilitated the process by gradually involving the most relevant actors at the beginning before up-scaling it to new participants. Thanks to the stakeholder analysis, we involved the NKU foresters and Doi Tiew herders into the first collaborative modelling sequence. The NNP rangers were not involved at the beginning because of their very strong top-down behaviour compared with the NKU foresters, but we plan to involve them later.

To make sure that communication and negotiation among the stakeholders would be carried out with equity, the herders from the three relevant different farm categories (B, C and D) were selected in proportion with their occurrence in reality. Thus farmers from type A were excluded since they do not rear cattle. Moreover, different modes of (individual and collective) cattle management were introduced to allow all types of herders from the three broad farm categories to share their perceptions with the others players.

In the second field workshop, more stakeholders were invited, including the manager and officials from NNP, DLD, Sob Khun Royal Project and the neighbouring headwater management units of Doi Kard and Sob Sai. However, only the NNP rangers and DLD officials showed up. Their collective interactions in this

[34] I used the cRPG-V3 tool with the Master students from the Faculty of Economics at Chulalongkorn University during the course titled "Ecological Modelling for Natural Resource Management." Two groups of 4 students each played the role of herders and one of them played the role of a reforestation officer. We found that the game was difficult for them at the beginning but they could learn it on the go. Negotiation to use the land between herder-players and the forester was observed. By the end, students learned that in natural resource management, the possibility for local resource users to maintain their activities is important and has to be taken into account.

phase showed that the communication and negotiation process among these stakeholders could lead to the design of a co-management action plan. In this case, the DLD preferred to support the provision of forage seed and technical training to herders upon request. Unfortunately, the park manager did not participate in the workshop and the low ranking officials representing the NNP had no authority to make any decision. Therefore, this could be improved in the near future by involving the park manager into the collaborative management process. Recently (August 2009), a new park manager was appointed replacing the previous one. It is possible to present the result from this ComMod process using DT-ABM.

In the third field workshop, out-scaling of the process was more clearly observed in the village. The former players requested us to conduct gaming sessions with their neighbours. They had communicated with their families and neighbours inside the village by explaining the results from previous gaming sessions, but those people did not feel any urgency to improve cattle rearing. As a consequence, the former players said: “making them play the game and understand by themselves is better. Then it will be possible to find alternative options to improve cattle more easily.” This was the starting point to the organization of the third field workshop with five new comers mixed with former players.

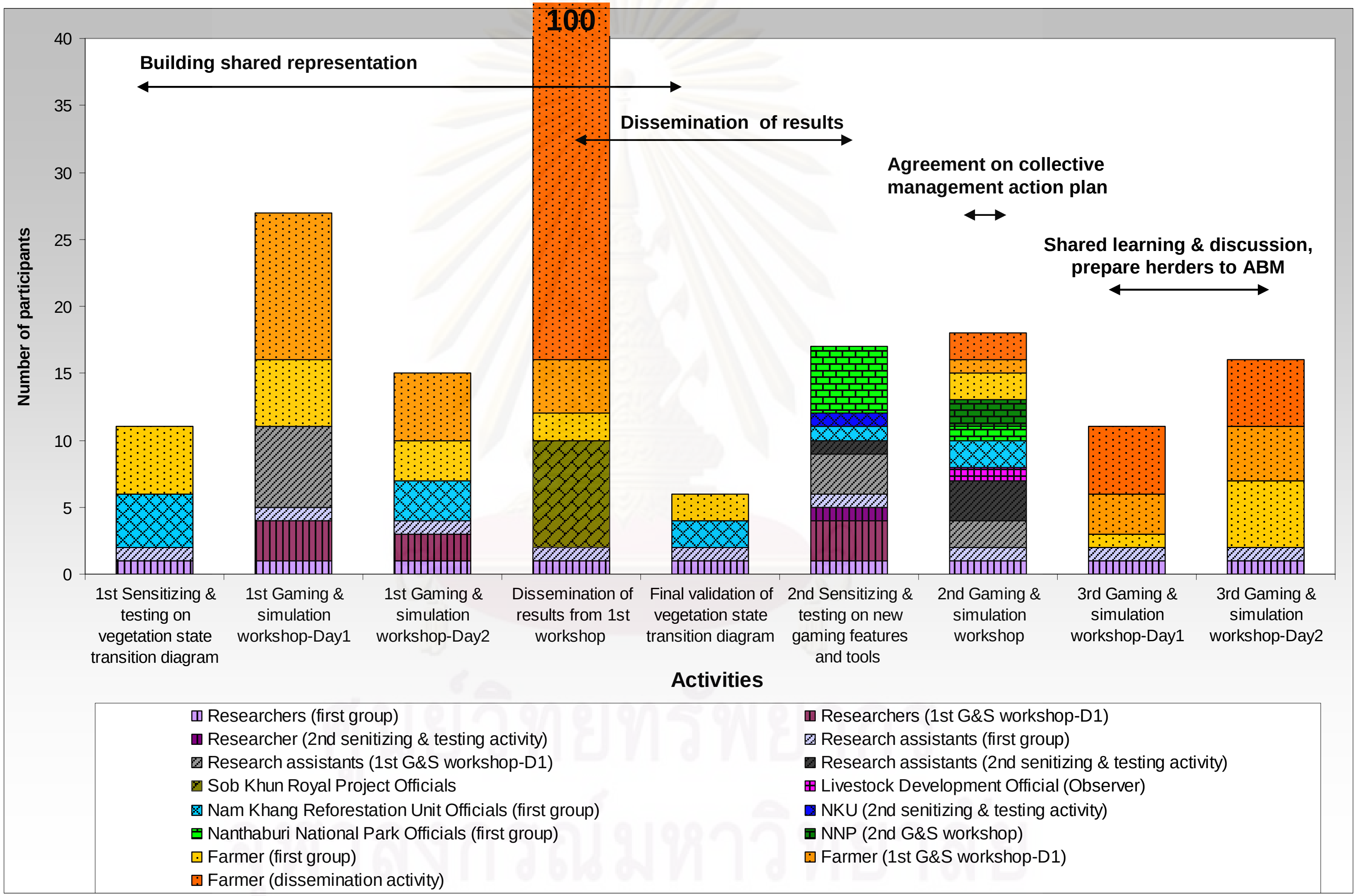

Figure 10.1. Dynamics of stakeholders' participation along the ComMod process implemented at Doi Tiew site of Nan Province, Northern Thailand.

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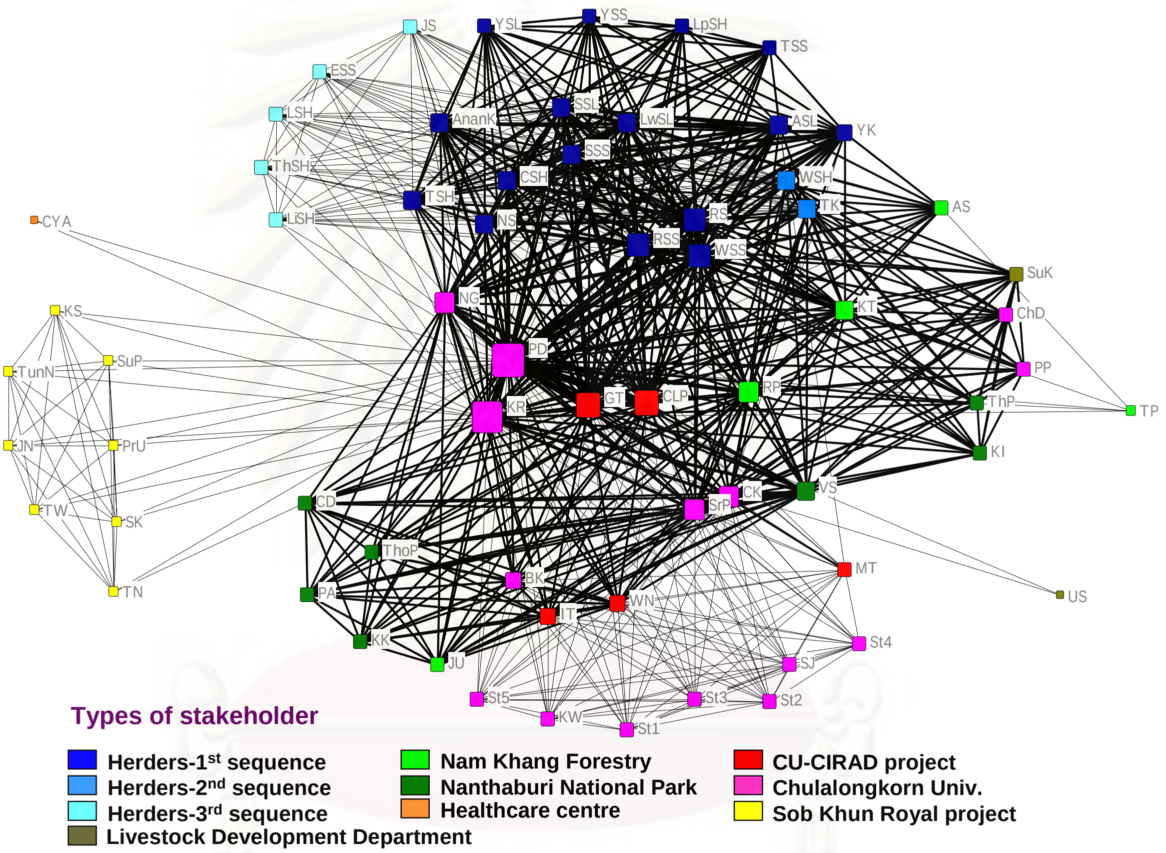
10.3.2. Degree of participation

Social network researchers measure network activity for a node by using the concept of degrees, that is the number of direct connections a node has (Hanneman and Riddle, 2009). During the implementation of the ComMod process at the study site, the interactions between active participants were observed and recorded and then used to create the network diagram of degree centrality (Figure 10.2).



Note: Line thickness is proportional to time spent interacting, node size is proportional to degree centrality.

Figure 10.2. Diversity of participants and distributed degree of centrality during the whole ComMod process

Not surprisingly, the lead researcher (PD) who facilitated the process at the beginning was the most active with the highest number of connections with the stakeholders, while three herders (RSS, RS and WSS) were found to be the most active among the group of participating herders. Along the process, these herders assisted the researchers and played an important role to invite other herders to share and learn in the workshops.

Moreover, we observed that these people who participated in the three workshops had well-understood the purpose of the gaming and simulation sessions and realized the important use of the gaming and simulation exercises. Therefore, it could be interesting to keep in touch with these herders in order to further involve them in the next set of activities, including implementing and monitoring the experimental ruzi pasture plot in reality.

10.3.3. Degree of involvement

Although some collaborative modelling schools pay attention to the co-design of conceptual models (Renger *et al.*, 2008), the ComMod approach attempts to involve the stakeholders along the whole modelling and simulation process. For this case study, the actual degree of involvement among the different stakeholders is presented in Table 10.3. The local stakeholders, especially the NKU foresters and the herders, were clearly observed to be involved in the design of the conceptual model by improving the range of vegetation states and producing the vegetation state transition diagram. They were also very much involved in the validation steps, identification of scenarios and exploratory simulations. However, they were not involved in the model implementation phase as it was mainly done by coding the ABM in the laboratory under the CORMAS platform.

10.3.4. Importance of group size on shared learning

In the second field workshop, the lead researcher attempted to balance the number of participants between the government side and the local herders' side. Therefore, 12 local participants took part in this workshop. This number was considered as suitable to allow the design of a co-management action plan through negotiation facilitated by the simulation tools and still be manageable by the research team. However, we found that the herders also paid attention to the learning aspects and not just to the negotiation of the collective action plan with the foresters. After the workshop, the herders said that more herder-players were needed in the gaming sessions to allow better knowledge exchanges and learning from each other. Therefore, balancing the research purpose and the stakeholders' needs and preferences is important when conducting ComMod activities.

Table 10.3. Stakeholder's involvement along the ComMod process implemented at Doi Tiew village of Nan Province, Northern Thailand.

Step	Type of stakeholders	Stakeholder	2007										2008												2009												2010		
			3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
1. Sensitizing activities	Resource users	Herders	1																																				
	Local administrator	DLD	1																																				
	Gov. officer	NKU, NNP	2																																				
	Researcher	Researcher	5																																				
2. Definition of the key question	Resource users	Herders				2																																	
	Local administrator	DLD				2																																	
	Gov. officer	NKU, NNP				2																																	
	Researcher	Researcher				5																																	
3. Collection of information related to issue	Resource users	Herders		1	1	1	1	1	1	1	1	1	1			1	1	1				2	2																
	Local administrator	DLD		1	0	0	0	0	0	0	0	0	0			0	0	0				2	2																
	Gov. officer	NKU, NNP		1	1	1	1	1	1	1	1	1	1			1	1	1																					
	Researcher	Researcher		5	5	5	5	5	5	5	5	5	5			5	5	5				5	5																
4. Eliciting knowledge for modelling	Resource users	Herders		3	3	3						3		2	2								2	2															
	Local administrator	DLD		1	0	0						0		0	0								0	2															
	Gov. officer	NKU, NNP		3	3	3						3		2	2								2	2															
	Researcher	Researcher		5	5	5						5		5	5								5	5															
5. Conceptual model design	Resource users	Herders																	0	0	4		0	5		0		0	0										
	Local administrator	DLD																	0	0	0		0	0		0		0	0										
	Gov. officer	NKU, NNP																	0	0	4		0	5		0		0	0										
	Researcher	Researcher																	5	5	4		5	5		5		5	5										
6. Model implementation	Resource users	Herders																		0	0			0	0	0	0		0	0	0	0	0	0	0	0	0	0	0
	Local administrator	DLD																		0	0			0	0	0	0		0	0	0	0	0	0	0	0	0	0	0
	Gov. officer	NKU, NNP																		0	0			0	0	0	0		0	0	0	0	0	0	0	0	0	0	0
	Researcher	Researcher																		5	5			5	5	5	5		5	5	5	5	5	5	5	5	5	5	5

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Step	Type of stakeholders	Stakeholder	2007										2008												2009												2010		
			3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
7. Model verification, calibration and validation	Resource users	Herders																		0	4				0		3					3		0			0	0	0
	Local administrator	DLD																		0	0				0		0					0		0			0	0	0
	Gov. officer	NKU, NNP																		0	4				4		3					0		0			0	0	0
	Researcher	Researcher																		5	5				5		4					5		5	5	5	5	5	5
8. Identification and definition of scenarios	Resource users	Herders																		0	0						4					0		0					0
	Local administrator	DLD																		0	0						0					0		0					0
	Gov. officer	NKU, NNP																		0	0						4					0		0					0
	Researcher	Researcher																		5	5						4					5		5					5
9. Exploratory simulations	Resource users	Herders																			3						4					4							0
	Local administrator	DLD																			0						3					0							0
	Gov. officer	NKU, NNP																			4						4					0							0
	Researcher	Researcher																			4						4					4							5
10. Dissemination of the outputs	Resource users	Herders																				4			4														
	Local administrator	DLD																				3			3														
	Gov. officer	NKU, NNP																				3			3														
	Researcher	Researcher																				3			3														
11. Monitoring-evaluation of the effects of the ComMod process	Resource users	Herders																														1							
	Local administrator	DLD																														1							
	Gov. officer	NKU, NNP																														1							
	Researcher	Researcher																														1							

Note: DLD = District Livestock Development officials, NKU = Nam Khang Headwater Conservation and Development Unit, NNP = Nanthaburi National Park.

Degree of stakeholder involvement in modelling process: Bold character represents decision-controller. Arrow represents flow of information.
0 = No direct interaction | 1 = Information [Stakeholder ⟵ **Modeller**] | 2 = Consultation [Stakeholder ⟶ **Modeller**]
3 = Co-thinking [Stakeholder ⟷ **Modeller**] | 4 = Co-designing [**Stakeholder** ⟷ **Modeller**] | 5 = Total control [**Stakeholder** ⟷ Modeller]

10.4. Learning effects along the process

A characteristic of the ComMod approach is the construction of simulation models integrating diverse stakeholders' points of view to facilitate collective learning, coordination and negotiation processes (Barreteau and Others, 2003). In this section, we present the effects of the process on stakeholders' learning at both individual and collective levels.

