Advances in Asian Human-Environmental Research

Satoshi Yokoyama
Kohei Okamoto
Chisato Takenaka
Isao Hirota *Editors*

Integrated Studies of Social and Natural Environmental Transition in Laos

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Advances in Asian Human-Environmental Research

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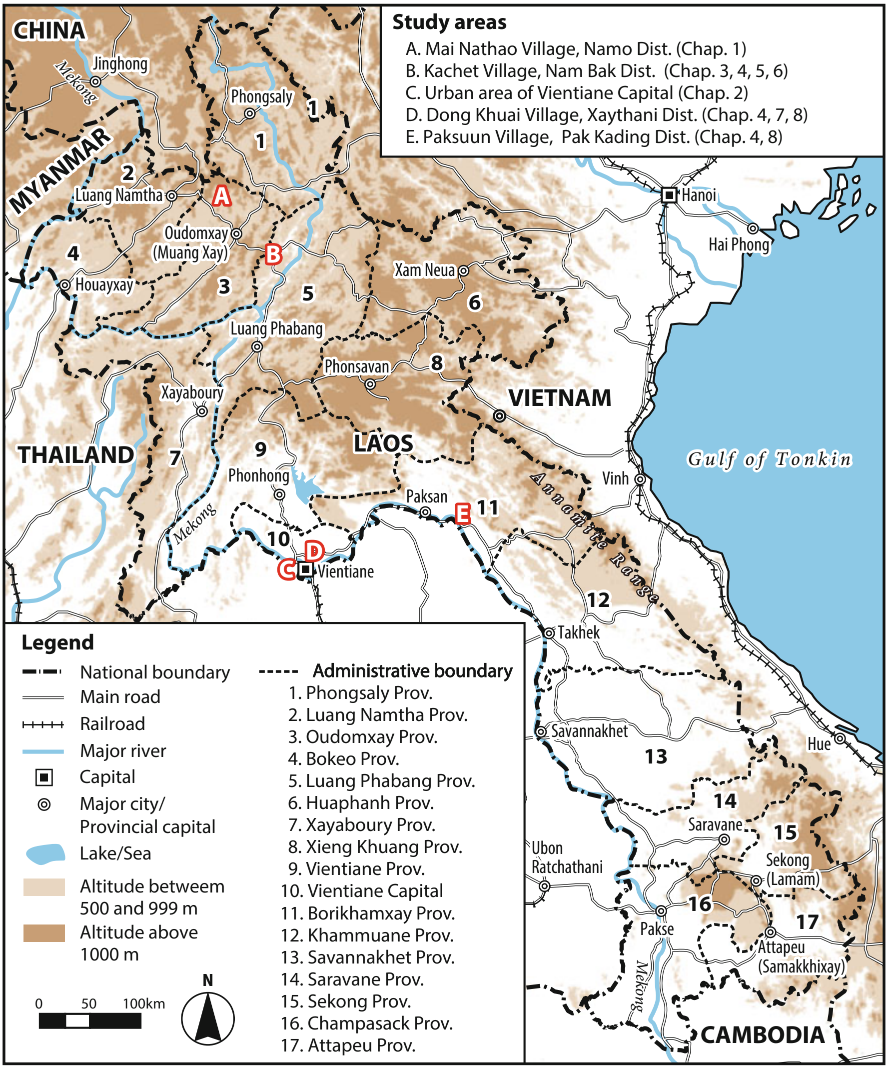
Study areas
A. Mai Nathao Village, Namo Dist. (Chap. 1)
B. Kachet Village, Nam Bak Dist. (Chap. 3, 4, 5, 6)
C. Urban area of Vientiane Capital (Chap. 2)
D. Dong Khuai Village, Xaythani Dist. (Chap. 4, 7, 8)
E. Paksuun Village, Pak Kading Dist. (Chap. 4, 8)
CHINA
MYANMAR
THAILAND
LAOS
VIETNAM
CAMBODIA
Gulf of Tonkin
Annamite Range
Mekong
Jinghong
Phongsaly
Luang Namtha
Oudomxay
(Muang Xay)
Houayxay
Luang Phabang
Xam Neua
Phonsavan
Xayaboury
Phonhong
Vientiane
Paksan
Hanoi
Hai Phong
Vinh
Takhek
Savannakhet
Hue
Saravane
Sekong
(Lamam)
Ubon
Ratchathani
Pakse
Attapeu
(Samakkhixay)
Legend
National boundary
Main road
Railroad
Major river
Capital
Major city/
Provincial capital
Lake/Sea
Altitude betweem
500 and 999 m
Altitude above
1000 m
0
50
100km
N
Administrative boundary
1. Phongsaly Prov.
2. Luang Namtha Prov.
3. Oudomxay Prov.
4. Bokeo Prov.
5. Luang Phabang Prov.
6. Huaphanh Prov.
7. Xayaboury Prov.
8. Xieng Khuang Prov.
9. Vientiane Prov.
10. Vientiane Capital
11. Borikhamxay Prov.
12. Khammuane Prov.
13. Savannakhet Prov.
14. Saravane Prov.
15. Sekong Prov.
16. Champasack Prov.
17. Attapeu Prov.

Preface

This book examines social and natural environmental changes in present-day Laos and presents a new research framework of environmental studies from an interdisciplinary point of view. In Laos, after the Lao version of perestroika, *Chintanakaan Mai*, in 1986, for better or worse, rural development and urbanization have progressed, and people's livelihoods are about to change significantly. Compared with those of the neighboring countries of mainland Southeast Asia, however, many traditional livelihoods such as region-specific/ethnic-specific livelihood complexes which combined traditional rice farming with a variety of subsistence activities, have been carried over into the present in Laos. The biggest challenge this book presents is to elucidate livelihood strategies of people who cope successfully with both social and environmental changes and to illustrate how to maintain this rich social and natural environment of Laos in the future.

Laos is a country rich in nature. The ancient tradition here is of a self-sufficient lifestyle lived in harmony with nature, in which natural resources are found in the forests and the rivers. This way of life is coming into contact, and conflict, with a more modern lifestyle that has developed under the new market economy. Moreover, climate changes possibly connected to global warming have influenced traditional rice farming. In these ways, the local people in Laos are faced with many intricate problems related to the environment.

Deforestation is the prime example of such problems. While recent land reclamation and urbanization has brought deforestation in part of the lowlands, Laos has maintained rich forests in mountainous areas. Nowadays there are international subsidies in place, and a policy of tree planting has been implemented in an attempt to curb the effects of global warming. As part of general environmental policy measures, traditional slash-and-burn agriculture has been seen to bring about environmental deterioration, and ever greater volumes of land are being used as continuous farming land for commercial crops. Other problems include the breakup and privatization of previously commonly owned forest, which has brought about shifts in social structure such as changes in how many people earn a living. While on the one hand levels of forestation in Laos might be sustained by the banning of swidden agriculture and the introduction of cash plants, at the same time water cycles, native biodiversity, and livelihood sustainability are being significantly impacted. Thus the possibility of other, different environmental challenges are having to be faced. This is an example of how the "treatment" arbitrarily prescribed and implemented by so-called developed countries can lead to damaging side effects.

To correctly perceive social and natural environmental changes and find a better future direction, a multilateral dialogue is indispensable. Previous environmental studies can be divided into diagnostic-type studies that analyze mechanisms of nature and their relations with human society—broadly covered by traditional fields of earth sciences, ecology, geography, and so on—and treatment-type studies that consider technological or regulatory measures to tackle environment problems—covered by traditional fields such as engineering, agricultural science, and the social sciences. There have been few research projects to combine these two approaches. This book is an effort to integrate multiple approaches to environmental issues.

Our teams bring together graduate students and faculty members from diverse disciplines to work together with locally based staff to investigate and discuss each research situation. The aim is to come closer to finding methods of treatment that can be applied to maximum effect with minimum risk of adverse side effects. These efforts and findings are crucial to the effective construction of clinical environmental studies.

The studies in this book were carried out as part of the Nagoya University Global Center for Excellence (GCOE) Program "From Earth System Science to Basic and Clinical Environmental Studies" funded by the Japanese Ministry of Education, Culture, Sports, Science and Technology from FY 2009 to FY 2013. The program brought together young scholars including doctoral candidates and faculty members from various disciplines to work together with locally based personnel in Laos to investigate and discuss each research situation. Intensive field surveys were conducted in Vientiane Prefecture, the capital of Laos, two highland villages, Mai Nathao in Namo District of Oudomxay Province and Kachet in Nam Bak District of Luang Phabang Province, and two lowland villages, Dong Khuai in Xaythani District of Vientiane Prefecture and Paksuun in Pak Kading District of Borikhamxay Province. All chapters of the book are based on original data from field surveys.

We are very grateful to the people of those villages for their kind help. We also wish to sincerely thank Dr. Bounthong Bouahom, Director General of the National Agriculture Research Institute (NAFRI) in Laos and researchers in NAFRI for their cooperation and support in our research. We hope this book contributes not only to area studies of Laos but also to environmental studies in developing countries.

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Part I
Tradition and Development

Chapter 1
Laos in Transition: The Runner in Front, Leading the Race or Lagging a Lap Behind?

Satoshi Yokoyama

Abstract Laos is a landlocked and mountainous country surrounded by China, Vietnam, Thailand Myanmar and Cambodia. From an economic standpoint, Laos is considered a least less developed country (LLDC) by the criteria of the UN. Income generating opportunities, especially in rural areas, are limited because of geographical difficulties and a lack of infrastructure. Therefore, people in rural areas have, for a long time, been heavily dependent on swidden agriculture and the gathering of forest products. Their livelihoods have thus relied on indigenous eco-knowledge for the cyclical use of forest resources. The government of Laos has been encouraging foreign investment with the goal of raising the country above the status of an LLDC by 2020 and has simultaneously implemented the Land and Forest Allocation Program. This program was launched in 1996 and focuses on forest conservation and poverty eradication in rural areas with support being provided by development assistance agencies. However, the implementation of this government forest policy has resulted in the rapid introduction of various cash crops into rural areas, causing dramatic changes to people's livelihoods and land use. This chapter discusses the political and economic changes that have occurred due to this radical policy shift, by focusing on the impacts on a specific rural village in northern Laos.

Keywords Cash crop • Forest policy • Livelihood change • Swidden agriculture • *Thammasat*

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1.1 Introduction

1.1.1 From Landlocked Country to Land-Linked Country

Today's Lao People's Democratic Republic (hereafter, Laos) started its history when France approved its attributive independence as Kingdom of Laos in July 1949 and the territory of the current nation-state was formed. However, regardless of the achievement of the Lao's independence, a civil war broke out between the Royal Lao Government and a liberation force, the Pathet Lao. In the end, the Pathet Lao declared the inauguration of a new government, in accordance with the end of the monarchy which was delivered by a communist group, the Lao People's Revolutionary Party (LPRP). In the aftermath of the formation of the new government, the most crucial priority facing the new state was reconstruction, following the damage of the long raging civil war which had continued for around 25 years. In particular, there was an urgent need to settle the approximate 700,000 internally displaced people in the country at the time (Stuart-Fox 1986, p. 36). Despite such efforts, by the latter half of the 1970s, a massive outpouring of internally displaced people had emerged occurred due to ongoing economic crisis, strict political controls and anxieties about facing "re-education" following arbitrary arrests (Stuart-Fox 1986, pp. 38–39). Under such a situation, with the aim of shifting the nation to market socialism, the LPRP halted agricultural collectivization as early as 1979 and conducted reforms, such as granting permission to sell surplus products at the markets (Stuart-Fox 1986, p. 40). Subsequently, when they successfully ensured self-sufficiency in food products in the 1980s, the LPRP started further reforms, focusing on the management of state-owned enterprises.

In 1985, Mikhail Gorbachev initiated the economic reform policy, "Perestroika," when he assumed the office of General Secretary of the Communist Party in the Soviet Union and under the influence of this reform, in 1986 when Laos was firmly following the socialism of the former Soviet Union, they also developed an economic reform policy the so-called "Chintanakan Mai" (New Thinking) in the Fourth Party Congress. Through "Chintanakan Mai," economic liberalization was promoted within the framework of socialism and the liberalization was also brought about in both politics and society. As such, the country brought an end their 40 years history as a reclusive "landlocked country."

For mainland Southeast Asia including Laos, the period from the latter half of the 1980s to the first half of the 1990s was a turbulent time. Chatichai Choonhavan, who became prime minister in Thailand in August 1988, called for Indochina countries to transfer "from battlefield to market place" in his inauguration speech and consequently, the peace agreement of Cambodia was established in the Paris Accords in 1991. Following that, Indochina countries headed straight into the market economy (Maisrikrod 1992; Murray 1994). In fact, it appears that their transformation into market economies was not brought about by entering the globalized economy, but rather by the driving force of vigorous intra-regional flows of people and commodities. Particularly, the structure of economic partnership in Southeast Asian countries was greatly altered by the fact that Laos, the only landlocked country in this area, dramatically shifted their efforts towards a market economy. Laos is located in a geopolitically important region, as it is sandwiched between China-Thailand, and Vietnam-Thailand. As such, the development of Laos which had been previously hindered by having no access to the sea changed significantly following the 1990s when they started to take advantage of the borders they shared with China, Vietnam and Thailand. This signified a policy change for Laos towards becoming a land-linked country (Jerndal and Rigg 1999; Lintner 2008).

1.1.2 Economic Development and Poverty Reduction

At the dawn of the 1990s, the government of Laos (GoL) started to gradually open their closed boarders and revive the flow of people and commodities with Thailand, China, and Vietnam. This action was triggered by the implementation of an economic cooperation program of the Greater Mekong Sub-region (GMS), led by the Asian Development Bank (ADB) in 1992. The GMS represents five countries, Thailand, Cambodia, Laos, Vietnam and Myanmar, and areas located along the Mekong River which runs across two Chinese provinces, Yunnan and the Guangxi Zhuang Autonomous Region. The program aimed to promote economic development by improving the infrastructure and trade in an economic corridor which covered the concerned areas, reinforcing the region's competiveness through the participation of the private sector, promoting human resources development and environmental protection (Than 1997). In fact, 59.3 % of the foreign direct investment (FDI) to Laos for the years 2000–2009 was provided by their three neighbors, Thailand, China and Vietnam, which highlights the extent to which regional integration in GMS has been developing (Goto 2011). Laos became a member of the Association of South-East Asian Nations (ASEAN) in July 1997 through their active participation in the GMS and omnidirectional diplomacy and subsequently, in the following year, 1998, they became a full member of the ASEAN Free Trade Area (AFTA): attaining the status of a recognized member of the international community.

The GoL, in the Sixth Party Congress held in 1996, set a goal to escape from the category of being a least less developed country (LLDC) by 2020 (Yamada 2013, p. 28). In 2013, the estimated figure of gross domestic product per capita (current prices) is US$1,587. As Fig. 1.1 indicates, when comparing Laos to other LLDCs in Mainland Southeast Asian countries, such as Cambodia and Myanmar, the GDP of Laos displays a distinctive growth pattern after 2005. Indeed, from these figures, the country appears to have moved towards prosperity. In fact, in the capital, Vientiane, the number of automobiles increased dramatically, resulting in significant traffic during commuting time in the morning and afternoon. However, a question here is whether people in rural areas benefit from such prosperity. The Lao expenditure and consumption surveys (LECS) conducted in 2007–2008 displays that poverty in

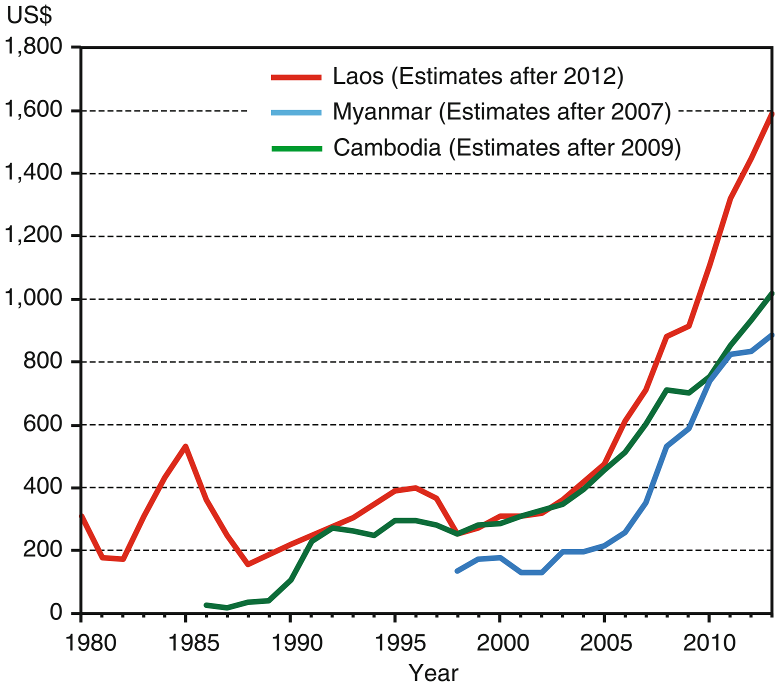

Fig. 1.1 GDP per capita (current prices) of Laos, Myanmar and Cambodia between 1980 and 2013 (IMF, World Economic Outlook Databases, http://www.imf.org/external/data.htm)

rural areas is double that in urban areas and it also revealed the fact that around 39 % of mountainous areas were in poverty (Government of the Lao PDR (GoL) and United Nations (UN) 2013, pp. 23–24). With attention exclusively placed on economic development, the improvement of people's life in rural areas seems to have been shelved. On the other hand, in regard to the impact of rapid economic development on the natural environment, substantial arguments, such as debates on dam construction, draw international attention (Keskinen et al. 2012; Orr et al. 2012; Delang et al. 2013). Nevertheless, the impact on the natural resources that people in rural areas have been utilizing has not yet been revealed. Accordingly, this chapter will discuss the changes in the access to the forest resources that are necessary for people in mountainous areas to survive and changes in livelihood activities which have occurred in accordance with development.

1.2 Forest Policies in Laos

1.2.1 Forest Policy Development

In the Food and Agriculture Organization of the United Nations (FAO) conference held in November 1985, the implementation of the Tropical Forest Action Plan (TFAP) was adopted. This project aims to maintain biodiversity and, at the same time, is designed to halt the deforestation of tropical forests. To do so, in the countries that possess the tropical forests, this project supports to develop action plans for preservation, regeneration and proper utilization of the tropical forest.

In Laos, at the Fourth Party Congress, which adopted the "Chintanakan Mai" in 1986 as noted above, the Second Socio-economic Development Plan 1986–1990 was announced and in this plan a concept was presented which contended that the stabilization of swidden agriculture was necessary to preserve the forests (Ministry of Agriculture and Forestry (MAF) 2005, p. 3). This plan was quickly put into practice with the influence of TFAP, and in May 1989, the National Forestry Conference was held to establish new forest policy directions. One of the main strategies adopted in this conference was to stabilize swidden agriculture and to allocate land to swidden farmers (United Nations Development Programme (UNDP) 2001, p. 50). Shortly thereafter, in October 1989, the Council of Minister (CM) Decree No.117 (No.117/CM) on the Management and Use of Forest and Forest Land was promulgated. According to this decree, villagers are allocated 2–5 ha of forest and forest land per household and some 100–500 ha per community, as community forests. Community forestry was officially rationalized by the GoL in this decree and the areas allocated were inadequate to maintain conventional swidden agriculture practices. This was also the first decree which presented the concept of land allocation to individual households.

No.117/CM was later replaced by the Prime Minister's (PM) Decree No.169 (No.169/PM), which was enacted in 1993 (Ministry of Agriculture and Forestry (MAF) 2005, p. 5). No.169/PM provided a basic framework for forest operation and management with provisions on forest definition, ownership, categorization and contract management. In this decree, forest lands were classified into five categories: protection forests, conservation forests, production forests, regeneration forests and degraded forests. These five categories were adopted into the TFAP in an unchanged form. Any development and forestry activity in the protection and conservation forests were prohibited, and swidden fallows were also regarded as regeneration forests in order to let forest cover recover. Regarding the ownership of forests and forest land, villagers can own, use, transfer and inherit them for tree plantation, but on the other hand, the decree states that forest and forest land are defined as a national heritage and are controlled by the Ministry of Agriculture and Forestry (MAF). Boundaries of forest lands, therefore, were set in village areas by Decree No.169/PM.

In 1994, the PM Decree No.186 (No.186/PM) on the Allocation of Land and Forest Land for Tree Plantation and Forest Protection was promulgated.

No.186/PM provides a basic framework for the allocation of land and forest land. More specifically, households, companies, national organizations and public organizations were allocated the degraded forests for tree plantation. This is regarded as a prototype of the present Land and Forest Allocation Program (LFAP). However, the criteria and the procedures of allocating land were not described in the decree. In terms of the allocation process, at the working-level, the MAF developed Instruction No.822 (No.822/MAF) on Land and Forest Allocation for Management and Use in June 1996.

In November 1996, the TFAP was finally promulgated. The articles of the TFAP adhered fundamentally to No.169/PM and No.186/PM, but further emphasized the allocation of forest and forest land to individuals and organizations for management and use (Tsechalicha and Gilmour 2000). As the TFAP went into effect it replaced the two previous decrees.

In addition to the TFAP, the GoL issued the Land Law in April 1997, and land in Laos was classified into eight categories: agricultural land, forest land, water-area land, industrial land, communication land, cultural land, land for national and security defense, and construction land. Subsequently, village lands in mountainous areas have generally been divided into agricultural land and forest land. Agricultural land in the mountainous areas is commonly meant to be swidden fields, and thereby swidden fields and degraded forests were allocated to individual households by the LFAP. As such, the land user is guaranteed rights of use, transfer and inheritance, but must use the land according to the appropriate land use plans formulated by the local government.

In Laos, the decrees regarding forests and their management, the TFAP and the Land Law are organically combined with each other, and some of the decrees were later replaced by the TFAPs. Therefore, it is hard to grasp the larger picture of governmental forest policy. However, at least it is certain that the establishment of these legal systems in the middle 1990s officially paved the way for the implementation of the LFAP.

1.2.2 The LFAP Implementation

According to the Forestry Strategy to the Year 2020 (FS2020) issued in 2005, the MAF described that the objectives of the LFAP were to promote crop production to replace swidden agriculture, to protect forest, and to utilize the allocated forests in a sustainable manner (Ministry of Agriculture and Forestry (MAF) 2005, pp. 5–6). In the meantime, the Resolution of Nation-wide Review Conference on Land Management and Land-forest Allocation, held on July 19, 1996, stated that the objectives were to prompt a reduction and gradual elimination of swidden agriculture and to enhance the promotion of commercial production (Asian Development Bank (ADB) 2001, p. 77). While the FS2020 highlights aspects of forestry, it originally emphasized aspects of agriculture. These developments regarding land and forest use show that the interpretations of the LFAP are numerous and vary, depending on the organizations involved. However, whatever the case may be, for the authorities concerned the LFAP places stabilizing swidden agriculture as one of the primary objectives for implementation.

The LFAP was legally started by enacting the TFAP and No.822/MAF in 1996, but actually, the pilot implementation was carried out in two northern provinces, Luang Phabang and Sayaboury, from 1990 to 1996 through the support of ADB, FAO and the Swedish International Development Cooperation Agency (SIDA) (Thattamanivong 2003; Ducourtieux et al. 2005). In particular, SIDA has supported the development of an implementation manual with the Department of Forestry, the MAF (Thongphanh 2004). Based on the result of the pilot implementation by the SIDA, instruction No.822/MAF which presents the eight-step participatory procedure for allocating land and forest land was created.

The eight steps of the procedure described in No.822/MAF are: (1) preparation, (2) initial discussion with villagers to reach understanding, (3) collection of actual village data, (4) a general meeting to agree on land use, forest and forest land categories and the village boundary, (5) measurement of land in group based on production units or commodity groups, (6) land use planning and land allocation completion activities, (7) extension, and (8) monitoring and evaluation. With the progress in the LFAP implementation, however, various problems, especially technical issues, including with participatory planning and communication, data analysis, mapping and surveying, land use zoning, preparation of land and forest land management agreements, monitoring, and evaluation, were manifested by the Lao-Swedish Forestry Program (Sysomvang et al. 1997). Among them, the most serious problem was the last step of the process, monitoring and evaluation, which has not often been completed (Thattamanivong 2003; Thomas 2003, p. 5). In fact, there are remarkably few studies comparing the land use before and after implementation of the LFAP (Ducourtieux et al. 2005).

In order to recognize problems in the LFAP, monitoring and evaluation following implementation is imperative. Moreover, to understand the problems that farmers or villages are facing, monitoring and evaluation are the most important step of the implementation process. Since little attention has been devoted to monitoring after implementation of the LFAP, little is known regarding what agricultural practices farmers switch to from their previous upland rice farming in swidden fields, and thereby what effect and impact the LFAP has had on farmers and farming communities.

Usually, three plots of approximately 1 ha are allocated by LFAP. The original scenario of LFAP suggested that it will be difficult to produce rice in these three plots by the method of swidden agriculture which uses the land in rotations, but instead, growing and selling cash crops will enable the farmers to purchase rice. With the GoL tightening the forest management and shifting the swidden fields to upland fields, during the period from the late 1990s to the mid of 2000s, international organizations, official development assistance organizations, and NGOs conducted a substantial number of projects, such as projects of community-forestry, forest management, and introduction of cash crops, in order to support the LFAP. However, the situation in the fields gradually deteriorated following the introduction of the LFAP. More and more households became unable to afford a subsistence amount of rice, even when they grew and sold cash crops instead of rice. In some areas, those farmers who could not live on cash crops continued to conduct swidden agriculture for their self-supply in the limited land allocated to them, as they previously had (Tanaka et al. 2007). In addition, many areas faced with a lack of fallow land, repeated swidden agriculture in their limited space and thus deteriorated the fertility of the soil, which resulted in further accelerating the poverty (Asian Development Bank (ADB) 2001; Ducourtieux et al. 2005). What, then, was the problem? To answer this question, the next section will introduce the livelihood activities in villages which were transformed by the influence of the development of regional integration and strict forest policies.

1.3 Demise of Swidden Agriculture

1.3.1 LFAP and the Involvement of an NGO

Mai Nathao is a village of Khmu, located around 22 km distance of Meo Chay, where the local boundary with China exists (see Map). This village has a short history beginning in 1977 with a migration to seek for suitable sites for rice paddies from three villages which used to be located in the mountainous area of the La district, on the east side of Namo district. As of the end of 2006, 192 people, 33 households and 41 families live in this relatively small village. In this village, LFAP was conducted in the spring of 2004 with the support from an international NGO and lands were allocated to each household. In order to prepare support, the international NGO initiated activities in Mai Nathao village in 2003. In August 2004 prior to when LFAP was initiated, the author carried out field research on the traditional plant use by those residents who conducted swidden agriculture, and subsequently, in January 2007, examined land use following the implementation of LFAP. In the 3 years of 2004–2007, life in the village has dramatically changed with many traditional things disappearing and new ones being introduced. This chapter, accordingly will discuss, with a focus on the changes in land use and villagers' life, what changes were brought about in the rural areas located near the borders with China, in northern Laos, before and after the LFAP and how the changes happened will also be explored.

LFAP was conducted in Mai Nathao village in 2004 with the land in the village categorized into forest land, agricultural land, and residential areas. Then as the second step, the land categorized as agricultural lands were divided and allocated to each household. As the lands are ultimately owned by the nation, allocation here means, more accurately, to provide each household with the land titles of the tradable land. In the land categorized as forest, it is prohibited to conduct swidden agriculture so if farmers want to conduct swidden agriculture, they need to use land categorized as agricultural land. Yet, the agricultural land allocated to each

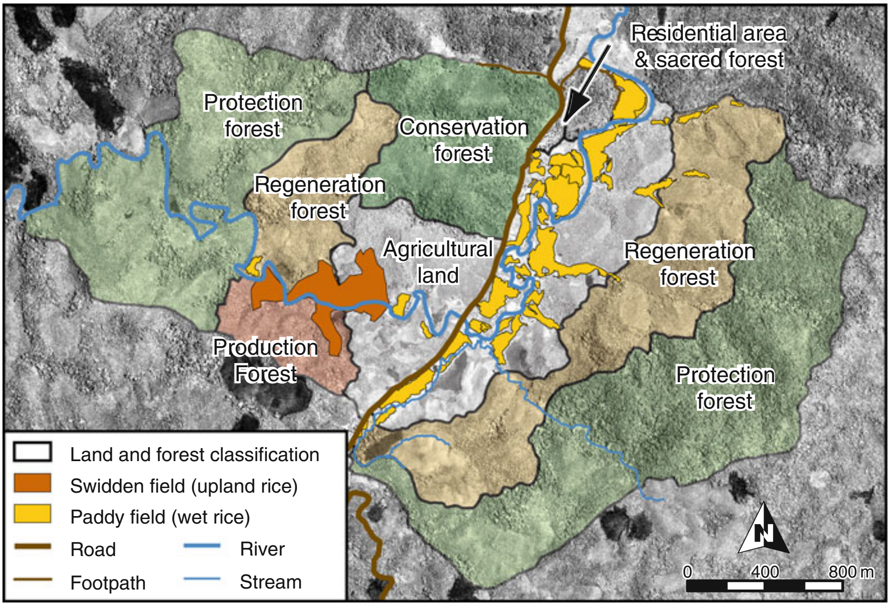

Fig. 1.2 Boundaries of land and forest classification and actual land use in 2004 (Surveyed by author using satellite data and GPS in August, 2004)

household was of a limited space of around 3 ha for one household. Thus, it was impossible for the farmers to conduct swidden agriculture as they previously rotated multiple fallow lands to enable such a system. Accordingly, transitioning to upland fields was inevitable.

Field research in 2004, was conducted immediately after the implementation of LFAP and thus any changes in land use through land categorization were observed. In fact, as Fig. 1.2 indicates, residents in Mai Nathao village were conducting traditional swidden agriculture using a large space of 18.89 ha in a site designated to be regeneration or production forests. In practice, LFAP is implemented by the District Agriculture and Forestry Office (DAFO), which is a terminal organization of the MAF, while the central government trains the DAFO staff for technical tasks, such as surveying, and clerical tasks, which include making title certificates of land. However, the LFAP which was initiated in 1996 embraces many technical issues (Sysomvang et al. 1997). In addition, it is difficult for DAFO, which has a small budget, to cover the necessary labor costs for the implementation of this project. In the case of Mai Nathao village, the technical and financial support from the international NGO enabled the LFAP to become feasible. In practice, the international NGO had begun its activities to prepare support for Mai Nathao village since 2003, repeatedly discussing what kind of crops should be introduced in the land allocated in order to transform it from swidden fields to upland fields and how sustainable agriculture should be conducted while preserving the natural environment.

As a result, in accordance with LFAP, the international NGO introduced as many as 22 agricultural and forests products in total eight open-field crops (soybeans, peanuts, maize, sesames, cassava, garlic, pineapples, and shallots), nine fruit trees (banana, mandarin oranges, oranges, lychees, longans, prams, pomelos, mangos, and limes) and five forest products (*Peuak muack* (*Boehmeria* sp.), agarwood (*Aquilaria agallocha*), rattan (*Calamus* sp.), cardamom (*Amomum villosum*) and wild ginger (*Alpinia galangal*)). The reason for introducing such a substantial number of crops at once was due to the promotion of mixed cropping, which cultivates multiple crops in an agricultural parcel. Monoculture cultivates single crops and thereby enables efficient mass production and the stabilization of distribution routes through the simplifying of technology. However, in disasters such as unexpected extreme weather or disease and pestilence, monocultures run a higher risk of the entire crops being disrupted. Alternatively, in mixed cropping, the dispersion of risk against disasters is possible to a certain extent. Moreover, *Crotalaria* sp., the leguminous green manure crop, was introduced and cultivation was encouraged without the use of fertilizers. Agriculture conducted in the allocated land does not utilize the flatlands but rather the slopes where swidden agriculture used to be performed (Fig. 1.3). As such, in order to prevent soil flowage, the NGO instructed the villagers in a new farming method, the so-called alley cropping systems, which involves planting trees aligned along the contour and cultivating annual crops between the lines of the trees. One case I actually saw put in practice was the planting of Faboideae in a line, which fixes nitrogen in the soils, and then the cultivating of maize in-between the trees. The maize, the international NGO recommended, was not a hybrid breed but an indigenous variety of Laos which was developed in the National Agriculture and Forest Research Institute located in Venetian. They also confined the scope of the seeds used for other vegetables to the species available in Laos. Furthermore, another distinctive feature of the method employed involved the introduction of forest products in addition to the open-field crops and fruit trees. Planting forest products in the agricultural land was a new attempt for Mai Nathao village as the villagers previously gathered such forest products from wild species growing naturally. In northern Laos, since 2000, various agricultural development projects have started to cultivate forest products as a trial (Sodarak et al. 2005; Jensen 2005) and it appears that the influence from those agricultural projects was behind the introduction of forest products into Mai Nathao village.

In summary, the distinctive features of the agricultural development project conducted by the international NGO in accordance with the implementation of LFAP were; the introduction of both eco-friendly crops which produce their yield without pesticides or chemical fertilizers and of cash crops, such as fruit trees and forest products, based on a calculation of the market trends. However, when the villagers practice mixed crops in land with only limited space, the yield for each species remains small and, moreover, there is no market located near the Mai Nathao village. As such, it is very hard for the villagers to sell small amounts of crops since they cannot sell the crops at a market on their own. In response to this situation, the international NGO organized a commercial group in the village and

Fig. 1.3 An allocated upland field to the mountain slopes which had been practiced swidden agriculture. Maize, banana and many kinds of fruits trees are planted. (Photo by author in January 6, 2007)

this enabled an increase in the trade volume by collecting the harvests from the villagers and thus a middleman who lived in the urban area could come to buy the collectively gathered crops. Hence, the international NGO's goal was to entrench the agricultural method that introduces multiple varieties of crops and grows them through mixed cropping in an agricultural parcel.

1.3.2 Land Use and Livelihood Changes by Implementing LFAP

In January 2007, the author visited Mai Nathao village again and conducted a survey on the land use applying GPS after the implementation of LFAP (Fig. 1.4). This survey focused on the agricultural land in practical use and thereby the map in the survey did not reflect the farming sites which were not allocated or utilized. When looking at the land use of Mai Nathao village, centered on the stream running from the west to the south in Fig. 1.4, it could be seen that upland fields were distributed on the slopes located upstream on the west side, while paddy fields were widely distributed in the lowlands which was along the main road. In addition,

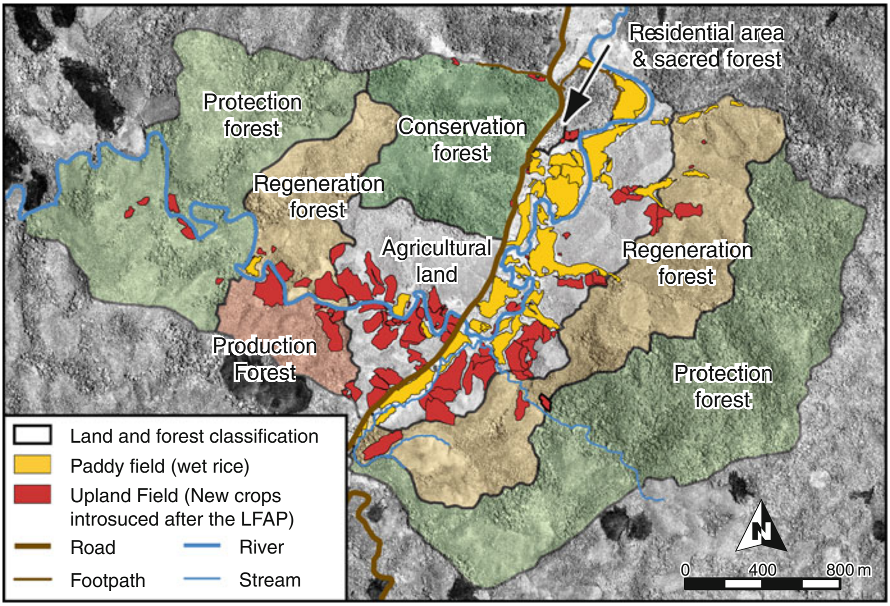

Fig. 1.4 Boundaries of land and forest classification and actual land use in 2007 (Surveyed by author using satellite data and GPS in January, 2007)

32 fishponds were also distributed: however recognizing those fishponds on the map is difficult due to the limited size of the ponds.

Although only agricultural lands in the category were allocated, Fig. 1.4 reveals that upland fields were also reclaimed in forest land, including areas designated as regeneration, production, conservation, and protection forests. In fact, DAFO does not mind the performance of agriculture in the site categorized as forest land, in so far as swidden agriculture is not performed. Consequently, most of the swidden fields that were in use in 2004, as indicated in Fig. 1.2, were transformed into upland fields in 2007. According to the villagers, since 2006, swidden agriculture had not been conducted in the village. Around the alluvial lowland of the riverside where paddy fields are easily reclaimed, there were a very limited amount of suitable spaces for paddy fields available. Therefore, the majority of the land allocated to each household did not include sites where paddy fields could be cultivated but slopes in the mountain which previously were utilized for swidden agriculture. This means that the households that previously provided rice for themselves only through swidden agriculture, prior to the implementation of LFAP, were placed in a challenging situation in which they needed to purchase rice through the cash income they earned by selling their crops cultivated in upland fields or livestock.

However, some of the households in the village continued to practice swidden agriculture. The swidden fields were located not in Mai Nathao village but in Mixay village which was a neighboring village located to the south. In Mixay village, the LFAP has not yet initiated and thus swidden agriculture was still performed. Some households in the village established contracts with Chinese firms in 2005 and ensured lands to plant para-rubber. Subsequently, the households that established the contracts allowed the villagers of Mai Nathao to conduct swidden agriculture in the land where para-rubber was supposed to be planted. This opportunity benefited both villages, as the households from Mai Nathao village that were in trouble due to a shortage of rice without available swidden agriculture land, could grow rice while the households in Mixay village that were about to plant para-rubber could log the trees and level the land without too much cost. According to one household from Mai Nathao village which conducted swidden agriculture in Mixay village, they gathered 1.5 tons of rice at the first harvest in 2005, using the conventional method of swidden agriculture. Subsequently, in 2006, the same site where swidden agriculture was performed in the previous year was fired again and leveled along the contour. Following that, the nursery plants of para-rubber were planted and the upland rice was cropped in-between the para-rubber, which resulted in a harvest of 1 ton of rice. For the third year, in 2007, they stated their plan to plant the upland rice again. Yet, a limitation of cropping upland rice in this manner is that by the third and fourth year, the rice yield decreases significantly as the para-rubber grow taller and the productivity of the land declines. However, despite this, all over northern Laos, para-rubber planting has been initiated (Manivong and Cramb 2008). As noted above, before the para-rubber grew too tall, some households continued to cultivate upland rice, while others grew pineapples. In terms of the trees and agricultural products that are produced in the same arable space, this can be recognized as agroforestry for the short term. In the two villages sharing the borders, one conducted LFAP, while the other remained free from LFAP: and then para-rubber planting from China was introduced. These conditions created the above-mentioned unusual situation in which villagers carried out swidden agriculture in another village.

1.4 Trans-Boundary Influence of Chinese Economy

1.4.1 Introduction of Contract Farming with Chinese Firms

In Mai Nathao village, which was targeted for assistance by the international NGO from a developed country up to 2006, para-rubber planting was not conducted as the international NGO did not promote it. However, other influences from China other than the para-rubber planting had been reaching the Mai Nathao village. In other villages located near the Mai Nathao village, since 2004, contract farming with Chinese firms had been fully established. For instance, in Na Savang village which is a neighbor located to the north of Mai Nathao village, contract farming of rice crops, using an improved high-yield variety was began in 2004, watermelons and green peppers were introduced in 2005 and pumpkins in 2006. In Mai Nathao

Fig. 1.5 Watermelon cultivation in paddy fields during the dry season. (Photo by author in January 6, 2007)

village, subsequently, in the autumn of 2006, the final year of the NGO's project, contract farming with a Chinese firm began, involving the cultivating of green peppers and watermelons in the land allocated.

The green peppers are planted in October and then harvested in January. On the other hand, the cultivation of watermelons' nursery plants started in December and subsequently was transferred to ridged paddy fields in January, and then gathered in May (Fig. 1.5). For the green peppers and watermelons, a set of materials to enable cultivation are provided by the contracted firm which includes the seeds, chemical fertilizers and pesticides, as well as polyethylene film for mulch farming. Thus, the villagers are not required to make any initial investment, instead the amount of money for the input materials are subtracted from their payments. The purchase price for both products was 650 kip/kg (about 0.65 US$/kg) in 2007 and supposedly as much as 30 tons/ha can be harvested, if there is no occurrence of disease and pestilence and the instructions regarding fertilization are obeyed. Yet, as the green peppers and watermelons can have a replant failure, 2 years for the green peppers and 3 years for watermelons, are required to fallow the land. However, in the paddy fields where the watermelons were cultivated, wet-field rice can be cultivated as usual during the summer season.

Exactly when the author conducted his research in January 2007, the first green peppers were harvested and the village was in the middle of the rush of preparations for the shipping operation. When the author asked the villagers about the shipping of the green peppers, they noted that the Chinese firm do not buy ones with slight scratches nor ones with distorted shape or color unevenness. As such, shippable green peppers falls to two thirds of the total amount of harvests that are gathered in a well-managed plot, half the total amount in land with normal conditions, and one third in badly managed land. The green peppers that were not bought by the Chinese firm are sometimes purchased at a cheap price by middlemen who visited from the urban area but they did not buy a large amount, since the demand for green peppers in Laos is limited.

Contract farming of cash crops, such as green peppers and watermelons for the Chinese market brings dozens of times more income per unit of area than the income from the eco-friendly agricultural and forest products that were introduced by the international NGO, even when taking the fallow period required after the cultivation and yield ratio into consideration. Consequently, in fact, many of the Mai Nathao villagers are planning to introduce contract farming for cash crops targeting the Chinese market in the future. However, topographically, the green peppers and watermelons can be introduced only in flat fields. Therefore, villagers possessing only inclined land, are considering tree planting for the Chinese market, such as para-rubber and eucalyptus, rather than the cash crops. In fact, one household planted eucalyptuses in 0.35 ha of their land which they had never previously used, since it was allocated trough the LFAP. The household explained this situation noting that they planted around 100 eucalyptus trees in 2006 because the Chinese firm came over and asked them to plant the nursery plants.

1.4.2 Livelihood Change by the Inference of Outside the Village

Within only 3 years after the implementation of LFAP, Mai Nathao village experienced rapid changes in land use and the structure of livelihood. The international NGO introduced eco-friendly agriculture into Mai Nathao village and organized commercial groups in order to promote the sales of agricultural and forest products. However, even although it is appealing when environmental protection and poverty eradication are focused on as the path of development assistance performed by a developed country, it would be too simplistic to legitimize the agriculture and agricultural development that the international NGO promoted on this basis. These development assistance activities were not required in the village when swidden agriculture was performed. All households that the author interviewed, noted that they never had experienced any terrible shortage of rice when they had conducted swidden agriculture. Swidden agriculture did involve fluctuations in the yield of rice in accordance with the weather and land condition of the year concerned. Yet, as the allocation of swidden fields in Mai Nathao village was conducted based on the amount of labor force in one household, the space of swidden fields never fell below what was necessary. However, swidden agriculture was no longer feasible due to the fact that the LFAP distributed land and restricted access to the forests. In practice, it might even be the case that the international NGO led the village into a situation where it needed to introduce new agricultural method and as a result, generated poverty in the village. While it is true that the villagers had almost no financial income before the international NGO began their support, it is also the case that they have been unable to earn any substantial income from the fruit trees they grow in the upland fields, even now. As a result, eventually they fell into the situation in which they need to rely on the gathering of forest product and cattle husbandry. In fact, they often cannot afford rice even when they sell their livestock.

Thereby, the villagers have been attempting to find a solution to breakthrough this severe economic situation through cash crop cultivation and the para-rubber planting based on contracts with a Chinese firm. In this way, they can utilize the

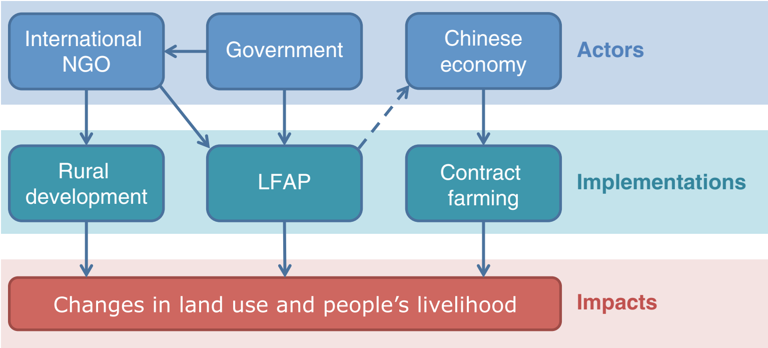

Fig. 1.6 Three actors that influenced the changes in land use and people's livelihood in the village implemented the LFAP

land allocated efficiently since the cash crops can be grown in the flat fields while para-rubber planting can be performed on inclined land. However, according to the vice village head, the international NGO attempted to discourage the villagers from beginning contract farming with the Chinese firm. This is due to the fact that Chinese agriculture makes significant use of pesticides and fertilizers and thus the methods involved do not fit with the agricultural concepts of the international NGO. Furthermore, the international NGO must have found the contract farming to be based on an unacceptable structure in which the Chinese firms are able to extract profit from the villagers by buying the agricultural products at a very low price.

Despite the efforts by the international NGO, however, the villagers chose to cultivate green peppers and watermelons just prior to the end of the international NGO's activities in 2006. The international NGO could not prevent the villagers from engaging in contract farming for cash crops with the Chinese firm due to the fact that the lands involved were categorized and allocated to each household through the LFAP which the international NGO supported. Thus, the management of the land was delegated to the village and the particular use of the allocated land falls solely under the responsibility of the owner. If the international NGO had not supported the LFAP, the cultivation of green peppers and watermelons could never have experienced such a rapid development. Clearly, a dilemma exists here. Yet, in one sense, the international NGO's activity was not only the reason for this situation but the LFAP itself was a failure.

The LFAP by GoL, the development assistance by NGOs and crossing the border by the Chinese economy: all these things came into the village when the villagers were not prepared for such change. Subsequently, these three developments have been mutually influencing one another throughout the same period and thus the livelihood structure in the village was rapidly changed (Fig. 1.6). The villagers had no time to reflect on what is good and what is bad for them. Instead, one after another, new things that they had never experienced before were brought into the village by outsiders. The contract farming with the Chinese firm is very far from the conventional agriculture that was practiced in Laos. In addition, the current situation in Laos gives the clear impression that indigenous eco-knowledge, with which the villagers used to engage in their livelihood activities, including swidden agriculture and the gathering of forest resources, will be corrupted.

1.5 Indigenous Eco-Knowledge and *Thammasat*

1.5.1 Vulnerability of Indigenous Eco-Knowledge

Even though the existing livelihood structure had continued in an unbroken line based on indigenous eco-knowledge, it was easily destroyed by the introduction of a new forest policy. Originally, it appears that the government and international NGOs considered swidden agriculture to be an undeveloped agricultural method in comparison to modern intensive agricultural methods. Modern agriculture supplements the soil nutrients though the use of chemical fertilizers and prevents the propagation of weed by herbicides. Alternatively, swidden agriculture enables the land to have a sufficient fallow period after the cultivation period and ensures a succession of vegetation, from herbaceous plant to woody plant: this process reduces the weeds growing before the initiating of cultivation. Furthermore, by doing so, decomposed organic matter from dead and decaying plants are accumulated in the soils and the heat from intentional burning provides additional nutrients though the dissolution of organic subsistence, as well as enabling the sterilization the soil (Giardina et al. 2000; Kendawang et al. 2004; Boonyanuphap et al. 2007). Swidden agriculture, therefore, is not an undeveloped agricultural method, rather it enables sustainable and circulative crop cultivation, through the utilization of the potential of nature.

Nevertheless, swiddenners are considered to be a primitive today and their method is regarded as a primary factor involved in the destruction the tropical forests (O’Brien 2002). The ancestors used to make use of forest resources through maintenance of the pattern of cultivation and fallow suited for their land and sustained swidden agriculture for centuries. However, as swidden agriculture inevitably requires the process of logging and burning of trees, it started to be treated as a fundamental factor behind forest destruction and thus was restricted across the world. Consequently, the forest land for swidden agriculture has rapidly shrunk and the practice is facing extinction (Padoch et al. 2007; Fox et al. 2009). In Laos, various forest policies were thus implemented to mitigate the decrease in forest land. In particular, a discourse, which claims that swidden agriculture is destroying the forest, was accepted and thereby the LFAP was put into practice (Lestrelin 2010).

Meanwhile, a reevaluation of swidden agriculture is now occurring. Harold Brookfield who supports the idea of agrodiversity, argues that practices of small farming, including multiple cropping and land use depending on different purposes, contributes to the sustainability of food production and biodiversity. He further introduced an example of swidden agriculture in Borneo, clarifying that they sustained complex livelihood practices, which combined swidden agriculture growing upland rice as the main crop together with cash income crops, such as para-rubber (Brookfield 2001 pp. 103–122). These positive evaluations on swiddenners have substantially began to appear since 2000 in research conducted in mountainous areas of tropical and subtropical zones (Brookfield et al. 2003; Cairns 2007).

Up to the present, in Laos, the author has been attempting to highlight the value of swidden agriculture and to the end, has been conducting research on the swidden fallows that are inevitably formed through the performance of swidden agriculture and on various botanical resources which are gathered from the fallows, as well as on the relationship of swidden agriculture with livelihood. To introduce the results briefly, firstly, it is revealed that swiddenners in northern Laos gather a diverse range of useful plants not only from the swidden fields, where they grow upland rice as their self-support staple, but also from various ecosystems in which natural vegetation transfers from the farm land to the secondary forest. Thus, they are earning income by selling those plants (Yokoyama 2004). Secondly, it became clear that swidden fallows function as grazing lands for cows (see Chap. 4) and as a site to provide various animal and plant resources that are used not only to earning cash but also for daily life (see Chap. 6). Thirdly, strict rules were applied to the use of swidden fallows and external middlemen who came in order to buy forest products were also involved in setting those rules (Yokoyama 2010). When looking at the gathering of forest products from another aspect, it can be recognized that a method of utilization of the swidden fallows was established in a way to sustainably produce profits in the interactions among actors from inside and outside of the fallows: which clearly indicates that swidden fallows do not exist only to enable the next cultivation.

The discussions which argue that swidden agriculture is a cause of environmental destruction, ignore that the value of swidden fallows are derived over 10 years in the recovery of the forests and instead, focus only on the practice of cutting and burning trees involved with the formation of farm lands. Past arguments regarded the farm lands and fallows of swidden agriculture as completely different spaces, and thus when calculating forest cover rate, for instance, whether a land should be categorized into agricultural land or forest land was determined by the land use at one random point (FAO (Food and Agriculture Organization) 2000). Yet, the swidden field where crops were cultivated changed into fallow lands to gather herbaceous plants in the next year, and several years later, turned into fields to gather woody plants. Hence, not only the resource included in a land but the activities of swiddenners are also changed in accordance with the number of years that a fallow field has existed: following crop cultivation, stubble grazing is performed at the same land, and plants, insects and small animals are also hunted and gathered.

In summary, swidden agriculture should be characterized not by "classification" but by "continuity." The land for swidden agriculture is a "field" to produce foods for the first year after burning the trees, and following that the invasion and succession of plants are repeated over a long period, which means that the land functions effectively as a “forest” where various living things live. Therefore, the swidden fields function both as field and forest and thus it is not appropriate to consider the swidden agriculture as an agricultural method which destroys the forests. This method also possesses another feature, a continuity of livelihood in addition to the continuity of an ecological system. The villagers in mountainous areas of Laos inherited the methods to utilize nature in a continuous manner, namely, the indigenous eco-knowledge, over generations.

1.5.2 Thammasat

In this article, the knowledge and skills to survive and perform livelihood activities were referred as “indigenous eco-knowledge.” It is difficult to find the exact Lao word to match the meaning of this English term. However, there is a Lao word, *thammasat*, which has a very similar meaning to “indigenous eco-knowledge.” *Thammasat* refers to the concepts of nature, native and indigenous. For instance, *thammasat* agriculture means extensive farming without the use of chemical fertilizers and herbicides and *Thammasat* life refers to primitive life, while those words are also suggestive of eco-friendly agriculture and a living in harmony with the rhythms of nature. Thus, the term, *thammasat*, is somewhat ambiguous as it can refer to both meanings.

If there was no electricity, you can get up with sunrise and go to bed with the sunset and regarding meals, seasonal wild vegetables are available. Villagers in local areas of Laos do not attempt to conduct greenhouse cultivation or to import fresh vegetables from the opposite side of the earth, in order to consume the same vegetable throughout the year. However, their lives have a natural rhythm, namely; a rhythm within the term of one day and another rhythm within the term of one year. Following these rhythms enables them to live an affluent life. The life they live is in harmony with the natural rhythm, something which we lost in the past, and this can be called a *thammasat* life. It is up to us whether or not this lifestyle is regarded as an undeveloped lifestyle or this is the most advanced life, involving a harmonization with nature.

In Laos, which witnessed great transformations in its politics and economy, as noted above, after the “Chintanakan Mai” dramatically impacted people’s lives in the rural areas, changed their access to forest resources and introduced the liberalization of economy, developments were promoted which had both positive and negative impacts. Nonetheless, in comparison to their neighbors such as Thailand, Vietnam and China, Laos has largely preserved *Thammasat* still to this day. In regards to agriculture, for instance, neighboring countries are promoting the standardization of agriculture into more intensive and productive methods, while Laos retains diversity with variations depending on ethnic groups and regions. As with Mai Nathao village, which was mentioned previously, the introduction of cash crops is proceeding in those areas located around the borders with China with the planting of trees, such as para-rubber and eucalyptus, advancing across Laos. Nevertheless, people's lives in rural areas of Laos are sustained by a form of complex livelihood, including; rice cultivation for self-supply, gathering forest products, hunting wild animals and insects and fishing. With all of these activities being conducted in ways which are unique to the specific community or ethnic group.

Now, consideration will be given to the factors that have enabled *Thammasat* to be maintained up to present in Laos in comparison with the neighboring countries, with particular focus on the relationship with agriculture, which is the main livelihood activity in Laos. Firstly, much of the land in Laos is comprised of hilly terrain. These topographical features restricted national land development and the scale of expansion of villages. In addition, together with civil conflicts, the exodus of internally displaced people after the formation of socialist regime and delays in improvements to the hygienic measures, the population density in Laos has been kept at a very low level in comparison with the surrounding countries. Yet, despite such difficulties, the staple food of rice has been produced consistently across Laos. In northern Vietnam, the author saw buffalo being used to cultivate on slope, which seemed too steep for a person to climb, and in the mountains of northern Thailand, maize and upland rice were planted as far as I could see. I suppose that no farmers in Laos have had the idea to convert such steep land into upland fields and grow crops as the Vietnamese do, or to cut all the trees in the mountain and replace them with crops as practiced in Thailand. Up to the present, Laos has retained a low population density and agricultural productivity has been practiced at a standard level, meaning there was no pressing need to cultivate inappropriate land for agriculture or expand agricultural lands through the use of chemical fertilizers.

However, population density and agricultural productivity were not the only factors sustaining the *thammasat*. In addition to these, another important factor is the delay in the improvement of infrastructure in rural areas. France, when French Indochina existed, was inactive in the development of Laos. As such, they did not build anything in Laos, a landlocked country, whereas they constructed rail roads in Vietnam and Cambodia, which are bordered with oceans, and developed summer resorts in the plateau area, the so-called hill station, which have currently become major tourist sites (Spencer and Thomas 1948). In particular, improvements to infrastructure, such as the construction of roads, were carried out only in southern Laos, to a limited extent, and only when connections led to Vietnam and Cambodia. Almost nothing has been built in the northern and middle part of the country as they are more mountainous. The limited roads that do exist were not well maintained after the formation of socialist regime. As a consequence, until recently, when efforts to transform to a land-linked country were announced by the GoL in accordance with the community development in the areas along the Mekong River, the so-called GMS, people in the rural areas were able to use the land and forests free from control by the GoL. Scott (2009) noted that those minorities, who led their lives away from the surveillance of the central government, escaped from the control of the nation by choosing such life styles and that this was represented a strategy to escape from authority and attain freedom and autonomy.

The third factor for Laos unique situation is thought to be the incomplete control operated by the GoL. Following the formation of socialist regime, the GoL endeavored to make agricultural development and as such, since the latter half of the 1970s, collectivization of agriculture was promoted grounded in communist ideology; with cooperatives being introduced into each village (Stuart-Fox 1986, p. 38; Evans 1990, p. 58). However, cooperatives were not introduced into all villages across Laos and even in those villages where it was introduced agricultural productivity was not necessarily improved (Stuart-Fox 1986, p. 39; Evans 1990, pp. 62–63). Several possible explanations for this failure exist. According to the villagers in Vientiane province, it was the laziness of the villagers that led to the lack of rice. In addition, those villagers who did not posses paddy fields joined the cooperatives, and thus the system to equally distribute the harvest based on the labor force caused complaints from the farmers who had developed the paddy fields prior to the introduction of the cooperatives. Evans (1990, p. 146) also reported the same opinion of the villagers as those of the author's interviewees. He noted that due to the problem of the laziness of some of the farmers and the distribution of the harvests, i.e. the lack of political control, the cooperatives disappeared in the latter half of 1980s. This case indicates the fact that the control of GoL did not fully extend to the farmers in rural areas.

Thus, it is believed that these factors sustained *Thammasat* life and *Thammasat* agriculture in a community-unique style. In summary, the current *Thammasat* was an outcome of a complicated mixture of the three factors mentioned above, namely: Laos' unique nature environment, the social environment and specific historical factors.

1.6 Conclusion

This article introduced and examined the situation in which villager's indigenous eco-knowledge, or *Thammasat* in Laos, which were transmitted over hundreds of years, were erased and destroyed within only 10 years or so. This was caused by official forest policies, such as LFAP, international organization's support for these policies through their activities, and FDI from neighboring countries, through recent globalization and regional integration. In the present, even the GoL considers the introduction of LFAP into the mountainous areas to be a failure and in the 2010s, the government has not been as strong in its attempts to control swidden agriculture as in the 1980s when the LFAP was first introduced. However, once the policies were introduced, the situation in the effected villages can never return to how it was in the past. Currently, new policies to help recover from the failures of LFAP are being sought for. Nonetheless, private companies in neighboring countries are continuing to proactively invest in the rural areas where land resources are abundant and are promoting the villages to convert the upland fields and plantation areas for cash crops. Consequently, in the near future, swidden agriculture might be sustained in a very limited area and remembered as an agricultural method of the past.

As a tactic for a small country such as Laos, it appears that political transformation from landlocked country to land-linked country was successful. However, Laos should realize that indigenous eco-knowledge or *thammasat*, which is disappearing in accordance with the transformation, will never return to its original condition easily.

In 1991, when almost no surveys in rural villages were carried out, Koji Tanaka, a Japanese agronomist, visited the rural villages across Laos and conducted survey on the rice-cropping techniques (Tanaka 1993). In his article, one farmer's comment, "Our agriculture is *thammasat*," was noted. Furthermore, in regard to the agricultural practice of *thammasat*, which accurately captures both the positive and negative natural conditions and allows the farmers to gather the maximum amount of harvests through utilizing effectively the natural blessings, Tanaka summarized, as below:

> In terms of economic and technological development, the present performance of Laotian agriculture cannot be compared with that of Thai agriculture, for example. However, very rapid changes in accordance with this development have begun to produce adverse effects in Thailand. The increased application of artificial measures in agricultural inputs, like the use of chemical products and fossil fuels, has brought about not only socioeconomic but also environmental problems. Harmonization of the *Thammasat* nature of Laotian agriculture with various schemes for promoting the modernization of rice-based farming systems is the key issue, so that Laos will not follow earlier examples. (Tanaka 1993, pp. 139–140)

In Laos today, while some *thammasat*-oriented technology is maintained, other type of technology, such as those utilized in developed countries have been introduced. Thus, Laos is currently in a transition period in which they are confronted with the choice of whether they should follow the path which developed countries experienced or alternatively should maintain and further pursue the direction of *thammasat*. While people's life in rural areas of Laos fall behind when we take modern lifestyles which are supported by science and technology as a standard, they are at the forefront in terms of leading lives which utilize and are in harmony with nature.

If likened to a competition in track and field, Laos situation could be compared with a runner who appears to be leading the pack but may in fact be lap behind, with the reality depending on the value attribute to indigenous eco-knowledge. The introduction of "Chintanakan Mai," could also be compared to the runner making a sudden spurt of effort but again whether this effort is being directed effectively largely depends on perspective.

It appears that the people in Laos are dealing with this situation in an opportunistic way, namely, "accept it if it seems to be successful in the future, reject it if it appears to lead to failure, or compromise if there is no alternative." However, the determining factors of people's responses, whether they accept, reject or compromise are mutually entangled with physical characteristics, ethnicity, politics, and regional eco-history, etc. If we, as outsiders, desire to help them to become front runners when they are actually a lap behind, such action will inevitably result in imposition coming from the side of developed countries. What we need to do now instead is to present them with multiple choices. Hence, the imperative role for developed countries is to offer support for the local people who have previously never had the opportunity to choose the best option from among a range of choices for their future and by their own will. Now, the GoL is required to choose between the same development path that other countries have experienced or to take their own unique path making use of the valuable *Thammasat* resource, which has continued to survive to this date.

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Chapter 2
The Impact of Urbanization on Land Use and the Changing Role of Forests in Vientiane

Kohei Okamoto, Ayyoob Sharifi, and Yoshihiro Chiba

Abstract This paper investigates urbanization in Vientiane, the Laotian capital city, and its vicinity. The intent is to address the relationship between urbanization and land use, especially focusing on the changing role of suburban forest. In the Vientiane suburbs, forests still supply many items to villagers: firewood, charcoal materials, wild vegetables, mushrooms, insects, small animals and others. However, when off-farm work increases and commuting to factories is prevalent among villagers, the time to collect and hunt forestry products declines. Foods except for rice are purchased from stores in cash and firewood and charcoal are replaced by propane gas. In the near future, forests may become unnecessary for villagers from an economic aspect. What meaning do suburban forests have? For one, they have cultural and environmental meanings such as the securing of better landscapes and biodiversity, but their more important role is to act as a barrier to prevent urban sprawl.

Keywords Forest • Land use • Non-farm job • Paddy field reclamation • Urbanization • Vientiane

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2.1 Introduction

A general characteristic of urbanization in Monsoon Asia is numerous old and large cities in existence before modern industrialization. These cities have been supported by rice cultivation with high carrying capacity. Rural areas also have had relatively high population density and have been spreading their populations to urban areas. "Urbanization without industrialization," based on the transfer of populations forced out of farming villages, has generated urban economies relying on informal sectors and extensive slums. With increasingly accelerated urbanization along with recent progress in industrialization, many megacities with populations greater than ten million are expected to appear in Asia. It has become a challenge to cope with environmental problems caused by these ballooning megacities and large city aggregations, such as lack of water and energy, waste and air pollution.

Another characteristic of urbanization in Monsoon Asia is areas that appear to be neither urban nor rural. Such peri-urban areas spread widely around Asian cities and environmental problems there, such as soil and water contamination caused by invasion of polluting firms and accumulated waste, have recently become serious. How to curb urban sprawl and secure green space and quality farm land in city fringes has become a major challenge.

Laos is an exception in that it is less densely populated, despite its location in Monsoon Asia. Together with Bhutan, Laos ranks as the lowest population density country there. This is because Laos is mountainous, and the majority of its territory is covered by forests. Plains are limited to small-scale lowlands along the Mekong River. This paper addresses urbanization in Vientiane, the capital city, and considers how urbanization affects the forest.

2.2 Urbanization in Laos

Before the Second World War, Laos was a French colony. During the colonial era, French Indochina had been an important economic interest for France and the French government invested in Vietnam and Cambodia, establishing commercial ports in both countries. Because Laos was a landlocked country, it lacked importance in this respect and received little investment in terms of traffic infrastructure, remaining unsuited to land transport until recently. Following the Second World War, the United States of America (US) invested heavily in Laos to prevent it from falling under the influence of communist countries. However, their efforts were limited to Vientiane, and Vientiane became isolated from other regions of Laos. Close to Vientiane and even in suburban areas, Laotian people continued to live traditional rural lives (Askew et al. 2007). After the end of the Vietnam War in 1975, the US evacuated Laos, and the population of Vientiane remained small because of a controlled urban economy, and migration under a socialist regime. In about 1980, Vientiane had a population of less than 200,000, though it was the most populated city in Laos. The urban population in Laos had not increased significantly because of the scarce population in rural and mountainous regions, and there was minimal migration to the cities. Laos did not experience huge population flows to cities as a result of the "push factor" of migration, which was commonly seen in other Asian developing countries. Thus the urbanization of Laos was different from that in other countries in Monsoon Asia, because of these geographical, historical and political factors.

The situation in Laos drastically changed after a market economy was introduced in 1986 by the central government advocating "Chintanakan Mai" (New Thinking). Since the turn of the century, commercial and urban development has progressed, brought about by improvements in traffic infrastructure and an inflow of foreign capital. This has resulted in Laos beginning to share similar urbanization characteristics to those in other regions in Monsoon Asia. Migration from rural areas to Vientiane has soared, mainly among young generations motivated by an increasing demand for cash income, the growing demand for factory workers in Vientiane, and expansion of the urban economy into rural areas. Therefore, the population of Vientiane, which topped half a million in the 1990s, is expected to reach one million in the 2010s (United Nations Department of Economic and Social Affairs, Population Division 2010). In addition, conversion of forest and farmland to factory and residential land has increased, along with extensive development of urban areas.

2.3 Recent Land Use Changes in Vientiane

We studied recent land use changes in Vientiane using satellite images. The study area was the Vientiane prefecture (or Vientiane Capital), which includes core urban districts of Vientiane (Chanthabuly, Sisattanak) and surrounding rural districts (Naxaithong and Xaythany for example) (Fig. 2.1).

Data were selected for detecting land use changes from three time periods: 1995, 2005, and 2011. To control for seasonal effects, we only used the Landsat imagery data acquired during the dry season. Data for 1995 were obtained from Landsat 5 Thematic Mapper (TM). Satellite images for 2005 and 2011 were obtained from Landsat 7 Enhanced Thematic Mapper Plus (ETM+). Gaps in the Landsat 7 images were filled using the NASA gap filling software known as "Frame and Fill". For each of the time periods, the following three Landsat scenes were used: path 129/row 47; path 128/row 47; and path 128/row 48. A resolution of 30 m was used for all images.

Before beginning the analysis, we undertook two tasks to improve the accuracy of land use change detection. First, we removed atmospheric interference from the selected imagery using the QUAC (Quick Atmospheric Correction) method of the ENVI Atmospheric Correction Module. Second, using the ENVI image-to-map registration method and appropriate topographic maps, the images were aligned to a common UTM coordinate system. Land classification was performed using ENVI's

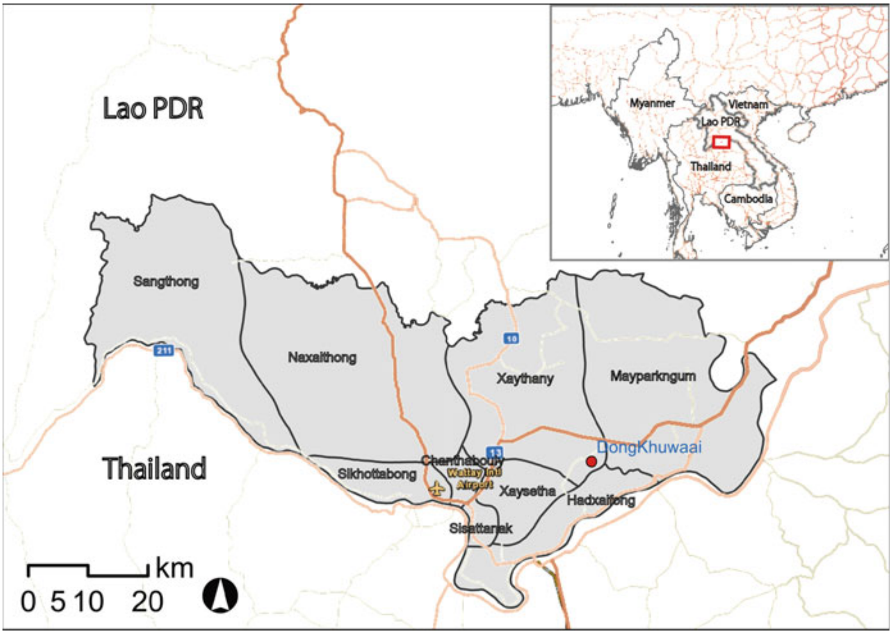


Fig. 2.1 Study area

Maximum Likelihood Supervised Classification method. We classified the images into five categories: forest, water, farmland, barren land, and built-up area.

The results from the classification are illustrated in Fig. 2.2, which shows the patterns of urban expansion in Vientiane. Figure 2.2a shows that until 1995, built-up lands were mainly concentrated around the core urban area. Figure 2.2b shows that between 1995 and 2005, the existing urban areas became denser. This demonstrates that the urban area expanded outside the core urban area, and sprawled into surrounding farmland and forests. Another significant change was the increase in development along the major transport corridors. In particular, new built-up areas were concentrated around National Road 13 North, National Road 10, and National Road 13 South (Fig. 2.1). Urban growth outside the core urban area was characterized by sprawl into land that in the previous period was forest or farmland. Figure 2.2 also shows the increasing area of farmland. Between 2005 and 2011, large areas of forest were changed to farmland.

We used a Normalized Difference Vegetation Index (NVDI) analysis to reinforce the knowledge gained from applying the QUAC method to the ENVI. NDVI is a graphical indicator that indicates the amount of green biomass in an area (Conway and Hackworth 2007).