Three collaborative sequences with three progressively developing versions of the cRPG tools were implemented with local stakeholders, which led to diverse types of knowledge exchanges along this ComMod process, as shown in Figure 10.3. By looking at the time spent on information exchange between the different types of stakeholders with different kinds of knowledge during several activities, we found that 42 percent of the time was spent sharing the herders' "empirical/indigenous" knowledge and 24 percent regarding the "scientific and academic" knowledge from the main researcher and the ComMod trainees, while 10 percent of the time was spent exchanging "technical" and "institutional" knowledge brought by the NKU, NNP and DLD representatives, particularly at the end of the process when technical issues related to land allocation for the joint experiment of establishing a ruzi pasture system became more important. Below, we explain how such knowledge sharing activities provided insights to the local stakeholders.

10.4.1. Individual learning and perception change

10.4.1.1. Herders

Learning about the land management problem being examined: The ComMod activities stimulated the participating herders' awareness of the problems related to the future lack of grazing land. During the first gaming and simulation field workshop, scenario exploration showed that shrubby fallows and secondary forest could dominate the landscape in the near future (5-7 years). The herders realized that if they continued to practice their usual cattle rearing system while reforestation activities became increasingly constraining then the quality of their animals would decrease in parallel with forest regeneration. All of them agreed that the existing cattle rearing system in the village needed to be improved and they started to think collectively on how this could technically be achieved.

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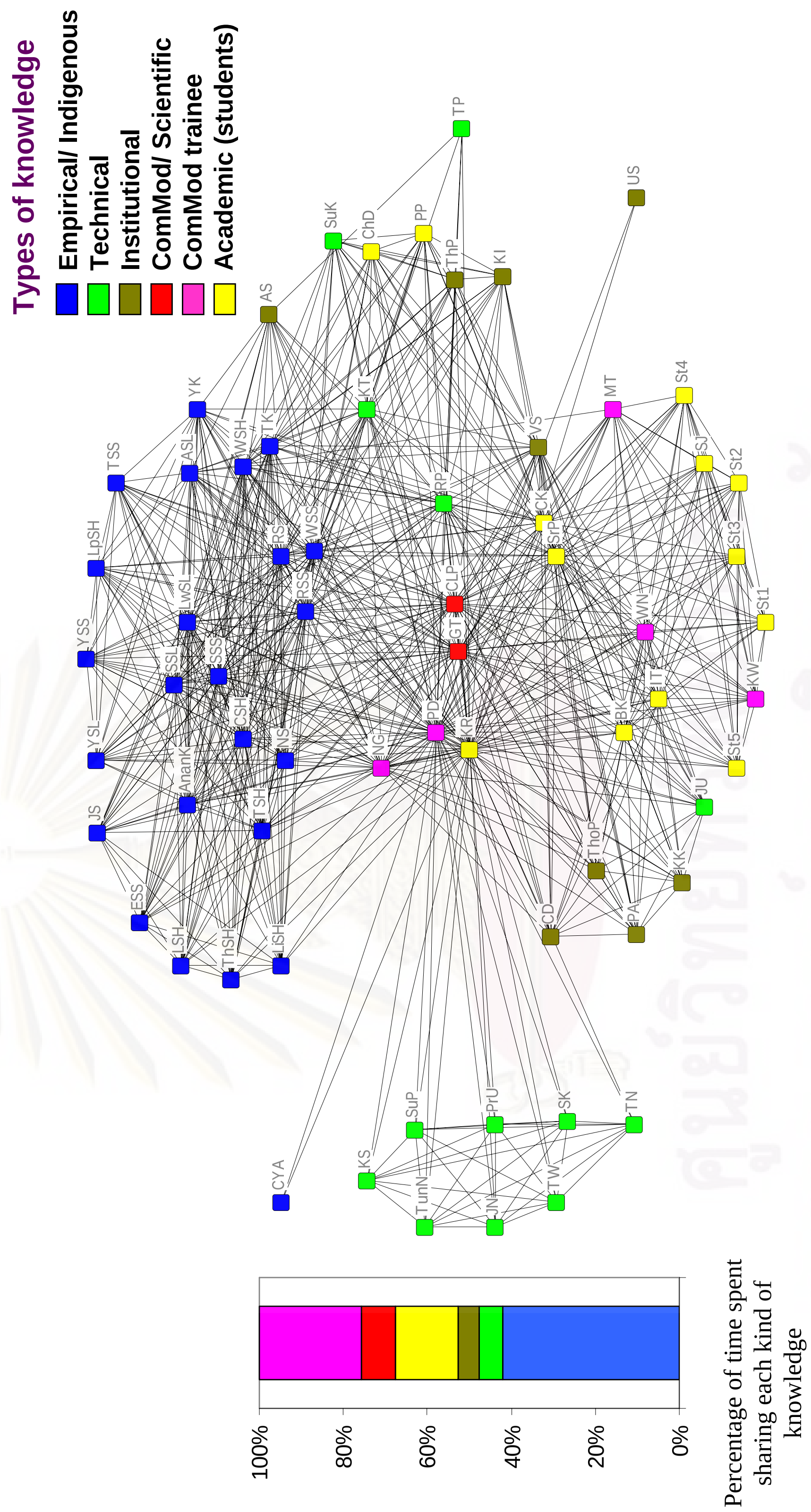

Note: Percentage of knowledge shared was calculated from the time spent of stakeholders having different types of knowledge.

Figure 10.3. Exchange of different types of knowledge among the participants during the ComMod process at Doi Tiew study site, Nan Province, Northern Thailand.

Knowledge acquisition: Through collective exchanges and by observing other players behaviour during the gaming and simulation sessions, individual herders gained new knowledge. Large stockholders (Type D farmers) were inspired to use a new technique like the ruzi pasture to feed their cattle in reality. Medium and smallholders (Type C and B farmers) learned how to manage their herds differently. Some of them started to think about selling several animals in reality to adjust their herd size to match the availability of forage. Previously, they just let their animals become thin and sold them when necessary. Others started to look for their own areas to establish ruzi pastures. At the individual level, they also realized the importance of collective exchanges to mitigate the land use conflict by finding alternative practices to improve their current farming system.

Perception change: Before the ComMod activities, the herders did not think about trying to improve their cattle rearing system, but after their participation in the field workshops, they identified alternative ways to continue and improve cattle rearing activity in their village. Gaming and simulation sessions with different modes of communication and debriefing allowed them to better understand and accept each other's different perceptions. This had the effect of raising their motivation to look for a better coordination of cattle management, for example when they decided to pool their herds together during gaming sessions. Following the completion of the first and second field workshops, it was easy to see that the herders had adopted a better feeling for NKU foresters and DLD officials after those officials proposed to help them to improve their cattle rearing system.

10.4.1.2. NKU foresters

Learning about the land management problem being examined: During the first gaming session, the NKU foresters faced the difficulty of finding new plots for reforestation. They realized that negotiation with the villagers and a compensation mechanism was needed in order to be able to continue to acquire land for their reforestation activity.

Knowledge acquisition: During the negotiations that occurred in the gaming session of the first workshop, the NKU foresters learned that the villagers were more aware of the forest resource problem than they had expected. Initially, they thought that the herders would not give them any cells for reforestation. But after exchanges on the reasons for reforestation activities and the subsequent negotiation, the herders better understood their need and agreed to give them two cells for reforestation. Moreover, they learned the benefit of using the gaming and simulation sessions to communicate with the villagers. They consulted the lead researcher to build a game to represent sustainable land use based on the agro-forestry concept. Therefore, this supported that the NKU foresters also found interest in these activities, but for different purposes compared to the herders.

Perception change: Before conducting the workshops, the NKU foresters had a negative feeling regarding cattle rearing. But after listening to the herders and seeing their dimmed future because of the limited access to grazing land in the first workshop, they preferred to help the herders to improve the existing cattle rearing system by allocating an approximately 10 ha plot to establish an experimental ruzi pasture to study how to manage it efficiently under the local conditions.

10.4.1.3. NNP foresters

Only low ranking rangers from NNP participated in some of the ComMod activities. However, they gained some benefit from them.

Learning about the land management problem being examined: As some of the NNP foresters played the role of herders during the testing session, they realized how difficult it was to find areas to establish paddocks under the increasingly constrained reforestation efforts. They also agreed to introduce the ruzi pasture technique to improve the existing system. But, they still wanted to enforce the formal legal rule by saying that “the pasture area should not be located inside the park.”

Knowledge acquisition: By observing the herders’ decisions and behaviour during the gaming sessions, they learned more on how they make their decisions and choose their cattle rearing practices.

Perception change: The gaming and simulation sessions allowed these NNP officials to better understand the herders’ constraints, but they did not change their interpretation of the park law and did not show any flexibility regarding its local enforcement.

By comparing the behaviour of NNP rangers and NKU foresters, this research showed that a mechanism for the co-management of the land could be set up more easily with government agencies maintaining more contacts with the local people.

10.4.1.4. Livestock developer

This research involved a DLD official in the second gaming and simulation field workshop. He said that such land use conflicts between foresters and herders are common in the region and he was interested by the use of gaming and simulation as a communication platform because it makes things easy to understand for the different parties. After observing the herders’ decision-making in the gaming session, he could see technical points that could be suggested to them to improve their cattle rearing practices in reality, like the creation of a permanent pasture. He also said that this activity allowed him to better understand what herders really needed to improve their cattle rearing. This is because, usually, he would just visit villages to promote cattle rearing techniques to herders without first asking what their specific needs are.

10.4.1.5. Researchers

The researchers also gained a better understanding of the system from the ComMod activities.

Learning about the land management problem being examined: The preliminary diagnostic analysis helped the research team to better define and understand the origin of the local land use conflict, and to identify the key actors to be involved in the subsequent collaborative modelling process.

Knowledge acquisition: The gaming and simulation sessions allowed researchers to improve their understanding of the stakeholders’ decision-making processes related to cattle and forest resource management. Moreover, the researchers learned how to better use the simulation tools and to facilitate the search for a collaborative management plan with them.

Perception change: At the beginning of situation, we did not believe that foresters and villagers would communicate with each other. But after completion of three collaborative modelling sequences with these local stakeholders, we found that both of them wanted to solve the conflict. They just needed a facilitator and an excuse to bring them to talk together.

10.4.2. Collective learning

10.4.2.1. Regarding the cattle raising and forest regeneration issue

The ComMod step-by-step process, as facilitated by the researchers, allowed the integration of knowledge from the herders, foresters and researchers to co-construct a vegetation state transition diagram that was instrumental in the model implementation phase. Moreover, the visual representation of the vegetation dynamics produced with the cRPG-V1 tool during the first workshop stimulated both herders and foresters to think about how to improve cattle and land management collectively, to mitigate the current land use conflict and to avoid the looming future risk of a lack of grazing land. This collective learning on joint management at the landscape scale, based on changes in their individual behaviours, led to their subsequent agreement on setting up a co-management action plan.

10.4.2.2. Trust building

In natural resource management, trust amongst the concerned parties and institutions is important to achieve the stated goal. Trust can be defined as "the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party" (Mayer *et al.*, 1995). Based on this definition, at the beginning of the research reported in this dissertation, the level of trust between the main parties engaged in the local land use conflict was very low. But, at the end of the second workshop, both sides started to cooperate to establish a joint experiment, supporting the notion that the collaborative modelling activities implemented at this site had helped to raise the level of trust amongst these two conflicting parties. However, the long term monitoring of their interrelationships is still required because trust can diminish if the management goal is not achieved (Kim, 2009).

10.4.3. From co-learning to capacity building and improved capacity for adaptive management of the land

Beyond the immediate effects on the stakeholders presented above, this ComMod process also supported long term forest-farm land management at the study site in the following way:

Ecology: Forest and land management tend to be improved by the coordination between herders and foresters practices. Herders may introduce the ruzi pasture technique in the system and future research on its sustainable management is important.

Individual adaptive capacity: Thanks to the exploration of several scenarios during the past 3-5 years with the cRPGs simulation tools, the participating herders can better envision future possibilities for the management of their forest-farm land area. This motivated them to think about and imagine future plans to improve their cattle raising system (as presented in details above in the herders' learning section).

Social interactions among herders: Before conducting the workshop, all the participating herders had no idea how they would be able to pursue their cattle rearing practices. After two workshops, they realized the importance of exchanges in the search for a collective solution. They intensified the communication channels and, by inviting new herders to join them in the third workshop, they showed that social interactions became stronger inside the village.

Social interactions among different types of stakeholders: The ComMod research involved diverse types of stakeholders into the process and allowed them to improve their future cooperation. For example, very practically, the herders learned how to request forage seeds from the DLD office.

10.5. Strong points and limitations of the ComMod process

10.5.1. Strong points

An evolving, flexible and adaptive process: The ComMod process implemented in this case study progressively developed based on the local stakeholders' suggestions and requests. The simulation tools and the choice of land management changed accordingly. By doing this, the process increased the sense of ownership of the models in the participants because the artefacts used integrated their knowledge and preferences. This was confirmed by the request from the herders to continue to use the model with their neighbours. It could be said that, gradually, the family of models made available to them constituted a useful way to think about their system.

Regarding the flexibility of the approach, the simple addition of the “select upland rice” step in the third workshop motivated the herders to think beyond livestock rearing and about other issues related to farming in this village. Therefore, the ComMod process could be adapted to either focus more on cattle management, or on other natural resource management or farming issues in the village, such as crop management, water conservation, forest conservation, etc., depending on the villagers interest. We could even think about adapting such tools to introduce the topic of adaptation of farming to global issues, such as climate change.

Usefulness to improve decentralised forest management: The cRPG tools used in the ComMod process allowed stakeholders from different institutions (villagers and government agencies), and equipped with varying levels of decision-making power (i.e. different farm types), to participate in a collective learning and negotiation process. Although the number of participants in each workshop was severely limited, they represented the relevant categories of stakeholders, including the resource-poor people, in the process. Therefore, the ComMod approach can be used to support the decentralised management of common resources with attention to social equity.

Iterations between field and laboratory work: This is a fundamental principle of the ComMod approach. In this case, iterations between field and laboratory activities allowed researchers and stakeholders to gradually exchange and validate the information and knowledge used to build the model together. For example, the first version of the pictograms used to design the vegetation state transition diagram proposed by the researchers based on their understanding, was validated with the stakeholders in the field. Moreover, the cRPG-V1 was developed by using data from the field survey and the literature. Then, it was used in the first gaming and simulation field workshop. During the gaming sessions and interviews, stakeholders were asked to comment on these models and by doing this, the models were “socially validated” (Moss, 2008) by confronting the views of diverse type of stakeholders. Later on, the different stakeholders came to accept the results of these simulations during the scenario exploration phase.

10.5.2. Limitations of the process and how to further improve it

10.5.2.1. Pace of the ComMod process

The ComMod approach is trans-disciplinary. It involves different kinds of expertise working together and takes into account the different points of view of local stakeholders to co-construct a model accepted by all of them. Such a process took almost three years to be completed at the Doi Tiew site due to the following several external factors:

Availability of the participants to join in the collective activities: It was difficult to work with Hmong herders, an ethnic group that used to cultivate "the art of not being governed" as stated by Scott (2009) in his recent book. This was especially the case during the cropping season because they usually stayed overnight in their fields. Moreover, unexpected external factors, such as fluctuating market price of their main economic crop, motivated them to suddenly disappear from the village to sell their product. This was the case in January 2009 when, although the research team made a firm appointment with them before, not even a single herder showed up at our meeting! Therefore, the process facilitator needed to be flexible and to be able to modify the work plan when working in such conditions. For example, at the end of the process, during the third gaming and simulation field workshop we actually conducted the gaming and simulation sessions in the evening, after the daily farm work was finished.

Pace of ABM programming: In this case study, the gaming and simulation field workshops were conducted every six months. This could be seen as rather slow paced, especially considering the urgency of the problem to be mitigated. Certainly, after the completion of the first workshop, both herders and foresters wanted to immediately use the model to explore new cattle and land management strategies. If we could have conducted a second workshop faster, the setting up of a co-management action plan would have occurred faster and could have been implemented in the field earlier. However, it is not easy to build an ABM in CORMAS because it is not an icon-based or user-friendly platform. Therefore, quite a long time is needed to learn how to use it before being able to build an ABM. Programming skills are very important to make sure that the model, especially its computer part, is ready when it needs to be used.