NDVI is calculated using the following equation:

$$NDVI = \frac{NIR - RED}{NIR + RED}, \tag{2.1}$$

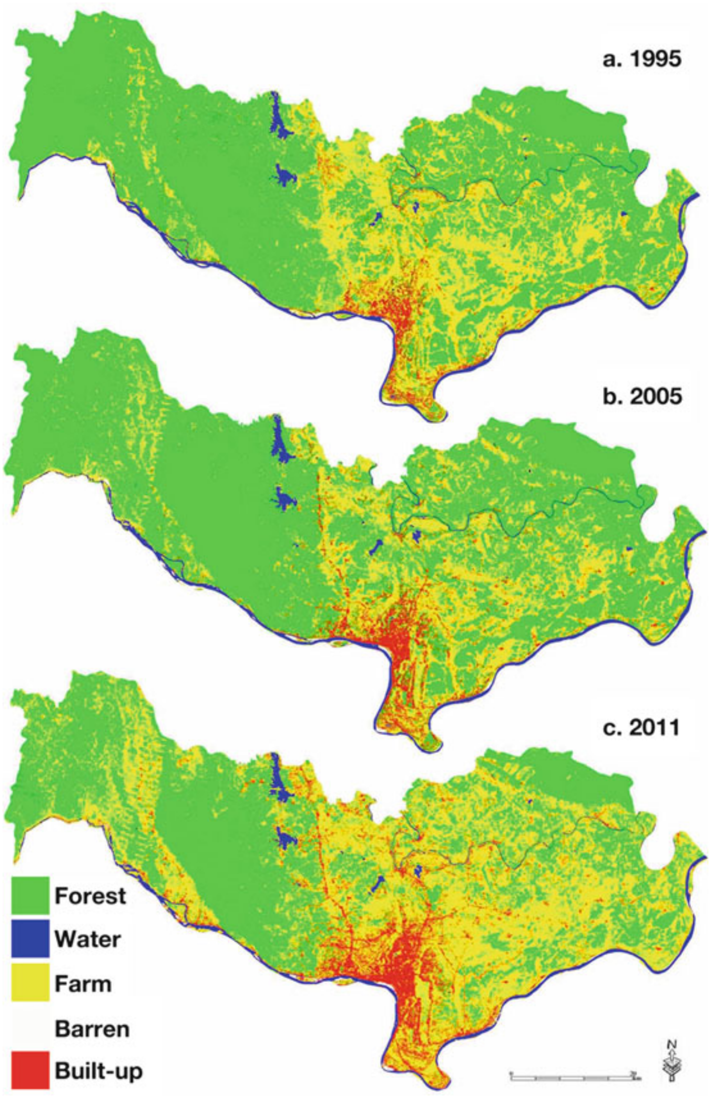
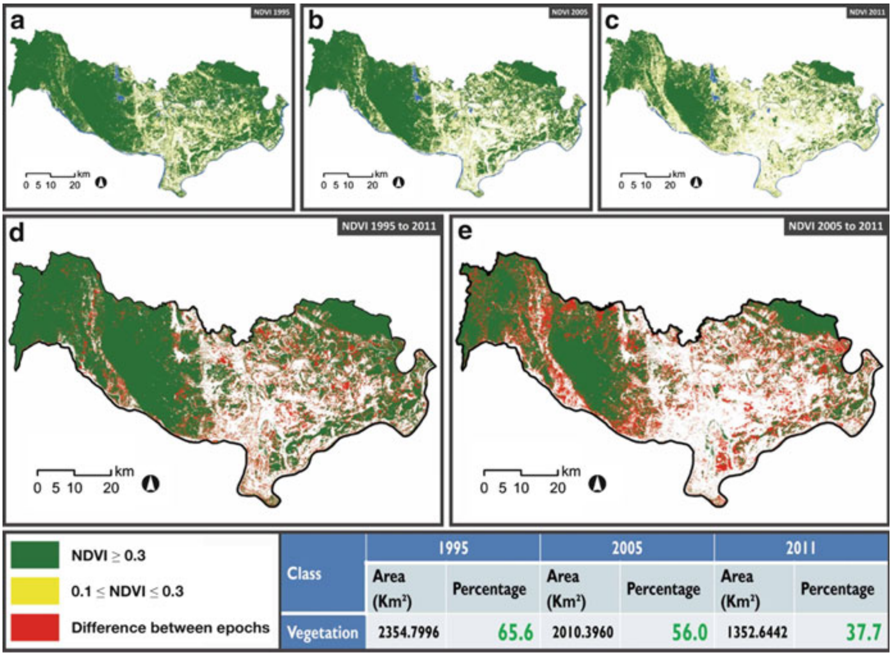


Fig. 2.2 Land use changes in Vientiane from 1995 to 2011 ((**a**), (**b**), and (**c**) respectively show the land cover in 1995, 2005, and 2011) (*Source*: Sharifi A, Chiba Y, Okamoto K, Yokoyama S, Murayama A." Rapid population, land-use and land-cover changes accompanying urbanization in Vientiane, Laos: Can master planning control and regulate urban development?" (Submitted for publication/ Under review))

where NIR and RED are the values for near infrared and visible red, respectively. "Highly vegetated areas have an NDVI value closer to 1, while locations dominated by water, impervious surfaces or bare soil have values closer to -1" (Conway and Hackworth 2007). All the NDVI analyses were performed using ArcGIS 10 software (ESRI, Inc.).



Class	1995		2005		2011	
	Area (Km^2)	Percentage	Area (Km^2)	Percentage	Area (Km^2)	Percentage
Vegetation	2354.7996	65.6	2010.3960	56.0	1352.6442	37.7

Fig. 2.3 Results of the NDVI analysis ((**a**), (**b**), and (**c**) respectively display the NDVI results for 1995, 2005, and 2011; (**d**) indicates NDVI difference between 2005 and 1995; (**e**) indicates NDVI difference between 2011 and 2005) (*Source*: Sharifi A, Chiba Y, Okamoto K, Yokoyama S, Murayama A." Rapid population, land-use and land-cover changes accompanying urbanization in Vientiane, Laos: Can master planning control and regulate urban development?" (Submitted for publication/ Under review))

The results of NDVI analysis are accurate, because it is designed for analyzing changes in vegetation. The main findings of the NDVI analysis are summarized in Fig. 2.3. The dark green color represents those areas for which the value of the NDVI index was ≥0.3. These are the areas where the density of forests was high. The yellow color shows the forests with low density ($0.1 \leq NDVI < 0.3$). Figure 2.3a–c show that the area covered by forests has decreased over time. The NDVI differences between any two epochs are illustrated in Fig. 2.3d, e. For instance, Fig. 2.3d shows the NDVI difference between 1995 and 2005.

As a whole, deforestation in Vientiane can be characterized as having taken place in two phases. First, forests were replaced by farmlands and pastures. Later, some of these areas were then replaced by built-up areas. There is an obvious resemblance between the results of the land use change analysis using the maximum likelihood supervised classification, and those from the NDVI analysis. The results clearly show that, over time, the forests inside and adjacent to the core urban area almost disappeared.

2.4 Land Use Changes in Suburban Farming Villages

We considered the current situation and future development using a suburban farming village of Vientiane as an example. Multidisciplinary research has been conducted from the perspectives of geography, history, agronomy, forestry, and city planning in the village of Dong Khuai, Xaithany District (Fig. 2.1), since 2004 (Nonaka 2008). Similar to other farming villages on flat land in Laos, Dong Khuai depends on rice cultivation in rain-fed paddy fields. In addition to rice cultivation, villagers also engage in fishing, collection of wild vegetables in forests, hunting of small animals, and production of salt.

In a straight line, the village is only about 20 km from the central Vientiane. However, until the access road to the village was slightly improved in 2010, it took more than an hour to reach the village by car. During the rainy season, it required even more time to travel to the village because some parts of the road would be flooded. Without any means of transport, it was impossible for residents to commute to Vientiane; therefore, the villagers have to work away from home to obtain cash.

When numerous foreign-capitalized factories progressed in and around Vientiane in the 2000, they provided commuting bus service from factories to secure workers. This integrated Dong Khuai into the commuting area. However, most commuters are currently young women working in factories; few men are so engaged.

Table 2.1 shows changes in land use in Dong Khuai during the past 50 years (Adachi et al. 2010). The area of rain-fed paddy fields has constantly increased, whereas that of forested land has decreased. This paddy field reclamation involves cutting down forests to convert the land into rain-fed paddy fields. However, the speed of paddy field reclamation has recently decreased. Even though the area of built-up land is increasing, it is still only a small part of the total area of the village. Land used for horticulture and commercial farming activities is only a small area in 2006. Village residents have made a living from transporting agricultural products collected in forests

Table 2.1 Land-use changes in Dong Khuai (Source: Adachi et al. 2010)

	Year1952		Year1982		Year1997		Year 2006	
	Area (ha)	Ratio (%)	Area (ha)	Ratio (%)	Area (ha)	Ratio (%)	Area (ha)	Ratio (%)
Rain-fed paddy field	172.4	6.7	423.6	16.4	663.0	25.7	749.4	29.1
Floating rice field	0.0	0.0	23.9	0.9	139.5	5.4	100.4	3.9
Irrigated rice field	0.0	0.0	0.0	0.0	53.4	2.1	55.6	2.2
Forest	1,539.3	59.7	1,362.8	52.9	1,182.0	45.9	1,085.1	42.1
Riparian forest	265.6	10.3	291.9	11.3	237.4	9.2	253.9	9.8
Grass field	493.3	19.1	366.6	14.2	187.1	7.2	197.9	7.7
Build-up area	2.5	0.1	4.2	0.2	9.8	0.4	16.0	0.6
Water area	104.8	4.1	104.9	4.1	105.6	4.1	111.1	4.3
Commercial farm	0.0	0.0	0.0	0.0	0.0	0.0	8.3	8.3

and paddies, such as mushrooms and bamboo shoots, to market. In 2005, only three out of 261 households cultivated vegetables. Furthermore, even though grazing of cows and buffaloes has become more prominent, it has been undertaken in forested land or meadows in the rainy season and in dried-up rain-fed paddy fields in the dry season.

Thus, Dong Khuai has still not reached the urbanization stage in terms of employment and land use. However, there are signs that urbanization will accelerate in the near future. The village of Don Daeng, located in the northeastern part of Thailand, is a good example for reference. With continuous involvement of Japanese research teams since the 1960s, the transformation of that village has been clarified (Fukui 1988; Funahashi 2006). Even though the village was dependent on rain-fed paddy fields until approximately 1980, irrigation in the village area has subsequently increased. Furthermore, with increased numbers of commuters to factories in surrounding areas of the neighboring city of Khon Kaen, the ratio of household workers having regular employment reached 40 % in 2002; in most households the level of income including that from self-owned businesses and daily employment has now surpassed that from farming. Few households are involved exclusively in fishing or vegetable cultivation, and in most households cash income from paid work has increased, with rice cultivation undertaken for only household consumption. Today, irrigated paddy land is the most common land use type, while the area of forested land is small. The roads within the village are paved, propane gas is provided, and several factories are located near the village.

2.5 Forests and Urbanization

Based on the examples of Dong Khuai and Don Daeng, and drawing on similar examples from Japan, land use transition in suburban farming villages in Monsoon Asia can be modeled, as shown in Table 2.2. The area of forested land significantly decreased during all three of the periods shown in Table 2.2. Dong Khuai is currently in transition from the paddy field reclamation period to the first stage of the part-time farming period, while Don Daeng is at the beginning of the second stage of the part-time farming period. Further economic development of Khon Kaen, the regional center for Don Daeng, will bring more urban land use changes to Don Daeng, resulting in a land use pattern similar to that in suburban farming villages in Japan.

Table 2.2 Stages of land use change in suburban villages in Monsoon Asia

	Paddy field reclamation period	Part-time farming (stage 1)	Part-time farming (stage 2)
Population	++	++	+
Paddy field	++	+	+/−
Forest	–	–	–
Urban land use		+	++

During the paddy field reclamation period, forests supplied firewood and charcoal, house construction materials, and forestry products such as wild vegetables, mushrooms, insects and small animals, as well as grazing lands during the rainy season. However, with the trend toward off-farm work, in future, the time during weekdays that villagers spend in their villages will continue to decrease, depriving them of opportunities to collect forestry products (Nishimura et al. 2010). Except for rice, foods will be purchased from stores using cash obtained from paid work. Raising of livestock will be undertaken on exclusive grazing lands by full-time breeders. Forests will decrease in importance as places for supplying food to villagers. Furthermore, the economic value of forests may decrease for residents in farming villages, if the demand for firewood and charcoal materials is reduced as a result of increasing propane gas use.

So what is the future of suburban forests? Forests provide important cultural and environmental values, and can enhance landscapes and biodiversity; however, a more important role of forests is preventing urban sprawl. As mentioned in the beginning of this chapter, one of the characteristics of urbanization in Monsoon Asia is the presence of regions that are neither urban nor rural areas. This is a result of institutional considerations such as city planning regulations, which are more lax in Monsoon Asia than in Europe, and the dominance of rice cultivation in the region. Because of seasonal variation in labor demand for rice cultivation, labor tends to be diverted to jobs other than rice cultivation during the agricultural off-season. Farmers who live near urban areas tend to have day jobs on construction sites, for example. Such a trend is remarkable in Southeast Asia, with its clearly distinguishable rainy and dry seasons. In addition, in the future, it is likely that the labor demand for rice cultivation will decrease as a result of the introduction of agricultural machines such as tillers and agricultural chemicals. Hence, rice farmers will start having additional non-farming jobs, and the features of urban life will become commonplace in farming villages. Consequently, mixed land use and landscape characterized by agricultural and non-agricultural activities will emerge in peri-urban regions.

Even if controls are implemented to reduce the introduction of urbanized land use into farming villages, such controls will be difficult to implement in regions where only rice paddies remain, after forests have been displaced by paddy field reclamation. This is because with the intention of only producing rice for household consumption, rice cultivation can easily be abandoned, with increasing income from other types of work. Near urban areas, the area of farmland for rice cultivation will be reduced with changes in land use. Urban sprawl will continue to advance when residents in farming villages change to being part-time farmers, or cease agricultural activities altogether. Therefore, it will become increasingly difficult to prevent urban sprawl after deforestation. Conservation of forests without paddy field reclamation is effective to curb this sprawl, so the role of forests in suburban farming villages may critically depend on such conservation.

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Chapter 3
Mountainous Livelihood in Northern Laos: Historical Transition and Current Situation of a Swidden Village

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Abstract Rapid changes in recent years are built upon historical changes in local livelihoods. In order to understand the current state of livelihoods, it is necessary to elucidate the livelihoods that have been changing gradually as well as to explore the rapid changes in the past 10 years. In this paper, we take up a swidden village, Kachet village, in northern Laos as our focus and seek to place the villagers' current livelihoods in their historical context by tracing the evolution of livelihoods in the past 30 years. While parts of swidden agriculture have changed technologically in Kachet village, its traditional methods are still fundamentally maintained today. Compared to technological change, material culture in the village has greatly changed in these 30 years. The changes in Kachet village can be divided into three stages: before 1975, from 1975 to 2000, and after 2000. In the first stage, the village was isolated from the market, and the people maintained a self-sufficient lifestyle. In the second stage, commercially valuable forest products became diversified as a result of Chinese immigration. In the third stage, cultivation of commercial crops became large-scale, and market-oriented economic reforms advanced greatly. Generally, market economy is promoting changes in the particular purposes of how land is used, such as

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for forestation and the introduction of commercial crops. Required is the implementation of measures for utilizing lands so that diverse livelihood activities can continue in the midst of advancing market-oriented reforms.

Keywords Food culture • Material culture • Non-timber forest products (NTFPs) • Plant utilization • Swidden agriculture • Swidden practice

3.1 Introduction

Societies in Asian developing countries are continuing their rapid changes in recent years. Infrastructure developments are progressing, and the impact of market-oriented economic reforms is being felt even in intermountain regions, which had been socially marginalized in the past (Thongmanivong and Fujita 2006). In northern Laos, the focus of our research, road networks for transport routes had expanded until 1975, the year the Laotian Civil War ended. Since the end of the war, flow of people and goods has grown on the foundation of the road networks. The market economy has especially advanced in Laos after the introduction of Chintanakan Mai ("new thinking") in 1976 (Yamada 2013). Since 2000, market-oriented economic reforms have further accelerated, and farming and mountain villages in Laos are facing even greater external pressure.

Residents in Laos' mountainous regions had led self-sufficient livelihoods. Slopes make up more than 90 % of mountainous land, and swidden agriculture is practiced, with upland rice as the main crop. While this type of agriculture is the main livelihood of the residents, it is done alongside pasturing, hunting, and collecting forest products. As such, the feature of the residents' livelihoods in these regions is their complex composition, of which swidden agriculture is the central component (Delang 2006).

The complex livelihood system in Laos' mountainous regions owes its origin to the regions' fragile production base. The risk inherent in the instability of rice production by swidden agriculture has been historically spread by the residents' engaging in different work (Yamada et al. 2004). The complex livelihood strategies evolved as residents strived to engage in sustainable activities under conditions of fragile livelihood for survival. Yet, as mentioned above, livelihoods in northern Laos have been experiencing great changes in recent years with the penetration of market economy. The principal causes of the changes are the introduction of commercial crops, including maize, sesame, and Job's tears; the growing influence of neighboring countries such as China, Vietnam and Thailand, which introduced rubber and eucalyptus plantations; population growth; and the restriction of land where swidden agriculture is permitted as a result of the government's Land and Forest Allocation Program (LFAP). Due to the impact of these developments, complex livelihood strategies, which had been maintained primarily to disperse risk, are changing greatly. Land use is being segmented and simplified. As a result, it has been observed that residents in mountainous regions face the danger that their livelihoods will become more vulnerable (e.g. Howden et al. 2007; Morton 2007).

While the changes in livelihoods as seen in northern Laos have been especially striking in the past 10 years, local society has also been changing as the country experienced the end of the civil war in 1975, the beginning of economic open-door policy in 1986, and the start of the LFAP in 1994. All the while, traditional livelihoods have been changing gradually yet steadily. Rapid changes in recent years are built upon historical changes in local livelihoods. In order to understand the current state of livelihoods, it is necessary to elucidate the livelihoods that have been changing gradually as well as to explore the rapid changes in the past 10 years. To examine in detail these changes in the people's livelihoods and the cultural aspects of these changes, we must look at the situations that current villages in mountainous regions are facing from a historical perspective. Therefore, in this paper, we take up a rural village in the northern Laos as our focus and seek to place the villagers' current livelihoods in their historical context by tracing the evolution of livelihoods in the past 30 years. Based on this examination, we can shed light on the current features of Laotian rural villages from a historical perspective.

3.2 Topography and Physical Conditions of Study Area

In this paper, we present a case study of Kachet (20°34′32.91″N, 102°18′56.90″E), a village in Nam Bak District of Luang Phabang Province in northern Laos. It is located about 140 km north of the town of Luang Phabang, a UNESCO World Heritage Site, and has an elevation of 800 m (See the map of Laos in the beginning part of this book). Residents of Kachet village lead a lifestyle dependent on natural resources, and still practice swidden agriculture today. Vegetation that is subject to swidden agriculture basically consists of mountain evergreen forests. However, pioneer species such as bamboo and Euphorbiaceae plants are mixed together with Fagaceae and Lauraceae tree species, which are climax species, due to human intervention such as intentional burning of vegetation, logging, and collecting non-timber forest products. The seasons in this region are made up of a rainy season and dry season. The level of annual precipitation is about 1,500 mm. The rainy season occurs roughly from the middle of April to the end of October. During this period, a variety of crops are cultivated in swidden lands, including upland rice.

As of 2011, the village is composed of 486 individuals (of which 258 are female) from 98 households belonging to the Khmu people. The Khmu are the indigenous people of this region, and is said to have practiced swidden agriculture for several thousand years now (Chazee 1999). Except for one household that had moved into the main village area to serve as teachers, all households still work in swidden agriculture today. The village was formed by clearing and leveling a topographically flat area in the midst of mountainous slope, which was then settled. Several small rivers flow at the bottom of the mountainous slope. The small rivers that villagers rely on are the Nam Mong, Nam Chet, and Nam Kathing, which become tributaries of the Ou River, a major river in northern Laos. While swidden agriculture is the primary livelihood of the settlement established on the mountainous slopes of Kachet village, because the area of the paddies is small, five households have recently cleared land in the mountain basin, and are cultivating rice there on a small scale. Upland rice is produced as the primary crop by swidden agriculture; however, the amount produced does not reach the level of self-sufficiency. Therefore, villagers must purchase needed rice, the main staple of their diets, from merchants. In Kachet village, important sources of cash income are gathering forest products, hunting, selling domestic animals, migrating from the village to work, and doing labor inside the village.

National Highway No. 13, which runs from Vientiane to China, passes through Kachet village. When the residents of Kachet village need to buy daily commodities at the market, they carpool in trucks and go to a market in Pak Mong village (20°34′34.86″N, 102°24′38.84″E), about 20 km away, or in Nam Thoam village, about 30 km away (20°29′32.74″N, 102°21′20.39″E). Even though a highway runs through Kachet valley, large-scale forestation is not as developed as the rest of northern Laos, nor is the introduction of commercial goods as advanced. Thus, even today the people of Kachet village maintain comparatively traditional livelihoods centered on swidden agriculture.

3.3 Present Swidden Practice in Kachet Village

The villagers of Kachet lead lives centered on swidden agriculture, and almost all their activities are related to swidden agriculture. While parts of swidden agriculture have changed technologically in Kachet village, its traditional methods are still fundamentally maintained today.

For swidden agriculture, the land planned for cultivating the next crop is selected to be burned. In northern Laos, selection of swidden land in general reflects the decisions of the heads of households. During the previous cultivation period, villagers communicate between one another on the swidden land where they wish to next apply swidden agriculture. Then, between December and January of the following year, agreement is reached within the village on the next swidden land. When deciding on swidden land, in general a few households, centered on blood relations, decide on individual swidden plots, so the swidden lands are small in scale. However, in Kachet village, swidden agriculture is practiced by all households on one plot of land. The advantages of carrying out swidden agriculture on a large scale include the prevention of animal damage. Rodents such as mice are the main cause of damages, but wild boars are also a nuisance. By practicing swidden agriculture on a large scale, the number of workers who serve as sentinels become greater compared with small-scale swidden agriculture.

After the swidden land is selected, deforestation takes place in February. Adult men and women from multiple households gather to cut down trees from the land, with relatives taking turns to work. The period of deforestation ends in about a month. Afterwards, the deforested vegetation is left to dry for about 1–2 months. Intentional burning of the land is carried out between the end of March and the beginning of April. In Kachet village, burning takes place at the beginning of the rainy season, where sunny and rainy days alternate. A day when the air is driest and

Fig. 3.1 Planting upland rice

the wind is strongest is chosen to be the day for burning. The day of the burning is decided in a meeting between the village elders and the village chief. Burning takes place from 1 p.m. to 2 p.m. The fire is lit by villagers with torches from the edge of the bottom part of the slope of the swidden land. The plot burns for about 2–3 h. If embers remain, they are collected to start the fire again, or to be used as firewood. Dregs of ember on the ground where rice is to be planted are cleaned away. As the villagers await the full start of the rainy season, they first plant cucumbers, and then upland rice. To plant cucumbers, seeds are scattered. For upland rice, seeds are planted spaced apart. To accomplish, in many cases men hold digging sticks. Each stick is made of a wooden pole of 2–3 m with a metal pyramid at the end. The men thrust the sticks into the ground. Women then place several grains of unhulled rice by hand into the holes opened in the ground (Fig. 3.1). During the period of cultivating upland rice in Kachet valley, weeding is done about three times (Fig. 3.2). Weeding is done by using a sickle-shaped tool called a "wer" (Fig. 3.3), and is carried out during the early and middle stages of the cultivation period. In the later stage of the period, weeds do not affect the rice plant due to the height of the stalks, so weeding is not necessary. In Kachet village, herbicides and insecticides are not being used.[1]

[1] In Kachet village, cattle are pastured on swidden fallow land. In the past, when herbicides were used, a large number of livestock was killed. Because cattle are valuable assets, herbicides and insecticides are now no longer used.

Fig. 3.2 Weeding by using "wer"

Fig. 3.3 Various kinds of "wer"

Rice harvesting is done from the end of October to the beginning of November. To harvest rice, sickles are applied to the ears of the stalks. The harvested rice are stored in sheds for 1 or 2 days, and then carried to rice stores near the village settlements.

In Kachet village, upland rice is basically cultivated only in the first year of the swidden agriculture cycle. In the second year and thereafter, weeds are allowed to run rampant, so rice cultivation is not carried out. However, if the amount of harvest can be expected to exceed the amount of labor, upland rice is cultivated in the same area in the second year. There are also times when cassava, which can be expected to provide a certain amount of harvest without much supervision, is cultivated. In Kachet village, cassava is grown for household consumption and to feed pigs.

Besides rice, the only other commercially valuable crop cultivated in swidden lands is cucumbers. Cucumbers grown on these swidden lands are highly praised for their taste, and are preferred over cucumbers grown by the Lao people in the lowland fields and by Mon people in the mountain regions through constant farming. These cucumbers are sold together with rattan (*Calamus* spp.), bamboo shoots, mushrooms, and other forest products at roadside village stores.

3.4 Present Non-timber Forest Products in Kachet Village

Currently, forest products with commercial value in Kachet value are bamboo shoots, broom grass (*Thysanolaena latifolia*), varieties of konjac (*Amorphophallus* spp.), the fruits of cardamom (*Amomum villosum*) and galangal (*Alpinia galanga*), benzoin (the resin of *Stylax tonkinensis*), rattan, and mushrooms. Bamboo shoots, rattan, and mushrooms are used for food; broom grass serves as a material for brooms; cardamom is a spice; galangal fruits are used as Chinese herbal medicine; and benzoin is an ingredient of perfumes. (For detailed description of the individual forest products, please see Chap. 6). With the exception of *Stylax tonkinensis*, the source of the resin benzoin, the forest products are generally found in northern Laos. *Stylax tonkinensis* is a special resource that grows in the areas around Kachet village. In Laos, it is found only in Nam Bak District and Ngoi District (Yokoyama 2010). Rattan, bamboo shoots, and mushrooms are mainly sold in shops opened by the village along roads. On the other hand, broom grass, konjak, fruits of cardamom and galangal, and the resin of *Stylax tonkinensis* are sold to merchants who come from the towns and villages of Pak Mong, Nam Thoam, and Luang Phabang to purchase them. These products are gathered at the village level. Mainly, the chief gathers the forest products inside the village and delivers them to merchants.

These commercially valuable products are primarily distributed in the swidden fallows. They appear at the different times during the lands' fallow period (see Table 6.3 in Chap. 6). For example, broom grass appears 1 year after the lands lie fallow. Konjak and galangal fruit appears in the fourth year of the fallow period. Cardamom appears from the fourth year. *Stylax tonkinensis* takes about 7–8 years to produce resin, after which resin can be tapped for 3–4 years. In swidden lands, different plants alternate in their appearance. The multilayered use of these lands improves the overall productivity of the swidden agricultural system.

Of the forest products in Kachet village, ownership rights apply to broom grass and *Stylax tonkinensis*. Meanwhile, for the other forest products, they can be basically collected by anyone no matter where they are in the village. Residents of neighboring villages can come to gather them, and Kachet villagers can also enter neighboring villages to collect these products; ownership of these products is relaxed. Also, to prevent excess gathering of cardamom and galangal, open dates for collecting them are established in August and September, respectively.

The ownership of *Stylax tonkinensis* is believed to be deeply related to how land in Kachet village is used. In northern Laotian villages where swidden agriculture is practiced, land is generally not allocated to each household; the land is basically communally owned by the entire village. Land ownership only takes effect during the cultivation period of a crop. In northern Laos, villages in general abandon the land after cultivation. Sometime after a fallow, except for plants with limited commercial value, the land becomes the property of the village. In Kachet village, however, ownership of land is clearly assigned to households even during fallow periods. As this reason, it can be pointed out that Kachet village has traditionally been an area of benzoin production. Benzoin has traditionally been an important forest product. In this region, it had been traditionally presented as tributes to the king of Luang Phrabang, and has great commercial value (Stuart-Fox 1998). In northern Laos, when plants of valuable forest products are distributed in fallow lands, oftentimes the ownership of the plants is established, even if the lands themselves are communally owned by the village. In the case of Kachet village, *Stylax tonkinensis* is widely distributed. This feature is believed to be related to the allocation of fallow land to each household.

3.5 Historical Transition and Events of Livelihood in Kachet Village

3.5.1 Historical Transition of Physical Condition

The historical period during which Kachet village was established is unclear. However, according to interviews with several village elders, Kachet was established about 200 years ago.[2] In the past, settlements in northern Laos were

[2] A legend exists concerning the origin of Kachet village's name. "Chet" means "seven," but the meaning of "Ka" is unclear. It can mean "fish" in the Khmu language, but this meaning is unrelated to the name of the village.

A long time ago, many wild animals came to drink at a pool of water in the village. One day a villager saw this and went out to hunt the animals. As he was moving toward the pool of water, he heard a voice telling him that his daughter suddenly had a terrible stomachache, and told him to go extremely small in general. In most cases, a settlement consisted of 5–10 households. Kachet village is assumed to share this history.

For a long time, the residents in this region practiced traditional swidden agriculture. However, the civil war from the 1950s to 1975 had a great impact on the people in the mountain regions. During the war, the Chinese army established a wide transport network in northern Laos. Highway No. 13, an important highway running through Kachet village today, was constructed in 1973–1974. Prior to this, there was only a narrow road for people in Kachet village. The people in the region also reported rare sightings of Chinese merchants passing through with luggage on big horses (*ro*), medium-sized horses (*ma)*, and small horses (*rowa*). In 1977, the road was paved, and it became crowded with cars. Despite this development, the residents still basically used walking[3] as the main mode of transportation. For example, when going to the market in Pak Mong to buy spices, they would leave early in the morning and arrive at the market in the evening. Forest products like benzoin and cardamom took 3–4 days to be transported to Luang Phrabang.

The 1980s witnessed improvements in infrastructure reaching the mountain regions. A health clinic was built in the Kachet village in 1984. An elementary school (up to the third grade) was built in the early 1980s. Also, this village was part of the Food and Agriculture Organization of the United Nations' benzoin program for several years, beginning in 2001, and field trials took place there. When the FAO left the village, villagers received 8,000 USD, which was used to install running water. In 2004, an elementary school (up to fifth grade) was built. Currently, when the children reach middle school, they go to a school in Nam Thoam village or nearby Mak Phuk village. Also, electricity became available in the village beginning in 2007 or 2008. Relatively prosperous families had been running generators to use appliances like TVs and CD players since the 1990s, but the full-scale use of electricity by the villager began in the early 2000s. Rice hullers had also been run on electrical generators, but with the introduction of running electricity, electric rice hullers become widespread. Currently, there are two rice hullers running on kerosene, and 14 running on electricity.

back to the village. He returned to find that his daughter was completely fine. The next day, the villager took another person with him and went to the pool. But again he heard a voice, this time telling him that his child had fallen from the stairs and is near death. He rushed home, only to find that nothing had happened to his child. The villager then went to the pool together with six other men. Again, as before, he heard a voice telling him to go back home. But he thought it was the voice of a ghost, and ignored it. When the men arrived at the pool of water, one of them took aim at a heet, an animal resembling a water buffalo, and fired his gun. All seven men fell dead at the same time. This is the origin of the meaning of "seven" in the name of Kachet village.

[3] Sandals are now main footwear. However, in the past most people went barefoot. If punctured tires were available, they were reportedly cut into strips and made into sandals. Villagers also wore clogs made of bamboo, but only for walking within the village when it is raining. They are no longer worn today.

3.5.2 Historical Transition of Swidden Practice and Related Activity

The greatest change in swidden agriculture in Kachet village is the decrease in the size of cultivation land per household due to an increase in the number of households. According to interview surveys, the number of households in 1972, 1991, 1999 and 2011 were 30, 35, 67, and 98, respectively. Assuming that the population per household was constant for the most part, simple calculation yields the conclusion that the population of the village grew to be more than three times as large today compared with 40 years ago. The Khmu people who makes up Kachet village is patrilineal, and land received from ancestors is allocated among male siblings. When a male besides the oldest male marries, he becomes the head of a new household. As mentioned above, land is allocated to each household. However, when a new household is established, a plot of land is split up to be re-distributed. Because the village's territory basically does not change, when the number of households increases, the size of the cultivation plot per household naturally decreases.

Meanwhile, Kachet villagers maintain the fallow period to a certain degree by borrowing and lending land within the village,[4] despite the decrease of the cultivation plot size. There is one reason that benzoin is included among Kachet village's important forest products. According to interviews, in fallow lands where *Stylax tonkinensis* trees grow en masse, villagers maintain a fallow period of 7–8 years. In fallow land where bamboo species dominate, shorter fallow period is maintained. Thus, the fallow periods are controlled so that the amount of upland rice production and the collection of forest products both do not slump.

In addition to great changes brought to the swidden agricultural system as a result of population increase, the techniques involved in form of swidden agriculture are also changing, becoming more efficient and less labor-intensive. Among the techniques used, the greatest change is found in the method of harvesting. In the settlements of the Khmu people, the traditional method of harvesting had been pulling ripened ears of rice through one's hands (Fig. 3.4). However, sickles have been adopted since the mid-1990s. The method of harvesting by drawing the ears of rice through one's hands does not require threshing, but compared with the use of sickles, it is slower, and the ears of rice often fall down during the course of harvesting. Because of this method's traits, harvesting often continued after the day became dark, and took a heavy toll on the body. In the mid-1990s, the village chief's group adopted the use of sickles, and this practice spread to the rest of the village.

Also, rituals associated with swidden agriculture have greatly changed. Currently, only a post-harvest festival called "boun kleuu" or "boun ted neum" in the

[4] The borrowing rate for land is as follows: Relatives pay 100,000 kip for approximately 1 ha of swidden land, which allows 5 kg of unhulled rice to be planted; for non-relatives, the amount is 200,000–300,000 kip.

Fig. 3.4 Traditional way of harvesting upland rice (an example of Oudomxay Province)

Khmu language is held in the village. However, until the 1990s, ceremonies were also held after planting and on the first day of the harvest. The ceremony held after planting expressed the wish for bountiful growth of rice. After about 10 cm of growth appeared after the planting of rice seedlings, the entire village gathered to perform the ceremony. In a hill near Kachet village's settlement is a preserved forest, where a deity is prayed to on the summit. There, one pig and one chicken are sacrificed to present as offerings. The sex of the pig and the chicken must be different. After the ceremony, all the villagers drink alcohol. Residents of other villagers are not permitted to participate.

The ceremony that had been held during the harvest was carried out by each family. The day of the start of harvest is chosen by each household's husband and wife, and a ceremony is held. On the first day of the harvest, the husband and wife are forbidden to cook, and siblings or relatives are asked to perform that duty. The husband and wife go to the harvest grounds, the wife bringing two small baskets and the husband two large ones. The husband also brings a bag woven from a vine plant from the bean family called "piad" acontaining money, rice, and food items. As they go to the swidden area, the couple is forbidden to talk between themselves. When they arrive in the swidden area, they express thanks for the rice, and place white and red rice on top of a talisman called "taleo" woven from bamboo. They place these items on the ground to be harvested. The ceremony ends with their praying while holding a betel leaf, after which the harvest begins. This ceremony

Table 3.1 Khmu traditional calendars of 10-day and 12-day cycle. Their calendar is based on 60 days by combining these calendars

10-day calendar	12-day calendar
1. kaap	1. seu ngaa
2. hreup	2. mod
3. reu wai	3. san
4. meung	4. lao
5. peuk	5. set
6. kad	6. geuu
7. kod	7. cheuu
8. ruan	8. prao
9. tao	9. nii
10. kaa	10. hmao
	11. sii
	12. seuu

had been performed in the past but no longer today, as there were more villagers who found it troublesome. The Khmu people traditionally use their own calendar (Lindell 1982). This calendar is based on 60 days and combines 10- and 12-day cycles (Table 3.1). Each day is considered lucky or unlucky for various activities, which serves as a basis for the villagers in carrying out their activities. In the past, this calendar was widely used. However, currently only the 10-day cycle calendar is used. In the past, there were many villagers who had knowledge about the calendar. However, currently there are only two or three people in Kachet village who understand it.

Currently being observed is the festival called "boun kleuu" or "boun ted neum." It is now celebrated in a simple style. In the past, ceremonies for this festival were performed by each household. One chicken and one pig were sacrificed, and offered to relatives and friends together with cassava, taro, squash, pumpkin, sweet potatoes, and different varieties of yams. Currently, however, the village as a whole performs this ritual. A cow or water buffalo is sacrificed and presented for each *neuai* (a co-op of about 5–10 households for swidden agriculture), and one chicken is offered by each household.

3.5.3 Historical Transition of Non-timber Forest Products

3.5.3.1 Changes in Types of Non-timber Forest Products

As described above, currently a variety of non-timber forest products are being gathered in Kachet village. Of these products, traditionally gathered products are benzoin, cardamom, and *khii sii* (resin of Depterocarpaceous trees). These products were brought as tributes to the king of Luang Phrabang, or used as cash products. With the opening and paving of roads after 1975, trade of bamboo shoots and rattan became commonplace. Afterwards, Laotian merchants in Nam Bak began selling peuak meuak (*Boehmeria malabarica*), paper mulberry (*Broussonetia papyrifera*), and broom grass to Chinese merchants in the early 1990s; the collection of these products then began in Kachet village. In the late 1990s, galangal fruits came to be gathered for use in Chinese medicine. Since 2010, Vietnamese and Chinese people have visited Kachet village, and *gle (Apinia* sp.), konjak (*Amorphophallus* sp1.), and *ya houa* (*Amorphophallus* sp2.) came to be collected. The merchants directly visit the village. Village representatives are appointed, and when a certain amount of product is collected, the representatives contact merchant to notify them to come and purchase the products. Recently, it is becoming more evident that products are delivered to places farther away, and that the merchants visit the village directly to purchase it.

3.5.3.2 Changes in Distribution of Non-timber Forest Products

Collection of forest products still took place during the civil war. Trade partners were both Pathet Lao and the Lao Kingdom. The Pathet Lao were the usual trade partners, but secret trade also took place with the U.S.-backed Lao Kingdom. When trading with the Pathet Lao, dealings were done with officials called "taa saen." The *taa saen* sold purchased products to Lao Loum merchants. When selling, tax must be paid to the *taa saen*. The price of forest products were determined by the *taa saen* in discussion with the Lao Loum merchants. Prices were fixed for 1 year. Meanwhile, selling forest products to the Lao kingdom was done secretly. For this, intermediates called "laam" played an important role. Good prices could be obtained by dealing with the U.S.-backed kingdom. *Laam* could be found among both the Lao and Khmu people. They were resourceful people skilled in both languages. *Laam t*ook their fee of mediation from the residents. Because their activities were done in secret, if they were discovered by the Lao National Liberation Front (Pathet Lao), they were reportedly sent to re-education facilities for 3–4 days.

After the war, the roads were paved, allowing many merchants to visit villages. Since 1990, many Chinese merchants have entered Laos, selling especially at the market in Nam Thoam village. Lao merchants also took on the practice of purchasing forest products.

3.5.4 Historical Transition of Food Culture

Over the past 30 years, the food culture in northern Laos' mountain regions has been changing greatly. Improvements in infrastructure have resulted in a variety of food products being brought into villages, greatly altering the residents' dietary habits. Use of cooking oil and chemical seasoning is now commonplace. They were first introduced about 20 years ago.

Before the opening of roads into Kachet village, the residents would walk for several days to salt evaporation ponds in La District, Oudomxay Province, to obtain the important seasoning salt. Payments were made by using "man," a currency during the French colonial period, or by bartering benzoin or other products. For cooking oil, lard had been used. However, because a pig must be killed to obtain the fat, it is rarely used. A vine plant called "mak kin" actually includes a great amount of oil, and it is mixed in when eating raw vegetables. Perilla oil and sesame oil are not used. Overall, the amount of oil intake by the people was less in the past than now. It has been 10 years since the use of vegetable oil began.

Herbs are also an important source of flavoring for the Khum people. Galangal, ginger (*Zingiber officinale*), and *phak nao* (*Acacia pennata*) are currently being used. Also used are garlic (*Allium sativum*) and green onion (*Allium fistulosum*), which were introduced to Kachet village after 1975. Previously, villagers used the traditional herbs of *sengeur seleep* instead garlic and *seuger chokmu* instead of green onions. Laotian products were used until 1990. When a new Chinese market opened in Nam Thoam, many Chinese products, bigger species, could be purchased, and thus they replaced traditional Laotian species. Chemical seasoning is also widely used today; however, it was not until after 1975 that they were popularly available. To draw out savory flavors (umami) from food, it was a common practice to use smoked wild animals. Savory dishes could be prepared by mixing smoked meats in soups. A plant called *keur doid* (*Ficus* sp.) is also known to draw out umami, and is frequently used in cooking. Condiments commonly used in Laotian cuisine, such as nam pla and soy sauce, are almost never found on the dining tables of the Khmu people.

3.5.5 Historical Transition of Plant Utilization

Kachet villagers still utilize many plants today in their daily lives. Before roads opened in 1975, it is no exaggeration to say that almost all tools used were made from plants, with the exception of metal and glass products. Even today, the walls of many houses are woven from bamboo, and the roofs are thatched with cogon grass (*Imperata cylindrica*). Farming and fishing implements, as well as hunting tools like traps, utilize plants in their entirety, with the exception of parts where metal is necessary. Clothes in the past were made entirely of plant products. Cotton (*Gossypium* sp.) was widely grown in Kachet village, and was an important material for clothes for the people. Plants are also used to make all dyes except for red dyes.[5] Unlike the Lao people, the Khmu did not use large-scale looms, but rather were known to weave from balls of threads hanging from their waists. This weaving method has partially survived to this day, and can be seen in the making of bags woven from vine plants. In the past, tobacco (*Nicotiana tabacum*), an important luxury item, was cultivated. However, it can now be purchased in markets.

[5] For red dye, lac insects were used in the past.

Another important use of plants is as drugs. Currently, drugs can be purchased from markets in Pak Mong. However, in the past the people had to treat themselves for illnesses. Therefore, Kachet villagers had to have knowledge on the medical use of various plants. In Kachet village, spirits doctors called “moo phii” and traditional herbalists called “moo yaa” are involved in traditional medicine. Only men can become *moo phii,* and there are about ten of them in a village. Becoming a *moo phii* not only requires learning incantations but also a long period of study. The position of *moo phii* is basically hereditary, and the practitioners have effective techniques for dealing with a variety of injuries and illnesses. Meanwhile, anyone of either sex can become a *moo yaa* if he or she has a wealth of knowledge about plants. There are fewer *moo yaa* today than in the past, but traditional medicine is still used by local people today. It is often said that traditional drugs are more effective than commercially available drugs.

3.5.6 Changes in Land Utilization

In recent years, the impact of globalization has reached northern Laos’ mountainous regions. As a result, cultivation of a variety of commercial crops has begun in mountainous villages. In northern Laos, commercial crops including rubber and maize have been widely introduced. However, changes in land utilization in Kachet village have not been major compared with other regions. In Oudomxay Province and Luang Namtha Province, the introduction of rubber has been rapid (Manivong and Cramb 2008); yet, it has not been introduced in Kachet village. Also, teak trees are widely planted in Luang Phrabang. A trend in their expansion could be seen in some parts of the region. However, teak is not being planted in Kachet village. Although small-scale planting has been tested by Chinese agriculturists, the elevation of the village is too high, so saplings could not grow.

The introduction of a variety of crops, such as tea and castor oil plants, has been attempted. Tea was introduced to about ten households by a Chinese company around 2005, and castor oil plants to about 20 households by a Laotian company in Luang Phrabang around 2008. However, in the end, they did not come back to purchase the crops, and cultivation of these crops remains in that state to this day. Currently the planting of tung-oil trees (*Vernicia cordata*), whose fruits can be harvested in 3–4 years and converted to biodiesel, is planned by about 20 households in Kachet village. The seeds of the trees are distributed by a company and their cultivation entrusted to the villagers. According to the contract, if fruits can grow, the company will buy them from the villagers. Many such small-scale contracts exist in northern Laos, allowing villagers to cultivate crops on a small scale. However, in the end the merchants who distributed the seeds and seedlings often break contracts with the villagers as a result of fluctuations in prices and changes in business plans. Such cases of broken contracts are frequently seen in the entire country of Laos.

Also, reclamation for new rice paddy fields by Kachet villagers is an example of voluntary utilization of land. Lands that can be developed for rice paddies if irrigation is provided are readily available inside Kachet village. Since 2006, villagers who have arable lands are actively working to develop them. In 2011, six households owned rice paddies, and the number has been growing since then. There is a strong trend in the growth of households who are increasing their income to purchase supplies necessary for irrigation to develop rice paddies. As can be seen in the case of Kachet village, there is a strong tendency to pursue rice paddies, even among people like the Khmu who have traditionally practiced swidden agriculture. It is believed that as they increase their cash income, they will develop arable lands in mountain basins.

3.5.7 Recent Disasters and Responses

In mountainous agricultural villages in northern Laos, because the basis of livelihoods is mountainous slopes, much of agricultural production is dependent on inevitable changes in the weather (Saito et al. 2006). Thus agricultural output is easily affected by droughts, floods, and heavy rains. Also, because the walls of houses are woven from bamboo, the roofs are thatched with cogon grass, and the pillars are made of wood, careful attention must be paid so that fire accidents do not occur. However, major disasters have occurred in the long run. Here, we discuss recent disasters and the villagers' responses.

The most damaging fire to Kachet village occurred in 1999. There were 67 houses in the village at the time. With the exception of three houses far from the fire, all the houses were completely burned down. The cause of the fire was children playing with fire. Because the fire occurred during daytime, all the adults were out working in the fields; this contributed to the extensive damage of the fire. All household assets were lost in the fire, and the villagers faced great hardship. Daily necessities such as dishes and blankets were provided by NGOs and the Laotian government. However, the villagers still led difficult lives in newly built simple houses. It took 2–3 years before their standard of living returned to the pre-fire level. Fires also broke out in 1972 and 1976, which reportedly destroyed more than half the households in the village.

Also, in the swidden agricultural villages in northern Laos, a fall in the production volume of rice on swidden lands is a serious matter. Failures in intentional burning of the lands in 1995 and 2011 resulted in great drops in Kachet village's rice production. For the swidden agricultural system in northern Laos, intentional burning takes place at the time just between the dry season and the rainy season. A day when the air is driest is chosen to be the day for burning. However, because the rainy season began indistinctly in 1995 and 2011, Kachet villagers lost the opportunity for intentional burning. As a result, rice could not be planted in almost all swidden lands. If the production of rice falls, the villagers must find ways to somehow obtain daily rice. Thus they purchase needed rice by selling forest products, leaving the village to work, and selling family assets. Villagers also ate foodstuff like cassava (*Manihot esculenta*), which is usually used as livestock feed, and Japanese yams (*Dioscorea* spp.) to make up for the lack of rice. The villagers responded to the burning failure in 2011 by increasing cultivation of cassava compared with usual years. To earn cash, the villagers performed non-farming work inside the village such as weeding, helping with collecting forest products, and sawing lumber. Outside the village, they participated in road construction and developing forest grounds for rubber in Oudomxay Province and Luang Namtha Province.

In the past, there had also been a rice bank in the village called "thanakan khao." This bank operated in the village, and could also be widely found in northern Laos. It lent rice to households lacking sufficient rice. Rice is returned after the harvest with an additional 20 % interest. In the mountain regions of northern Laos where production is unstable, this system dispersed general risk. However, after the 1999 fire, the rice bank depleted its emergency store of rice, and the banking system ended. The 1999 fire brought the village as a whole into poverty. It needed to borrow rice from the province and the Agricultural Promotion Bank. There was increasing number of villagers who did not pay back the bank. As a result, the rice banking system in the village collapsed.

3.6 Conclusion

The changes in Kachet village can be divided into three stages: before 1975, from 1975 to 2000, and after 2000 (Table 3.2). In the first stage, the village was isolated from the market, and the people maintained a self-sufficient lifestyle. In the second stage, commercially valuable forest products became diversified as a result of Chinese immigration. In the third stage, cultivation of commercial crops became large-scale, and market-oriented economic reforms advanced greatly.

Prior to 1975, the livelihood of residents in Kachet village was believed to be carried out in an almost self-sufficient environment. Along with self-sufficient production, collection of commercially valuable forest products such as benzoin, cardamom, and *khii sii* (resin of Depterocarpaceous trees) was traditionally carried out to present as tributes to the king of Luang Phrabang. Using these forest products, daily necessities such as salt and iron were traded. Around 1975, roads allowing the passage of automobiles were opened, changing greatly the items flowing into the village. As a result, the village's material culture and food culture changed significantly. Commercial forest products became diversified as a result of the establishment of nearby markets reachable by automobiles, and as a result of their sales by Chinese merchants. Also, because crop seeds could be purchased at markets operated by the Chinese, vegetables that had been traditional species cultivated in Kachet village disappeared. Since 2000, the market economy has continued to penetrate into the mountain regions of northern Laos to a striking degree. Crops such as rubber and maize were introduced on a large scale. In Kachet

Table 3.2 Historical transition of Kachet village

	Social events	Infrastructure	Commercial crops	Commercial forest products	Food culture	Swidden and paddy practice	House and clothes	Disaster	Number of household
–1975		Road construction (1973–1974)	Cucumber (from ancient to the present)	Benzoin, cardamom and *Khii sii* (resin of Depterocarpaceous trees) (from ancient to the present)	Salt from La district of Oudomxay Province, pig oil, traditional herb, traditional garlic, traditional leek, *keur doid* (*Ficus* sp.) for taste (from ancient to ca. 1975)	Using hands for harvesting upland rice (from ancient to 1990s)	Traditional house (cogon grass for roof and bamboo for wall) (from ancient to the present) Traditional clothes (cotton and dye from plants and luc insect) (from ancient to 1970s)	Earlier onset of rainfall and failure of burning (1968) A big fire (1972)	30 (1972)
1975–2000	End of civil war (1975)	Opening access to market in Pak Mong and Nam Thoam village (1975) Pavement or road (1977)			Garlic form Lao market, leek from Lao market (from ca. 1975 to 1990s)			A big fire (1976) Earlier onset of rainfall and failure of burning (1976)	
		Primary school to third year (beginning of 1980)			Chemical seasoning for taste (from ca. 1975 to the present)				
	Opening of market economy (1986)	Health facility (1984)							

	Land and forest allocation program (LFAP) (1994)	Electricity by generator (1990s)		*Peuak meuak* (*Boehmeria malabarica*), paper mulberry, broom grass (from early 1990s to until the present)	Chinese garlic, Chinese leek (from 1990s to the present)				
	Land Law (1997)			Fruits of wild galangal (from late 1990s to the present)	Plant oil from market (from early 1990s to the present)	Sticles for harvesting upland rice (from middle 1990s)		Drought (1995) Drought (1998) A big fire (1999)	67 (1999)
2000-		Water supply (2001) Primary school to fifth year (2004)					Concrete houses together with village reconstruction after a big fire (from early 2000s to the present)		
		Electricity (2007)	Tea (about ten households) (around 2005) Castor oil plant (about 20 households) (around 2008) Tung-oil tree (near future)	*Gle* (*Alpinia* sp.), konjak (*Amorphophallus* sp1.), *yaa hua* (*Amorphophallus* sp2.) (from 2010 to the present)		Land reclamation for paddy (from 2006 to the present)		Earlier onset of rainfall and failure of burning (2011)	98 (2011)

It can be divided into three stages: before 1975, from 1975 to 2000, and after 2000, and transitions of each component (social events, infrastructure, commercial crops, commercial forest products, food culture, swidden and paddy practice, house and clothes, disaster and number of household) are shown village, while the introduction of commercial crops has been on a small scale, merchants frequently promote the introduction of commercial crops. Also, rituals related to swidden agriculture have become simplified, and farming has rapidly become more efficient.

In the past 30 years, the pattern of life in Kachet village has changed greatly. In parallel with external influences, the population inside the village has grown, leading to a decrease in the cultivation plot size per household. As a result, self-sufficient swidden agriculture, which had been practiced until now, is now difficult to sustain. On the other hand, the permeation of market economy into Kachet village in recent years has brought value to a variety of forest products produced in swidden lands besides upland rice, and has also increased employment opportunities like migrant work. In other words, market-oriented economic reforms in Kachet village can be said to be a blessing at this time under the current conditions of the village, where cultivation lands for self-sufficiency has decreased as population grows. Furthermore, the diversification of cash income sources provided the villagers a means to avoid a crisis in 2011, when swidden agriculture was not possible. Market-oriented reforms can be considered to have brought benefits to Laos' mountain regions, not only during normal years but also when disasters occur.

Meanwhile, such a market economy is promoting changes in the particular purposes of how land is used, such as for forestation and the introduction of commercial crops in general (Thongmanivong et al. 2009). In Kachet village, the importance of cash has grown. Although commercial crops are being introduced, migrant work is increasing, and lands are being developed to improve agricultural productivity, self-sufficient livelihood in the primary form of growing upland rice on mountain slopes is still mainly practiced as before. The variety of activities that support the lives of villagers is carried out with close ties to the swidden agricultural system. If the utilization of lands becomes simplified, there is danger that the flexibility of livelihoods carried out in mountain regions will be lost. For example, lands available for collecting forest products will become reduced, as will lands for cattle grazing. Required is the implementation of measures for utilizing lands so that diverse livelihood activities can continue in the midst of advancing market-oriented reforms.

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Part II
Natural Environment

Chapter 4
Grazing Behavior and Local Management of Cattle and Buffaloes in Rural Laos

Masaki Shirai and Satoshi Yokoyama

Abstract Laos presently is undergoing rapid economic development, which is also bringing about changes in the livelihoods of rural residents. While there is concern that these changes will also impact the way in which cattle and water buffalo are kept as livestock, there are few reports in the literature on the grazing behavior of these animals. In this chapter, we report on an ethological study on the spatiotemporal use of swidden fallow in northern Laos by primarily free-grazing cattle and water buffalo. In Kachet village, practicing swidden agriculture in northern Laos, livestock are grazed freely on first-year fallow following swidden agriculture. The results of an ethological survey utilizing global positioning system data loggers indicate that Kachet village offers environments that are suited to the free grazing of cattle and water buffalo. Shorter- and longer-term fallows in Kachet village serve different functions that are presumably necessary for the animals to maintain their body condition. We conclude that the grazing of livestock on swidden fallow constitutes rational use of space created by swidden agriculture. As this practice is well-suited to the villagers' complex livelihood strategy, we must continue to evaluate the advantages of using swidden fallow for livestock grazing.

Keywords Biologging • Geographic information system • Global positioning system • Grazing method • Livestock grazing • Swidden fallow

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4.1 The Importance of Livestock in Developing Countries

When traveling in many developing countries, it is common to see a variety of livestock such as cows sleeping by the roadside or water buffalo wandering around with their calves, just outside of major urban areas. Although it may be hard to imagine from such scenes, to farmers in developing countries, and small-holder farmers in a particular, livestock play diverse roles that are integrated into the daily lives of local residents in their respective regions (Riethmuller 2003). Not only are the meat, milk, and hide of livestock used as products, in regions where daily life is centered around agriculture, for example, livestock are used as draft animals to perform agricultural work, pulling carts, etc. In addition, livestock play a role in local rituals and are featured in the celebrations following such rituals. For this reason, livestock have become an essential part of events such as New Year's or wedding celebrations and funerals. Furthermore, livestock can serve as personal property and can be a source of income since they produce offspring, which can then be sold. In this manner, livestock are a critical element in the conduct of everyday life.

When attempting to understand such animal husbandry in developing countries, it is perhaps important to note that the existing practices are not necessarily sustainable or efficient in terms of animal husbandry. At first glance, it would seem that, if the desired objective is sustainability and efficiency, there is little advantage to raising cattle and water buffalo under semi-wild conditions in which the animals are at risk of attack by wild predators. However, to clarify the advantage of such practices, it is necessary to first understand that animal husbandry in developing countries exists in the context of a "mutual utilization with agriculture" (Takai 2008). In other words, animal husbandry is part of the complex livelihood strategy pursued by local residents, and it is only when one has a bird's-eye-view of these livelihood practices that the advantages of seemingly inefficient animal husbandry practices becomes clear. The following section provides an overview of the current state of and problems associated with animal husbandry in Laos.

4.2 Animal Husbandry in Laos

4.2.1 Cattle and Water Buffalo Grazing

Cattle and water buffalo are the main livestock raised in the Laos (Wilson 2007). Due to differences in resource availability and conditions, the practices employed vary widely from region to region. Takai (2008) and Nonaka et al. (2008) provide detailed accounts of grazing in swidden and paddy rice areas of Laos, respectively. In regions of northern Laos where swidden agriculture is practiced, cattle and water buffalo are grazed on swidden fallow called *Pa Lao*. The herbaceous species-dominated fallows immediately following cultivation feature abundant growth of *Bambusoideae* spp. (known locally as *Nya Nyun*) and *Miscanthus* spp. (known

Fig. 4.1 The grazing of cattle on fallows belonging to Kachet village (Photo by Satoshi Yokoyama in August, 2012)

locally as *Nya Kha*) preferred by livestock, making the land suitable for grazing (Fig. 4.1). As the fallow period increases, the dominant vegetation transitions from herbaceous species to tree-species. Plots that have been left fallow for three or more years are heavily populated with trees and are no longer suitable for grazing by cattle or water buffalo. In northern Laos, swidden agriculture is typically practiced on about 5-year cycle (Roder 1997; Suzuki and Yasui 2002). Cattle and water buffalo are left to graze all day on first- and second-year fallows nestled among a patchwork of swidden fallows in different stages of recovery and featuring trees of varying heights. Such grazing represents a highly extensive practice in which cattle and water buffalo owners simply visit swidden fallows where they graze their animals every few days, walk around to check that their animals are alive, and provide the animals with salt.

Meanwhile, in areas where paddy rice cultivation dominates, different grazing practices are employed during rainy and dry seasons (Nonaka et al. 2008). While rice is under cultivation during the rainy season, owners bring their animals to grazing grounds only in the daytime. This is to prevent cattle and water buffalo from entering paddies where rice is being cultivated. At nighttime, the animals are tethered beneath the raised-floor sheds found on each owner's property (Fig. 4.2). In areas where a double copping is practiced, cattle and water buffalo owners must lead their animals to specific grazing areas year round. In areas where there is no

Fig. 4.2 Tethered cattle in Dong Khuai village (Photo by Satoshi Yokoyama in August, 2011)

second harvest, owners can use the paddy fields for grazing during the dry season, as these fields still contain rice straw. In areas where rice is only cultivated during the rainy season, the use of paddy fields as grazing grounds during the dry season enables farmers to use the dung left by grazing animals as fertilizer.

It is also reported that, in certain areas of northern Laos, cattle, water buffalo, pigs, and poultry are raised in satellite villages known as *Sanam* that are separate from home villages (Nakatsuji 2013). *Sanam*, which are utilized by Khmu people belonging to the Mon-Khmer linguistic group in northern mountainous areas who mainly engage in swidden agriculture, are said to be useful for preventing livestock disease and improving accessibility to grazing lands. As can be seen from the above, cattle and water buffalo have, up to now, been grazed using various methods that are able to co-exist with the livelihood practices of each region.

4.2.2 Changes in Cattle and Water Buffalo Husbandry

While traditional grazing practices continue to be employed, in recent years, livestock owners are facing new challenges resulting from the penetration of the market economy. Figure 4.3 shows the change in number of cattle and water buffalo since 1990. While the number of cattle and water buffalo has been increasing across

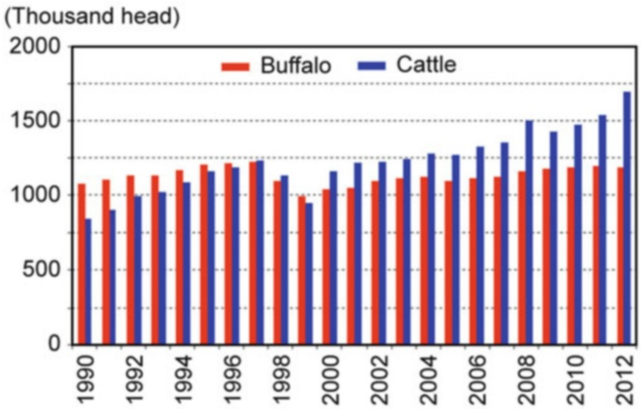

Fig. 4.3 Buffalo and cattle population (Data from National Statistical Center, Laos)

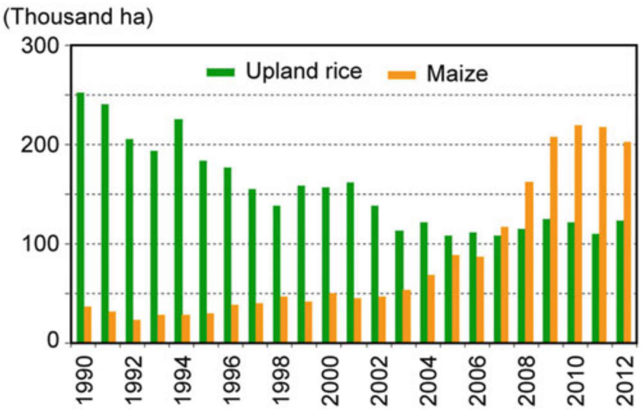

Fig. 4.4 Area of major upland crops (Data from National Statistical Center, Laos)

the whole of Laos, the number of water buffalo has not grown substantially since 2000. Up to now, water buffalo have been kept to help with the plowing of rice paddies. With the widespread use of tractors, however, they are no longer used as draft animals, and their numbers have fallen dramatically, particularly in areas where paddy rice cultivation dominates. According to the Lao Expenditure and Consumption Survey (LECS) household surveys conducted every 5 years by the Lao government, tractor ownership has risen sharply, from 7 % in 1997 (LECS-2), to 19 % in 2002 (LECS-3), and 28 % in 2007 (LECS-4).

At the same time, while cattle and water buffalo in mountainous regions of Laos are typically grazed on fallow lands created by the practice of swidden agriculture, as can be seen in Fig. 4.4, the area under upland rice cultivation has declined dramatically between 1990 and 2005 indicating that the land under swidden agriculture has been rapidly disappearing. This has resulted in the reduction of grazing land. Since implementation of the Land and Forest Allocation Program (LFAP) in 1996, land use has been tightly restricted (see Chap. 1). Because no land is allocated to swidden agriculture under the LFAP, former swidden lands in mountainous regions have increasingly been converted to upland fields. In swidden lands, the shift from cultivation of upland rice for subsistence to various commercial crops exemplified by maize has occurred especially rapidly since 2003. In addition to maize, the area allocated to para-rubber tree plantations has also increased throughout Laos and the transition to eucalyptus plantations has been especially dramatic in central Laos. Due to a lack of accurate data, however, these trends are not reflected in Fig. 4.4.

Inhabitants of mountain villages in Laos have traditionally adopted complex livelihood strategies, cultivating rice in swidden or paddies while harvesting forest products from the surrounding environment and combining this with the animal husbandry practices described above (Yokoyama 2004). Although subsistence has been the primary objective of such complex livelihood strategies, the establishment of infrastructure that has accompanied economic development has resulted in a shift to monoculture-based land use for the purpose of cash income. As the cultivation of commercial crops and tree plantations has expanded, the incidence of feeding damage caused by livestock grazing has increased and owners of affected farms have started to seek reparation from cattle and water buffalo owners. As such, grazing has become a high-risk practice for the owners of cattle and water buffalo, with the result that a growing number of farmers are opting to get rid of their cattle and water buffalo (Takai and Sibounheuang 2010). In order to prevent feeding damage due to grazing, it is necessary to increase the number of people monitoring the activity of cattle and water buffalo. The decline in swidden agriculture also directly impacts animal husbandry practice by increasing the pool of available labor. It is anticipated that livestock grazing in Laos will have to be practiced under increasingly limited space.

What impact will penetration of the market economy and the accompanying changes in livelihood have on animal husbandry practices? To be able to answer this question, it is first necessary to get an accurate picture of the current state of free grazing with respect to cattle and water buffalo. However, it is unexpectedly difficult to understand the behavior of free-grazing cattle and water buffalo. Grazing grounds are typical located away from villages, and it is not easy, even for villagers, to get a handle on all the activities of livestock that are able to range freely. Furthermore, the presence of observers influences the behavior and ecology of these animals. For this reason, we have not been able, up to this point, to collect detailed information regarding the behavior of free grazing animals. However, with recent advances in electronics, techniques now exist which enable researchers to precisely monitor the activity of animals with minimal interference. Such techniques collectively are referred to as biologging. In the next section, we will introduce several examples of biologging used in ethological research.

4.3 Use of Biologging Techniques in Ethological Research

Continuous observation of animal behavior, not just of livestock, is challenging. Animals encounter and respond to different environments as they move around. In order to adequately understand the relationship between an animal's behavior or ecology and its environment, we need research methods that are not constrained by the limits of human observation. Biologging technologies were developed to be able to continuously monitor animal behavior under conditions in which physical observation is difficult (Naito 2004; Takahashi and Yoda 2010). The term biologging—from the word *bio* (=living organisms) and *logging* (=recording data)—refers to methods that involves attaching small data loggers capable of measuring and recording animal activity and various environmental parameters to animals.

Biologging technology was first developed to help researchers study the diving behavior of seabirds, which, in the realm of bird observation, is considered particularly challenging. Various data loggers have subsequently been developed and improved, so that it is now possible to monitor not only water depth but, also, a variety of other parameters such as location, acceleration, and heart rate, etc. Data loggers have become standard research tools in disciplines involving the study of animal behavior and ecology. The use of biologging in research focusing on livestock has been increasing in recent years. For example, researchers have utilized global positioning system (GPS) data loggers to study the home range of grazing cattle and their preference for different environments (Turner et al. 2000; Putfarken et al. 2008). Heart rate data loggers have been used to study the energy consumption of grazing cattle (Brosh 2007). Acceleration data loggers affixed under cattle chins have been used to collect detailed information regarding the time allocation of different behaviors including browsing, ruminating, and resting (Watanabe et al. 2008). Biologging techniques enable a wide variety of parameters to be measured simply by using different sensors.

Furthermore, the geographic information system (GIS) has been widely adopted in recent years as a tool for analyzing space utilization by animals. Because GIS enables same-dimensional analysis by layering various types of regional data of differing dimensions (points, lines, and planes) on the same map, it expands the applicable range of ethological data and enables interactions between this data and environmental data to be visualized The combination of biologging and GIS techniques has enabled researchers to study animal behavior in spaces that are not readily accessible by people.

In the next section, we describe an ethological study conducted using GPS data loggers and GIS to investigate the spatiotemporal use of swidden fallows and paddy fields by grazing cattle and water buffalo and to clarify how these animals utilize the diverse environments that constitute swidden fallow.

4.4 Ethnological Survey of Free-Grazing Livestock

4.4.1 Survey Objectives and Methods

In order to investigate the behavior of cattle and water buffalo grazed on swidden fallows in Laos, we conducted a GPS data logger-based behavioral survey of cattle and water buffalo in Kachet village (20°34′N, 102°18′E), Luang Phabang province in northern Laos on August 3 and 4, 2011 and from June 25 to 27, 2013. After receiving permission from the livestock owners, we affixed small-form GPS data loggers to the animals (Fig. 4.5) and recorded the animals' locations (latitude, longitude, and time) during the survey period. In this study, we were able to collect data for 16 cattle and 7 water buffalo.

Further, in order to be able to identify unique features of cattle grazing in swidden fallows, we conducted a similar behavioral survey of cattle grazing in paddy fields in Paksuun village (18°17′N, 104°03′E) in Borikhamxay province and Dong Khuai village (18°01′N, 102°48′E) in Vientiane Prefecture, both in central Laos, on August 25 and 26, 2010, and from August 10 to 12, 2012, respectively. We collected data for seven cattle in Paksuun village and one cow in Dong Khuai village.

Using the location (latitude and longitude) data recorded by the GPS data loggers, we calculated the distances between pairs of points and estimated the total distance traveled by each animal during the day. In the case of Kachet and

Fig. 4.5 A cow fitted with a GPS data logger (Photo by Masaki Shirai in June, 2013)

Paksuun villages, in order to identify the points recorded by the GPS data logger concentrated in a small area of land, we calculated utilization distributions using the fixed-kernel density method (Worton 1989). In the kernel density estimation method, the distribution density of location data is treated as a probability density function. By calculating densities within a certain distance from high-density observation points, it is possible to visualize areas in which observations are concentrated. For example, in an area with a 95 % kernel density, it is possible, using the recorded location data, to exclude points within that area that are not utilized by the animal in question. The daytime and nighttime home ranges of cattle in Kachet and Paksuun villages were identified by 95 % fixed kernel density estimation method using the ESRI® ArcGIS 10 Spatial Analyst Density tool. In our study, daytime and nighttime were defined as 0600 to 1829 h and 1830 to 0559 h, respectively, based on the sunrise and sunset times in Vientiane during the survey periods (http://www.timeanddate.com/worldclock/sunrise.html).

4.4.2 Overview of the Study Sites

As in the case of other communities in northern Laos, the villagers of Kachet village practice swidden agriculture. As of 2011, the village comprised 486 individuals from 98 households belonging to the Khmu people. In 2011, the villagers of Kachet village practiced swidden agriculture on a 7-year rotation, and cattle and water buffalo were being grazed on first-year fallows that had been cultivated the previous year. As of 2011, approximately 100 cattle and 15 water buffalo were being kept in the village. By 2013, the number of cattle had fallen to 50 due to losses resulting from a hoof-and-mouth disease epidemic between 2011 and 2012 and selling off.

The villagers of Paksuun village practice agriculture based on paddy rice cultivation. As of 2010, Paksuun village comprised 510 individuals from 104 households belonging to the Lao and Tai Meuiy peoples in the Tai-Kadai language group. Paksuun village is located to the south of the Kading River. The village's cattle and water buffalo are kept on the other side of the river, where they are allowed to graze freely. The land on which the animals were being grazed had been previously used as paddy fields, but were not being used for that purpose in 2010. According to the village chief, approximately 30 cattle and 300 water buffalo were being kept in 2010.

Dong Khuai is a Lao village comprising approximately 1,250 villagers from 260 households practicing paddy rice cultivation (Nonaka 2008). Nearly 1,000 cattle were being kept in the village, with 58.4 % of the households owning an average of 6.7 heads of cattle (Nonaka et al. 2008). The grazing cattle are accompanied primarily by women and children who prevent the cattle from entering the paddy fields during the rainy season (Fig. 4.6). Each day the cattle are grazed in one of four locations, with the location being chosen on daily basis based on the weather and other conditions.