Frequency of activities: The organization of a workshop every six months was not suitable, in terms of the period between each session, for the local people to build on their learning of the gaming features and rules from one session to the next before they could forget them. In the future, we suggest conducting more frequent activities or simulations with the local people in order to sustain their learning capacity.

10.5.2.2. Difficulty to train local stakeholders to facilitate such a process

The process facilitator ("the human interface") at the study site is a key participant for the continuation of the process, especially when researchers are absent. In this case study, the herders discussed and suggested to the village headman and his village committee members to play such a role. Again, further monitoring of the effects of the reported activities is still needed to assess the feasibility of this proposition.

CHAPTER XI
CONCLUSIONS AND PERSPECTIVES

11.1. Conclusions

The implementation of a ComMod process in this research has been shown to be suitable and useful for reaching the research objectives. Both the researchers and the local stakeholders gained benefit from this research through collaborative knowledge sharing along the iterative and progressively developing modelling process. This was comprised of three main phases: a preliminary diagnosis, followed by three collaborative modelling sequences and then lastly ending with the construction of a final simulator and its use in the laboratory.

The preliminary diagnosis phase was very important to elucidate the background of natural resource management, the conflicting situation and the stakeholders' perceptions and strategic decision-making processes regarding the cattle and forest management for each main type of stakeholder. It was also useful for the construction of the researchers' own representation of the system under study.

This research demonstrated that the complex ecological and social dynamics related to cattle grazing and forest regeneration in these mountainous areas could be modelled with the stakeholders after simplifying the system by selecting only the key interactions between the resources and different users to be included in the shared representation. The results from the preliminary diagnostic activities were also very helpful to guide this simplification. We showed that a simplified spatial interface, characterised by a set of pictograms, can represent the complexity and heterogeneity of land use and land cover in the study system, and at the same time be easily understood by the local herders who have received very little formal education.

The collaborative modelling process delivered a family of models composed of three successive versions of a computer-assisted Role-Playing Game with different degrees of abstraction, and one Doi Tiew Agent-Based Model (DT-ABM). During this progressive development of the models, comments and requests from local stakeholders were taken into account and guided the modifications of the simulation tools in order to tailor them to these end users changing needs. Along the way, this process allowed the integration of (a) the “empirical/indigenous” knowledge from herders, (b) the “technical” and “institutional” knowledge from NKU, NNP and livestock development officials, and (c) the “scientific” knowledge from researchers into the models. This co-design and gradual improvement of the tools are important steps to create transparency, mutual understanding and trust between the researchers and the local stakeholders. This also helped to sustain the motivation of the local stakeholders to participate in the process because they could gain some benefits from it, had a sense of co-ownership of the tools developed along the way, and were able to propose scenarios to be simulated and assessed that were based on their interests.

Such models can be used as simulation tools to improve communication and to support co-learning on the interactions between stakeholders over, and to resolve, the apparent conflict of cattle rearing and forest regeneration. The differences in the formal education levels were not perceived as a serious obstacle to the use of the proposed tools, and indeed the ability to express their own opinions was encouraged by the non-threatening gaming environment. The interactive and visual features of the simulation tools also overcame the barriers of those participants with a lack of confidence in public speaking as well as the local language barrier. It also was shown that the features and rules of the simulation tools, which seemed rather complex to outsiders, were not found to be difficult to understand and use by the highland Hmong farmers and government officials because they were dealing with their everyday farming life and resource management practices.

During the participatory exploration of simulated scenarios, the stakeholders gained different types of knowledge by observing each other’s behaviour and taking part in discussions on various topics such as land and cattle management strategies and techniques. New ideas on how to mitigate the land use conflict and how to improve cattle rearing practices emerged from these social interactions, leading to the setting up of a co-management action plan acceptable to the conflicting parties.

The ComMod activities implemented so far have allowed for the construction of the DT-ABM simulator to explore different land and cattle management scenarios in the laboratory in a cost and time efficient way. The simulation results showed that human decisions regarding the management of the forest-farm land interface are an important driving factor of the system behaviour at the landscape level. Unfortunately, a lot of time had to be spent on the implementation of the collaborative modelling phase because of constraints imposed by the external factors at study site. Therefore, within the limited period of time available for this doctoral research, this final DT-ABM simulator could not be presented and used with the local stakeholders.

In summary, the ComMod approach was found to be very efficient to improve the understanding of the complex interactions between cattle raising and forest regeneration in this highland area, and to be a relevant way to facilitate collective learning and adaptive land management among the concerned stakeholders in a very interactive fashion.

11.2. Perspectives

Based on the results of the ComMod experiment reported in this dissertation, the suggestions to improve the process and tools used, as well as the future research to be carried out are as follows:

11.2.1. ComMod process and tools used

11.2.1.1. Training a local facilitator

In this case study, we found that the ComMod process is very useful for local stakeholders but nobody could facilitate the continuation of the process when the lead researcher cum process facilitator was absent. As a consequence, the ComMod process at this study site could not be sustained. Although we work closely with the local stakeholders, it is difficult for them to learn how to manage such a process by themselves. Therefore, we are going to seek a person, equipped with a high learning capacity and who is willing to use this collaborative approach, to train her about the ComMod principles and tools and on how to facilitate such a collaborative process.

11.2.1.2. Involve diverse stakeholders from government agencies

Several government agencies interact with each other to manage the forest-farm land system in these highlands. In this case study, only a few of them participated in the ComMod process. Although the implemented process could achieve a local co-management action plan at the village level, we think that if we could involve more government agencies into the process, it could be generate more appropriate action plans. But to do so, more effort and time in the field is required.

11.2.1.3. Balancing stakeholders' understanding of simulation and time spent

When using such models, it is necessary to balance the logistics of time management against the stakeholders' understanding and interactions. The objective for using the model should be set up clearly so as to be able to select the most appropriate participants for use in the simulation sessions. In this case study, the more realistic version of the model provided a more in-depth understanding of the issue being examined and better interactions compared with what happened with the earlier and more abstract versions.

11.2.1.4. Simulation of scenarios and "recommendations"

In Thailand, like in many other parts of the world, the past use of computer models has been dominated by the objective of predicting future situations. Therefore, much care and clarification are needed when introducing the ComMod modelling and simulation approach in such a context. The process designer needs to state repetitively that this is not the objective but that rather the main objective is of improved dialogue, sharing of perceptions and knowledge for joint learning to avoid misunderstandings during the collective exploration of scenarios and the analysis of key selected ecological and social indicators. The risk is always around the corner, but needs to be minimised, that what seems to be "the best scenario" in the gaming sessions will be taken home by some participants as a "recommendation" to actually be implemented on the farm.

11.2.2. Forest-farm land management and future research

Negotiation processes are required to find a collective agreement on the management of the forest-farm land interface in order to balance the natural resource conservation goal and the social viability of local people's livelihoods. However, the government agencies and local resource users need to better communicate and improve their understanding of the system together before setting up such negotiations. Moreover, collaborative activities between the villagers and government officials should be conducted more frequently to improve information and knowledge exchange, improve familiarity and trust and so strengthen or set up new coordination mechanisms relying on a higher level of trust amongst them.

The ruzi pasture pilot experiment is the first concrete outcome from this ComMod case study and it is possible because of the improved trust between the Doi Tiew herders and NKU foresters who participated in this ComMod process. There is still a need to continue to improve the sustainability of the initiated co-learning process. The sustainable use of ruzi pastures in this heterogeneous and variable highland environment is an appropriate research theme to be examined in the near future because there is currently very limited information on the subject while the local people are eager to assess this technological innovation. Moreover, it seems to be feasible to conduct such research in a collaborative way by involving the local DLD technician who already understands the ComMod process. By doing this, more pasture development techniques could be integrated in the existing farming system while improving the herders' and foresters' knowledge.

Furthermore, the out- and up-scaling of the implemented ComMod process is still needed in this region. The use of the DT-ABM simulator with newcomers assisted by former Hmong players could be an appropriate way to look at out-scaling activities where similar land use conflicts are occurring. Several conservation areas in Thailand are facing similar problems to this study site. It would be interesting to implement ComMod processes at a new site to gain a better understanding of the interactions where cattle rearing practices and the forest ecosystem are different.

The ABM simulator could also be used to up-scale the process with decision and policy makers at higher levels to help them to understand the local people land use strategies, practices and projects by simulating well-selected scenarios in a time efficient way.

In both out- and up-scaling activities, the important flexibility of the simulation tools used in this research, whether that be to make it simpler and very focused or more complex and more comprehensive, will be crucial to adapt the process to new themes and improve the feasibility of the proposed research.

Another complementary, and more medium term activity, that is very relevant to the current Thai Society would be to modify the existing versions of the models to use them in teaching and training programmes on participatory renewable natural resource management, both at the local school and university levels, in order to provide new perspectives to younger generations and boost their capacity to adapt to change.

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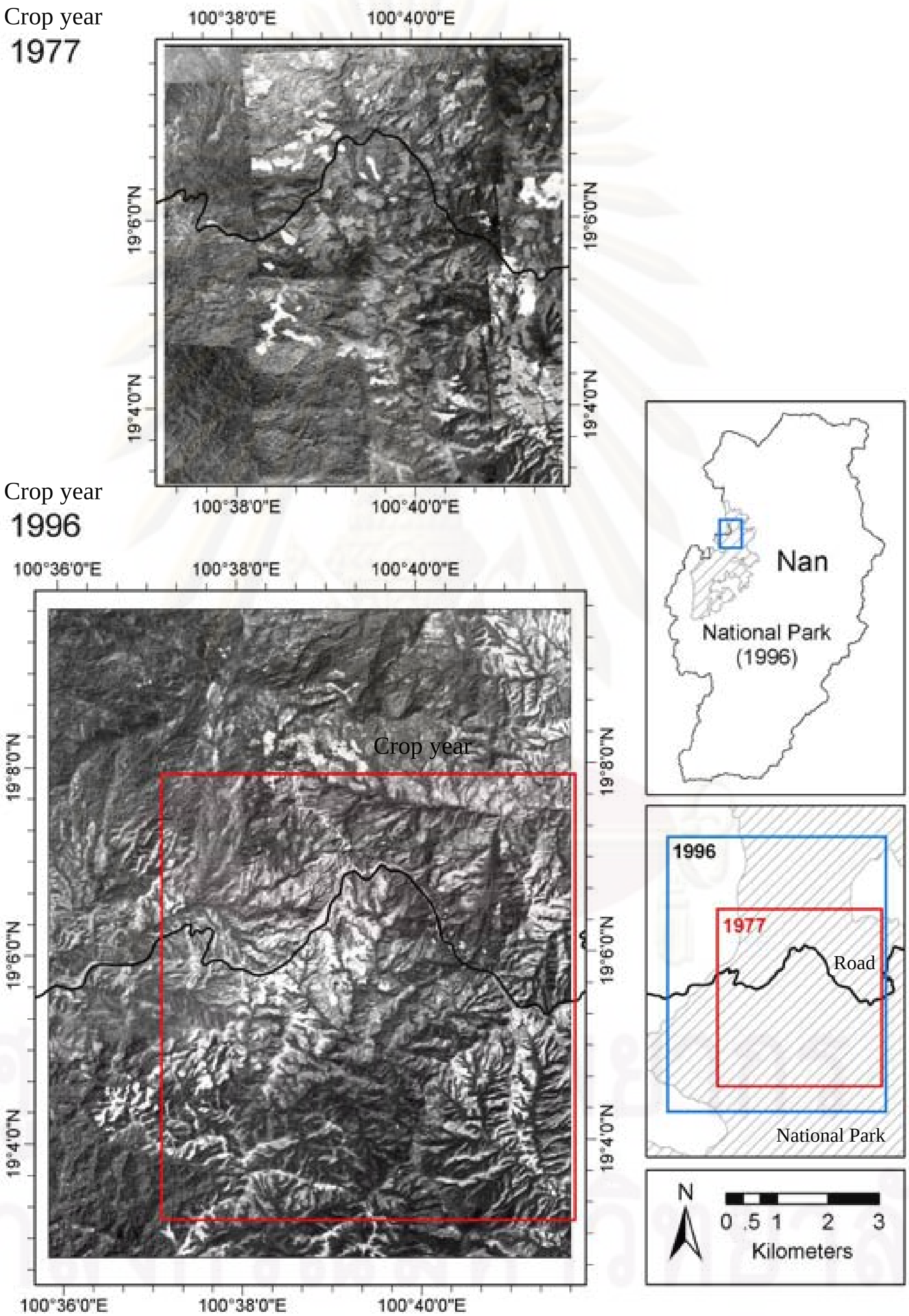
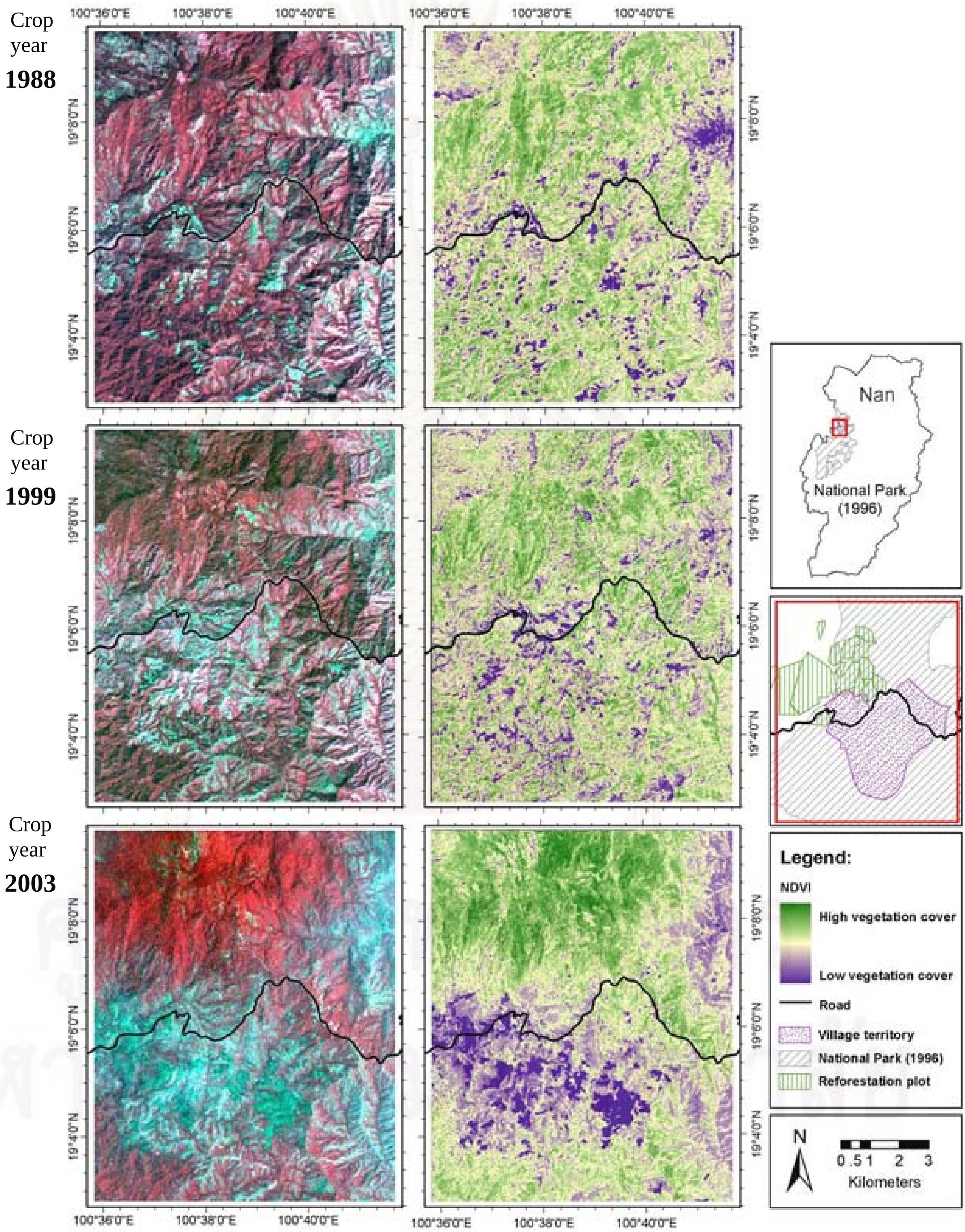
APPENDICES

Appendix A. Aerial photos of Doi Tiew village area (Scale: 1977 = 1: 15,000 and 1996 = 1: 50,000). Dark shade represent high vegetation cover and bright shade represent agricultural area and bare soil.



Source: - Royal Thai Survey Department.

Appendix B. False colour composite (Red Green Blue: Band 4, 3, 2) satellite images (left) which the shade of red representing high vegetation cover, and Normalised Difference Vegetation Index (NDVI) derived images (right) of Doi Tiew village area used for land use and land cover classification.



Source: - Downloaded from http://glcf.umiacs.umd.edu/data/landsat/ (accessed on July 2007).

Appendix C. AGB for different vegetation layers of the main land use types in the (a) wet and (b) dry conditions at Doi Tiew forest-farm land interface, Nan Province in June and December 2007.

a) Late June

	State	Pl_code	Above-ground biomass in wet season (kg/ha)				
			Tree	Sapling	Seedling	Grass	Herb (non-grass)
Grazed	Fallow	Fa6mo_G6mo	NA	NA	NA	NA	NA
		Fa_G1y	0 a	0 a	0 a	1,408.1 ± 531.0 bc	58.7 ± 85.5 a
		Fa2y_G2moH	0 a	2,495.8 ± 2,171.3 a	477.5 ± 489.6 bc	1,584.7 ± 830.9 c	298.6 ± 149.9 ab
		Fa_G2y	0 a	2,362.5 ± 2,007.4 a	46.6 ± 53.4 ab	3,211.0 ± 1,754.1 d	314.3 ± 191.2 ab
		Fa_G3y	9,938.3 ± 8,045.7 b	12,368.8 ± 7,874.6 b	256.2 ± 245.4 abc	88.3 ± 112.8 ab	806.8 ± 515.6 b
		Fa4y_G8mo	6,667.3 ± 1,0951.8 ab	12,506.7 ± 3,242.1 b	511.6 ± 245.5 c	26.0 ± 18.0 a	554.0 ± 467.1 ab
		Fa4y_G2yNf	NA	NA	NA	NA	NA
		Fa_G7y	10,369.0 ± 5,599.3 b	1,037.5 ± 926.2 a	0 a	62.4 ± 56.2 ab	440.1 ± 406.5 ab
		Fa_G10y	NA	NA	NA	NA	NA
		Fa_G12y	NA	NA	NA	NA	NA
		Fa_G15y	NA	NA	NA	NA	NA
	Fruit tree	Orc	14,143.0 ± 1,906.9 b	0 a	0 a	916.2 ± 693.7 abc	161.1 ± 71.1 a
	Tree plantation	Pl4_G4	0 a	393.8 ± 682.0 a	232.9 ± 161.4 abc	327.3 ± 135.0 abc	21.0 ± 9.1 a
		Pl6_G2	829.0 ± 789.9 a	1,064.5 ± 706.9 a	326.1 ± 290.9 abc	26.0 ± 9.0 a	560.6 ± 478.3 ab
Non-grazed	Pasture	Ruzi2y	0 a	0 a	0 a	6,266.2 ± 515.1 d	5.2 ± 9.1 a
	Fallow	Fa2mo_Rice	NA	NA	NA	NA	NA
		Fa2mo_Maize	NA	NA	NA	NA	NA
		Fa1y	0 a	16.7 ± 28.9 a	232.9 ± 201.7 a	2,894.1 ± 636.3 bc	521.4 ± 506.8 ab
		Fa2y	125.0 ± 216.5 a	667.7 ± 127.4 ab	582.3 ± 344.7 ab	4,697.0 ± 1,748.1 cd	31.4 ± 54.4 a
		Fa3y	0 a	16.7 ± 28.9 a	0 a	1,236.6 ± 1,067.7 ab	3,498.8 ± 2,291.6 cd
		Fa4y	0 a	281.3 ± 211.3 a	58.2 ± 53.4 a	9,622.7 ± 935.4 e	5.2 ± 9.1 a
		Fa6y	384.7 ± 337.2 a	343.2 ± 297.6 a	452.4 ± 345.0 ab	2,001.3 ± 786.2 ab	2,613.2 ± 1,839.7 bcd
		Fa7y	1,874.3 ± 2,847.5 a	2,810.4 ± 3,209.2 ab	0 a	3,273.4 ± 4,673.9 bc	1,445.9 ± 1,174.4 abc
	Fruit tree	Orc	16,208.7 ± 1,208.4 a	0 a	0 a	1,060.5 ± 1,083.5 ab	1,095.1 ± 969.0 abc
	Tree plantation	Pl1 (palm)	0 a	131.8 ± 126.5 a	357.4 ± 82.1 ab	24.1 ± 7.9 a	2,092.6 ± 378.5 abcd
		Pl1 (teak)	0 a	31.3 ± 54.1 a	920.1 ± 469.2 bc	1,345.7 ± 787.8 ab	1,964.6 ± 3,107.3 abcd
		Pl2	40,815.3 ± 18,628.9 a	3,852.1 ± 6,076.9 b	1,351.0 ± 833.7 c	717.0 ± 1,030.2 ab	1,806.4 ± 1,886.6 abcd
		Pl4	NA	NA	NA	NA	NA
		Pl11	46,244.6 ± 6,879.6 a	8,252.3 ± 2,030.3 c	22.1 ± 19.2 a	10.4 ± 18.0 a	67.7 ± 78.1 a
		Pl6	298,231.7 ± 24,356.9 b	0 a	0 a	0 a	4,124.2 ± 347.0 d
		Pl17	280,447.7 ± 43,727.8 b	0 a	0 a	97.0 ± 132.1 a	3,178.5 ± 457.7 cd
	Natural forest	Nat	489,639.0 ± 420,476.1 c	3,252.9 ± 873.7 ab	861.9 ± 610.5 bc	5.2 ± 9.0 a	0 a

Note: Where analyses of variance indicated significant differences among plots in within grazed or non-grazed areas, means followed by different letters indicate significant differences (Duncan's multiple means test; P < 0.05), NA: Not available plot for measurement.

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Appendix C (Cont'd.). AGB for different vegetation layers of the main land use types in the (a) wet and (b) dry conditions at Doi Tiew forest-farm land interface, Nan Province in June and December 2007.

b) Late December

	State	Pl_code	Above-ground biomass in dry season (kg/ha) Tree	Sapling	Seedling	Grass	Herb (non-grass)
Grazed	Fallow	Fa6mo_G6mo	0 a	77.1 ± 133.5 a	0 a	2,769.4 ± 2,457.3 bc	241.0 ± 292.1 ab
		Fa_G1y	0 a	0 a	23.3 ± 40.3 a	1,787.4 ± 406.9 abc	15.7 ± 15.7 a
		Fa2y_G2moH	0 a	1,682.5 ± 1,654.7 a	442.6 ± 106.7 a	228.6 ± 64.9 a	1,445.9 ± 166.3 ab
		Fa_G2y	0 a	1,595.8 ± 943.1 a	46.6 ± 80.7 a	2,634.3 ± 2,610.9 bc	408.6 ± 206.1 ab
		Fa_G3y	9,938.3 ± 8,045.7 a	5,304.2 ± 2,817.4 ab	23.3 ± 20.2 a	15.6 ± 0.0 a	1,922.7 ± 1,847.4 bc
		Fa4y_G8mo	6,667.3 ± 10,951.8 a	8,525.1 ± 6,452.1 b	687.3 ± 141.2 a	15.6 ± 15.6 a	527.3 ± 361.7 ab
		Fa4y_G2yNf	17,333.7 ± 16,787.2 a	15,627.1 ± 4,887.8 c	2,329.3 ± 290.9 b	581.9 ± 612.8 ab	89.1 ± 140.9 a
		Fa_G7y	10,369.0 ± 5,599.3 a	631.3 ± 131.3 a	0 a	26.0 ± 32.4 a	314.3 ± 272.2 ab
		Fa_G10y	1,005.0 ± 1,740.7 a	635.4 ± 173.5 a	104.8 ± 92.4 a	2,135.5 ± 2,914.4 abc	220.0 ± 354.2 ab
		Fa_G12y	55,891.0 ± 20,377.8 b	7,762.5 ± 4,793.2 b	582.3 ± 315.1 a	0 a	0 a
		Fa_G15y	192,521.0 ± 23,929.0 c	4,410.4 ± 3,096.2 ab	512.5 ± 290.9 a	0 a	15.7 ± 27.2 a
	Fruit tree	Orc	14,143.0 ± 1,906.9 a	0 a	0 a	139.4 ± 117.5 a	0 a
	Tree plantation	Pl4_G4	0 a	308.3 ± 218.4 a	244.6 ± 92.4 a	3,346.1 ± 943.7 c	943.0 ± 710.6 ab
		Pl6_G2	829.0 ± 789.9 a	385.4 ± 129.7 a	1,863.5 ± 1,651.2 b	2,836.9 ± 531.8 bc	3,080.4 ± 2,645.0 c
Non-grazed	Pasture	Ruzi2y	0 a	0 a	0 a	5,341.3 ± 320.0 b	41.9 ± 72.6 a
	Fallow	Fa2mo_Rice	0 a	0 a	2,900.0 ± 3,483.0 b	446.8 ± 565.7 a	838.2 ± 395.5 ab
		Fa2mo_Maize	0 a	0 a		129.9 ± 159.2 a	1,047.8 ± 65.4 ab
		Fa1y	0 a	535.4 ± 324.2 a	116.5 ± 106.7 a	4,697.0 ± 1,069.2 ab	136.2 ± 48.0 a
		Fa2y	125.0 ± 216.5 a	1,575.0 ± 416.0 a	151.4 ± 157.6 a	2,937.1 ± 1,043.9 ab	99.5 ± 50.5 a
		Fa3y	0 a	54.2 ± 93.8 a	0 a	20.8 ± 9.0 a	1,241.6 ± 1,024.7ab
		Fa4y	0 a	725.0 ± 706.4 a	46.6 ± 80.7 a	6,224.6 ± 2,056.2 bc	141.4 ± 15.7 a
		Fa6y	384.7 ± 337.2 a	560.6 ± 317.8 a	866.8 ± 802.1 a	2,440.6 ± 981.0 ab	1,682.4 ± 1426.7 ab
		Fa7y	1,874.3 ± 2847.5 a	1,293.8 ± 2,049.1 a	0 a	9,830.5 ± 8,226.1 c	2,965.2 ± 3,326.0 b
	Fruit tree	Orc	16,208.7 ± 1,208.4 a	0 a	0 a	209.8 ± 183.9 a	1,525.1 ± 599.6 ab
	Tree plantation	Pl1 (palm)	0 a	348.5 ± 127.4 a	34.9 ± 34.9 a	254.6 ± 294.2 a	6,416.0 ± 1,863.3 c
		Pl1 (teak)	0 a	325.0 ± 166.4 a	186.3 ± 40.3 a	3,642.3 ± 3,869.5 ab	618.2 ± 798.5 ab
		Pl2	40,815.3 ± 18,628.9 a	2,637.5 ± 3,471.0 ab	1,316.1 ± 982.3 a	2,577.1 ± 4,006.2 ab	1,194.5 ± 1,056.2 ab
		Pl4	4,829.3 ± 3,371.9 a	7,487.5 ± 11,036.9 b	11.6 ± 20.2 a	5.2 ± 9.0 a	5,333.1 ± 3,310.2 c
		Pl11	46,244.6 ± 6,879.6 a	7,671.9 ± 1,389.2 b	154.7 ± 142.1 a	20.8 ± 23.8 a	33.3 ± 28.9 a
		Pl6	298,231.7 ± 24,356.9 b	0 a	0 a	0 a	2,431.7 ± 235.9 ab
		Pl17	280,447.7 ± 43,727.8 b	0 a	0 a	0 a	2,390.6 ± 505.1 ab
	Natural forest	Nat	489,639.0 ± 420,476.1 c	2,925.0 ± 1,823.6 ab	1,024.9 ± 449.3 a	0 a	0 a

Note: Where analyses of variance indicated significant differences among plots in within grazed or non-grazed areas, means followed by different letters indicate significant differences (Duncan's multiple means test; P < 0.05). Not available plot for measurement.

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Appendix D. Guidelines for individual interviews of participating farmers after the first gaming and simulation field workshop.

Objectives of these individual interviews

(i) To obtain their personal assessment of the gaming and simulation tools used during the workshop,

(ii) To better understand their own decisions in the successive gaming sessions (Day 1 morning and afternoon, day 2 afternoon), regarding different important topics (such as the delimitation of paddocks, the allocation of cattle to paddocks, relationships between cropping and animal rearing activities, communication, exchanges and influence among members in each small group, etc.),

(iii)To obtain their opinion about what should be the orientation and contents of the next steps of the ComMod process.

Only for new comers: As you have never been interviewed before, why are you interested in joining this workshop? And what are your expectations?

1. **What do you think about the tools used in the successive gaming sessions? Are there major differences with reality** (differences which are important enough to be corrected in the next version of the simulation tool) **concerning:**
   a. Spatial representation of the land: were the initial and successive maps of the landscape given to players easy or difficult to use?
   b. Types of possible vegetation states: were they easy or difficult to understand?
   c. Rules of transition from a vegetation state to another one: were they easy or difficult to understand?
   d. Different types of farms (size, fields and paddocks, cattle population, etc.)
   e. Size and dynamics of own herd of cattle (natural growth, losses, sales, etc.)
   f. Decisions and actions players make in the game: is there anything important that you consider to be missing?
   g. Chance cards
   h. Were the results obtained during the session similar to reality? Are they realistic enough? Explain why?
   i. Could you understand what the computer was doing?

j. Is the association between a game and its computer support difficult to understand? Explain why?
k. Are the game and a computer simulation doing similar things? What is different?

Review these topics (if relevant, depending on the tool used in each session) for each of the successive sessions:

- Day 1 Morning,
- Day 1 Afternoon,
- Day 2 Afternoon (with foresters)

2. Own role and decisions in the gaming sessions

a. Day 1 morning session
    1. Step by step, review the informant's decisions made during the session and their determinants, and explain why you state such?
    2. Did you observe changes in vegetation states and did you agree with them? Explain why?
    3. Did you agree with the changes made in the size and status of your herd of cattle? Explain why?
    4. Did you observe the choice(s) of other players in your group? Who, when and how/ why? Did it influence your own choice? Did you ask for advice from any other player(s), and if so, who, when and why? Did he influence your choices?

b. Day 1 afternoon session (Same as the section above)
c. Day 2 afternoon session with foresters
    1. Same as in the 2 sections above.
    2. What do you think about the interactions with foresters in this gaming session?
    3. What do you think about the interactions with foresters in this workshop in general?

3. Conclusion and next steps

a. Did you learn something new from this gaming workshop?
b. What part of this workshop did you find to be the most interesting/and to the most rewarding

c. What could have been improved in the organization and proceedings of this workshop to make it more useful to the villagers?
d. After the workshop, did you talk with somebody else about the workshop? How did the person/people respond?
e. Do you think that the existing animal rearing -reforestation system in the village should be improved?
f. If yes, what other new scenario/issue/rule would you propose to explore next time?
g. Are you willing to attend another gaming workshop in late November? Explain why?
h. Who else do you think should take part in this kind of field workshop?
i. Where would be a suitable location for the next workshop?
j. For what purpose do you think that this game could be used in the village?

Appendix E. List of participants in different field activities.

a) Participants in the first game testing activity (4-5 September 2008).