Fig. 4.6 Villagers keeping watch of cattle so that they do not enter the adjacent paddy fields (Photo by Satoshi Yokoyama in August, 2012)

4.4.3 Analysis of Cattle Home Ranges

The home ranges of cattle in Kachet and Paksuun villages, as indicated by the GPS data logger records, are presented in Figs. 4.7 and 4.8, respectively. Both the daytime and nighttime home ranges of cattle in Kachet village were limited, indicating that the animals remain in a small area for a long period of time. In contrast, the daytime home ranges of cattle in Paksuun village were fairly extensive, while the animals spent a substantial amount of time at night in a small area. The limited nighttime home ranges observed in both Kachet and Paksuun villages are consistent with the general observation that cattle are not very active at night (e.g. Ganskopp and Bohnert 2006). The lack of nighttime activity is believed to be an innate protective strategy against predators (Rutter 2006). Although wild cattle in Mexico are known to travel long distances during the nighttime, this may also be a tactic to avoid capture by local ranchers during the daytime (Hernandez et al. 1999). Based on interviews with Kachet villagers, it is known that cattle were lost or harmed as a result of attacks by nocturnal predators such as wolves and tigers up to 2006. Johnson et al. (2006) also documented losses and harm to livestock in Laos due to tiger attacks. As such, the diurnal characteristics of cattle

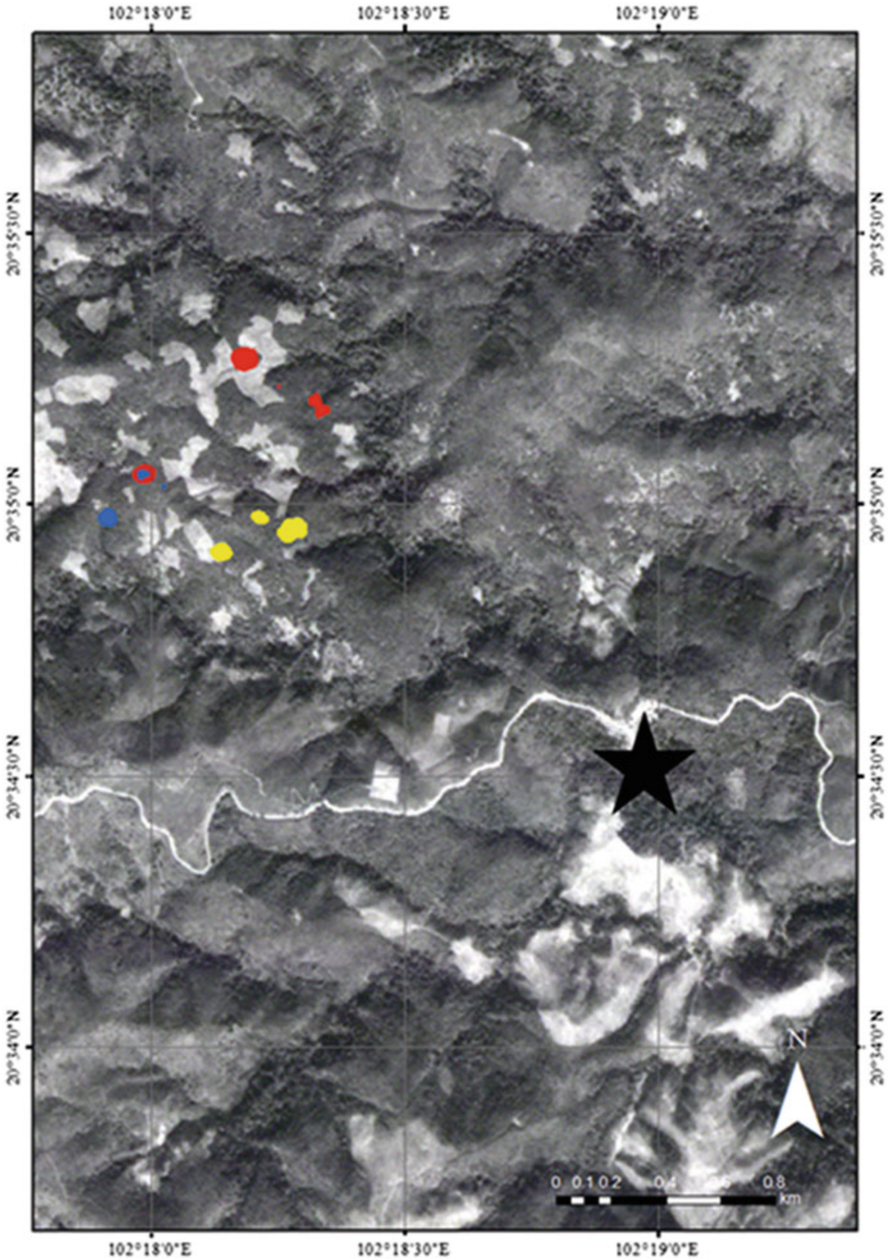

Fig. 4.7 Home ranges of cattle (17 individuals) in Kachet village. *Red areas* represent daytime home ranges (June 26), while *blue* and *yellow areas* represent nighttime home ranges on June 25–26 and June 26–27, respectively. The *star* indicates the location of Kachet village

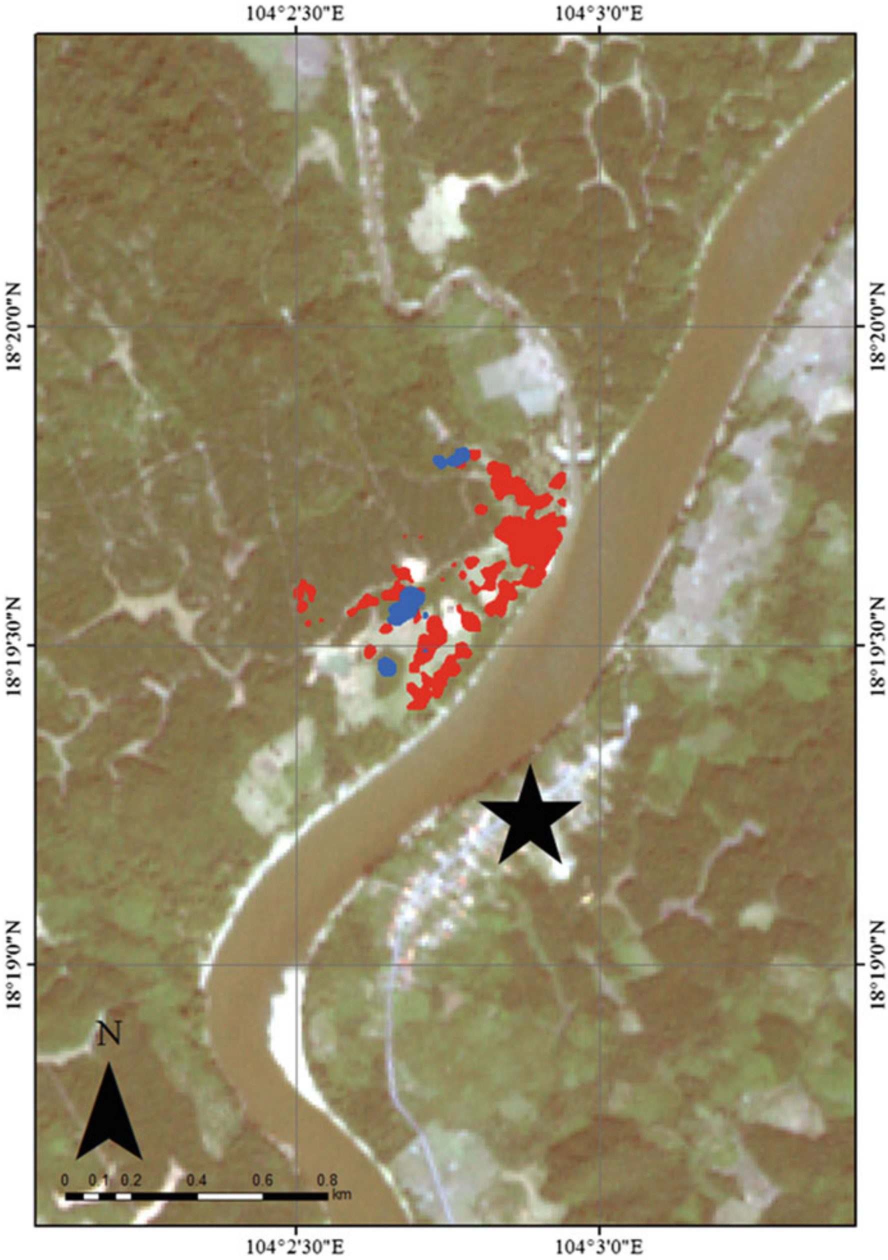

Fig. 4.8 Home ranges of cattle (seven individuals) in Paksuun village. *Red* and *blue areas* represent daytime and nighttime home ranges, respectively

home ranges in Kachet and Paksuun villages may also reflect behavior intended to avoid predation.

The daytime home ranges of cattle were clearly smaller in Kachet village (0.016 km^2) than in Paksuun village (0.109 km^2). The size of an animal's home range (H) is closely related to the animal's energy demand (E) and the productivity of the grazing area (P). In general, a larger home range is necessary to satisfy the higher energy demands of larger animals. Meanwhile, if the productivity of a given grazing area is high, an animal is able to satisfy its needs in a smaller home range. This relationship can be expressed by the following simplified equation (Harestad and Bunnel 1979):

$$H = E/P. \tag{4.1}$$

If we assume that the size and energy demands of cattle in Paksuun and Kachet villages are the same, the differences in daytime home range we observed may reflect differences in the productivity of the villages' respective grazing grounds.

The Kachet villagers are able to regenerate fertile land and increase soil productivity by establishing a 7-year fallow period following swidden agriculture. Furthermore, by using only first-year fallow as grazing grounds, it is ensured that the grazing grounds change each year, which may help prevent a buildup of grazing pressure and enable cattle to continually forage on high-productivity grazing grounds. In contrast, in Paksuun village, the grazing grounds do not change from year to year, resulting in a buildup of grazing pressure over time, which may lower the productivity of the grazing grounds over time.

The results of the behavioral survey using GPS data loggers suggest that swidden fallows are suitable grazing grounds for livestock. Moreover, as the type of grazing practiced in Kachet village does not require the animal owners to perform labor-intensive tasks such as grass-cutting to procure feed, it is advantageous to both animals and people. It is evident from the above that, within the context of swiddeners' complex livelihood strategy, the use of swidden fallows for cattle grazing constitutes an appropriate method for stably raising cattle that allows animal owners to simultaneously perform other livelihood activities.

4.4.4 The Impact of Various Grazing Methods

While the cattle of Kachet and Paksuun villages were allowed to graze both day and night, not all villages in Laos exist in environments where such grazing practice is possible. Each village employs grazing methods that are suited to their immediate surroundings. In order to compare swidden fallow grazing with other grazing methods, we affixed a GPS data logger to one cow in Dong Khuai village (where animals are only grazed during daytime in the rainy season) for 3 days and also accompanied the animal while grazing.

The animal and its owner left home and headed for the grazing grounds at approximately 0800 h in each experimental day. On the way to the grazing grounds, if the animal attempted to enter a paddy field or to eat any crops, the owner would attentively control the animal using a rod or similar item. During the observation period, the animal was grazed in three different grazing grounds (Fig. 4.9). The average distance traveled within a given grazing ground was 2.5 km, which was substantially lower than the average daytime travel distances recorded in Kachet (4.5 km) and Paksuun (3.7 km) villages. Grazing was ended at some point between 1500 and 1700 h, leaving sufficient time for the animal and owner to return home before sunset.

Unlike in Kachet and Paksuun villages, the owners in Dong Khuai village accompanied their grazing animals during the rainy season, and the animals were not allowed to graze at night. Although this strategy is effective in preventing the animals from causing feeding damage, the owners are unable to perform any other livelihood activities during that time. Such limitation on activity may represent a substantial opportunity cost in Laos where many people pursue complex livelihood strategies. Given that the cattle observed in Kachet and Paksuun villages exhibited low nighttime activity, it can be said that the nighttime tethering of animals in Dong Khuai village is consistent with the animals' natural behavioral patterns. Meanwhile, based on past research examining the impact of grazing period on behavior, it is known that shorter grazing periods generally result in higher proportions of time spent grazing and higher intake rates (Ayantunde et al. 2001, 2002). It is believed that this increased intake rate constitutes behavior to compensate for the shorter grazing period (Allden and Whittaker 1970). While it was found that the average distance traveled during daytime grazing was shorter in Dong Khaui than in the other villages, this may be attributable to a higher proportion of time spent grazing.

Because the land available for grazing is decreasing in Laos, it is becoming increasingly difficult to continue practicing free-grazing methods such as those utilized in Kachet and Paksuun villages. Villages that are forced to change their traditional grazing practices will undoubtedly emerge. High-opportunity-cost grazing practices such as that observed in Dong Khuai village may impact the time management of other livelihood activities practiced by the villagers. By identifying the advantages and disadvantages of various grazing practices, it will be increasingly important for villagers to proactively think about what kind of environment they can create for grazing livestock.

4.4.5 Analysis of the Behavioral Rhythms of Water Buffalo

In 2011, water buffalo in Kachet village were grazed all day in and around a first-year swidden fallow located 1.0–2.4 km south of the village. In order to better understand the use of swidden fallows by water buffalo, we delineated a boundary between first-year fallow and other fallows and calculated distance to the boundary

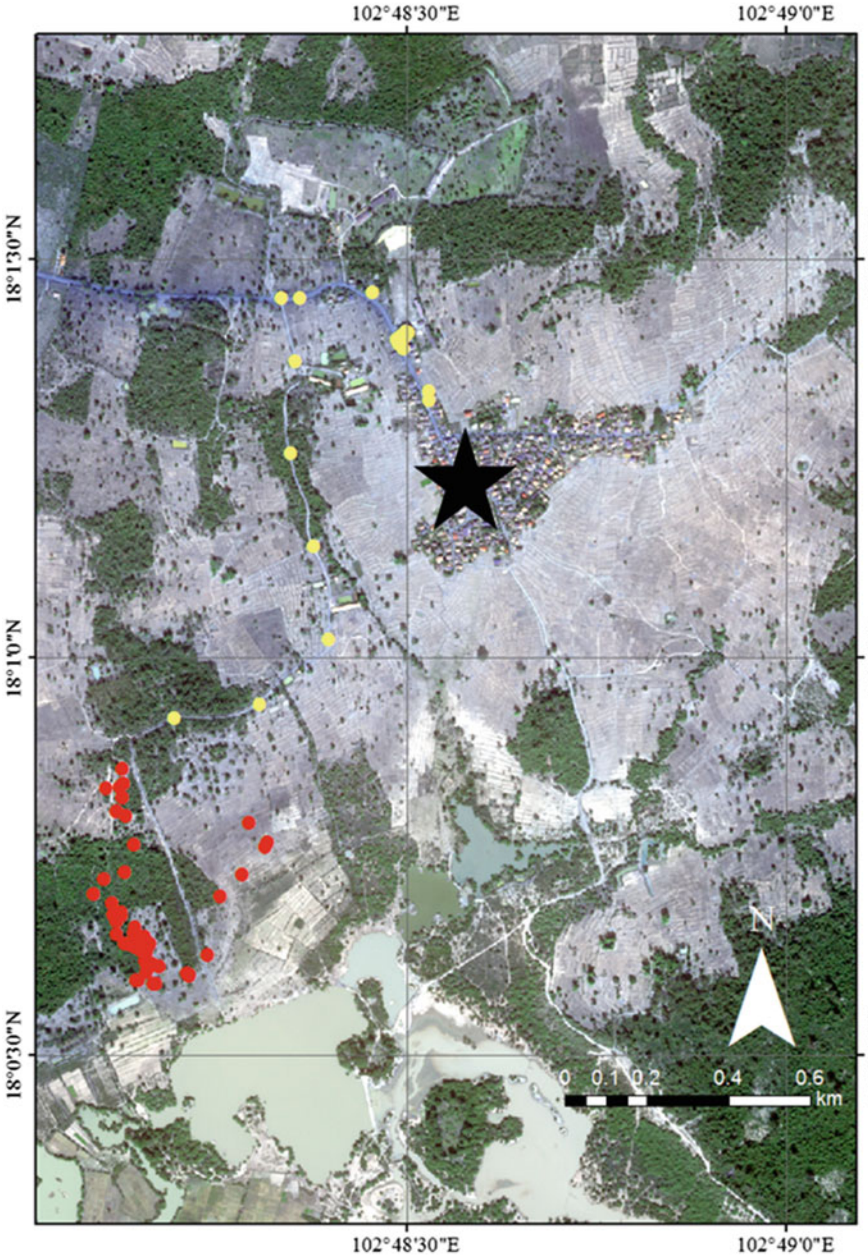

Fig. 4.9 Example of cattle grazing in Dong Khuai village (August 12, 2012). *Red areas* represent cattle locations (as recorded by GPS data loggers) within the grazing grounds, while *yellow areas* represent cattle locations outside the grazing grounds. The *star* indicates the location of Dong Khuai village

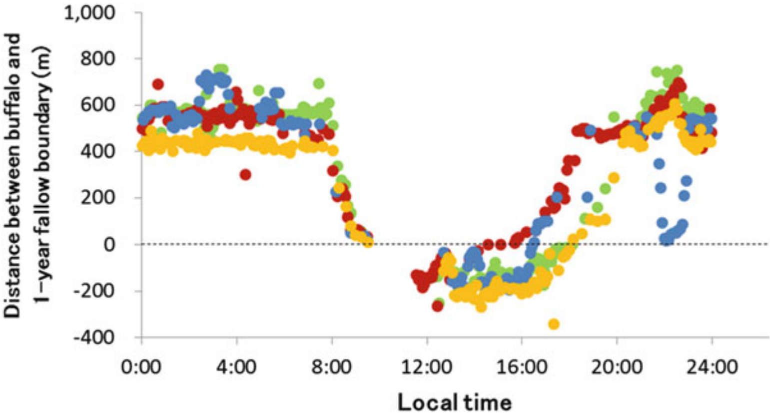

Fig. 4.10 Distance of water buffalo to the first-year fallow boundary by time of day (recorded in 2011). A *positive value* on the vertical axis indicates that the water buffalo was in the first-year fallow, while a *negative value* indicates that it was in the adjacent sixth-year fallow. The *different colors* represent different individuals

over time using the location (latitude and longitude) data from the GPS data loggers. The results of these calculations are presented in Fig. 4.10. The water buffalo spent nighttime in the first-year fallow and daytime in the adjacent sixth-year fallow. Water buffaloes tend to graze at night rather than during the day, which is believed to be related to the difference in magnitude of daytime and nighttime energy and water loss (Sinclair 1977). Because water buffalo have fewer sweat glands than cattle and other mammals, they have poor body temperature regulation (Koga et al. 1998). It is known that water buffalo cope with tropical environments through wallowing behavior in which they cover their entire body surface area with water to promote heat loss (Tulloch and Litchfield 1981). Furthermore, it has been demonstrated that effective use of shade by water buffalo lowers heat stress, rectal temperature, and water consumption (Khongdee et al. 2013). It is possible that the water buffalo observed in our study in 2011 spent daytime in the sixth-year fallow because the greater shade provided by taller trees in the longer fallow enabled the animals to lower their body temperatures. Meanwhile, we believe that the first-year fallow, which offers an abundant supply of the young sprouts preferred by the water buffalo (Momose 2002; Takai 2008), was used during nighttime as a grazing ground. These results suggest that shorter- and longer-term fallows serve different functions for the water buffalo.

In 2013, land adjacent to the village was the first-year fallow and used for grazing water buffalo. The water buffalo serving as our study sample were tethered in the village at nighttime and only allowed to freely graze during daytime. For this reason, we calculated the distance between the animals' daytime locations, as recorded by the GPS data loggers, from the center of Kachet village (Fig. 4.11). While being monitored using GPS data loggers, these water buffalo stayed at a location approximately 800 m from the village during the day and returned to the

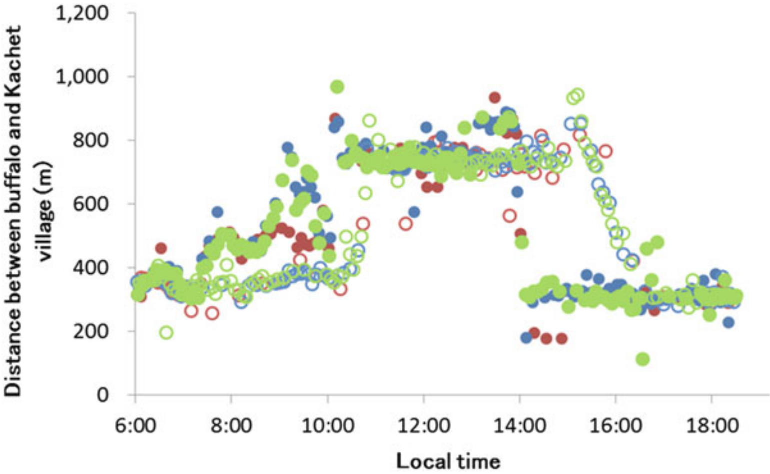

Fig. 4.11 Distance of water buffalo to the center of Kachet village during day-light hours. The *different colors* represent different individuals. The *closed* and *open symbols* represent data recorded on June 26 and June 27, 2013, respectively

village by themselves in the evening. It can be seen that, in contrast to 2011, the water buffalo in 2013 were diurnal, spending daytime in the first-year fallow. This behavior may have been influenced by the fact that the animals were provided water after returning home to their owners. Consistent with our study results, Ryan et al. (2006) reported that water buffalo preferentially use areas within 1 km of a water supply as their home range. The water buffalo may have exhibited diurnal behavior due to the presence of an accessible nighttime water source and a grazing ground (first-year fallow) close to the village.

The above results indicate that water buffalo are able to flexibly adapt to changes in available resources of the surrounding environment. They also suggest that the mosaic of diverse environments that constitute swidden fallow makes it suitable as a grazing ground for water buffalo, which have poor body temperature regulation function.

4.5 The Current State and Challenges Facing Livestock Grazing in Swidden Fallow

We conducted interviews with members of Kachet village, which served as a field site for this study, regarding the grazing of livestock on swidden fallows. It is necessary to provide cattle and water buffalo with salt on a regular basis. In Kachet village, salt was provided to the animals on more or less a daily basis. However, owners rarely entered fallows for the sole purpose of providing their animals with salt and, in most cases, provided salt in passing while carrying out their main task of collecting forest products. In other words, the harvesting of natural resources, raising of livestock, and cultivating of rice in swidden fields are all elements of the villagers' complex livelihood strategy.

When discussing animal husbandry, the method used to control livestock breeding and reproduction is an important point. In Kachet village, no attempt was made to limit breeding through the use of castration or other means. It is an accepted rule that any calf born belongs to the owner of the cow that bore it. Since one cow generally produces one calf each year, given the presence of 50 head of cattle in the village in 2013, it is expected that there will be 70 head of cattle in the following year. Cash earned from selling livestock is typically used to pay for house construction, bikes or televisions, children's education, or to buy rice. In villages such as Kachet that only have an elementary school, parents must send their children away if they are to continue studying in middle school and beyond. In most cases, the students must board in dormitories in the village where the middle school is located. Parents contrive to obtain the cash needed to pay such dormitories by selling their cattle and water buffalo.

In Kachet village, there have been years (such as 2008 and 2011) in which circumstances have arisen that have prevented swidden burning and, as a consequence, swidden agriculture has not been possible (see Chap. 3). According to interviews with villagers, in such years, the villagers and their children, as a first step, left the village to find work elsewhere and used the money earned to purchase rice. It is only when villagers could not purchase enough rice by such means that they would resort to selling off their cattle and water buffalo to buy rice. This behavior suggests that the villagers do not proactively desire to sell their cattle or water buffalo. Takai (2009) explains that "to the villagers of northern Laos, water buffalo are companions with whom they have formed an ecosystem over many years." It appears that this same mentality is deeply rooted in the minds of the Kachet villagers.

In Kachet village, we observed cattle returning to the village of their own volition every few days after grazing in the first-year fallow. The reason for this is unclear. At times it might be a single animal returning while at others it might be a group of 20 or so animals. Upon confirming that their cattle had returned to the village, the owners would immediately return their animals to the first-year fallow. There were two reasons for this. First, because there is a main road running right next to the village, if cattle are kept in the village, they might be stolen in the middle of the night by people pulling their cars up alongside the road. In addition, the animals are returned to the swidden fallow to lower the risk of accidents involving vehicles and livestock. Second, the villagers have received instructions from government officials to avoid raising livestock in the village itself on hygienic grounds and, thus, try to graze their animals on swidden fallow as much as possible. In this manner, the practice of grazing livestock on swidden fallow away from the village also plays a role in preventing theft and maintaining hygiene.

Meanwhile, the risk of grazing cattle and water buffalo is surfacing. In the past, livestock have been lost or injured as a result of predation by wild animals, with attacks by tigers being confirmed as recently as 1998 and attacks by wolves as recently as 2006. However, attacks by wild animals have not been confirmed in the past few years. When livestock grazing grounds are adjacent to swidden plots, there is a chance that the livestock will eat the rice crop. In such cases, the villagers cultivating the crops have had to construct fences to prevent the livestock from approaching the swidden plots. In cases where livestock enter a swidden plot even after a fence has been erected, the livestock owner is expected to pay reparations for any feeding damage caused. Takai (2008) provides a detailed account of disputes arising from feeding damage. In Laos, disputes related to feeding damage began to increase in frequency starting around 2000. If livestock enter a field and eat crops after breaking down a fence, it is customary for the livestock owner to pay an equivalent quantity of unhulled rice as the rice that was damaged or lost. Because the livestock owner is only required to pay partial reparation if the fence is found to have been faulty, some farms have begun to enclose their fields with barbed wire. While the use of barbed wire has not yet been observed in Kachet village, it seems there is a need to examine how conflicts between livestock grazing and crop cultivation can be resolved, especially as these become increasingly prominent.

When we visited Kachet village in 2013, we noted that the number of pigs being kept had increased. While the specific price depends on an individual pig's heart girth, a pig can be purchased for approximately 100,000 LAK and sold for as much as 2 million LAK after fattening. It appears that the pig husbandry is increasing in popularity as an alternative to large livestock such as cattle and water buffalo because it requires low initial capital and a reasonable level of investment. With regard to pigs and chickens that can readily be free-ranged or barn-raised even in small spaces, Takai et al. (2008) reported that small-scale animal husbandry remains deeply rooted in farming practice even while land use and lifestyle change. Thus, the raising of pigs may increase in popularity as the difficulties associated with raising cattle and water buffalo increase.

4.6 The Future of Livestock Grazing in Laos

It was demonstrated in our study that Kachet village offers environments that are suited to the free grazing of cattle and water buffalo. Following swidden agriculture, shorter- and longer-term fallows serve different functions for livestock, which are presumably necessary for cattle and water buffalo to maintain their body condition. Compared to other villages in northern Laos that, at present, are only able to maintain fallow periods of 5 years or less (Roder 1997; Suzuki and Yasui 2002), Kachet is able to maintain a relatively long fallow period of 7 years. It is this longer fallow period that enables good grazing grounds to be provided to cattle and water buffalo.

According to the GPS data logger-based ethological survey, the cattle of Kachet village congregate and spend long periods of time in a single location during the day. This observation indicates that the cattle of Kachet village do not need to move around to find food. In contrast, cattle in Paksuun village had more extensive home ranges than cattle in Kachet village and moved about to look for food. It is believed that these different cattle behaviors reflect differences in productivity of their respective grazing grounds. It is likely that Kachet village, which changes grazing grounds and swidden fields every year, is able to maintain higher-quality grazing grounds than Paksuun village, which grazes livestock in the same location year after year. Similarly, in Dong Khuai village, where livestock owners change cattle grazing grounds every day, it is believed that the rotation of grazing grounds is important for maintaining their productivity (Walton et al. 1981). The challenge of sustainably using livestock grazing grounds is related to the question of how grazing is managed. While the sustainability of grazing grounds varies depending on grazing method, among the methods discussed above, it is apparent that the use of swidden fallow is highly sustainable.

Meanwhile, considering the urbanization and changes in land use that are occurring in Laos, it can be predicted that the current cattle and water buffalo grazing practices on swidden fallow will become more difficult in the future. Even in Kachet village, which had maintained fallow periods of 8–15 years prior to 1996, fallow periods have become shorter due to the recent increases in population (see Chap. 6). If this trend continues, it is possible that the areas with tall trees utilized by water buffalo will be lost. In addition, in our interviews with villagers, we were able to catch glimpses of conflict between crop cultivation and grazing even in Kachet village. Such circumstances could potentially lead to social changes that abruptly alter the environment in which cattle and water buffalo are raised. The reported decrease in numbers of water buffalo being kept in northern Laos reflects the increasing difficulty associated with raising water buffalo that has resulted from not only changes in the natural environment but, also, changes in the social environment (Takai and Sibounheuang 2010).

The results of our study suggest that swidden fallows (a) are relatively more productive and constitute favorable grazing grounds for livestock and (b) enable villagers to graze their livestock with minimal effort. Swidden agriculture represents an agricultural system that utilizes the power of nature to cultivate crops in a sustainable and cyclical manner. In addition to serving as a location for food production immediately after burning, swidden land that is left fallow continues to serve as a location for harvesting forest products and for performing other livelihood activities (Yokoyama 2013). Our study results indicate that the grazing of livestock on swidden fallows is a rational way to utilize swidden space. The practice of grazing livestock on swidden fallows is not very efficient when compared to the integrated grazing systems employed in advanced countries. However, it is a practice that is extremely well-suited to the villagers' complex livelihood strategy. We must re-evaluate grazing methods after first understanding the value of such methods. The environmental and social problems associated with efforts to continue grazing livestock on swidden fallows are, by no means, few. In order to resolve these problems, it is necessary to clarify the various advantages of such grazing practices.

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Chapter 5
Analysis of Monsoon Climate Variability for Swidden Agriculture in Northern Laos

Kaya Kanemaru, Rezza Muhammad, and Isao Hirota

Abstract Most rice fields in Laos are rain-fed, so crops depend on rainfall amount. Especially in the north, upland rice is grown under swidden agriculture, which is affected by weather conditions in the rainy (monsoon) and pre-monsoon seasons. During the pre-monsoon season, trees and plants are cut and dried to enrich soil before rice planting. However, heavy precipitation during this period disturbs the drying, and is thus unsuitable to initiate burning. Furthermore, climate change, which alters rainfall (wet, normal and dry) and hampers determination of the optimal time of paddy planting, has recently become a problem. Prediction of monsoon season onset is essential for examining influences on the amount of and fluctuations in rainfall. This study investigates rainfall characteristics during the pre-monsoon and monsoon seasons around Kachet village in northern Laos. We diagnose climate impacts on local livelihoods via comparison between rainfall data and results of field survey interviews in the village, to compare actual recognition of villagers and objective data. In the pre-monsoon season, precipitation increased slightly over 47 years, and variance in precipitation tended to increase with a steeper slope than that observed for amount of precipitation. This suggests that weather in this season became unstable and precipitation prediction more difficult.

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A recent trend of early rainy season onset and increased precipitation has affected the livelihoods of people in the village. The villagers have long engaged in various agricultural activities, based on traditional knowledge. Although knowledge has been accumulated over many generations, it may not accommodate recent climate change.

Keywords Climate change • Local adaptation • Long term trend • Onset of rainy season • Teleconnection

5.1 Introduction

Laos is on the Indochina peninsula, which has distinct rainy and dry season climate characteristics. There are two wind regimes: the northeast and southwest monsoon flows into the region, which cause the rainy and dry seasons, respectively. Characteristics of the rainy season have been described in many studies (e.g., Zhang et al. 2002; Wang and Lin 2002; Wang et al. 2004). Since Laos is a landlocked country, rainfall varies annually according to the balance of strength between the two monsoons. An active monsoon during the southwest monsoon period brings frequent heavy rainfall. Wang and Lin (2002) obtained the monsoon onset date as pentads 25–27 (corresponding to the middle through end of May) in unsuitable to initiate burning. Villagers wait for a few dry days and burn the dry biomass to prepare cultivation fields. In this season, local people must therefore predict weather in northern Laos. Weather conditions during the rainy season in Laos fluctuate greatly and can induce disasters such as floods and droughts, which impact the livelihoods of local people involved primarily in agriculture.

Most rice fields in Laos are rain-fed, so crops are dependent on the amount of rainfall. Especially in the north, upland rice is grown under swidden agriculture. Swidden agriculture is affected by weather conditions in the rainy (monsoon) season and pre-monsoon season, which is the transition season from the dry to rainy season. During the pre-monsoon, cutting and drying of trees and herbaceous plants is done to provide rich soil before rice planting. The period from cutting to burning is 20–30 days. However, heavy precipitation during this period disturbs the drying process, so such a phenomenon affects the optimal time for burning. In the monsoon season, however, the availability of water that is essential for rice growth depends on local precipitation, and thus rainfall amount is important for swidden. Saito et al. (2006) evaluated the impact of intensifying upland rice cultivation and rainfall on upland rice productivity in northern Laos. Climate change, which alters rainfall characteristics (wet, normal and dry) in the monsoon season and hampers determination of the optimal time to begin paddy planting, has recently become a problem. For examining the factors that influence the nature and fluctuations of rainfall, prediction of monsoon season onset becomes a necessity.

This study investigates rainfall characteristics during the pre-monsoon (March–April) and monsoon (April through October) seasons around Kachet village in northern Laos. We diagnose climate impacts on local livelihoods via comparison between rainfall data and results of field survey interviews conducted in the village, to compare the actual knowledge of villagers and objective data.

5.2 Methodology

5.2.1 *Dataset*

The Asian Precipitation—Highly Resolved Observational Data Integration Towards Evaluation of Water Resources (APHRODITE) V1003R1 dataset was used in this study. This is a ground-based interpolated rain gauge dataset, developed by the Research Institute for Humanity and Nature (RIHN) and Meteorological Research Institute of the Japan Meteorological Agency (MRI/JMA) (Yatagai et al. 2009). The algorithms are described by Xie et al. (2007) and Yatagai et al. (2009). Data of 57 years, from 1951 to 2007, were analyzed. The analysis area was a grid box around Kachet village, located at 102.375°E and 20.625°N, plus eight surrounding grid boxes (between 102–102.75°E and 20.25–21.00°N).

Three indices of regional sea surface temperature (SST) in December, January and February were used to predict the probability of onset date. SST anomaly data of NINO.3, NINO.WEST, and Indian Ocean Basin Warming (IOBW) areas were obtained from JMA. These regions are shown in Fig. 5.1.

5.2.2 *Data Analysis*

5.2.2.1 Rain Index Related to Pre-monsoon Season

The 50-day period from 1 March to 19 April (hereafter, the "50-day period") was defined to focus on rainfall variability in the pre-monsoon season. This is the important period for local people to burn dry biomass and begin swidden

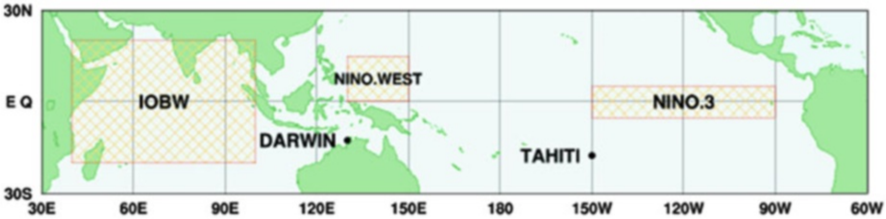

Fig. 5.1 Regions of SST anomaly. Indices of area are defined as IOBW (20°N–20°S and 40°E–100°E), NINO.WEST (15°N–Equator and 130°E–150°E), and NINO.3 (5°N–5°S and 150°W–90°W). (*Source*: http://www.data.jma.go.jp/gmd/cpd/data/elnino/index/dattab.html)

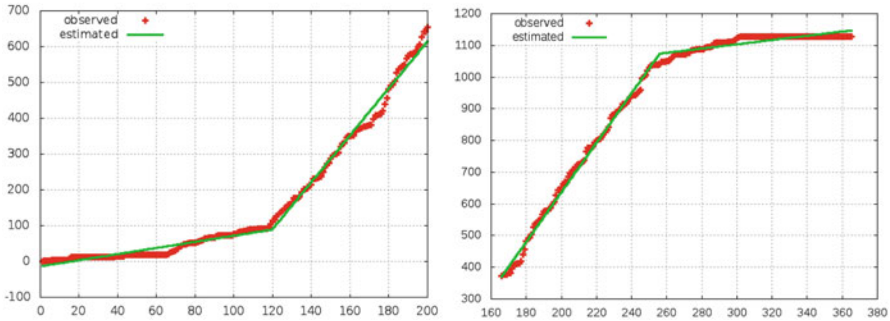

Fig. 5.2 Estimated onset (*left*) and termination (*right*) dates of rainy season in 2001. Y axis is cumulative rainfall amount (mm) and X axis is day of year

agriculture. The biomass drying period requires 10–20 days to dry wood. The precipitation pattern during this period is critical for the process because successful burning is critical for upland rice cultivation.