Research team			**Participation**
1	Mr Pongchai Dumrongrojwatthana (PD)	Ph D student (moderator)	4 -5 Sept
2	Mr. Kusol Raungprataungsuk (KR)	Master student (assistant)	4 -5 Sept
Local participants			
1	Mr. Anucha Serirat (AS)	NKU forester (Head)	4 Sept
2	Mr. Rabeap Paeng-ud (RP)	NKU forester	4 Sept
3	Mrs. Thanwa Paeng-ud (TP)	NKU forester	4 Sept
4	Mr. Kittisub Thippala (KT)	NKU forester	4 Sept
5	Mr. Chusak Sae Her (CSH)	Type D farmer (D1)	5 Sept
6	Mr. Anan Kittinapapong (AnanK)	Type D farmer (D2)	5 Sept
7	Mr. Narasit Songworrapan (NS)	Type C farmer (C1)	5 Sept
8	Mr. Wisut Sae Song (WSS)	Type C farmer (C2)	5 Sept
9	Mr. Ronnakit Sirichujitkul (RS)	Type B farmer (B1)	5 Sept

b) Participants in the first gaming and simulation field workshop and interviews.

	Participants	**Position / Status**	**Participation**	
Research team				
1	Mr Pongchai Dumrongrojwatthana (PD)	Ph D student (moderator)	22-26 Sept.	
2	Dr. Nantana Gajaseni (NG)	Advisor	22-24 Sept.	
3	Dr. Guy Trébuil (GT)	Advisor	22-26 Sept.	
4	Dr. Christophe Le Page (CLP)	Advisor	22-23 Sept.	
5	Mr. Kobchai Worrapimphong (KW)	Assistant	23-24 Sept.	
6	Ms. Manichara Thong-noi (MT)	Assistant	22-26 Sept.	
7	Ms. Chutapa Kunsook (CK)	Assistant	22-26 Sept.	
8	Mr. Sontaya Jampanin (SJ)	Assistant	23-24 Sept.	
9	Mr. Kusol Raungprataungsuk (KR)	Assistant	22-26 Sept.	
10	Ms. Sroiladar Podang	Assistant	22-26 Sept.	
11	Mr. Boonlue Kachenchart	Assistant	23-24 Sept.	
Local participants (Day 1 gaming and simulation: 23 Sep 2008)			**Session**[1]	**Group**[2]
1	Mr. Yang Sae Lee (YSL)	Type B farmer (B1)	(M, AF)	R, L
2	Mr. Laowaan Sae Lhao (LwSL)	Type B farmer (B2)	(M, AF)	R, L
3	Mr. Sorasak Sae Lhao (SSL)	Type C farmer (C1) (TAO representative)	(M, AF)	R, L
4	Mr. Narasit Songworraphan (NS)	Type C farmer (C2)	(M, AF)	R, L
5	Mr. Wisut Sae Song (WSS)	Type C farmer (C3)	(M, AF)	R, L
6	Mr. Anuwat Sae Lee (ASL)	Type C farmer (C4)	(M, AF)	R, L
7	Mr. Chusak Sae Her (CSH)	Type D farmer (D1) (Village headman)	(-, AF)	R, L
8	Mr. Ronnakit Sirichujitkul (RS)	Type B farmer (B3)	(M, AF)	L, R
9	Mr. Year Sae Song (YSS)	Type B farmer (B4)	(M, AF)	L, R
10	Mr. Tar Sae Her (TSH)	Type B farmer (B5)	(M, AF)	L, R
11	Mr. Thong Sae Song (TSS)	Type C farmer (C5)	(M, -)	L, R
12	Mr. Suchart Sae Song (SSS)	Type C farmer (C6) (Replace Mr.Thong: M)	(-, AF)	L, R
13	Mr. Rathakit Sae Song (RSS)	Type C farmer (C7)	(M, AF)	L, R
14	Mr. Laopoa Sae Her (LpSH)	Type C farmer (C8)	(M, AF)	L, R
15	Mr. Anan Kittinapapong (AnanK)	Type D farmer (D2)	(M, -)	L, R
16	Mr. Yutthakarn Kittinapapong (YK)	Type D farmer (D3) (Replace Mr. Anan: M)	(-, AF)	L, R

Local participants (Day 2 gaming and simulation: 24 Sep 2008)				
1	Mr. Anucha Serirat (AS)	NKU manager	(M, AF)	F
2	Mr. Kittisap Tippala (KT)	NKU officer	(M, AF)	F
3	Mr. Rabaeb Paeng-ud (RP)	NKU officer	(M, AF)	F
4	Mr. Laowaan Sae Lhao (LwSL)	Type B farmer (B1)	(M, AF)	L
5	Mr. Anuwat Sae Lee (ASL)	Type C farmer (C1)	(M, AF)	L
6	Mr. Sorasak Sae Lhao (SSL)	Type C farmer (C2) (TAO representative)	(M, AF)	L
7	Mr. Wisut Sae Song (WSS)	Type C farmer (C3)	(M, AF)	L
8	Mr. Ronnakit Sirichujitkul (RS)	Type B farmer (B2)	(M, AF)	R
9	Mr. Suchart Sae Song (SSS)	Type C farmer (C4)	(M, AF)	R
10	Mr. Yutthakarn Kittinapapong (TK)	Type D farmer (D1)	(M, AF)	R
11	Mr. Chusak Sae Her (CSH)	Type D farmer (D2)	(M, AF)	R

Note: 1. *M = morning, AF = afternoon.*
2. *L = left sub-group of landscape, R = right sub-group of landscape.*

c) Participants in the final validation of the vegetation state transition activity (23 December 2008).

Research team		
1	Mr Pongchai Dumrongrojwatthana (PD)	Ph D student (moderator)
2	Mr. Kusol Raungprataungsuk (KR)	Master student (assistant)
Local participants		
1	Mr. Narasit Songworrapan (NS)	Type C farmer (C1)
2	Mr. Wisut Sae Song (WSS)	Type C farmer (C2)
3	Mr. Kittisap Tippala (KT)	NKU officer
4	Mr. Rabaeb Paeng-ud (RP)	NKU officer

d) Participants in the second game testing activity (15 January 2009).

	Participants	Position / Status
Research team		
1	Mr Pongchai Dumrongrojwatthana (PD)	Ph D student (moderator)
2	Dr. Guy Trébuil (GT)	Advisor
3	Dr. Christophe Le Page (CLP)	Advisor
4	Dr. Nantana Gajaseni (NG)	Advisor
5	Dr. Ing-on Pattamadit Trébuil (IT)	Advisor
6	Mr. Warong Naivinit (WN)	Assistant (central desk)
7	Ms. Chutapa Kunsook (CK)	Assistant (assistant of game and computer)
8	Mr. Kusol Raungprataungsuk (KR)	Assistant (central desk)
9	Ms. Sroiladar Podang (SrP)	Assistant (central desk)
10	Mr. Boonlue Kachenchart (BK)	Assistant (photo, video)
Local participants		
1	Mr. Jaroon Upala (JU)	NKU officer
2	Mr. Rabaeb Paeng-ud (RP)	NKU officer
3	Mr. Viboonsak Siripan (VS)	NNP officer
4	Mr. Thodsaporn Panyana (ThoP)	NNP officer
5	Ms. Chularak Dee-ud (CD)	NNP officer
6	Ms. Pacharin Apiwan (PA)	NNP officer
7	Ms. Kanya Kongkheaw (KK)	NNP officer

e) Participants in the second gaming and simulation field workshop (10 March 2009).

	Participants	Position / Status	Participation	
Research team				
1	Mr Pongchai Dumrongrojwatthana (PD)	Ph D student (moderator)	8-12 Mar.	
2	Mr. Kusol Raungprataungsuk (KR)	Assistant	8-12 Mar.	
3	Ms. Chutapa Kunsook (CK)	Assistant	9-11 Mar.	
4	Mr. Puwadon Podaeng (PP)	Assistant	9-11 Mar.	
5	Ms. Sroiladar Podaeng (SrP)	Assistant	9-11 Mar.	
6	Mr. Chairat Dumrongrojwatthana (ChD)	Assistant	9-11 Mar.	
7	Mr. Surasak Sooksanguan (SS)	Assistant	9-11 Mar.	
Local participants (workshop date: 10 March 2009)			**Session[1]**	**Group[2]**
1	Mr. Surapol Katewang (SK)	DLD officer	M	O
2	Mr. Kittisap Tippala (KT)	NKU officer	(M, AF)	F
3	Mr. Rabaeb Paeng-ud (RP)	NKU officer	(M, AF)	F
4	Mr. Viboonsak Siripan (VS)	NNP officer	(M, AF)	F
5	Mr. Theves Prarom (ThP)	NNP officer	(M, AF)	F
6	Mr. Komsan In-sri (KI)	NNP officer	(M, AF)	F
7	Mr. Thanasak Kittinapapong (TK)	Type C farmer	(M, -)	L
8	Mr. Ronnakit Sirichujitkul (RS)	Type B farmer	(M, AF)	L
9	Mr. Wisut Sae Song (WSS)	Type C farmer	(M, AF)	L
10	Mr. Rathakit Sae Song (RSS)	Type C farmer	(M, AF)	R
11	Mr. Wasan Sae Her (WSH)	Type B farmer	(M, AF)	R

Note: 1. M = morning, AF = afternoon.
2. L = left sub-group of landscape, R = right sub-group of landscape, F = forester, O = observer.

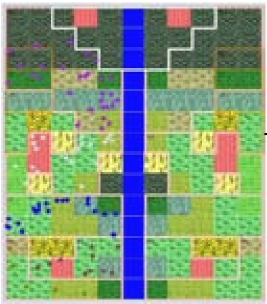
f) Participants in the third gaming and simulation field workshop.

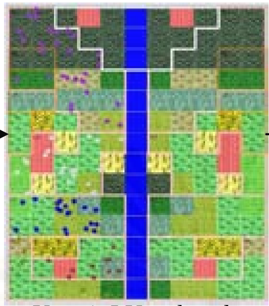
	Participants	Position / Status	Participation	
Research team				
1	Mr Pongchai Dumrongrojwatthana (PD)	Ph D student (moderator)	21-26 Aug 09	
2	Mr. Kusol Raungprataungsuk (KR)	Staff (assistant of game)	21-26 August 09	
Local participants (Day 1 (D1): 24 August, Day 2 (D2): 24 August 2009)			**Session**	**Group[1]**
1	Mr. Rathakit Sae Song (RSS)	Type C farmer	(D1, D2)	L
2	Mr. Jirapat Songworraphan (JS)	Type B farmer	(D1)	L
3	Mr. Likhit Sae Her (LiSH)	Type C farmer	(D1, D2)	L
4	Mr. Eakapong Sae Song (ESS)	Type B farmer	(D1, D2)	L
5	Mr. Lar Sae Her (LSH)	Type C farmer	(D1, D2)	R
6	Mr. Thongdee Sae Her (ThSH)	Type B farmer	(D1)	R
7	Mr. Suchart Sae Song (SSS)	Type C farmer	(D1)	R
8	Mr. Anan Kittinapapong (AnanK)	Type D farmer	(D1, D2)	R
9	Mr. Ronnakit Sirichujitkul (RS)	Type B farmer	(D1, D2)	R
10	Mr. Chusak Sae Her (CSH)	Type D farmer, Village Headman	(D2)	-
11	Mr. Thanasak Kittinapapong (TK)	Type C farmer, TAO	(D2)	-
12	Mr. Sorasak Sae Lhao (SSL)	Type C farmer, TAO	(D2)	-
13	Mr. Narasit Songworraphan (NS)	Type C farmer	(D2)	-
14	Mr. Wisut Sae Song (WSS)	Type C farmer	(D2)	-
15	Mr. Wasan Sae Her (WSH)	Type B farmer	(D2)	-
16	Mr. Laowaan Sae Lhao (LwSL)	Type B farmer	(D2)	-
17	Mr. Tar Sae Her (TSH)	Type B farmer	(D2)	-

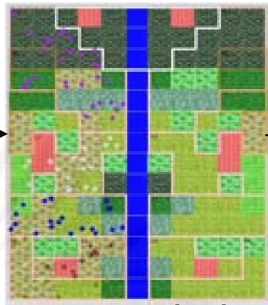
Note: 1. L = left sub-group of landscape, R = right sub-group of landscape.

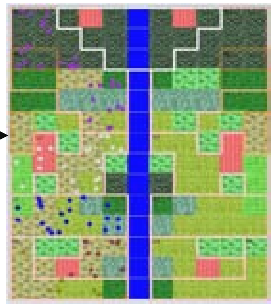
Appendix F. Poster for the dissemination of the results from the first gaming and simulation field workshop.

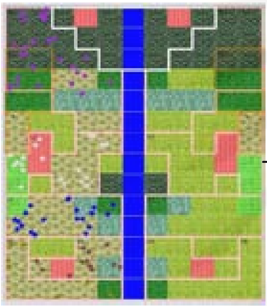
Appendix G. a) Landscape dynamics during the simulation of the “Fixed paddock, no reforestation activity” scenario.

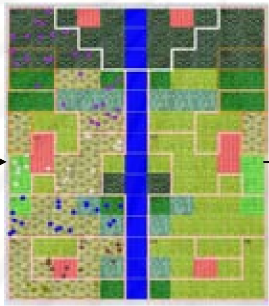

Year 1: LU and cattle raising decisions in WS

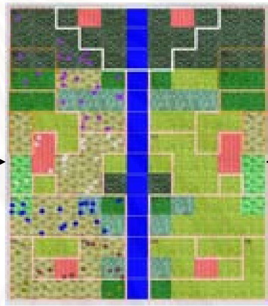

Year 1: LU and cattle raising decisions in DS

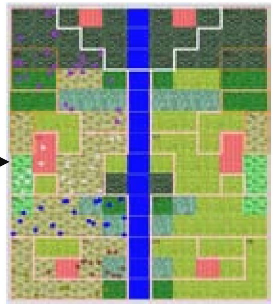

Year 2: LU and cattle raising decisions in WS

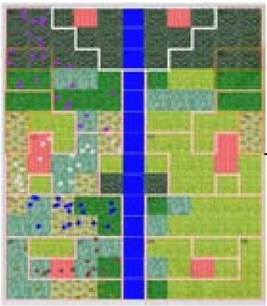

Year 2: LU and cattle raising decisions in DS

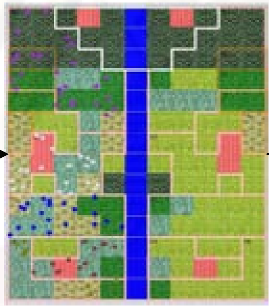

Year 3: LU and cattle raising decisions in WS

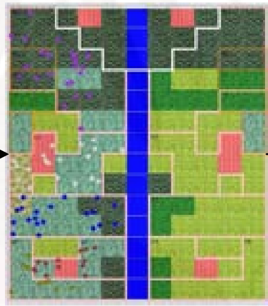

Year 3: LU and cattle raising decisions in DS

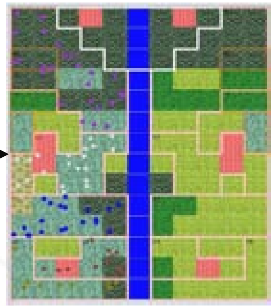

Year 4: LU and cattle raising decisions in WS

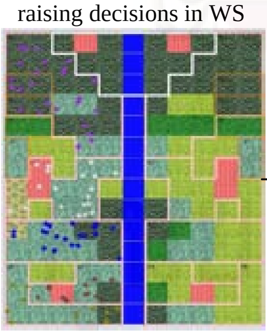

Year 4: LU and cattle raising decisions in DS

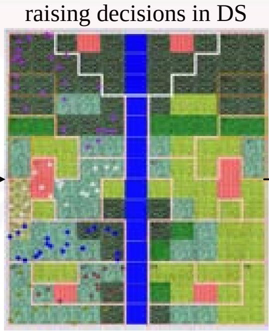

Year 5: LU and cattle raising decisions in WS

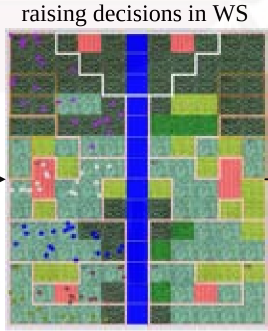

Year 5: LU and cattle raising decisions in DS

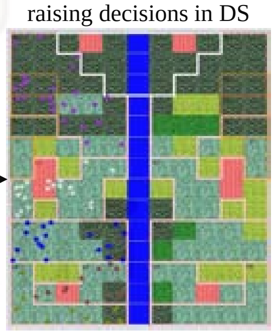

Year 6: LU and cattle raising decisions in WS

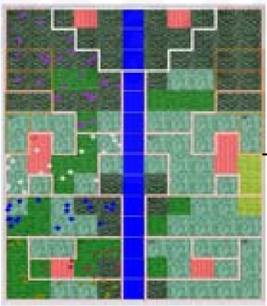

Year 6: LU and cattle raising decisions in DS

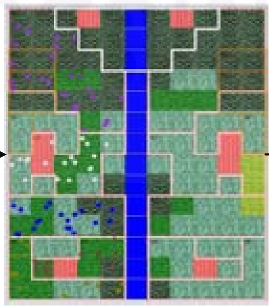

Year 7: LU and cattle raising decisions in WS

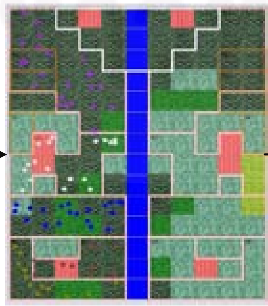

Year 7: LU and cattle raising decisions in DS

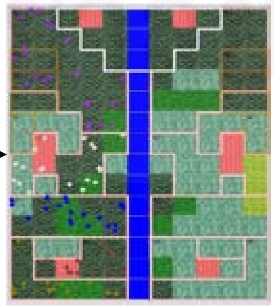

Year 8: LU and cattle raising decisions in WS


Year 8: LU and cattle raising decisions in DS

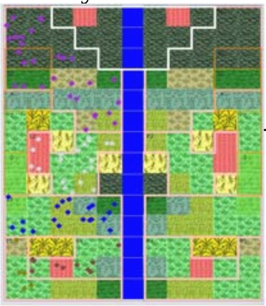

Year 9: LU and cattle raising decisions in WS

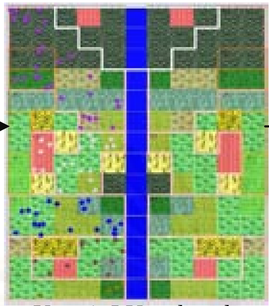

Year 9: LU and cattle raising decisions in DS

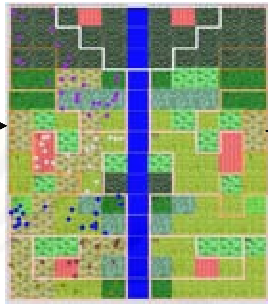

Year 10: LU and cattle raising decisions in WS

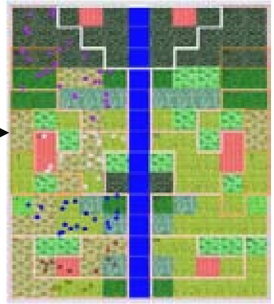

Year 10: LU and cattle raising decisions in DS

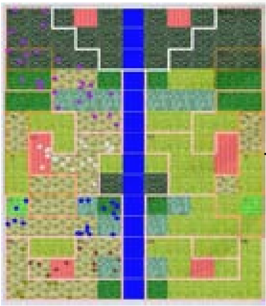
b) Landscape dynamics during the simulation of the "Fixed paddock & reforestation activity" scenario.

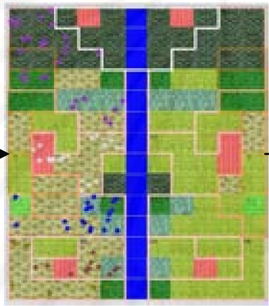

Year 1: LU and cattle raising decisions in WS

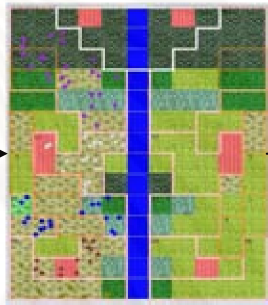

Year 1: LU and cattle raising decisions in DS

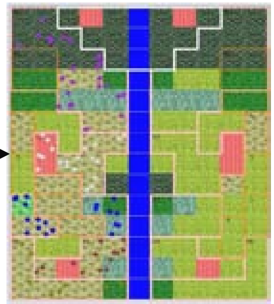

Year 2: LU and cattle raising decisions in WS

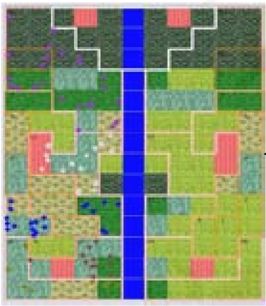

Year 2: LU and cattle raising decisions in DS

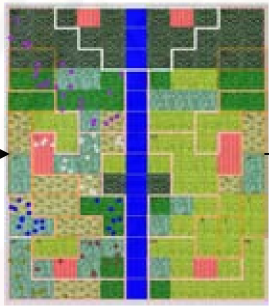

Year 3: LU and cattle raising decisions in WS

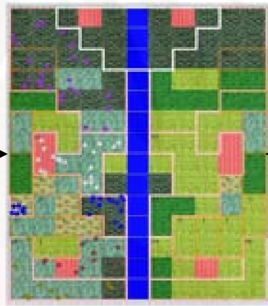

Year 3: LU and cattle raising decisions in DS

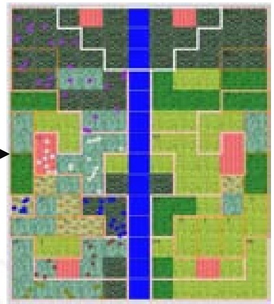

Year 4: LU and cattle raising decisions in WS

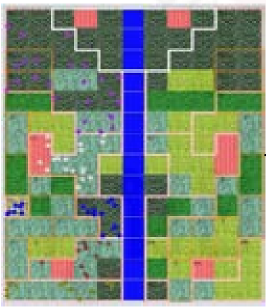

Year 4: LU and cattle raising decisions in DS

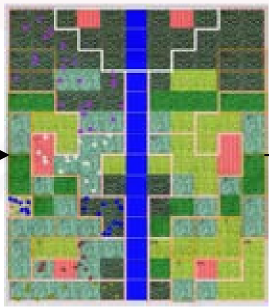

Year 5: LU and cattle raising decisions in WS

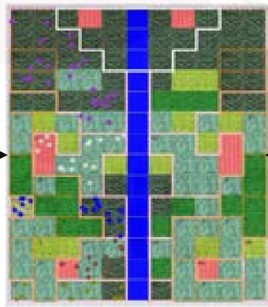

Year 5: LU and cattle raising decisions in DS

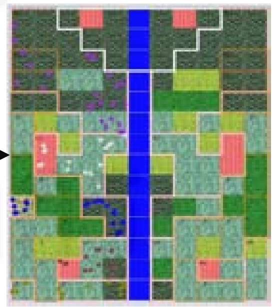

Year 6: LU and cattle raising decisions in WS

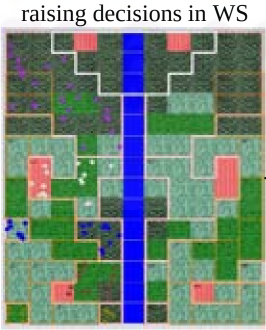

Year 6: LU and cattle raising decisions in DS

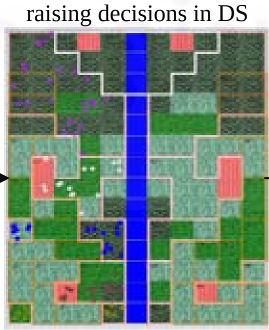

Year 7: LU and cattle raising decisions in WS

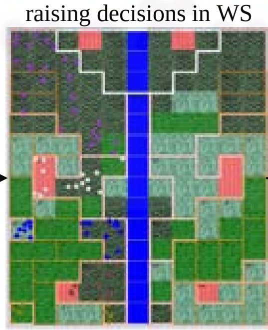

Year 7: LU and cattle raising decisions in DS

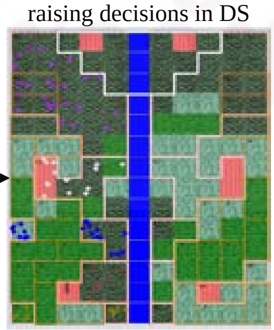

Year 8: LU and cattle raising decisions in WS


Year 8: LU and cattle raising decisions in DS

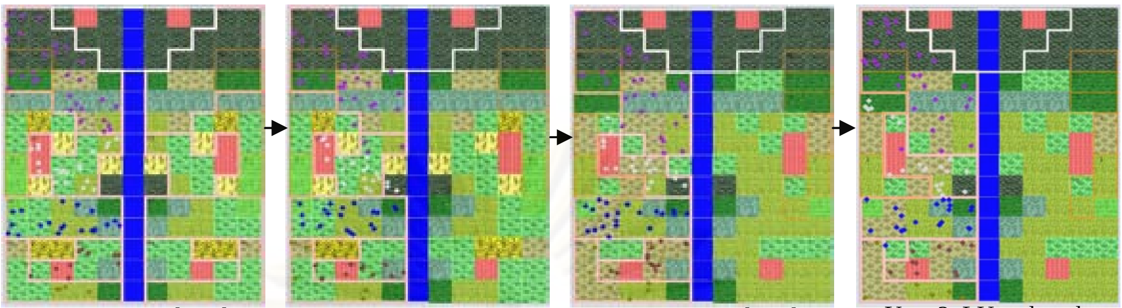

Year 9: LU and cattle raising decisions in WS


Year 9: LU and cattle raising decisions in DS

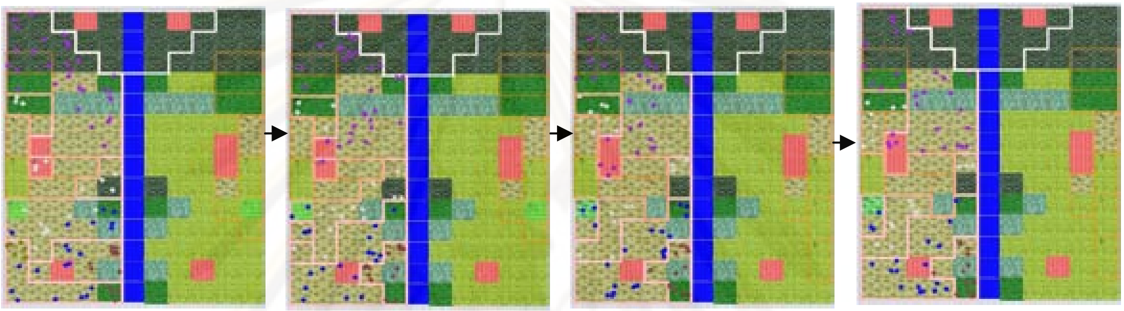

Year 10: LU and cattle raising decisions in WS


Year 10: LU and cattle raising decisions in DS

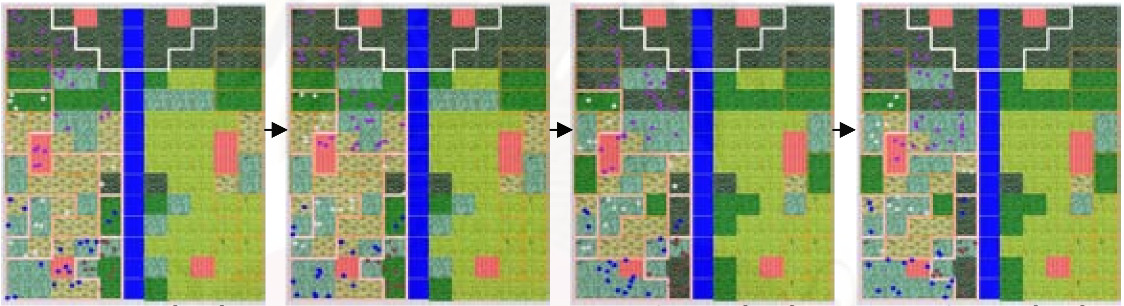
c) Landscape dynamics during the simulation of the “Individual cattle management” scenario.



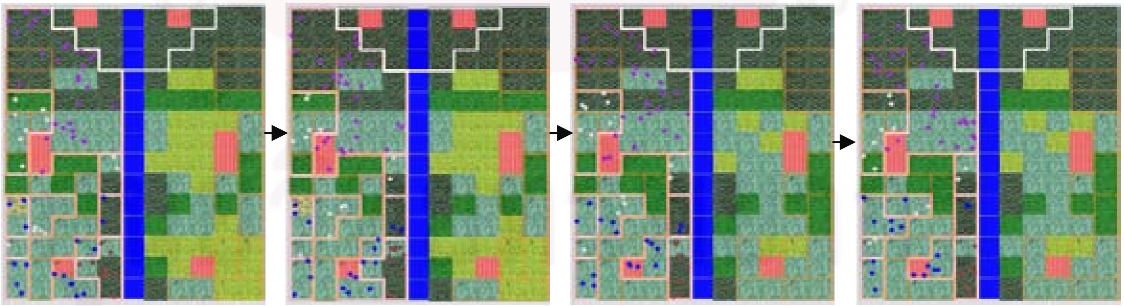
Year 1: LU and cattle raising decisions in WS | Year 1: LU and cattle raising decisions in DS | Year 2: LU and cattle raising decisions in WS | Year 2: LU and cattle raising decisions in DS



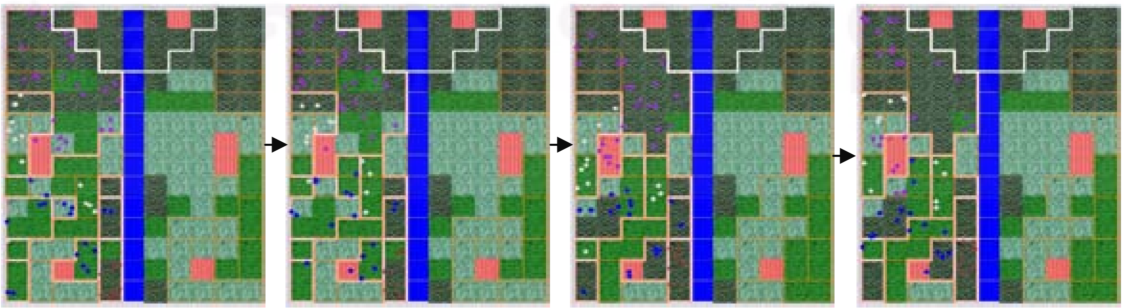
Year 3: LU and cattle raising decisions in WS | Year 3: LU and cattle raising decisions in DS | Year 4: LU and cattle raising decisions in WS | Year 4: LU and cattle raising decisions in DS



Year 5: LU and cattle raising decisions in WS | Year 5: LU and cattle raising decisions in DS | Year 6: LU and cattle raising decisions in WS | Year 6: LU and cattle raising decisions in DS

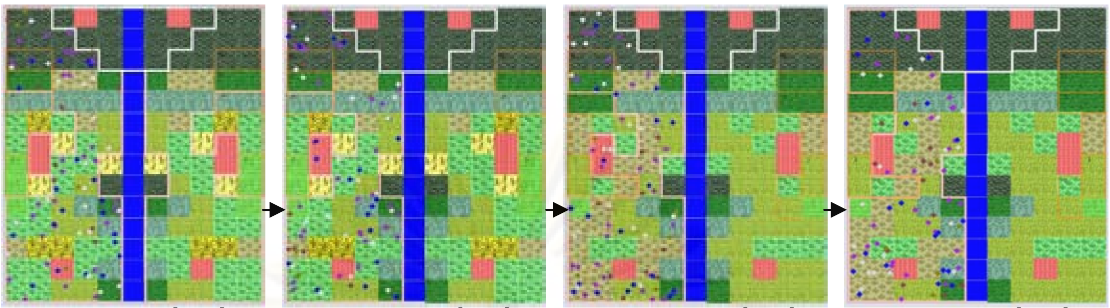


Year 7: LU and cattle raising decisions in WS | Year 7: LU and cattle raising decisions in DS | Year 8: LU and cattle raising decisions in WS | Year 8: LU and cattle raising decisions in DS

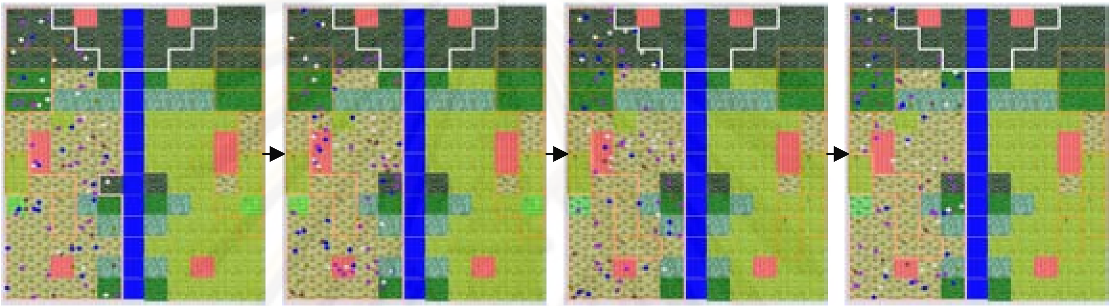


Year 9: LU and cattle raising decisions in WS | Year 9: LU and cattle raising decisions in DS | Year 10: LU and cattle raising decisions in WS | Year 10: LU and cattle raising decisions in DS

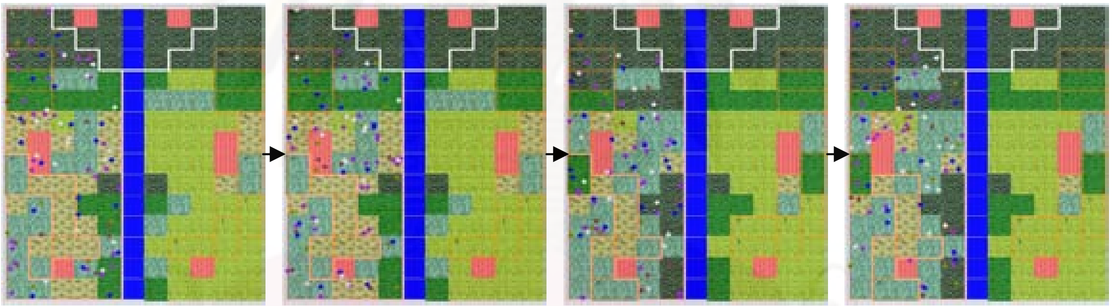
d) Landscape dynamics during the simulation of the “Collective cattle management” scenario.