5.2.2.2 Determination of Monsoon Onset and Termination

The analysis steps are as follows. Rainy-season rainfall indexes onset date (OR), termination date (TR) and period duration (PR) were estimated using an accumulative rain amount method (Cook and Buckley 2009). Linear regression was done to determine trends of interannual variability. Figure 5.2 shows an example of how OR and TR were estimated. The periods of rainy and dry seasons were defined by identifying the intersection of two linear approximate equations of TR-OR.

5.2.3 *Surveyed Village*

The village surveyed is Kachet, which is in the Nam Bak district of Luang Phabang Province in northern Laos. We conducted a field survey during 2–5 August 2011, interviewing village heads and leaders. There were 98 households and the total population was 486 villagers. All households were engaged in swidden agriculture. In the swidden system, villagers cut trees in February, burn them from the end of March to mid-April, sow upland rice around the end of April, weed during cultivation, and harvest from October to November. Villagers burn dry biomass between the dry and rainy season (March–mid-April). During this period, rain is sporadic and dry days gradually become less frequent. Villagers wait to burn dry biomass after several consecutive dry days, so that the biomass is sufficiently dry for burning. If the appropriate days for drying are not chosen correctly, the rainy season begins and no biomass can be burnt. Therefore, timing of the drying and burning is sensitive and important in swidden agriculture. In Kachet village, many villagers were unable to burn biomass in 2011. Climate change is believed to have occurred in recent years. One motivation for the present study to identify whether there is a relationship between climate change and the inability to burn swidden fields in Kachet village.

5.3 Result

5.3.1 General Rainfall Characteristics of Kachet Village

Figure 5.3 shows time series and yearly variability of monthly rainfall in Kachet village. Monthly rainfall is substantial from April through August in the rainy season and less in the dry season, from November through February. Rainfall climatology is also shown in Fig. 5.4. Daily rainfall from November through February is less than 1 mm. Precipitation is heavy from April through October, with a maximum in August. The interior of Southeast Asia, including northern Laos, is in a buffer zone between the Indian summer monsoon (ISM) and western North Pacific summer monsoon (WNPSM) regions (Wang and Lin 2002). Northern Laos has less rainfall than the central and southern parts of the country (Fig. 5.5, left panel).

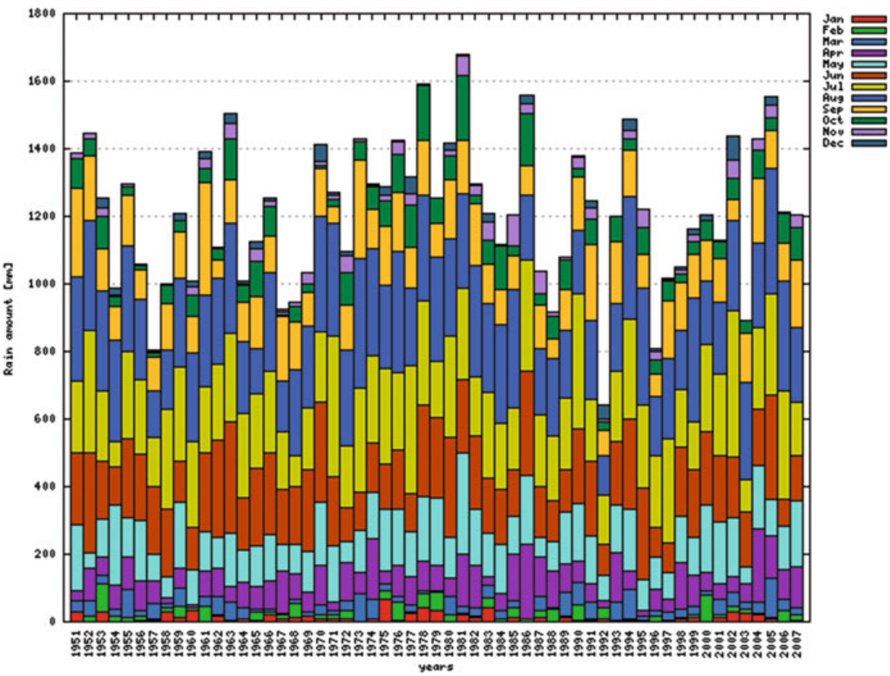

Fig. 5.3 Monthly rainfall index for each year (mm)

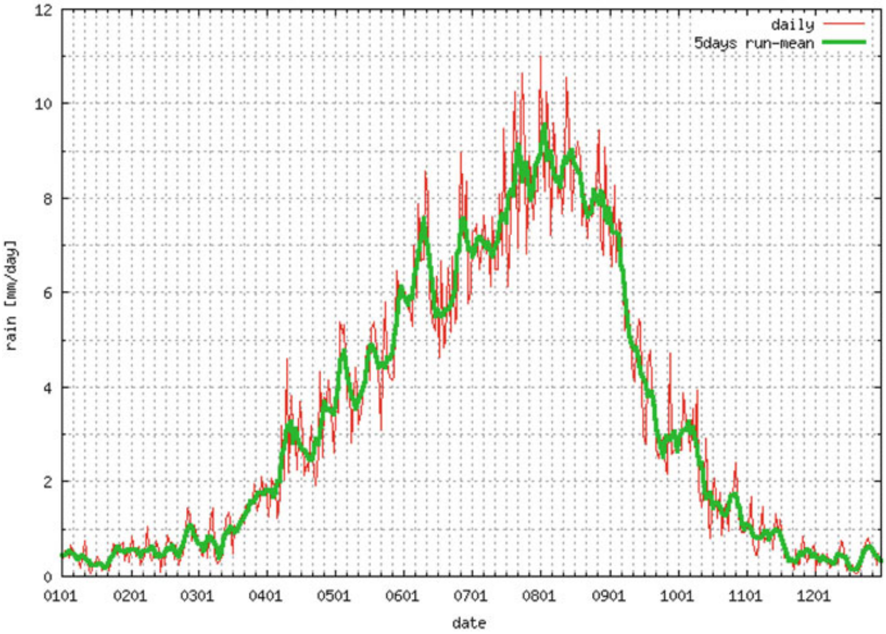

Fig. 5.4 Climatological rainfall calculated by daily rainfall index (*red*) together with its 5-day running mean (*green*)

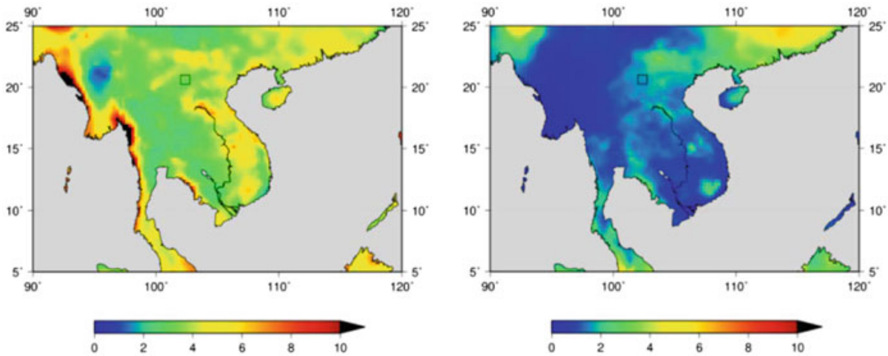

Fig. 5.5 Climatological map of precipitation for 57 years between 1951 and 2007. Annual mean (*left panel*) and 50 days between 1 March to 19 April averaged daily precipitation (*right panel*). Unit is mm/day

5.3.2 Interview Results

Based on interviews of inhabitants of Kachet village, there were a few (~12) families with lowland rice fields of small areas. However, all households were engaged in swidden agriculture. Villagers cultivated upland rice, corn, cassavas, pumpkins, cucumbers, and vegetables (chili, eggplant, Chinese mustard) in

Table 5.1 Calendar of agricultural activities and NTFPs (*Source*: Kachet village interviews, July 2011)

No.	Activities, crops and NTFPs	Months											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Hunting, Houa Douk Deua (a species of konjak), Nya hak diang, rattan, taro, sweet potato												
2	Nor khom (bamboo shoots)												
3	Broom grass (Dok kheam)												
4	Harvest resin benzoin, Paper mulberry, *Termitomyces* spp. (Het Pouak)												
5	Nor van, Nor lun, Nor kuod, Nor hak, hunting, fishing and planting												
6	Hunting, fishing												
7	Het bi (mushroom)												
8	Cucumber												
9	Cardamom, Ka khom, galanga fruit												
10	Benzoin tapping and harvesting												
11	Upland rice												
	Slash												
	Burn												
	Planting												
	Weeding												
	Harvesting												
12	Stick lac												

Table 5.2 Interview results of irregular climate years

Irregular condition	Years
Earlier rain	1954, 1968, 1976, 2011
Drought condition	1995, 1998

Earlier rain means that rain fell early, from March through May. Drought condition means that precipitation was less during the rainy season

swidden fields. Many crops are grown in May–June. With respect to harvesting time, cucumber was first (in August), followed by vegetables (over several months), rice, pumpkin, corn, and cassava (September–November). Table 5.1 shows the agricultural activity schedule of the villagers. Local histories of flood and drought years were also obtained during the interviews (Table 5.2). Local people remembered irregular climate years causing variation of agricultural production, including serious decreases. The interview results were analyzed and compared by trend analysis and interannual variability.

5.3.3 Rainfall Trends of Climatology and 50-Day Period

Figure 5.5 shows a climatological map of precipitation. Black squares indicate precipitation at Kachet village. Annual mean precipitation (Fig. 5.5, left panel) in the village was uniform compared with surrounding areas. However, precipitation during the 50-day period (Fig. 5.5, right panel) was greater than to the west and south of the village. Time series of annual mean and the 50-day period are shown in Fig. 5.6. This figure shows time series of annual and 50-day period precipitation and the standard deviation at the village. Annual mean precipitation (top panel) and standard deviation from the linear regression both had positive trends, but these were not statistically significant. In contrast, the 50-day period precipitation and standard deviation trends (bottom panel) were statistically significant. The trend of precipitation amount was 0.21 mm/decade (95 % significance level) and the standard deviation was 1.00 mm/decade (99 % significance level). The trend of standard deviation of precipitation was greater than that of precipitation amount, suggesting that precipitation amount changes and precipitation characteristics varied strongly compared with previous periods.

To assess irregular years from information gleaned during the interviews, variability of precipitation in the 50-day period was investigated. Figure 5.7 shows time series of the first rain day exceeding the threshold 1 mm/day. Climatology of the first day was obtained for the 10 days following 1 March. The interview result indicates that 1968 and 1976 of earlier rain years (years with earlier onset of rainy season) and 1995 and 1998 of drought years were consistent with the first rain day anomaly. Villagers did not recognize the earlier year of 1954 in the analysis. Natural variability is large, so the first rain-day anomalies do not explain the irregular climate years. If rain falls during the 10–20 day drying period following cutting, the cut wood will remain wet. However, drying not only depends on precipitation; it might be related to other weather conditions (e.g., number of sunny days, humidity and temperature).

5.3.4 Trends of Onset, Termination and Duration of Rainy Season

Figure 5.8 shows variability of termination and onset dates and duration of the rainy season from 1951 to 2007, based on the definition above. As shown in Fig. 5.8, the onset had a weak trend toward becoming earlier over the 57 years. In contrast, termination did not have a clear trend (Table 5.3). Duration of the rainy season lengthened because of the onset becoming earlier.

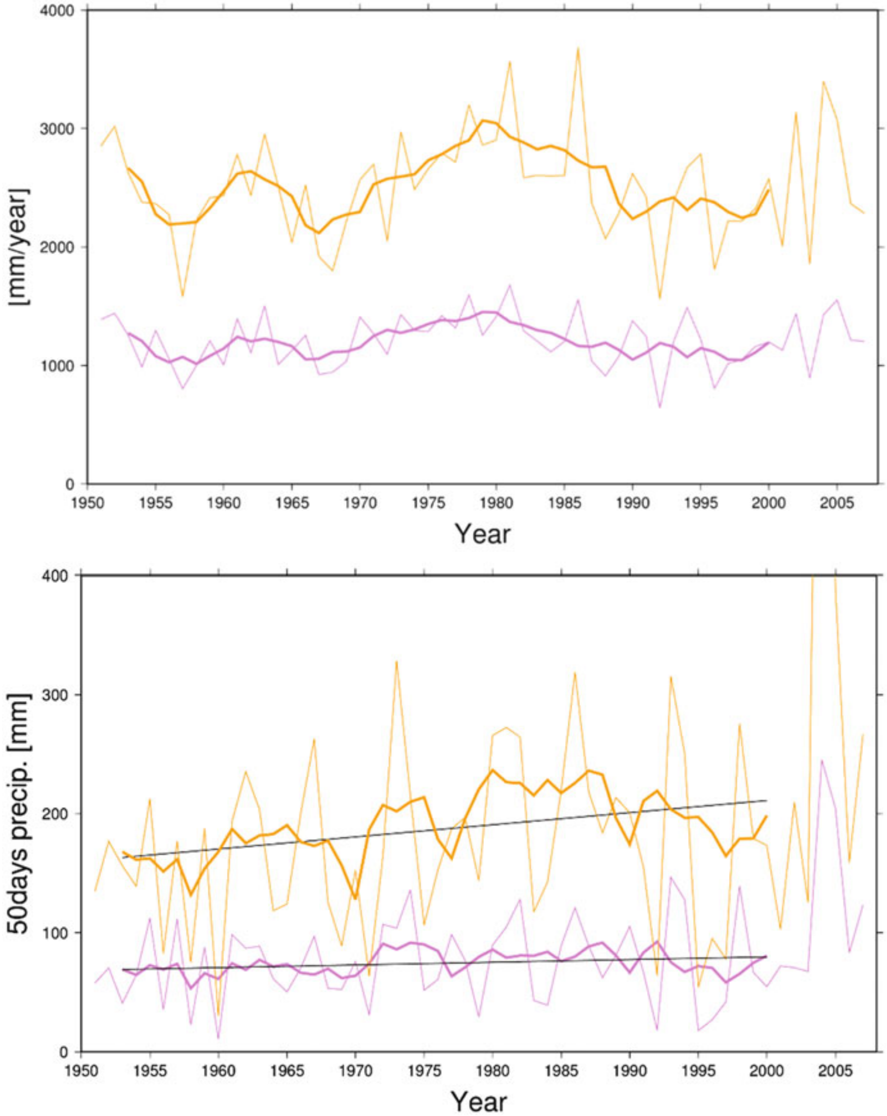

Fig. 5.6 Time series of annual accumulated precipitation and the standard deviation from 1951 to 2002 (*top panel*). *Pink* and *orange lines* show amount of precipitation and the standard deviation, respectively. *Thin* and *thick lines* show yearly variation and 5-year running mean. The *bottom panel* is same as *top*, but for 50 days from 1 March to 19 April. *Black lines* show linear trend regressions. Slopes of precipitation amount and standard deviation were 2.1 and 10.0 mm/decade

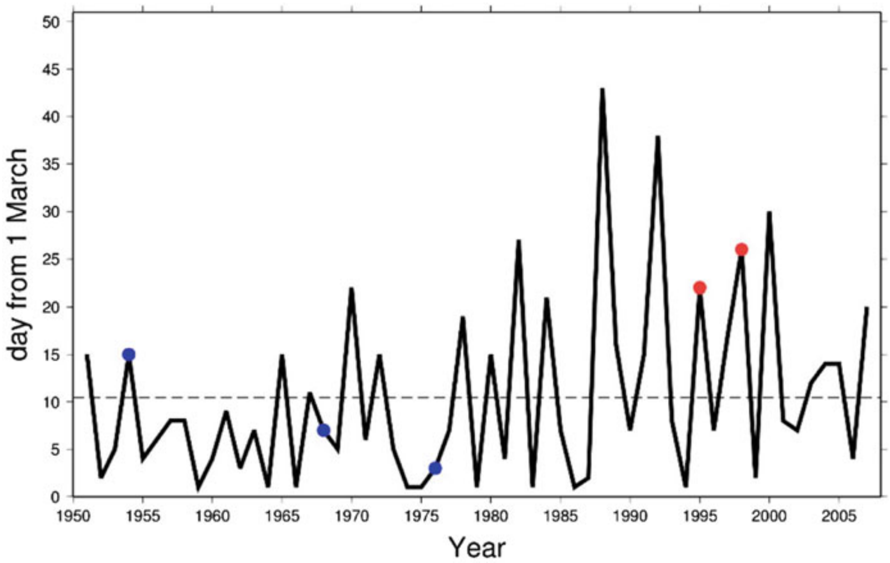

Fig. 5.7 Yearly time series of the first day of precipitation exceeding a threshold of 1 mm/day. Y axis corresponds to the day from 1 March (50 corresponds to 19 April). *Circle symbols* show years with earlier rain (*blue*) and drought conditions (*red*). *Dashed horizontal line* is average first rain date

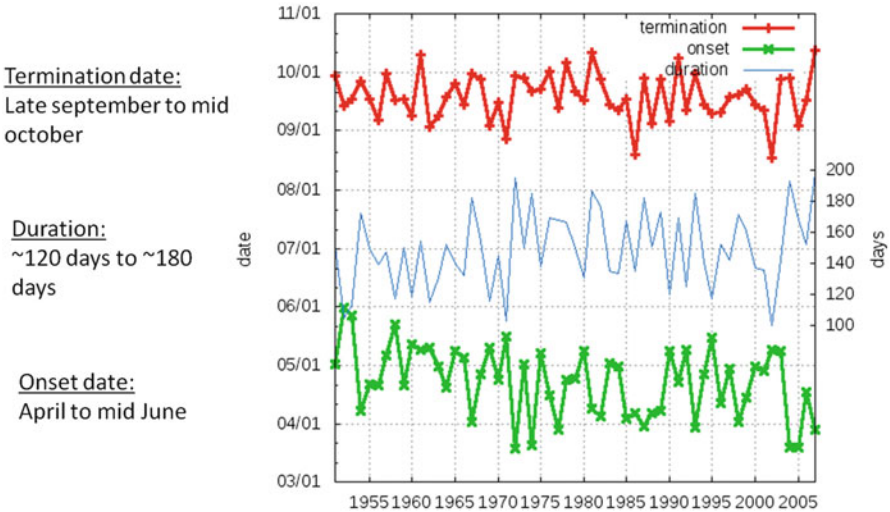

Fig. 5.8 Variability of termination date (*red*), duration/period (*blue*), and onset date (*green*)

Table 5.3 Linear trend and correlation coefficient of onset, termination, and duration dates, from 1947 to 2001

	Gradient (day/decade)	Correlation coefficient
Onset	−4.065	−0.3678
Termination	−0.444	−0.061
Duration	3.621	0.244

Table 5.4 Multivariate regression results for SST anomalies of NINO.3 and IOBW for onset date

Onset		
Time lag (month)	Month	R squared
1	Feb	0.014
2	Jan	0.012
3	Dec	0.073

Table 5.5 Slope and R squared of linear regression between onset or period of rainy season at Kachet village and SST anomalies of three regions (IOBW, NINO. WEST and NINO.3) in December, 1951 to 2007

	Slope	R squared
Onset		
NINO.3	1.2402	0.0061
NINO.WEST	−15.411	0.0521
IOBW	10.627	0.0202
Period		
NINO.3	−1.0485	0.0024
NINO.WEST	11.124	0.0151
IOBW	−16.97	0.0285

5.3.5 Teleconnection Between Study Site and Three Major Regions of Pacific Ocean

To attain more effective prediction of rainy season onset at Kachet village, we investigated teleconnection between the study site and three major regions of the Pacific Ocean (IOBW, NINO.WEST and NINO.3). In Table 5.4, we analyzed a multi-regression result of SST anomalies of NINO.3 and IOBW for 3 months (December, January and February) and the onset date at the village. SST anomalies of NINO. WEST and that at the village did not have obvious correlation. Among the 3 months, SST anomalies in December and onset date in the village had higher correlations. Thus, we chose data from December for the investigation of teleconnection.

We analyzed the correlation between the three regions in December from 1951 to 2007. The slope and R squared of linear regression are shown in Table 5.5. The onset of the rainy season in Kachet village was correlated with SST of NINO. WEST, followed by lesser correlation with IOBW and NINO.3. Duration of the rainy season in the study area was correlated with SST of IOBW, followed by NINO.WEST and NINO.3. Correlation of duration between the village and IOBW was higher than those of the other areas.

5.4 Discussion

The long-term trend of rainfall characteristics in the vicinity of Kachet village analyzed using the APRODITE data and local villager perceptions were determined. Although Laos is inland, dry and rainy seasons are generally distinct as in other areas of Monsoon Asia (Figs. 5.3, 5.4, and 5.5). People in Laos have traditionally engaged in various agricultural activities. In the mountainous area of the north, swidden is widely practiced in combination with various activities (Table 5.1). In the swidden system, the timing of burning is very important and prediction of that timing is difficult. This is because the timing is around the transition from the dry to the rainy season, or in the so-called pre-monsoon season. If timing prediction fails, local people cannot carry out swidden or cultivate upland rice.

Analysis shows that in the pre-monsoon season, precipitation increased slightly over 47 years, and the variance in precipitation tended to increase with a steeper slope than amount of precipitation (Fig. 5.6). This suggests that weather conditions in this season became unstable and precipitation prediction more difficult. In addition, monsoon onset dates shifted earlier. Kajikawa et al. (2012) showed that the monsoon onset date defined by Wang and Lin (2002)) over Southeast Asia became earlier in recent decades. However, the trend of rainy season termination was unclear compared with that of onset (Fig. 5.8). Cook and Buckley (2009) showed that the monsoon termination date in Thailand had no significant trend, as did the trend at Kachet village. Regional differences of long-term trend may be related to the global circulation, so detailed understanding of the mechanism at global scale is indispensable. In addition to the difficulties of relationships among regions, the inland location of Laos in the buffer zone between the ISM and WNPSM, which are major climatological regimes, further complicates understanding of the mechanism operating in this area.

In accord with the objective data, villagers complained about recent changes of climate. Although villager perceptions of drought years matched for late onset of the rainy season, their perception of earlier onset did not match the real situation (Fig. 5.7). The villagers recognized climate conditions in consideration of rice yield, and their perceptions did not match simple definitions of climatology. However, swiddenners accurately remember climate conditions because these are critical to their livelihood. In addition, they have engaged in rotational swidden agriculture and remember its cycle well. Villagers remember historical events with the memory of the rotation of swidden fields. Thus, we consider the perceptions of villagers to be reliable if we can define the objective data correctly.

As mentioned above, prediction of the timing of burning is important for local people. For this purpose, we examined the possibility of prediction using meteorological data from the aspect of teleconnection. From the results of Table 5.4, we chose December data as the most appropriate, when the sign of teleconnection could be observed. Early onset of the rainy season in the study area is more related to the SST anomaly of NINO.WEST than other regions. Although the correlation coefficient was 0.0521 and it is necessary to improve understanding of the mechanism of teleconnection, its weak signal can be observed. Since Laos is near the boundary of two major monsoon regimes, a more holistic analysis is needed.

In Kachet village, the recent trend of early rainy season onset and precipitation increase has affected the livelihoods of local people. These people have been engaged in various agricultural activities, based on traditional knowledge. Such knowledge has been gained and accumulated through generations, but it may not accommodate recent climate change. To maintain sustainable livelihoods, prediction of climate variability will be important. An understanding of teleconnection is an option, as is local adaptation of cropping systems.

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Part III
Human–Nature Interaction

Chapter 6
Land Use Management and Plant Utilization of a Swidden System in Northern Laos: A Case Study of Kachet Village, Nam Bak District, Luang Phabang Province

Takuya Koyama, Phanxay Ingxay, Yoichi Watanabe, Yoshitaka Jin, and Isao Hirota

Abstract Swidden agriculture is an important food production system for rural communities in Kachet village, northern Laos. In swidden system, land is cleared and abandoned for several years to allow regeneration. These fallow areas provide non-timber forest products (NTFPs) such as benzoin, and cardamom, and can be used for other purposes. In Laos, "Forest Law" and factors associated with population growth shortened the fallow period to less than 4 years. This study aimed to clarify the plant utilization and its temporal-spatial distribution in fallow forest and to rethink present land use management based on these information. We used interviews with villagers, geographic information system data, vegetation surveys, and satellite imaging data from 2000 to 2010. Swidden area information was

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used to estimate the swidden cycle. The farmers in Kachet village used 120 plant species. The results show that the numbers of plant species in edible and medicine use subcategories dramatically increased as the fallow period became longer, and most NTFPs with economic value were observed in forests with a relatively long fallow period (6 or 7 years). The fallow period was maintained by exchanging fields among villagers for swidden agriculture, which is conducted by the whole village. The average area used for swidden agriculture from 2000 to 2010 was 160 ± 11 ha year^{-1}, and the average swidden cycle was about 7 years, which is longer than that found in other regions in northern Laos. Recently, market economy has infiltrated to mountain villages and some villagers start to select commercial crops in swidden fields. However, villagers also have conducted sustainable land use to match the situation. Keeping the land use management and plant utilization in the fallows is important for sustainable development of this area.

Keywords Fallow forest • Satellite imaging • Swidden agriculture • Swidden cycle • Vegetation surveys

6.1 Introduction

Swidden agriculture is an important food production system in mountainous tropical regions. In a swidden system, a part of the forest is cleared, burned, and used to grow crops in the rainy season, and then abandoned for regeneration of vegetation. The area left to regenerate, the secondary fallow forest, does so through natural processes which restore the land for cultivating crops. The fallow provides various non-timber forest products (NTFPs), which are important to rural livelihoods (Douangsavanh et al. 2006). It can be used for many other purposes such as fishing, hunting, and grazing cattle and water buffalo. This system is sustainable when the fallow period is long enough to recover the plant biomass and soil fertility (Fujisaka 1991).

A few decades ago, the traditional fallow period was around 10–15 years; however, in 1996, in addition to restricting the use of forests, the "Forest Law" in Laos divided forest land into five classifications: Protection Forest, Conservation Forest, Regeneration Forest, Production Forest, and Degraded Forest. Consequently, conflicts between village communities occurred. Additionally, upland rice cultivation areas have been expanding with a growing population. These factors have shortened the fallow period, and affected the lifestyle of local people who depend on swidden agriculture and NTFPs.

The Lao Government aims to advance the country beyond Least Among Less Developed Country status as United Nation defined, and economic growth of northern mountainous areas where residents undertake self-sufficiency practices is important. However, livelihood quality in mountainous areas has been estimated only from the perspective of upland rice production. However, other activities in mountainous areas include gathering NTFPs, hunting, and animal husbandry.

Therefore, estimating the whole agro-ecological system is important to providing a comprehensive understanding of sustainable development in mountainous areas.

Plant utilization is the most important activity for villagers in mountainous areas (Yamada et al. 2004). The objective of this study was to clarify the level of plant utilization and distribution in fallow forests, and to demonstrate how villagers maintain a sustainable livelihood under the pressures of population growth including through implementation of land use policy.

6.2 Study Site

6.2.1 Kachet Village

Kachet village is located in a mountainous area in the northwest of the Nam Bak district, Luang Phabang province, northern Laos. The altitude of the village ranges from 400–900 m above sea level, and most of the area is sloping land. The residential area of the village is located at 20°34′N, 102°18′E. We determined the boundary and calculated the village area using geographic information system (GIS) data and information from interviews of villagers in the field (Fig. 6.1). The village area was about 1,890 ha. People in Kachet village belong to the Khmu ethnic group, who practice swidden agriculture (Chazee 1999). In 2011, there were 98 households and 486 people (258 females; 228 males) in Kachet village, all of whom were swiddenners.

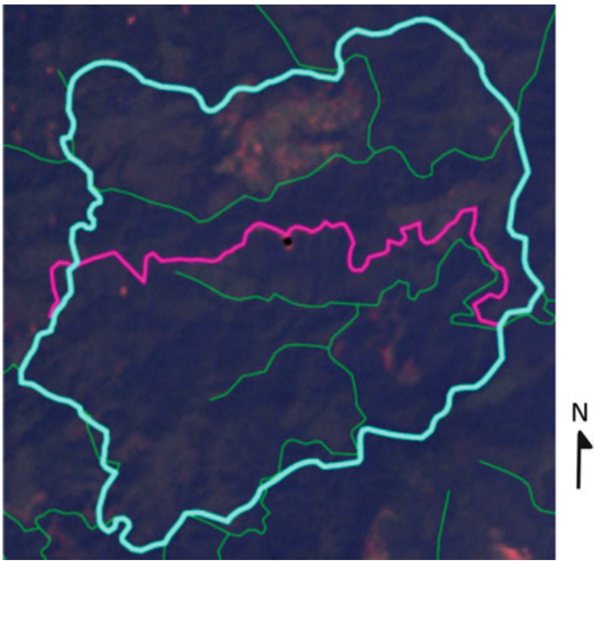

Fig. 6.1 Locations of the village boundary, road, and streams. The village boundary was determined by interviewing the villagers, geographic information system (GIS) data around the village, and interviews in the field. The *aqua*, *purple*, and *green lines* denote the village boundary, road, and streams, respectively

The Ou River and many streams (e.g., Nam Mong, Nam Chet, and Nam Kating) run through Kachet village; since 2009, some villagers have reclaimed and begun cultivating paddy rice in some areas. Most of the cultivated varieties are upland rice. In 2011, though the area of upland rice was 46.10 ha, production was still not enough to sustain the village population. Average consumption was about 130 kg of polished rice per head per year (District Agricultural and Forestry Office of Nam Bak District 2011). The interviews we conducted suggested that households in Kachet village generally suffer from a shortage of rice for about 3 months each year. During food shortages, the villagers needed to gather NTFPs for sale and self-consumption, and earn money by various other activities.

The residents in Kachet village accessed the local Pak Mong market by public service bus or a village truck; the village is located on 13 Road (National Road), which goes from Luang Phabang to the border of China. The distance from the village to Pak Mong market is around 22 km. In this village, selling NTFPs is an important way to earn money. Benzoin production is one of the main sources of cash income for residents in Kachet village; the village has a large area of benzoin-producing trees, which have been managed by the farmers for a long time. Only two districts in Luang Phabang province, Nam Bak and Ngoy districts, are suitable for growing *Stylax* trees (*Stylax tonkinensis*), from which benzoin is derived (Kashio and Johnson 2001).

6.2.2 Swidden Agriculture in Kachet Village

In northern Laos, most of the upland farmers practice swidden agriculture and cultivate upland rice for self-consumption. In Kachet village, farmers first slash the forests from January to February, burn the forests in April, and then seed upland rice in the swidden fields in May. Mostly cultivated are yam, taro, cassava, sweet potato, cucumber, melon, gourd, Job's tears, tobacco, pumpkins, chili pepper, eggplant, corn, and/or sesame with upland rice. After seeding, the farmers weed two or three times until harvesting, or as required. From September to October, they harvest the crops, and after harvesting the fields are abandoned.

6.3 Plant Utilization

Most scientists describe use of a fallow is mainly understood in the context of resting the land. During a fallow period, the land is abandoned to improve soil fertility and/or disrupt pests and diseases (Ruthenberg 1971). For farmers, fallow land is also important as a place for providing various kinds of timber and NTFPs. These products sustain livelihoods by providing food, fodder, firewood, and cash income.

In this section, we first discuss the importance of a fallow period for upland rice production. Then, we focus on NTFPs with economic benefits, and argue that their

Table 6.1 Khmu and English names of NTFPs with economic value in 2011, and the fallow period and harvest time for these NTFPs. Black shades in the right row indicate the harvest time

Name of NTFP			Fallow year								
English	Khmu	Price (kip kg^{-1})	1	2	3	4	5	6	7	8	9
Benzoin	Nyan	70,000				■	■	■	■	■	■
Cardamom	Mak neng	60,000					■	■	■	■	■
–	Nha hak deng	45,000					■	■	■	■	■
Konjak	Houa douk deua	25,000					■	■	■	■	■
–	Mak kha khom	10,000			■	■	■	■	■	■	■
Galangal fruit	Mak kha	5,000					■	■	■	■	■
Bamboo shoot	No mai	5,000			■	■	■	■	■	■	■
Broom grass	Khem	3,500		■	■	■	■	■	■	■	■
			■	■	■						

benefits are related to the fallow period. We also report on investigations of the other NTFPs used by farmers in Kachet village, using vegetation surveys in each fallow year to emphasize the importance of a long fallow period.

6.3.1 Fallow Period and Upland Rice Production

The interviews from six families revealed that upland rice yield is considerably different among fallow years. Rice yields from older forest fallows were much higher than those from fields with young secondary growth or from fields that had been cultivated for several years. Rice production in Kachet village ranged from 1 to 1.8 t ha^{-1} for a 6-year fallow period, and average rice production was around 1.3 t ha^{-1}. The farmers said that if they cultivated upland rice in the same fields, there was a 40–50 % decrease in rice yield in the second year compared with the first year; this is because cultivation in the same fields for 2 years resulted in flourishing of weeds. This phenomenon can also be observed in other crops such as corn and Job's tears.

6.3.2 Fallow Period and NTFPs with Economic Value

There are hundreds of kinds of NTFPs species in Kachet village, too many to describe all of them. Therefore, we focus on six important NTFPs with commercial value (Table 6.1).

6.3.2.1 Benzoin (*Styrax tonkinensis*)

In 2007, the price of benzoin decreased and benzoin production became less attractive for farmers. Consequently, the Kachet people stopped tapping benzoin.

However, after the price increased to around 60,000–70,000 kip kg^{-1} in 2010, they began tapping benzoin again. Since then, benzoin production is one of the most important sources of farmers' income. *Styrax* trees are tapped from September to October.

In 2011, the area of *Styrax* tree plantations was 100 ha, and the price of benzoin was 70,000 kip kg^{-1} (Table 6.1). *Styrax* resin is harvested in fallows more than 5 years old (Table 6.1). In 2011, the average yield of benzoin that could be harvested from a 6 or 7 year-old fallow was around 30–40 kg ha^{-1} year^{-1}, and residents could earn around 2.1–2.8 million kip ha^{-1} year^{-1}. In contrast, in the older fallows, residents could tap more resin from tree densities of around 250–300 ha^{-1}. Therefore, the average yield of benzoin from an 8 to 10 year-old fallow was relatively high at around 70–100 kg, and residents could earn around 5–7 million kip ha^{-1} year^{-1}.