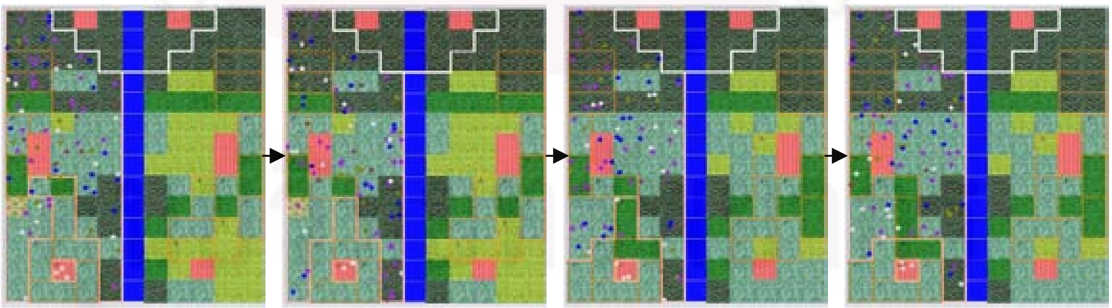
Year 1: LU and cattle raising decisions in WS | Year 1: LU and cattle raising decisions in DS | Year 2: LU and cattle raising decisions in WS | Year 2: LU and cattle raising decisions in DS



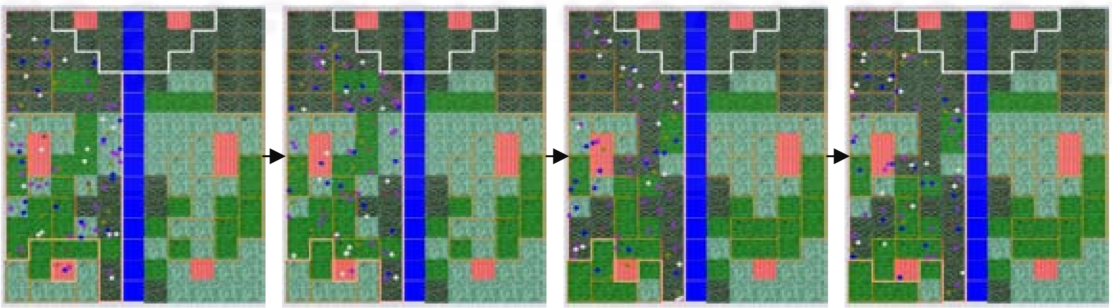
Year 3: LU and cattle raising decisions in WS | Year 3: LU and cattle raising decisions in DS | Year 4: LU and cattle raising decisions in WS | Year 4: LU and cattle raising decisions in DS



Year 5: LU and cattle raising decisions in WS | Year 5: LU and cattle raising decisions in DS | Year 6: LU and cattle raising decisions in WS | Year 6: LU and cattle raising decisions in DS

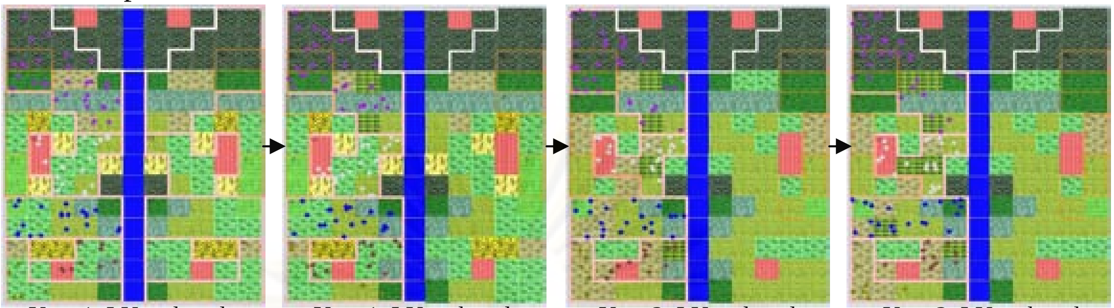


Year 7: LU and cattle raising decisions in WS | Year 7: LU and cattle raising decisions in DS | Year 8: LU and cattle raising decisions in WS | Year 8: LU and cattle raising decisions in DS

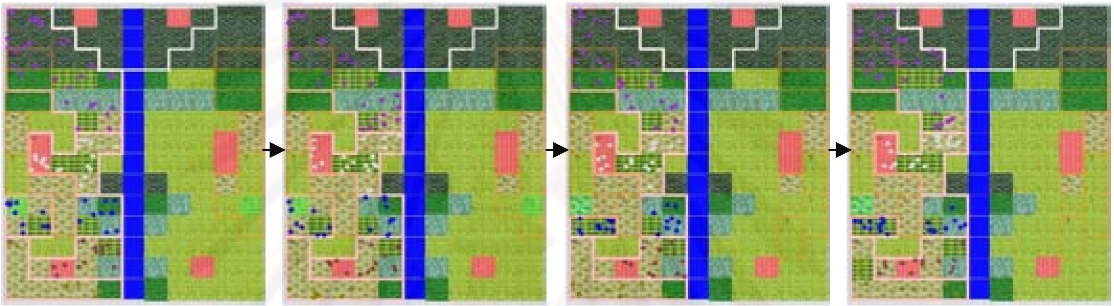


Year 9: LU and cattle raising decisions in WS | Year 9: LU and cattle raising decisions in DS | Year 10: LU and cattle raising decisions in WS | Year 10: LU and cattle raising decisions in DS

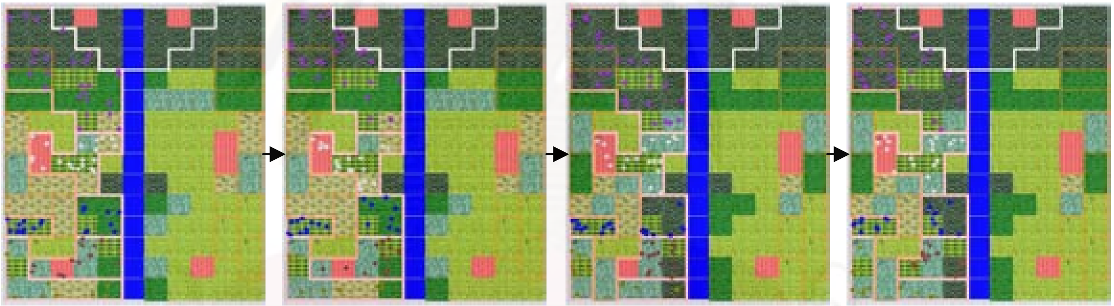
e) Landscape dynamics during the simulation of the “Individual cattle management with ruzi pasture” scenario.



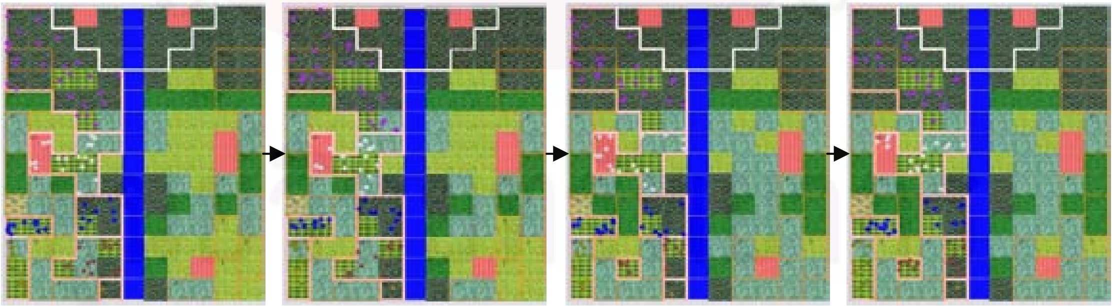
Year 1: LU and cattle raising decisions in WS
Year 1: LU and cattle raising decisions in DS
Year 2: LU and cattle raising decisions in WS
Year 2: LU and cattle raising decisions in DS



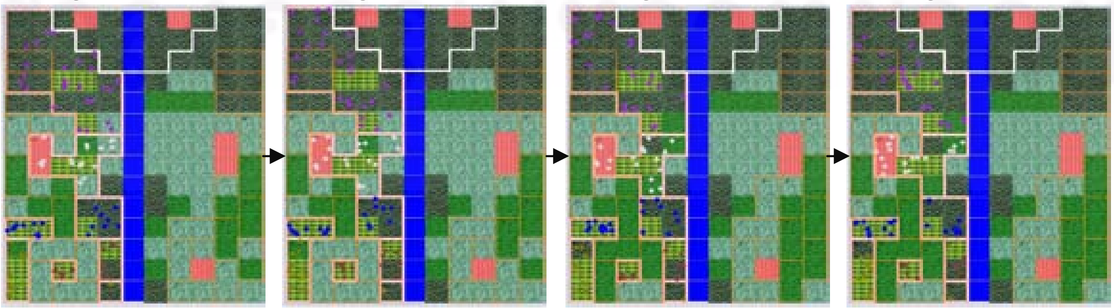
Year 3: LU and cattle raising decisions in WS
Year 3: LU and cattle raising decisions in DS
Year 4: LU and cattle raising decisions in WS
Year 4: LU and cattle raising decisions in DS



Year 5: LU and cattle raising decisions in WS
Year 5: LU and cattle raising decisions in DS
Year 6: LU and cattle raising decisions in WS
Year 6: LU and cattle raising decisions in DS

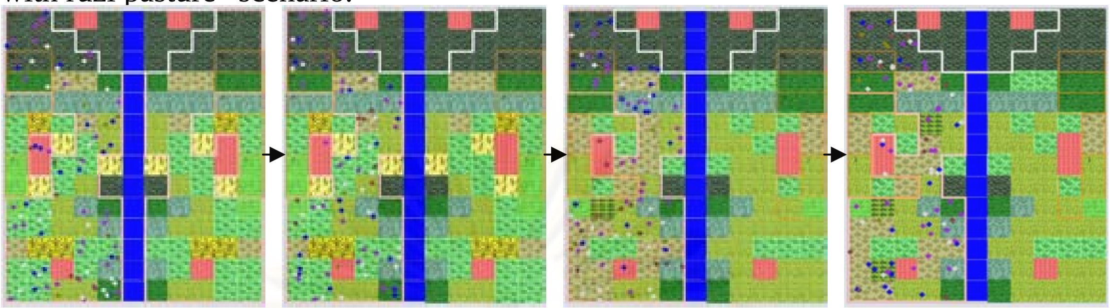


Year 7: LU and cattle raising decisions in WS
Year 7: LU and cattle raising decisions in DS
Year 8: LU and cattle raising decisions in WS
Year 8: LU and cattle raising decisions in DS

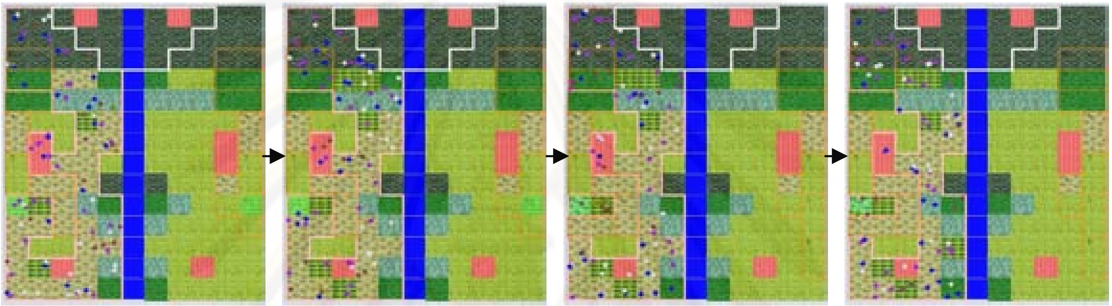


Year 9: LU and cattle raising decisions in WS
Year 9: LU and cattle raising decisions in DS
Year 10: LU and cattle raising decisions in WS
Year 10: LU and cattle raising decisions in DS

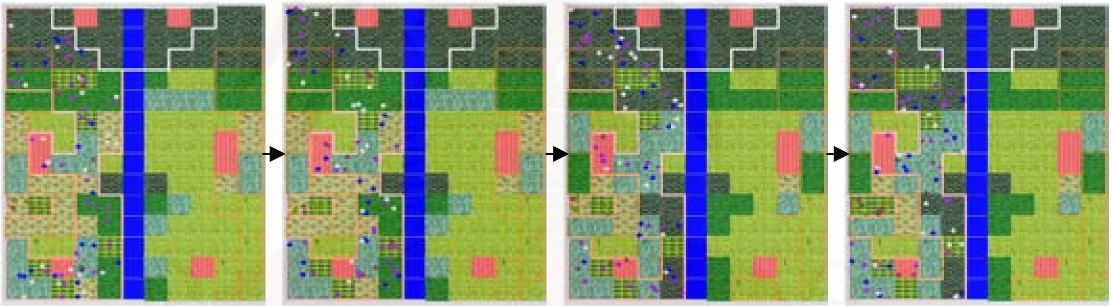
f) Landscape dynamics during the simulation of the “Collective cattle management with ruzi pasture” scenario.