Styrax trees are found only in the Bak and Ngoy districts of Luang Phabang province. They grow in the swidden fields. The farmers in these districts first slash and burn a field for upland rice cultivation, and after harvesting the rice they leave the *Styrax* trees and other vegetation. In most cases, villagers avoid weeding *Styrax* trees so that the trees can grow faster. *Styrax* trees require a fallow period of at least 5 or 6 years to start producing benzoin (Kashio and Johnson 2001). Benzoin production was integrated into the traditional practice of swidden agriculture by Kachet people many years ago. Originally, the fallow period was around 10–15 years, and the farmers could harvest benzoin. However, in 1996, the land of Kachet village was allocated by the district authority, and the farmers were in danger of having to quit benzoin production. Therefore, they changed their fallow management, and succeeded in maintaining benzoin production. We describe these management practices in detail in Sect. 3.1.

6.3.2.2 Cardamom (*Amomum villosum*)

Cardamom is an important cash product. It can be harvested from July to early October. However, 5 years ago, the residents of Kachet village over-harvested the cardamom each day from July to October, which resulted in no cardamom fruit in the next season. The village committee then decided to harvest cardamom seeds only in July; the residents could gather cardamom fruits after the village head announced the day of harvest. The average yield of cardamom is 4–6 kg of dry seeds person^{-1} year^{-1}. Cardamom is harvested in fallows more than 6 years old (Table 6.1), and in 2011 it had a price of 60,000 kip kg^{-1} (Table 6.1).

6.3.2.3 Konjak (*Amorphophallus* spp.)

Konjak has potential as a new source of cash income. It is used in Chinese food, and in 2007, as trade with China grew in importance, export of Konjak to China began. The price of Konjak in 2011 was 25,000 kip kg^{-1} (Table 6.1). Konjak can be harvested in fallows more than 4 years old (Table 6.1). The tuber can be harvested throughout the year, though the Chinese traders buy the tubers only in January.

6.3.2.4 Galangal fruit and root (*Alpinia galanga*)

Galangal fruit and root are used as herbs. The fruits are mainly collected and sold to Chinese traders. The root and shoot is consumed by the local people. Galangal can be harvested from the end of July to the beginning of October. Galangal are planted with upland rice. Additionally, it grows naturally and can be harvested in fallows more than 4 years old (Table 6.1). The average local price in 2011 was 5,000 kip kg^{-1} (Table 6.1).

6.3.2.5 Broom grass (*Thysanolaena latifolia*)

The price of broom grass in 2011 was 3,500 kip kg^{-1} (Table 6.1). Broom grass can be harvested in 1–4 year-old fallows, though it is not found in fallows more than 4 years old because of canopy cover from the regenerating trees in the fallow forests (Table 6.1). Broom grass is usually harvested from February to April. Flowering stems need to be harvested within a month before they become too old. One farmer can collect 10 kg day^{-1} of broom grass twice a week. Broom grass has become an increasingly important source of cash income in recent years, and villagers have increasingly started planting it. As of 2010, there were 5.7 ha of broom grass plantation in Kachet village.

6.3.2.6 Bamboo shoot (*Indosasa sinica, Dendrocalamus* spp., *Phyllostachys* spp.)

Bamboos are the most important plant material in Kachet village and one of the most important sources of cash income from NTFPs. It is consumed in Kachet village and throughout Laos. No khom (*Indosasa sinica*) is a popular food in the towns, and fetches a higher price than other species during the beginning of the season. The farmers harvest the bamboo shoots in February. No khom is harvested in fallows more than 2 years old (Table 6.1). The price of No khom in 2011 was 5,000 kip kg^{-1} (Table 6.1); the price of the other species was 500 kip kg^{-1}

The farmers in Kachet village usually harvest five species of bamboo: No khom, No van (*Dendrocalamus* sp.), No lan (*Phyllostachys* sp.), No kud (unidentified), and No hok (*Dendrocalamus* sp.). They produce shoots in different seasons. No khom is harvested in February, No van, No lun, and No kud are harvested from May to July, and No hok is harvested from the beginning of July to the end of August.

Table 6.2 Number of species in overall categories and use subcategories, as observed in each fallow year

Category of use		Fallow year						
Category	Subcategory	1	2	3	6	7	8	Total number of species
Tool	Band	2			1	2	1	5
	Trap	1		1		2		4
	Wood fuel	1	2			1	4	4
	Broom				1		1	3
	Tool handle	1	1		1	1		2
	Wrapper			1		1		2
	Birdlime				1			1
	Bowstring				1			1
	Paste					1		1
	Offering				1	1	1	1
	Prayer				1			1
	Perfume	1				1	1	1
Food and feed	Edible	9	11	9	20	18	20	52
	Medicine	2	2	3	4	10	9	22
	Pasture		1		2	3	3	4
	Nonessential grocery item						1	1
Building	Post	1	1	2	10	2	1	12
	Beam					1	1	2
	Thatch		1					1
	Fence					1		1

These data were the results of a vegetation survey

The farmers can easily sell their harvest because a Lao trader who is a representative of a Chinese bamboo drying factory located in Pak mong village, Nam Bak district, comes to buy bamboo shoots every day during the harvest period.

6.3.3 Fallow Period and Forest Products

In addition to those NTFPs described above, the farmers of Kachet village use other NTFPs to make a living. To clarify the spatial distribution of these NTFPs, we investigated their use and the fallow period. On 2–5 August 2011, we placed two quadrats (10 × 10 m) in each of the 2, 3, 7 and 8 year-old fallows and 1 quadrat in each of 1 and 6 year-old fallows. We called the quadrats placed in the 1, 2 and 3 year-old fallows short fallow year quadrats, and those placed in the 6, 7 and 8 year-old fallows long year quadrats. We collected the leaves and branches of all plant species from these quadrats, and asked local residents whether each plant species was useful. For those that were useful, we recorded the plant name in Lao and/or Khmu as well as its use, the useful part of the plant, and the harvest season.

We found that 120 plant species were utilized by the farmers in Kachet village (Table 6.2). The numbers of species observed in the short fallow year quadrats were less than those observed in the long fallow year quadrats (Fig. 6.2). The average

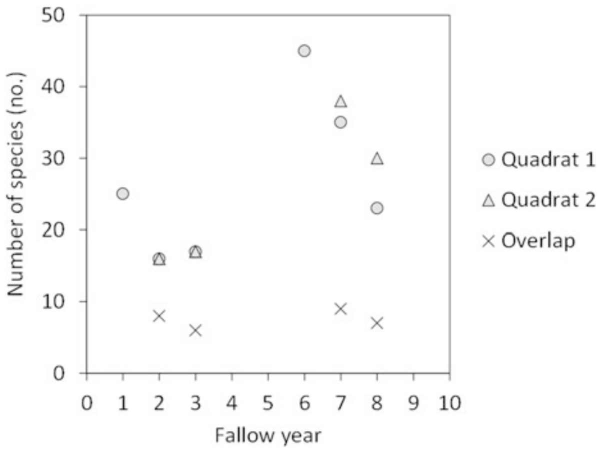

Fig. 6.2 Number of species observed in each of the fallow year quadrats. Some overlap was observed among quadrats from the same fallow year. These data were the results of a vegetation survey

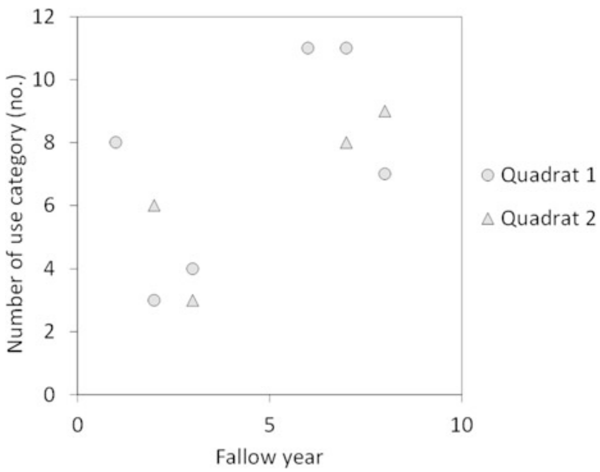

Fig. 6.3 Number of subcategories observed in each of the fallow year quadrats. These data were the results of a vegetation survey

number of species in the short and long fallow year quadrats was 18 and 34, respectively. Both quadrats from each of the 2, 3, 7 and 8 year-old fallows had 8, 6, 9 and 7 species in common, respectively. The uses of each plant species were divided into three categories, and 20 subcategories (Table 6.2). The numbers of species in the edible and medicine use subcategories increased with increasing fallow years.

The numbers of subcategories of plant species from the short fallow year quadrats were less than those from the long fallow year quadrats; they had averages of 5 and 9, respectively (Fig. 6.3). Band use was the most frequently observed subcategory in the tool use category (Table 6.2). Trap use and wood fuel use were the second most frequently observed subcategories in the tool use category. Edible use was the most frequently observed subcategory in the food and feed use category. Medical use was the second most frequently observed subcategory in the food and feed category. Posts for use in building was the most frequently observed subcategory in the building use category.

Table 6.3 Observed NTFPs with economic value in each fallow year, as identified in this study and by Yokoyama (2004). These data were the results of a vegetation survey. Black shades in the right row indicate the fallow year in which each NTFP was observed

			Fallow year					
Local name	Scientific name	Use	1	2	3	6	7	8
Mak neng	*Amomum villosum*	Medicine [Cardamine]				■	■	■
Nyan	*Styrax tonkinensis*	Perfume [Benzoin]	■				■	■
Mak wai	*Daemonorops* sp.	Food [Rattan fruit]						■
Khem	*Thysanolaena latifolia*	Tool [Broom]				■		■
Gre	*Alpinia* sp.	Medicine [Wild ginger]				■	■	■
No khom	*Indosasa sinica*	Food [Bamboo]					■	
Mak kha	*Alpinia galanga*	Medicine [Ginger fruit]				■		
No lan	*Poaceae* sp.	Food [Bamboo]				■		

Yokoyama (2004) identified the NTFPs with economic value: mak neng (*Amomum villosum*), nyan (*Styrax tonkinensis*), peuak muack (*Boehmeria* sp.), po sa (*Broussonetia papyrifera*), wai (*Calamus* spp.), kha (*Alpinia galanga*) and khem (*Thysanolaena latifolia*) in Ngoy district, which is adjacent to Nam Bak district. Our research has identified the important food crops: gre (ginger, *Alpinia* sp.), no khom, and no lan, and we did not identify peuak muack or po sa (Table 6.3). Most of the other important NTFPs were observed, though only in the long fallow year quadrats. Mak neng was observed in the 6, 7 and 8 fallow years quadrats. *Styrax* trees were observed in the 1, 7 and 8 fallow years quadrats. Mak wai was observed in the 8 fallow years quadrats, and Mak kha was observed in the 6 fallow years quadrats. Khem was observed in the 6 and 8 fallow years quadrats, and Gre observed in the 6 and 7 fallow years quadrats. No khom was observed in the 7 fallow years quadrats, and no lan was observed in the 6 fallow years quadrat.

The numbers of species and numbers of subcategories observed in the short fallow years quadrats were less than those observed in the long fallow years quadrats (Figs. 6.2 and 6.3). Moreover, most of the NTFPs with economic value were observed only in the long fallow year quadrats of the vegetation survey (Table 6.3). Yokoyama (2004) showed by field surveys that villagers gathered most of the NTFPs with economic value from fallow swiddens that were more than 6 years old. These observations indicate that villagers receive more benefits from NTFPs over longer fallow periods.

The numbers of species in the edible and medicine use subcategories were higher than those in the other subcategories; species in the trap use subcategory were the second most frequently observed in the tool use category (Table 6.2). Additionally, the important foods from NTFPs were observed only in long fallow years quadrats (Table 6.3). From these results, villagers are likely to be highly dependent on foodstuffs from slash and burn forest. Delang (2006) reported that wild food plants remained a preferred alternative to commercial food crops because gathering wild food plants is a more efficient use of time than engaging in the market economy. Shackleton and Shackleton (2006) revealed that poor households used more resources per capita for four NTFPs (fuel wood, wild fruits, edible herbs, and grass hand brushes) than did other wealth classes. Additionally, a significantly higher gross annual direct-use value was evident within poorer households for fuel wood and edible herbs (Shackleton and Shackleton 2006). In this study, the numbers of species in the edible and medicine use subcategories dramatically increased as the fallow periods became longer (Table 6.2). This suggests that longer fallow periods contribute to food security in Kachet village.

We found 120 useful species for villagers (Table 6.2). Delang (2006) discussed the villagers' vast traditional knowledge of edible and medicinal plants, which would be lost to future generations if the villagers stopped gathering these plants from the forests. In southern Laos, domestication of cardamom, 'si siet' bark, broom grass, rattans, and bamboo has been reported (Foppes and Ketphanh 2000). Most of the useful species identified were not yet domesticated by villagers in Kachet village. Therefore, these plants might be a potential source for domestication in fallow fields in Kachet village. Belcher et al. (2005) reported that cultivation of these plants tended to provide a higher income compared with other local crops, and higher returns per unit of land compared with non-cultivated NTFP production.

Our results indicate that villagers in Kachet village would receive more benefits from NTFPs as the fallow period becomes longer, and the results provide useful knowledge for future generations in Kachet village.

6.4 Fallow Management

Fallow period and area are important factors when trying to understand the swidden system, and when identifying possible alternatives. In northern Laos, many swidden villages have faced a decrease in the fallow period of 3–5 years, which is associated with a decline in soil fertility, weed infestations, forest destruction, and loss of biodiversity. Thus, fallow management plays an important role in sustaining production of upland rice and NTFPs.

In this section, we describe the current status of land use management for the swidden system in Kachet village. First, we provide information on the current status of fallows in the swidden system by interviewing villagers. Then, we confirm the period and area of fallows by analyzing satellite images.

6.4.1 Historical Changes in the Period of Fallow and the Rotation Cycle

A few decades ago, farmers who conducted swidden agriculture used to keep the land fallow for 20–30 years. A single plot was used for up to 5 or more years until the soil fertility declined, or weeds grew too much to cultivate crops and the farmers had to move to other plots. At that time, the farmers were not controlled by forest

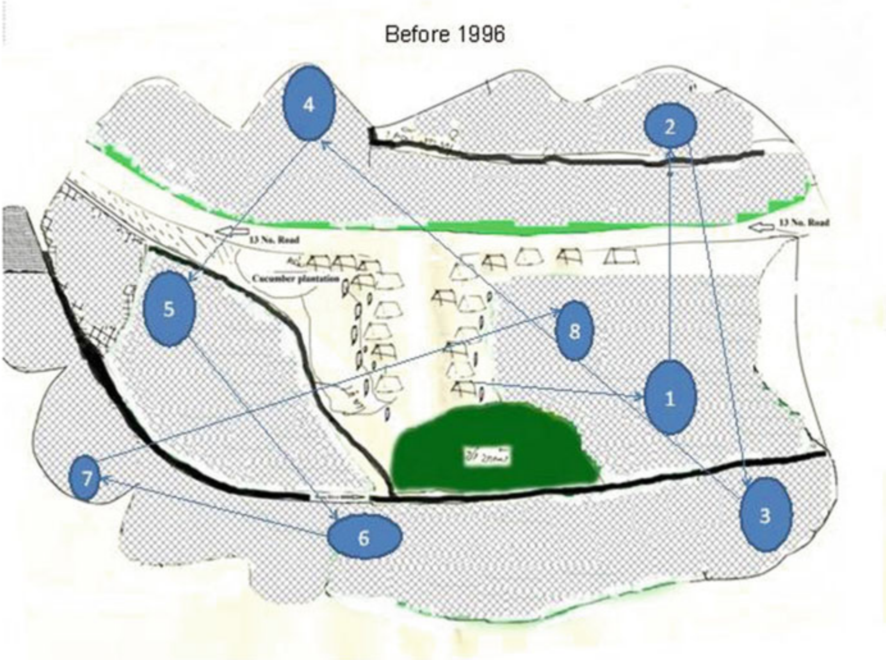

Fig. 6.4 Land use management before 1996. At that time, the land was not controlled by forest policy and the population was low in the village; hence, the fallow period depended on the number of plots of land owned by each household. The *blue circles* denote an example of land use management

policy, and the village population was low; residents were living too far from the road and lacked communication with other communities.

Before 1996, the fallow period in Kachet village depended on the number of plots of land owned by each household. For example, if a household owned eight plots of land, the fallow period for swidden agriculture was 8 years (Fig. 6.4). At that time, a fallow period was usually 8–15 years for each household, depending on the number of plots. However, in 1996, the land area of Kachet village was allocated by the district authority, except for the land that had been traditionally used and cultivated. Half of the total land where farmers conducted swidden agriculture for self-consumption was allocated to a forest area: Protection Forest, Conservation Forest, Regeneration Forest, Production Forest and Degraded Forest (Fig. 6.5). As a result, villagers were forced to change the fallow period.

In 1997–2002, while some households had many plots and were less affected by the government program and kept a fallow period of 6–7 years, others needed to change their fallow period to less than 4 years. Fallow periods of only 3 or 4 years of are insufficient for recovery of forest vegetation or NTFPs; therefore, in 2003, this problem was solved by undertaking two management practices. First, they selected and divided swidden agriculture areas into six zones (Fig. 6.5). Second, swidden agriculture was conducted by the whole village rather

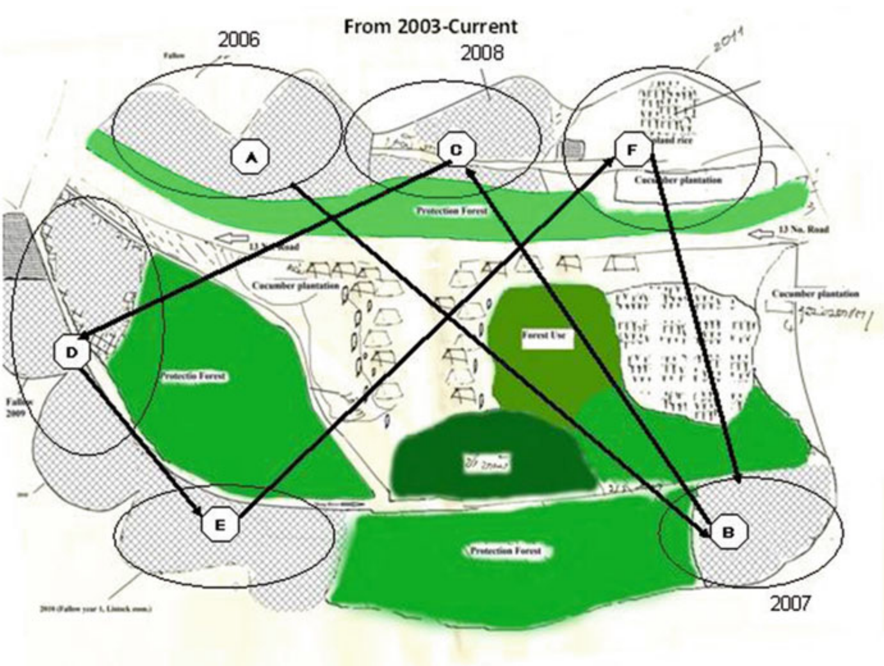

Fig. 6.5 Land use management from 2003 to the present. The *green area* denotes the forest area, as allocated by the district authority as either protection forest, conservation forest, regeneration forest, production forest or degraded forest in 1996. The *circles* from A–E indicate six zones, as allocated for Kachet village in 2003. Using these six zones, swidden agriculture was conducted by the whole village, rather than by each household

than by each household individually. Now all households can conduct swidden agriculture and implement a fallow period of 6 or 7 years by exchanging their land to match the local system.

6.4.2 Fallow Area

To confirm the results of the interviews, we checked the six zones by analyzing satellite images. We used Landsat-ETM+satellite images (ID is Row46/Path129) over 12 years to investigate land use in the Kachet village. Landsat 7 equipped with a sensor was launched on 15 April 1999. The list of data used in this study is shown in Table 6.4. We were unable to obtain the information for 2011 because there were no data for sunny days.

We extracted the swidden area in the village from the true color image of Landsat-ETM+. The extraction was carried out using the following steps. First, we compared the images of a given year with those of the previous year. If there

Table 6.4 Date of Landsat-ETM+imaging from 1999 to 2011

No.	Date (yyyy. mm. dd)	No.	Date (yyyy. mm. dd)
1	1999. 11. 16	9	2006. 12. 21
2	2000. 11. 02	10	2007. 10. 21
3	2001. 11. 21	11	2007. 11. 06
4	2002. 11. 08	12	2008. 11. 08
5	2003. 11. 11	13	2008. 11. 24
6	2004. 11. 13	14	2009. 11. 11
7	2006. 01. 19	15	2010. 11. 14
8	2006. 11. 03		

These images were selected on the basis of harvest date

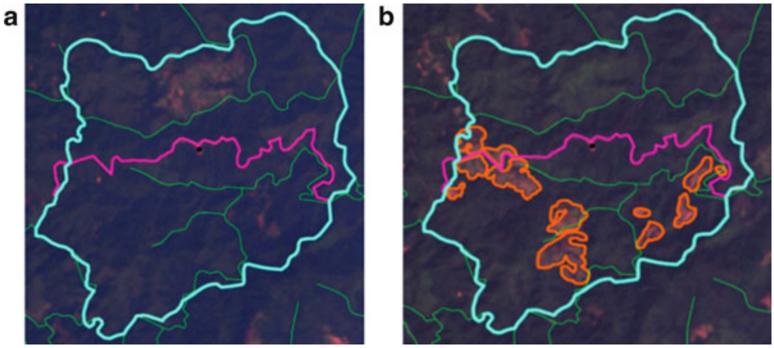

Fig. 6.6 Extraction procedure for the swidden area. Images (**a**) and (**b**) show before and after harvest, respectively. Images (**a**) and (**b**) were taken on 21 November 2001 and 8 November 2002, respectively. The orange polygons in Fig. 6.6b are bare areas

were bare areas in the images where a bare area did not exist in the same region in previous images, we depicted the area as cultivated regions using polygons. Then we compared the images with those of the subsequent year. If there were bare areas in the subsequent images in the same regions, then the polygons were eliminated because these areas might have been used for other purposes than crop cultivation. These areas were quite small (less than 10 ha).

Figure 6.6 shows images of the extractions of the swidden areas. Figure 6.6a, b are the data for 21 November 2001 and 8 November 2002, respectively. The polygons in Fig. 6.6b were the bare areas, while the regions in Fig. 6.6a were covered by forests. Using this method, we estimated the swidden area from 2000 to 2010. Ground-truthing was carried out using Global Positioning System (GPS) data, photos, and interviews in the field.

Figure 6.7 shows the distribution of cultivated regions from 2000 to 2010. There was a road along the center of the village (purple line). To the north of the road, the village had four large areas used for the swidden agriculture. There were three huge areas of swidden agriculture to the south side, and small areas to the southeast side. Swidden agriculture has not been carried out in the forest around the village

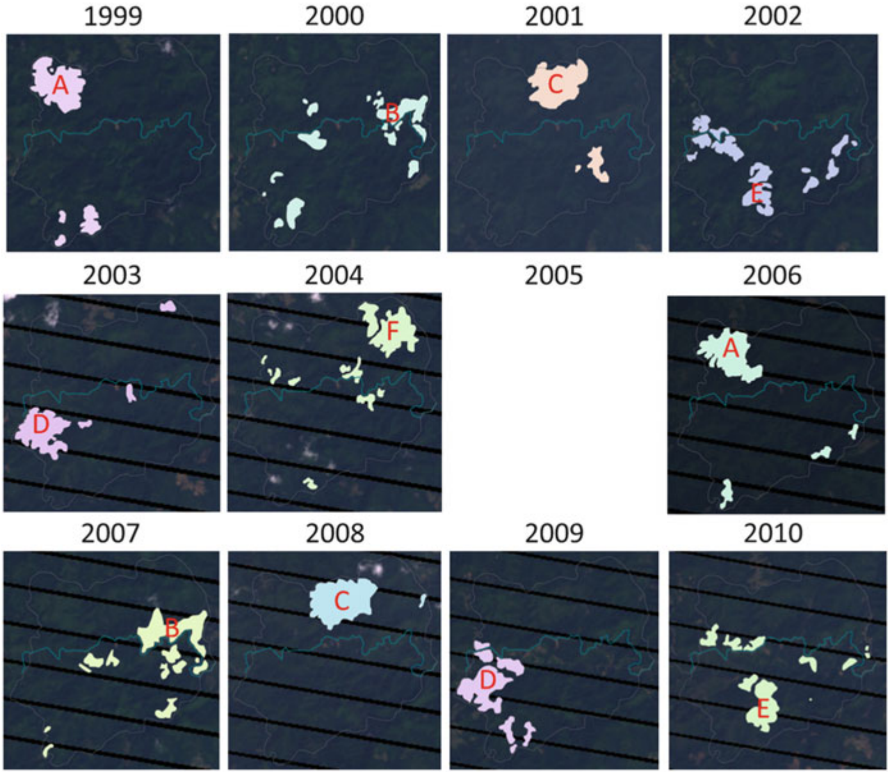

Fig. 6.7 Distribution of harvested areas from 1999 to 2010. Each *letter* denotes the zone and letters used in Fig. 6.5

because it is categorized as protection forest to avoid fire. However, we found that most of the region had been used for swidden agriculture.

Next, we calculated the swidden area from the polygons for each year. The average area from 2000 to 2010 was 160 ± 11 ha year^{-1} (Fig. 6.8). If the swidden cycle is assumed to be 7 years, then the village would need seven units of land, and must allocate 1,120 ha for swidden agriculture (i.e. 160 ha $\times$ 7 year). The area of swidden agriculture was about 750 ha because the village area was about 1,890 ha. Moreover, if forest that has not been used for more than 10 years is categorized as conservation forest, then that forest area would be about 200–300 ha. Therefore, if swidden agriculture is carried out using the same cultivation area as in the past, then an area of about 400–500 ha would be available and can be used for other purposes such as cash crop cultivation.

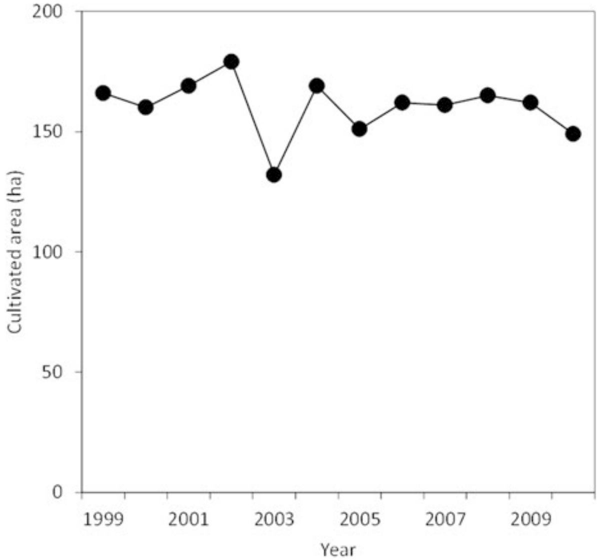

Fig. 6.8 Swidden area calculated from the pixels of the images in Fig. 6.7 from 2000 to 2010

6.4.3 Swidden Cycle

From the swidden area information, we estimated the swidden cycle. We defined the swidden cycle as the period from the first slashing and burning of forest to the next slashing and burning of forest in the same area. For example, if swidden agriculture was carried out in one area and then that area was left fallow for 6 years, then the swidden cycle would be 7. Figure 6.9 shows the swidden cycle for Kachet village from 2006. The cycle for 2011 was estimated from interviews and GPS data. Over 20 years, the average swidden cycle in Kachet village was about 7 years. Inoue et al. (2010) showed that more than 90 % of the swidden areas in northern Laos were fallow for less than 2 years from 1993 to 2005. Therefore, the results of our study indicate that the swidden cycle in Kachet village was longer than in other regions.

6.5 Discussion

Government policy and population pressure have influenced the lifestyle of local people who depend on swidden agriculture and NTFPs. We lacked detailed information on changes in plant utilization and land use management for swidden agriculture; therefore, we investigated the plant utilization and land use management of swidden agriculture using interviews, a vegetation survey, and by analyzing satellite images.

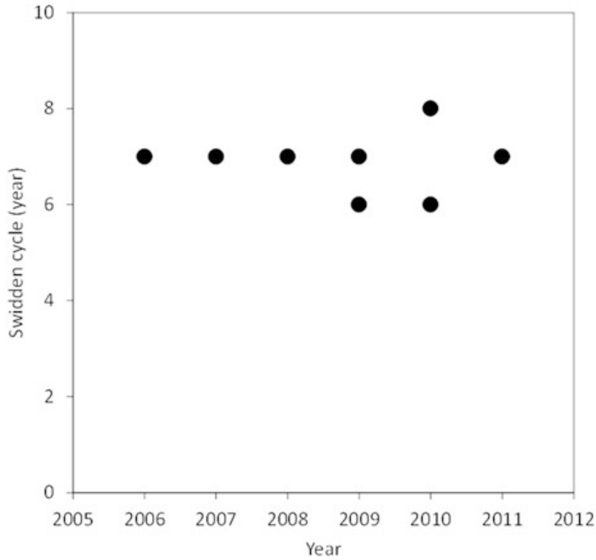

Fig. 6.9 Swidden cycle in Kachet village from 2006 to 2011. The swidden cycle was determined from the swidden area in Fig. 6.8. We defined the swidden cycle as the period from the first slashing and burning of forest to the subsequent slashing and burning in the same area

The interview questions and vegetation surveys revealed that most of the NTFPs with economic value were observed in long fallow year quadrats (Figs. 6.2 and 6.3, Tables 6.2 and 6.3). The numbers of species and use subcategories observed in the short fallow year quadrats were less than those observed in the long fallow year quadrats. These results indicate that villagers receive more economic benefits from NTFPs in forests that were fallow for longer periods.

Additionally, because they had fewer weeds, rice yields from older forest fallows were higher than those from fields having young secondary growth. The numbers of species in the edible and medicine use subcategories were higher than those in the other subcategories; trap use was the second frequently observed subcategory in the tool use category. Moreover, the important foods from NTFPs were observed mostly in long fallow year quadrats. Therefore, longer fallow periods should contribute to food security in Kachet village.

Longer fallow periods have contributed to the livelihood of residents in Kachet village for a long time. However, in 1996, the land area of Kachet village was allocated by the district authority, which threatened traditional management of swidden agriculture. In 2003, two activities were deployed to avoid shortening of the fallow period. First, villagers selected and divided swidden agriculture areas into six zones. Within the six zones, the villagers exchanged fields for swidden agriculture, and managed to retain a relatively long fallow period. Second, swidden agriculture was conducted by the whole village, rather than by each household individually. As a result, all households could conduct swidden agriculture, and keep a fallow period of 6 or 7 years. We confirmed these activities by analyzing satellite images. From these results, we conclude that the villagers of Kachet village changed their fallow management and succeeded in maintaining a suitable fallow period to produce NTFPs.

Recently, market economy has infiltrated to mountain villages and some villagers start to select commercial crops in swidden fields. However, villagers also have conducted sustainable land use to match the situation. Keeping the land use management and plant utilization in the fallows is important for sustainable development of this area.

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Chapter 7
Spatial Analysis of Flood Area and Its Impact on Rice Production on Vientiane Plain

Tomoya Abe, Takashi Sekiya, Kaya Kanemaru, and Kohei Okamoto

Abstract We used spatial analysis of flood area to estimate the impact of 2011 floods on rice production in Dong Khuai Village, Xaithany District, Vientiane Prefecture, Laos. We investigated the following: (1) Change of rice paddy area using Global Positioning System (GPS) tracking and information from interviews; (2) variability of flood area estimated by numerical modeling; and (3) land use classification using satellite imagery. Overall, we found that the flooding in 2011 had a significant impact on rice production in Dong Khuai Village. GPS data, flood simulations, and satellite imagery showed that many rain-fed rice cultivation areas decreased as a result of the massive floods. The flooding caused the loss of rice seeds, which prevented villagers from continuing floating rice cultivation. Based on our analysis, we propose conversion of wastelands to floating rice fields, and the creation of a buffer zone based on flood risk information. In addition, we recommend establishment of a sharing system for floating rice seed to reduce the risk of seed loss.

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Keywords Flood model simulation • Lowland rice production • NDVI • NDWI • Risk management

7.1 Introduction

Rain-fed paddy fields in Laos are spread across lowlands along the Mekong River. However, rain-fed rice production in lowland areas is strongly vulnerable to flooding during the rainy season. Interannual rice yield changes under the influence of rainfall amount and seasonal water level fluctuation in rivers (Adachi et al. 2010b; Ono et al. 2011). In the rainy season, the water level of Mekong River tributaries rises 4–5 m and the flood plain is submerged. A trend of high annual precipitation has been observed since the 1990s, and flood disasters are frequent (Ono and Sivilay 2007).

Before 2010, water level and river flooding fluctuations in the rainy season were mainly associated with rainfall amount. However, massive artificial floods in 2011 had a critical impact on rice production in the lowlands of the Mekong Valley. In that year, two tropical storms, Haima and Nock-Ten, successively struck the Vientiane Plain, and heavy rains surged into the rivers, including the Nam Ngum. Water in the Nam Ngum 1 hydropower plant reservoir increased to dangerous levels. As a result, water was released from the reservoir. The rapidly rising water level affected the lowlands on the Vientiane Plain, including the Xaithany District. This study clarifies the effect of the 2011 floods on rice production in Dong Khuai Village in Xaithany District, Vientiane Prefecture, Laos.

Dong Khuai Village is about 30 km by road from the center of Vientiane Capital (Fig. 7.1). The Mak Hiao River, a branch of the Mekong River, flows along the southern boundary of the village (Fig. 7.2). Dong Khuai is believed to have existed for more than 150 years on the Vientiane Plain (Adachi et al. 2010a). Its population in 2005 was 1,289, with 255 households (Oba et al. 2008). Ninety-three percent of households are engaged in rain-fed rice production. The village covers 2,528 ha, including 820 ha of paddy fields (Adachi et al. 2010a, b). Most settlements are on hills or river terraces adjacent to the flood plain (Ono and Sivilay 2007). The lowest paddy fields are close to branches of the Mekong River and to ponds. The villagers live traditionally, undertaking rice production during the rainy season and using various natural resources to secure cash income (Nishimura et al. 2010). Village activities include fishing in rivers, ponds, or rice fields, hunting and gathering of plants, insects and small animals in the forest, grazing of cattle and buffaloes, and production of charcoal and salt (Ikeguchi and Nishimura 2007). Over the last 20–30 years, rice paddies have been established in lowland areas prone to river flooding during the rainy season (Adachi et al. 2010b).