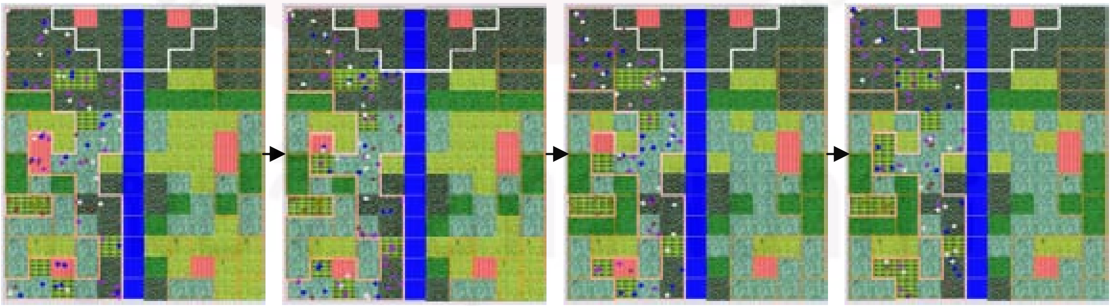
Year 1: LU and cattle raising decisions in WS | Year 1: LU and cattle raising decisions in DS | Year 2: LU and cattle raising decisions in WS | Year 2: LU and cattle raising decisions in DS



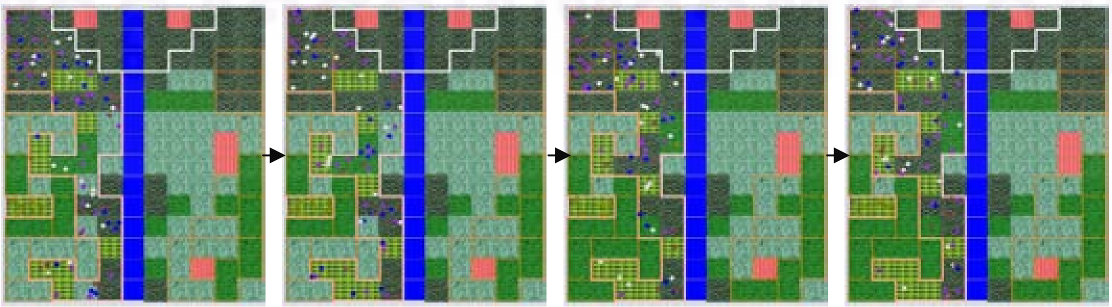
Year 3: LU and cattle raising decisions in WS | Year 3: LU and cattle raising decisions in DS | Year 4: LU and cattle raising decisions in WS | Year 4: LU and cattle raising decisions in DS



Year 5: LU and cattle raising decisions in WS | Year 5: LU and cattle raising decisions in DS | Year 6: LU and cattle raising decisions in WS | Year 6: LU and cattle raising decisions in DS

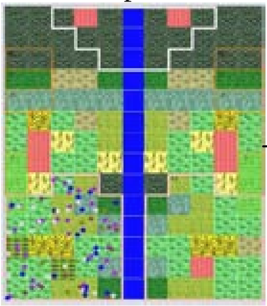


Year 7: LU and cattle raising decisions in WS | Year 7: LU and cattle raising decisions in DS | Year 8: LU and cattle raising decisions in WS | Year 8: LU and cattle raising decisions in DS

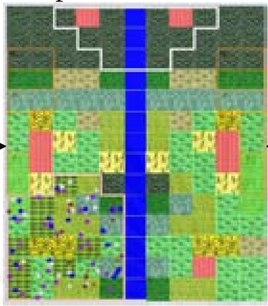


Year 9: LU and cattle raising decisions in WS | Year 9: LU and cattle raising decisions in DS | Year 10: LU and cattle raising decisions in WS | Year 10: LU and cattle raising decisions in DS

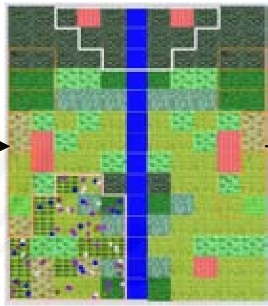
g) Landscape dynamics during the simulation of the "Collective cattle management with ruzi pasture in small paddocks" scenario.



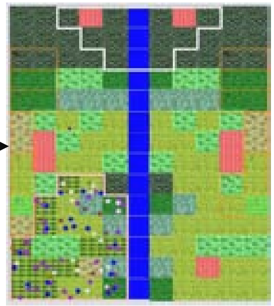
Year 1: LU and cattle raising decisions in WS



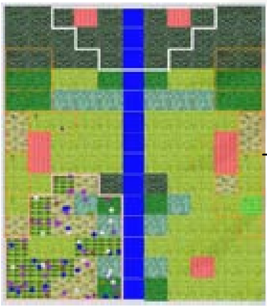
Year 1: LU and cattle raising decisions in DS



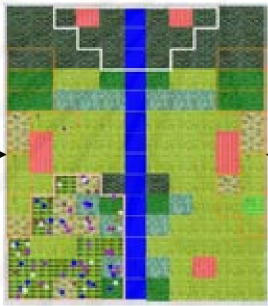
Year 2: LU and cattle raising decisions in WS



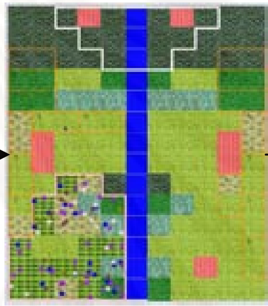
Year 2: LU and cattle raising decisions in DS



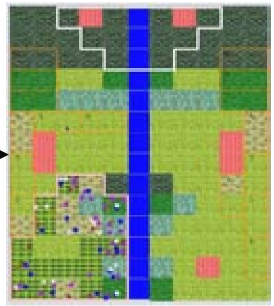
Year 3: LU and cattle raising decisions in WS



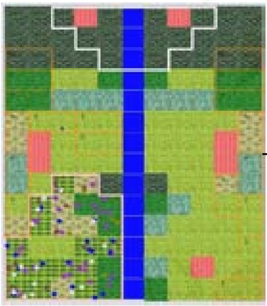
Year 3: LU and cattle raising decisions in DS



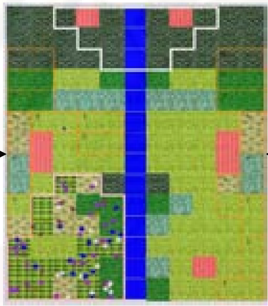
Year 4: LU and cattle raising decisions in WS



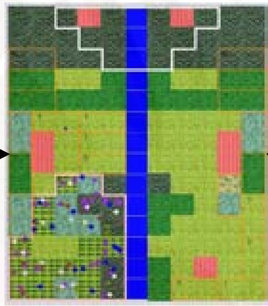
Year 4: LU and cattle raising decisions in DS



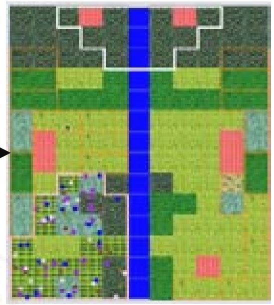
Year 5: LU and cattle raising decisions in WS



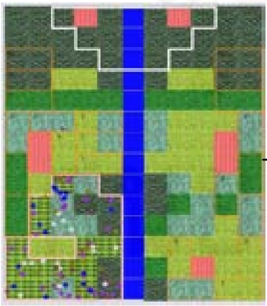
Year 5: LU and cattle raising decisions in DS



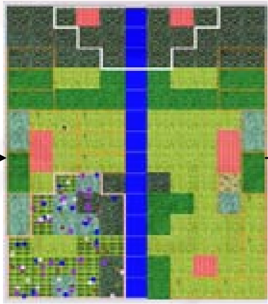
Year 6: LU and cattle raising decisions in WS



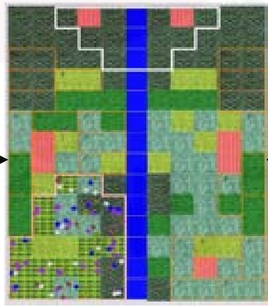
Year 6: LU and cattle raising decisions in DS



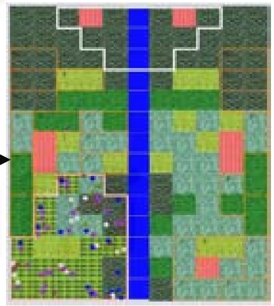
Year 7: LU and cattle raising decisions in WS



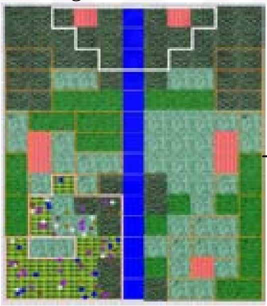
Year 7: LU and cattle raising decisions in DS



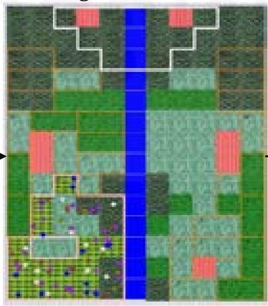
Year 8: LU and cattle raising decisions in WS



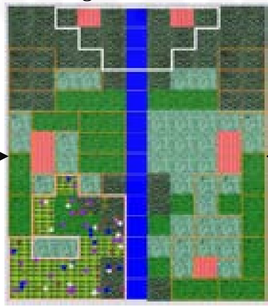
Year 8: LU and cattle raising decisions in DS



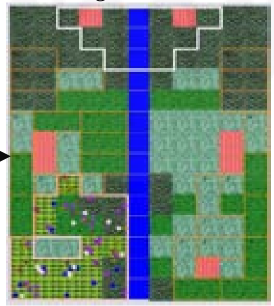
Year 9: LU and cattle raising decisions in WS



Year 9: LU and cattle raising decisions in DS



Year 10: LU and cattle raising decisions in WS



Year 10: LU and cattle raising decisions in DS

Appendix H. List of publications.

Journal articles (International)

Ruankaew, N., Le Page, C., **Dumrongrojwatthana, P.**, Barnaud, C., Gajaseni, N., van Paassen, A., and Trébuil, G. 2010. Companion modelling for integrated renewable resource management: a new collaborative approach to create common values for sustainable development. *Journal of Sustainable Development & World Ecology* 17 (1): 15-23

Dumrongrojwatthana, P., Le Page, C., Gajaseni, N., and Trébuil, G., 2009. Co-constructing an agent-based model to mediate land use conflict between herders and foresters in northern Thailand. *Journal of Land Use Science (under review)*

Barnaud, C., Trébuil, G., **Dumrongrojwatthana, P.**, and Marie, J. 2008. Area Study Prior to Companion Modelling to Integrate Multiple Interests in Upper Watershed Management of Northern Thailand. *Southeast Asian Studies* 45(4): 559-585

Journal articles (National)

Dumrongrojwatthana, P., Le Page, C. Gajaseni, N., and Trébuil, G. 2009. Companion Modelling for Land and Forest Management: Case Study of Cattle Raising and Reforestation in Highland of Nan Province. *ThaiSim Journal (In Press)*

Proceedings and conferences (International)

Dumrongrojwatthana, P., Le Page, C. Gajaseni, N., and Trébuil, G. 2009. Co-constructing an agent-based model to mediate land use conflict between herders and foresters in northern Thailand. *Proceedings of the 24th Annual Landscape Ecology Symposium, Landscape Patterns and Ecosystem Processes.* April 12-16, 2009. The Cliff Lodge, Snowbird, Utah, USA. p 55.

Dumrongrojwatthana, P., Trébuil, G., Gajaseni, N., and Le Page, C. 2009. Using role-playing game for learning and mitigating land use conflict between herders and foresters in upper Nan Watershed, northern Thailand. *The 1st DELTA (Dragon Research and Global Observation Network) Asia Summit: Connecting great deltas, great rivers and great lakes*. June 22-25, 2009. Angkor Century Hotel, Siem Reap, Cambodia.

Dumrongrojwatthana, P., Trébuil, G., Gajaseni, N., and Le Page, C. 2009. Participatory design and use of simplified landscape in simulation model for mitigating land use conflict in Northern Thailand highlands. *S4 (Spatial Simulation for Social Science) International Conference: Emergence in Geographical Space: Concepts, Methods and Models*. November 23-25, 2009. Institut des Cordeliers, Paris, France.

Dumrongrojwatthana, P., Barnaud, C., Gajaseni, N., and Trébuil, G. 2007. Companion modelling to facilitate adaptive forest management in Nam Haen sub-watershed, Nan Province, Northern Thailand. *Proceedings of the 2nd International conference on Asian simulation and modeling.* January 9-11, 2007. Sheraton Hotel, Chiang Mai, Thailand. pp 327-333.

Barnaud, C., **Dumrongrojwatthana, P.**, Marie, J., Le Page, C., Trébuil, G.. 2006. Initial diagnostic analysis for companion modelling to accommodate multiple interests in upper watershed management. In: *Proceedings of the 2nd NAFRI International conference on Sustainable Sloping Lands and Watershed Management (SSLWM)*, Luang Prabang, Lao PDR: p. 317–335.

Dumrongrojwatthana, P., Gajaseni, N., and Barnaud, C. 2006. Companion modelling to facilitate adaptive forest management in Nan Province, Northern Thailand. *Abstracts of the 11th Biological Sciences Graduate Congress*. December 15-17, 2006. Chulalongkorn University, Bangkok, Thailand. p 179.

Proceedings and conferences (National)

Dumrongrojwatthana, P., Trébuil, G., Gajaseni, N., and Le Page, C. 2009. Facilitating participatory management between herders and foresters using Role-playing game. *Proceedings of the 5th National Agricultural Systems.* July 2-4, 2009. Ubon International Hotel, Ubon Ratchathani Province, Thailand. pp 414-427.

Dumrongrojwatthana, P., Le Page, C. Gajaseni, N., and Trébuil, G. 2009. Companion Modelling for Land and Forest Management: Case Study of Cattle Raising and Reforestation in Highland of Nan Province. *Proceedings of the 1st Thai Simulation and Gaming Conference.* April 20, 2009. Thonburi University, Bangkok, Thailand.

Dumrongrojwatthana, P., Barnaud, C., Gajaseni, N., and Trébuil, G. 2008. Area Study and Companion Modelling to Integrate Multiple Interests in Upper Nan Watershed. *Proceedings of the 4th National Agricultural Systems.* May, 27-28, 2008. The Empress Convention Centre, Chiang Mai, Thailand. pp 371-378.

Posters

Dumrongrojwatthana, P., Gajaseni, N., Le Page, C., Trébuil, G., Landy, F. and Marie, J. 2010. Companion modelling to mitigate a land use conflict between herders and foresters in Northern Thailand. Poster presented at the International conference on Integrated Landscape Modelling (LandMod2010), 3-5 February 2010, INRA/Sup’Agro, Montpellier, France.

Dumrongrojwatthana, P., Bousquet, F., Barnaud., C., and Gajaseni, N. 2006. Agent-Based Modelling to Facilitate an Adaptive Forest Management: the Case of Arenga Palm in Nan Province, Northern Thailand. *The* 2^{nd} *International Conference on Sustainable Sloping Lands and Watershed Management (SSLWM)*, 12-15 December 2006.Luang Prabang, Lao PDR.

Dumrongrojwatthana, P., Gajaseni, N., Trébuil, G., Le Page, C., Landy, F. and Marie, J. 2010. Companion modelling to mitigate land use conflict between herders and foresters in Northern Thailand. ThaiSim Annual Conference: Learning from experience through games and simulations, 25-27 March 2010. Rajamangala University of Technology Srivijaya, Thailand.

Dumrongrojwatthana, P., Le Page, C., Gajaseni, N., and Trébuil, G. 2008. First gaming and simulation workshop between Doi Tiew villagers and Nam Khang Unit foresters. Exhibited at Doi Tiew Healthcare centre and Nam Khang Unit, Nan Province (*in Thai*).

Invited lecture and seminars:

- January 8-13, 2010: *Companion modelling for watershed management: Case study in Nan Province, Northern Thailand*. Invited lecture for Master Students in Faculty of Economics, Chulalongkorn University, Bangkok, Thailand.
- June 28, 2009: *Companion modelling for mitigating land use conflict between herders and foresters in Upper Nan Watershed*. Invited lecture for Master Students in

Faculty of Natural Resources, Print of Songkla University, Hat Yai, Songkhla, Thailand.

- November 6, 2009: *Companion modelling to mitigate land use conflict between herders and foresters in Northern Thailand*. Seminar at Green Research Unit, Montpellier, France.

- September 20, 2009: *Participatory design and use of simplified landscape to simulate and mitigate a land use conflict in Northern Thailand highlands*. Seminar at Maison de la Télédétection (House of Remote Sensing), Montpellier, France.

BIOGRAPHY

The author who is responsible for this dissertation is Mr. Pongchai Dumrongrojwatthana. He was born on 26 September, 1979 at Surat Thani Province, Thailand.

He graduated with Bachelor of Science in Biology (1997-2000) from the Faculty of Science, Chulalongkorn University, Thailand. He completed Master of Science in Zoology (2001-2004) from the Department of Biology, Faculty of Science, Chulalongkorn University, Thailand. He started his doctorate study in 2005 academic year under the program “cotutelles de thèses (co-advisor system)” between Chulalongkorn University, Thailand and Université de Paris Ouest Nanterre La Défense, France.