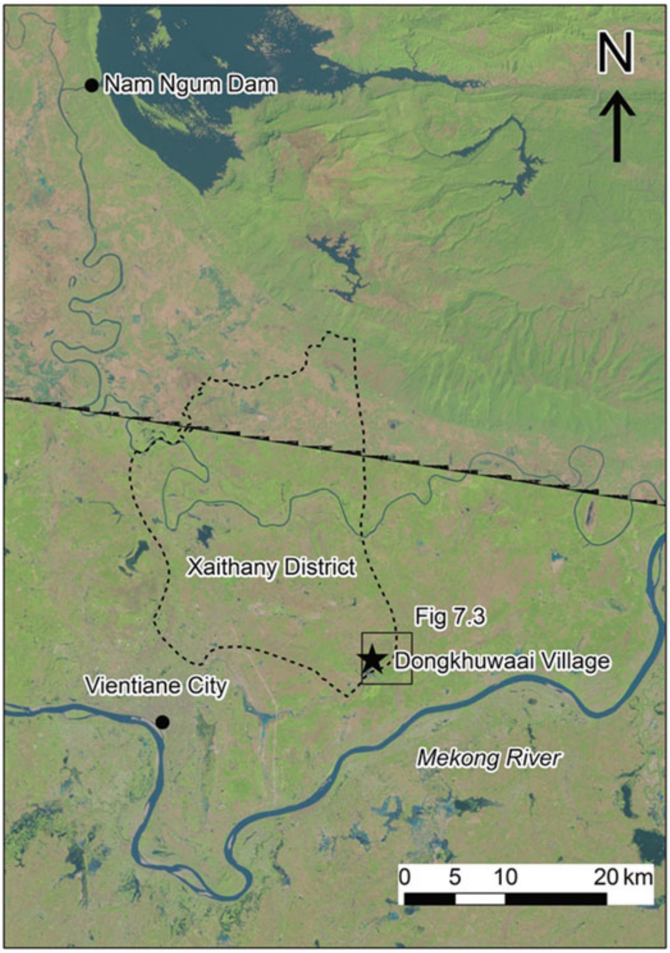

Fig. 7.1 Landsat image (2009 dry season) showing location of Dong Khuai village

7.2 Impact of 2011 Flooding on Rice Cropping Area and Rice Production

7.2.1 GPS Survey of Paddy Field Distribution

To clarify effects of the 2011 floods, we compared the distribution of rice fields in 2012 with that in 2006 (Fig. 7.2) reported by Adachi et al. (2010b). The boundary between cropping and non-cropping fields in the lowlands of Dong Khuai Village was identified based on field surveys, using Global Positioning System (GPS) instrumentation (Dakota 20; Garmin Ltd., USA). The surveys were conducted during the rainy season (August 8–14, 2012).

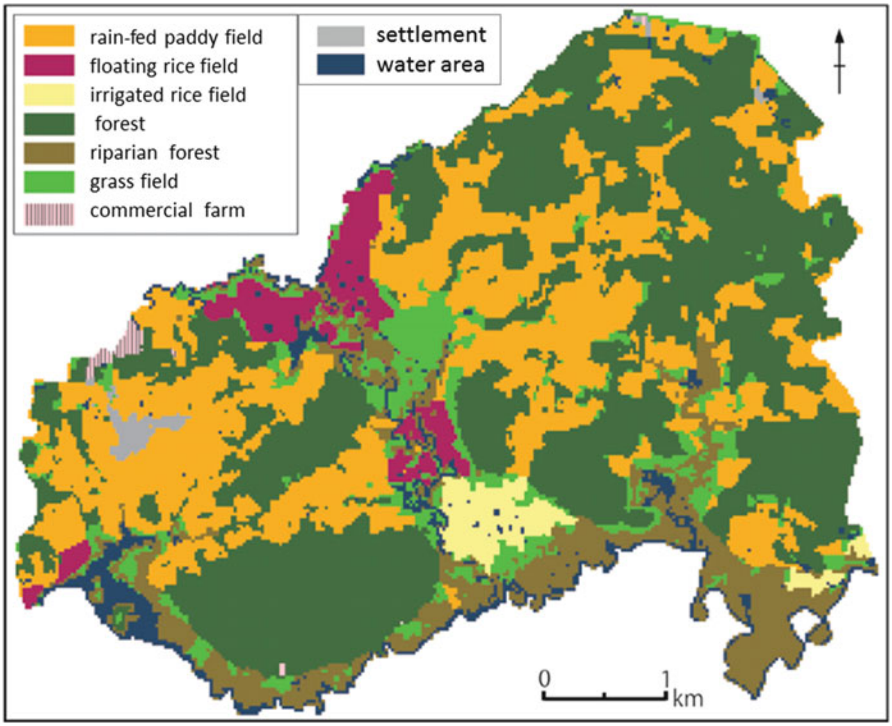

Fig. 7.2 Land use in Dong Khuai village in 2006 (Adachi et al. 2010b)

We focused on two areas, Area 1 to the southwest of the settlement, near the Mak Hiao River, and Area 2 to the northeast of settlement, near a pond (Fig. 7.3a). Major land uses in 2006 were floating rice fields and rain-fed paddy fields in Area 1 and 2 (Fig. 7.2). From our 2012 GPS survey, we found that rain-fed paddy field areas had decreased and floating rice fields had disappeared in Area 1 (Fig. 7.3b). The area of rain-fed paddy fields also decreased in Area 2 (Fig. 7.3c) from 2006 to 2012. The decrease of cropping area at the Area 1 site (12.8 ha) was larger than that of the Area 2 site (4.6 ha). In Area 1, the 6.5 ha of floating rice fields in 2006 had disappeared by 2012, and the rain-fed paddy field area in 2012 decreased to about one-third its size in 2006 (from 10.0 ha to 3.6 ha). In Area 2, the rain-fed paddy field area in 2012 decreased to about three-fifths its area in 2006 (from 12.6 ha to 8.0 ha) By 2012, rice fields at both sites had been set back to higher areas near the forest and villagers' houses.

7.2.2 *Interviews of Deputy Village Head and Villagers*

7.2.2.1 Deputy Village Head Interview

We interviewed a deputy village head on the recent situation of rice cultivation in the village. The interview results are summarized as follows. (1) The number of

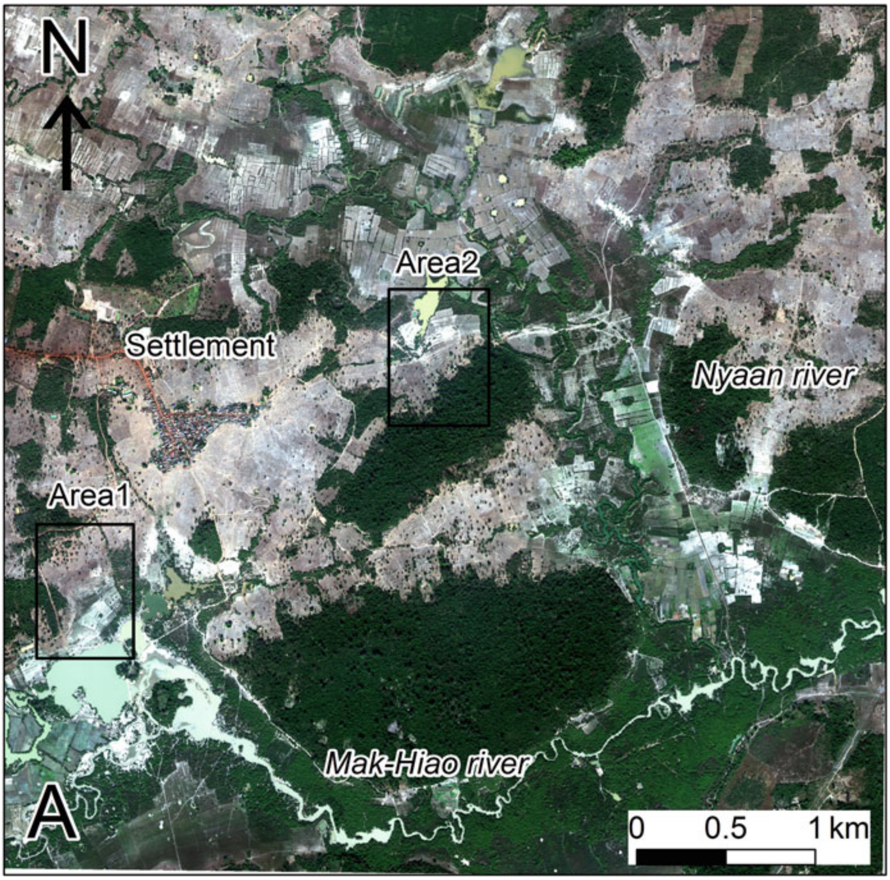

Fig. 7.3 Location of GPS survey sites, Mak Hiao river, Nyaan river and village settlement (**a**). Decreases of rice cropping areas from 2006 to 2012 in Area 1 (**b**) and Area 2 (**c**). WorldView-2 image from 2011 dry season was used as base map

villagers cultivating floating rice considerably decreased in recent years, because of the loss of seeds from the massive 2011 floods. (2) The harvest of floating rice is more difficult than that of rain-fed rice. (3) Most floating rice cultivated is non-glutinous (uruchi mai in Japan). (4) Floating rice is cultivated in lowland areas, where there is high flood risk during the rainy season. (5) Floating rice production is intended to generate cash income for households rather than for self-consumption. (6) Most households have their rice paddy fields at higher altitude, and 40 % of households have the rice paddy fields at lower altitude. (7) Nam Ngum Dam discharged water in 2011 because of heavy rainfall during the rainy season. (8) About 10 % of households cannot grow enough rice annually for self-consumption because of low rice yields.

Fig. 7.3 (continued)

7.2.2.2 Villager Interviews

We interviewed nine village households regarding rice yield from rain-fed paddy fields and floating rice fields in 2010 and 2011. Results are summarized as follows. (1) Rice yield per household from rain-fed paddy fields was 1,000–5,880 kg in 2010 and 850–6,600 kg in 2011. (2) Yield per household from floating rice fields was 0–3,600 kg in 2010 and 0–1,250 kg in 2011. (3) Most households (8 of 9) had no yield from their floating rice fields in 2011, associated with the rapidly rising water level caused by the massive floods during the rainy season (Table 7.1).

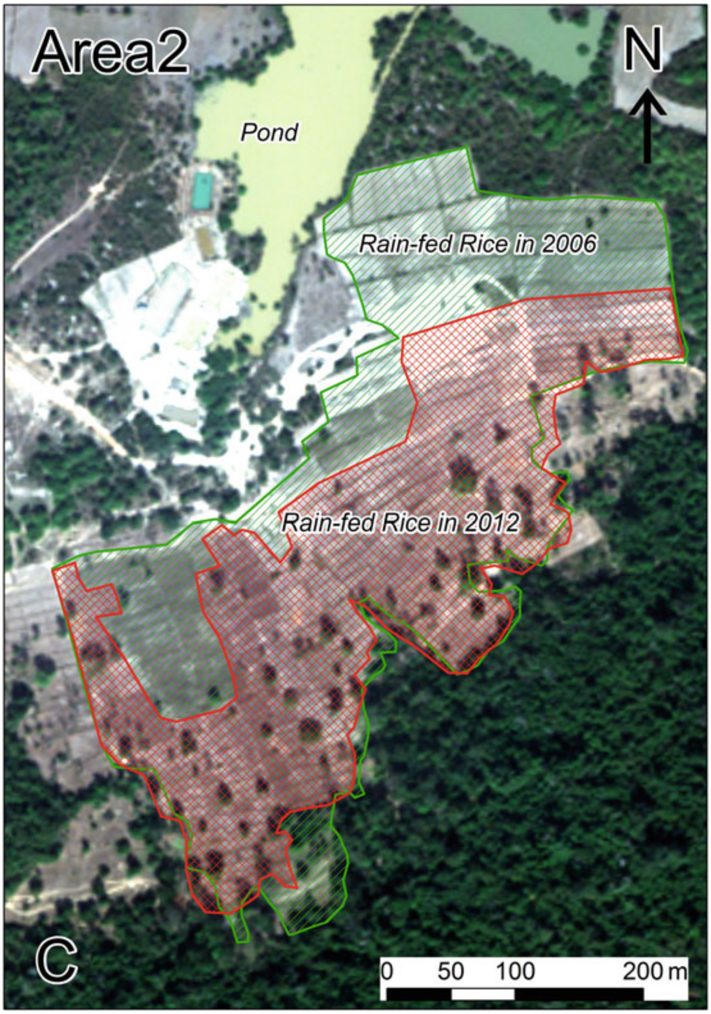

Fig. 7.3 (continued)

Table 7.1 Yield of nine households from rain-fed paddy fields and floating rice fields in 2010 and 2011

	Yield from rain-fed paddy field (kg)		Yield from floating rice field (kg)	
Households	2010	2011	2010	2011
1	1,000	1,400	0	1,250
2	2,500	2,500	1,000	0
3	2,510	2,510	3,200	0
4	4,000	850	1,950	0
5	1,000	1,000	1,000	0
6	2,400	1,900	3,600	0
7	2,750	4,500	No cropping	No cropping
8	5,880	6,600	1,150	0
9	No cropping	No cropping	750	0

7.3 Variability of Flood Area Distribution

In Dong Khuai Village, paddy fields are influenced by extraordinary river water levels (Ono et al. 2011). Moreover, paddy fields have been expanded to lower areas (Adachi et al. 2010b). Because low-lying areas are easily flooded, paddy fields can be more impacted by high water levels.

Flood simulation is an effective means of assessing the impact of flooding on land use. This simulation has been used to evaluate groundwater resources, nutrient transport, flood control, and risk of large-scale waterborne infection in the watershed of the Mekong River (Kazama et al. 2007, 2009, 2012; Yoshimura and Takeuchi 2007). However, such simulation has not been used to evaluate the impact of flooding on a village scale in the Mekong River area. In Japan, Yoshimura and Hoshikawa (2012) investigated comprehensive flood control measures, including topography and land use. We developed a numerical model to assess flood impact on a rice paddy field in Dong Khuai Village, focusing on the relationship between the 2011 flood and decrease in paddy field area. In addition, we measured the water area boundary in the village to validate the flood simulation.

7.3.1 Flood Model

We developed a numerical model for flood simulation in Dong Khuai Village. The model consists of river flow, floodplain flow, and overflow modules. Although the model considers rainfall and infiltration processes, it does not treat evaporation, groundwater flow, or other processes. We used a dynamic wave model in the modules of river and floodplain flow. That model is suitable for flood calculation on flat topography, such as that of Dong Khuai. The description of each module is presented below.

7.3.1.1 River Flows

River flows are estimated using a one-dimensional dynamic wave model. The model consists of a continuity equation and momentum equation, as follows.

$$\frac{\partial h}{\partial t} + \frac{\partial M}{\partial x} = 0 \tag{7.1}$$

$$\frac{\partial M}{\partial t} + \frac{1}{2}\frac{\partial vM}{\partial x} + gh\frac{\partial H}{\partial x} + g\frac{n^2|v|M}{h^{4/3}} = 0, \tag{7.2}$$

where h is water depth of the river, M (=vh) is discharge flux (m^2/s), g is gravitational acceleration (m/s^2), v denotes river flow speed (m/s), H is water table depth (m), and n is the Manning coefficient.

Table 7.2 Summary of formulations and parameters used in the model

	Formulation/Parameter
Surface flow	2D-dynamic wave model (Fukuoka et al. 1985)
River flow	1D-dynamic wave model
Overflow	Overflow formula (Honma 1940a, b)
Manning roughness	0.2
Infiltration capacity	10 mm/h
River depth	Mak Hiao river: 1 m
	Nyaan river: 50 cm
River width	Mak Hiao river: 50 m
	Nyaan river: 25 m

The previous two equations were discretized using a finite difference technique, expressing a forward difference in time and central difference scheme in space. For the nonlinear term in Eq. (7.2) (second term on left side), an upward difference was used. The friction term in that equation (fourth term on left side) was solved implicitly. These exceptions were applied for stabilizing calculation. Spatial resolution and time step were selected as 90 m and 1 s, respectively. Other model parameters are given in Table 7.2.

7.3.1.2 Floodplain Flow

A two-dimensional dynamic wave model was used to calculate water distribution on the floodplain. The model equations are written as

$$\frac{\partial h}{\partial t} + \frac{\partial M}{\partial x} + \frac{\partial N}{\partial y} - q = 0 \tag{7.3}$$

$$\frac{\partial M}{\partial t} + \frac{\partial uM}{\partial x} + \frac{\partial vM}{\partial y} + gh\frac{\partial H}{\partial x} + g\frac{n^2 M\sqrt{u^2 + v^2}}{h^{4/3}} = 0 \tag{7.4}$$

$$\frac{\partial N}{\partial t} + \frac{\partial uN}{\partial x} + \frac{\partial vN}{\partial y} + gh\frac{\partial H}{\partial y} + g\frac{n^2 N\sqrt{u^2 + v^2}}{h^{4/3}} = 0, \tag{7.5}$$

where h is water depth on the floodplain; M (=uh) is discharge flux (m^2/s) in the x direction; N (=vh) is discharge flux (m^2/s) in the y direction; u and v denote the speed of water flow (m/s) in the x and y directions, respectively; g is gravitational acceleration (m/s^2); H represents water table depth (m); n signifies the Manning coefficient; q refers to inflow per unit area, such as rainfall, overflow, or infiltration. The differential scheme is the same as the river flow module. Spatial resolution and time step were adopted as 90 m and 1 s, respectively.

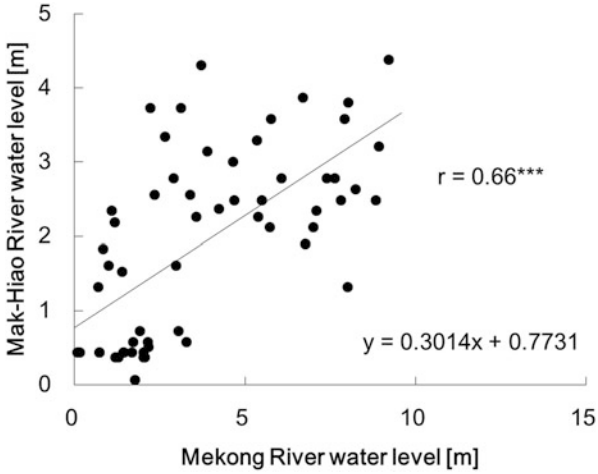

Fig. 7.4 Scatter diagram of Mekong and Mak Hiao rivers (m) during January 2009 through March 2010. Fitted line and correlation coefficient (r) are overlaid

7.3.1.3 Overflow

River water flows to the floodplain area in the rainy season. In our model, overflow between the river and floodplain is calculated as complete overflow and submerged flow under supercritical and subcritical flow, respectively. If river water flows on dry land, complete overflow occurs. If river water flows in wet areas, submerged overflow occurs. The complete flow (Qc) and submerged flow (Qs) are calculated by

$$Q_c = 0.35Bh_1\sqrt{2gh_1} \tag{7.6}$$

$$Q_s = 0.91Bh_2\sqrt{2g(h_1 - h_2)}, \tag{7.7}$$

where B is width of the overflow, h_1 is river water height from the river bank, and h_2 is water height of the floodplain above the river mound.

7.3.1.4 Dataset

Water levels of the Mak Hiao River were used as boundary conditions for flood simulation. These levels were estimated from measured water levels of that river (Ono et al. 2011) and the Mekong River. Measured water levels of the Mak Hiao are available from September 2008 to March 2010. Figure 7.4 shows a scatter diagram of Mekong and Mak Hiao river data during this period, indicating a positive correlation ($r = 0.66$), significant at the 99 % confidence level. Using this relationship, we estimated water levels of the Mak Hiao after April 2010. We used

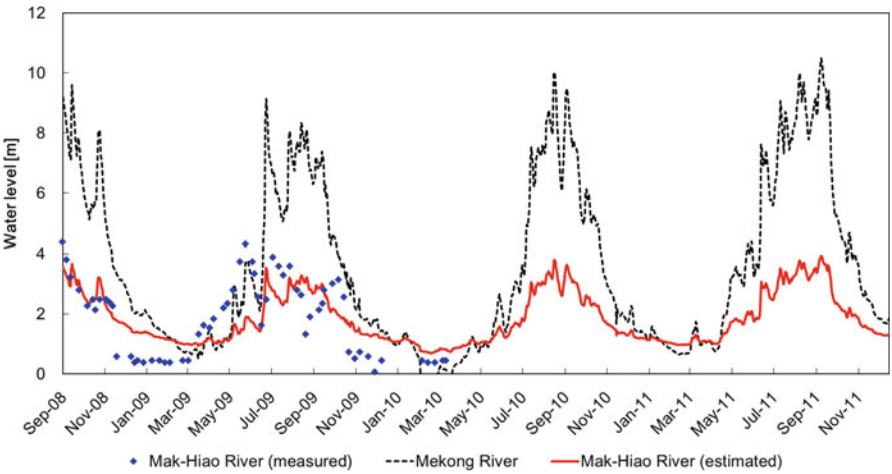

Fig. 7.5 Measured water levels of Mekong (*dashed line*) and Mak Hiao (*blue dots*) rivers and estimated water level of Mak Hiao (*solid red line*)

an average of water levels measured at Vientiane and at km 4, Thadeua Road in Vientiane as the Mekong River water level. Figure 7.5 presents measured water levels of the Mekong and Mak Hiao and estimated levels of the Mak Hiao.

The finished 3 arcsecond Shuttle Radar Topography Mission (SRTM-3) dataset derived from C-band radar (Hensley et al. 2000) was used for elevation in the flood simulation. Rainfall data were taken from the United States National Climatic Data Center (ftp://ftp.ncdc.noaa.gov/pub/data/gsod/). Water boundaries were measured by GPS for simulation validation. Location accuracies were about 20 m in this survey.

7.3.2 Result and Discussion

7.3.2.1 Comparison of Simulation with Water Boundary Data

We performed simulation for 2012 for the validation. Because water level data of the Mekong River were unavailable, 2009 water level data were used for the simulation. Figure 7.6 shows elevation and simulated water levels of the floodplain on August 11, 2012. The simulated water boundary (red line) generally agrees with the measured one (black dots), suggesting that the simulation is valid. However, two points are about 90 m from the simulated water boundary. These discrepancies are due to a lack of model spatial resolution. The model cannot consider the effects of subgrid scale (<90 m) landforms.

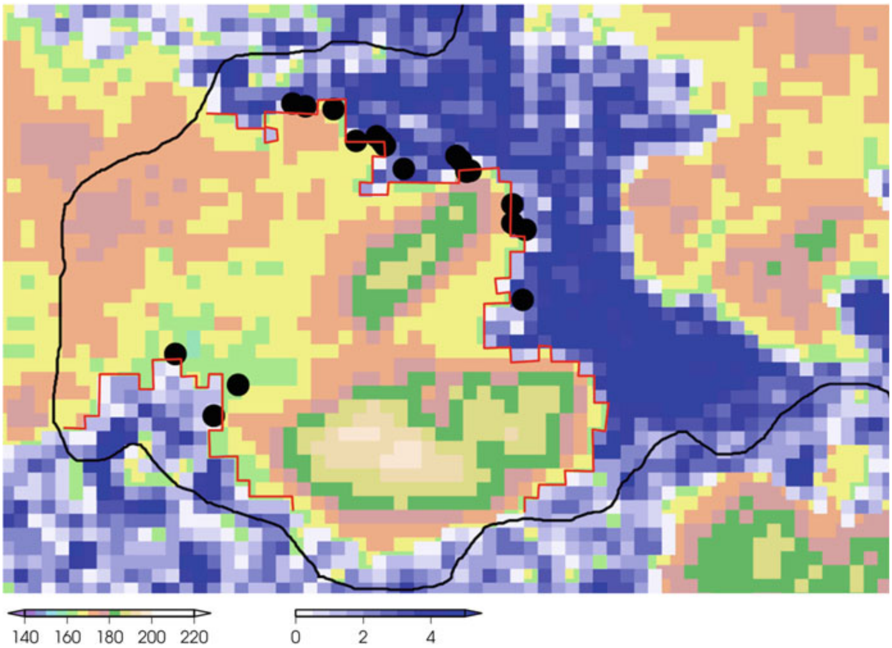

Fig. 7.6 Elevation and simulated water level of floodplain (*blue areas*) on August 11, 2012. *Red line* is simulated water boundary, *black dots* outline water boundary measured by GPS. *Triangle* is Dong Khuai village settlement

7.3.2.2 Flooding in 2011 and Its Relationship to Change of Paddy Fields

We performed simulations for 2011 and 2009. Although the focus was on the 2011 floods, we conducted simulation for 2009 as a reference. Figure 7.7a presents elevation and simulated water levels of the floodplain on September 23, 2011. Flood areas are distributed along the Mak Hiao and Nyaan rivers. In particular, the southwest part of the village along the Mak Hiao (Area 1 in Fig. 7.3) and northern and central parts along the Nyaan were flooded near the village settlement. We focus on Area 1 because decreases in rain-fed and floating rice fields were measured there (Sect. 2.1). Decreases of the paddy fields were also measured in the northern part of the village. However, we do not focus on this area, because the scale of the decrease is small compared with model resolution. In addition, the simulation bias is large there.

Figure 7.7b, c respectively shows an enlarged map of Fig. 7.7a and a GPS waypoint of a surviving paddy field. Diminished paddy field was found in the south of the surviving paddy field, as mentioned in Sect. 2. The simulation shows that the area of decreased paddy field was flooded by more than 3 m. We compared water levels of the area in 2011 with those in 2009 (Fig. 7.7d). Average water levels from July through September 2011 were 0.5 m higher than those in 2009 in the simulation.

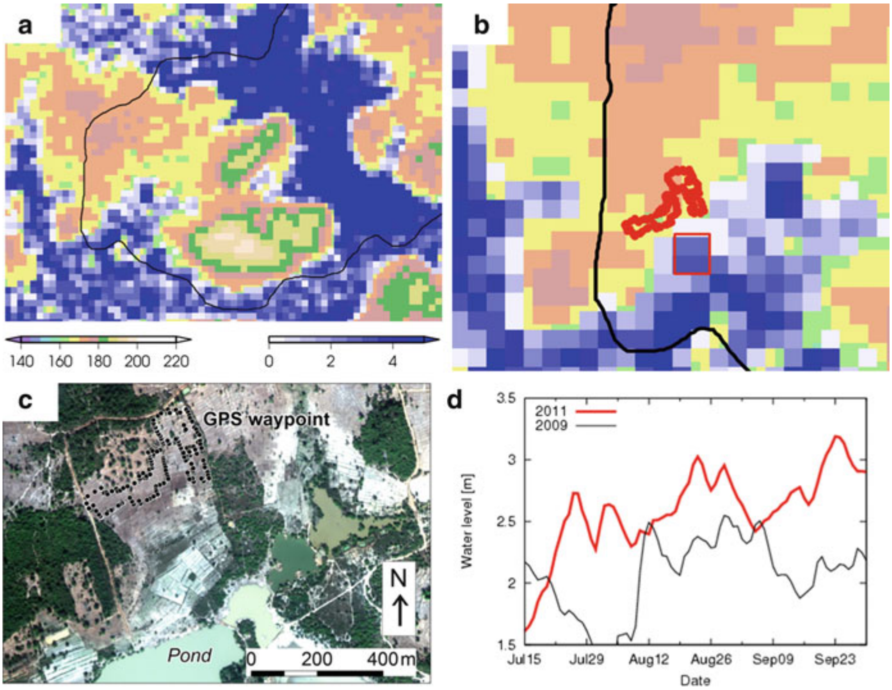

Fig. 7.7 (**a**) Elevation and simulated water level of floodplain on September 23, 2011. (**b**) Enlarged map of panel **a**. (**c**) GPS waypoint of surviving paddy field. (**d**) Time series of water level in 2009 and 2011. Time series is averaged over area indicated by square in panel **b**

The highest water level on September 23, 2011 was about 1 m higher than that on the same date in 2009.

The simulation includes some uncertainties, such as lack of resolution and the estimated water levels of the Mak Hiao River, because water level on the floodplain is strongly dependent on river water level and the elevation. Simulated change of floodplain water level can be also biased low or high. Nevertheless, the simulated flood area corresponds to the diminished paddy field in the southwest area of the village. The result indicates that this reduced paddy field area was partly attributable to the 2011 floods.

7.3.2.3 Assessment of Mak Hiao River Improvement

We assessed the impact that dredging of the Mak Hiao River would have on the flood area, using the model. Although river improvement is planned in Dong Khuai Village, a detailed plan was unavailable. We assumed dredging of 2 m in the simulation. We evaluated the impact of dredging given the conditions on September 23, 2011. The flood area in the dredging case (Fig. 7.8b) was drastically reduced relative to that of the current case (Fig. 7.8a).

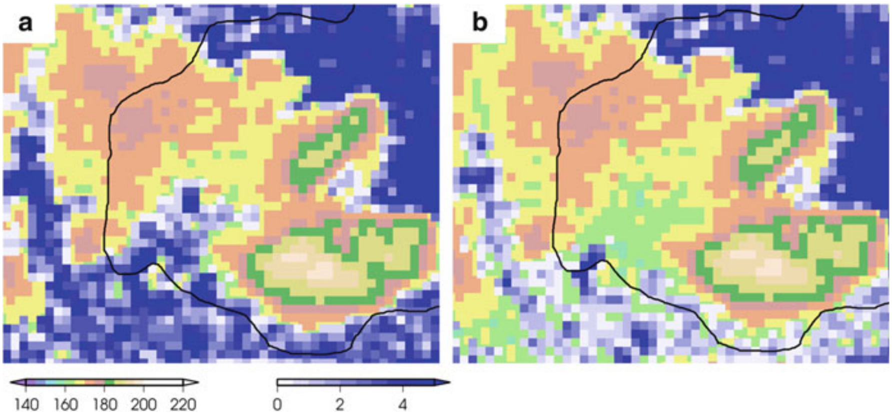

Fig. 7.8 Elevation and simulated water level of floodplain on September 23, 2011 in the non-dredging case (**a**), and the 2-m dredging case (**b**)

Dredging of the Mak Hiao River can reduce damage to paddy fields caused by massive flooding, such as in the case in 2011. However, decreasing the flood area may prevent villagers from engaging in major livelihood activities, such as fishing. A prior assessment of river improvement is needed, which should consider the impact on villagers' livelihoods.

7.4 Flood Risk Impacts and Spatial Analysis

In Sect. 7.3, the simulation revealed the area affected by flooding. To confirm the performance of the flood simulation, validation is needed to compare it with natural variation. A satellite remote sensing technique is useful to determine the spatial pattern of land use. Methods to estimate the water surface from satellite images have been developed in previous studies (e.g., Gao 1996; McFeeters 1996). Takeuchi and Yasuoka (2004) developed a means to estimate land use by various relationships of the differences in sensor channels. In this section, we evaluate spatial distributions of the water surface in the rainy season and compare the simulation result with satellite images.

7.4.1 Data and Methodology

We used satellite images from the Landsat 7 Enhanced Thematic Mapper Plus (ETM+) provided by U.S. Geological Survey (USGS). We introduced the

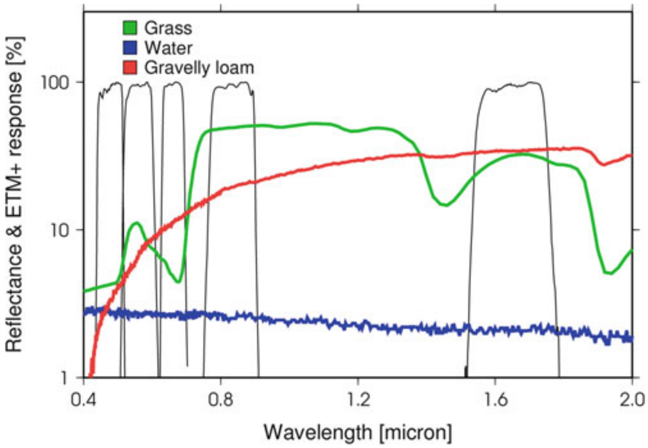

Fig. 7.9 Reflectance properties of land cover and response functions of Landsat 7 ETM+ bands (*black*) 1–5. *Colored lines* indicate gravelly loam (*red*), green grass (*green*), and water (*blue*)

normalized difference vegetation index (NDVI), an indicator of green vegetation (Tucker 1979), to describe the land use pattern:

$$\text{NDVI} = \frac{\rho_4 - \rho_3}{\rho_4 + \rho_3}, \tag{7.8}$$

where ρ is the surface reflectance of an ETM+ band number. Takeuchi and Yasuoka (2004) pointed out that the normalized difference water index (NDWI) indicates water area. NDWI is analogously calculated by the band relation of reflectance ρ between ETM+ bands 3 and 5, where

$$\text{NDWI} = \frac{\rho_3 - \rho_5}{\rho_3 + \rho_5}. \tag{7.9}$$

NDVI and NDWI were obtained at 30-m spatial resolution. Figure 7.9 shows response functions of ETM+ bands 1–5 and reflectance properties of land cover. The response functions of ETM+ provided by Kotchenova et al. (2006) and land cover properties provided by Baldridge et al. (2009) were used. The difference in bands is an indicator to capture the spatial distribution of the land surface.

The ETM+ product originally contained radiance at the top of the atmosphere (TOA). In this study, ρ was estimated from TOA radiance by the Second Simulation of a Satellite Signal in the Solar Spectrum (6S) radiative transfer code (Kotchenova et al. 2006). The TOA radiance contains not only surface properties but also information on atmospheric conditions (e.g., air temperature, water vapor, ozone mass, and aerosols), so that contamination of atmospheric conditions is removed by 6S algorithm using atmospheric data. This process is known as the atmospheric correction. The present study used vertical profiles of air temperature, water vapor,

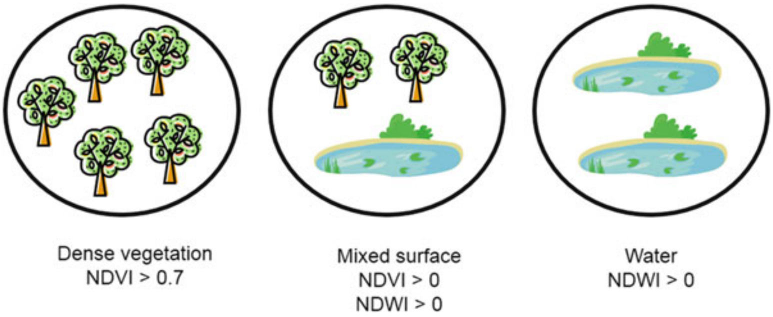

Fig. 7.10 Method of land-use classification in current study. NDVI and NDWI were used as thresholds to categorize land-use types

and ozone from the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA-Interim reanalysis data (Dee et al. 2011) to estimate ρ. We did not, however, apply the aerosol correction and remove clouds. Satellite images from August 19 and September 20, 2010 were free from cloud contamination and small influence of aerosols because of the rainy season in Laos. Water area simulated by the flood model (Sect. 3) was compared with satellite images. The flood simulation results were originally obtained at a 90-m resolution and resampled to a 30-m resolution.

We developed a technique of land-use classification using NDVI and NDWI. The current method categorizes four land use types, dense vegetation, water, mixed, and other (Fig. 7.10). Dense vegetation was defined as NDVI > 0.7. A threshold is theoretically estimated as surface type green grass (Fig. 7.9). Water surface was defined as NDWI > 0. Takeuchi and Yasuoka (2004) showed that the water surface type has only positive values, compared with other classifications. Mixed surface was defined by positive values of both NDVI and NDWI. In Fig. 7.9, the reflectance spectrum of green grass increases with wavelength; in contrast, that of water surface decreases with wavelength. Therefore, a mixed surface is introduced to explain the discrepancy of sign of NDVI and NDWI.

7.4.2 *Results of Satellite Images*

Comparisons between land use estimated by satellite images and simulation results are shown in Fig. 7.11. Water area simulated by the current model corresponds overall to satellite estimates (cyan color). Water area was widespread at the southwest of the village. The mixed surface, including water and vegetation, was near the village settlement, presumably corresponding to rice fields. The dense vegetation area was at high-elevation forest area. Thus, land use estimation was reasonably captured by satellite. Moreover, the simulation result consistently

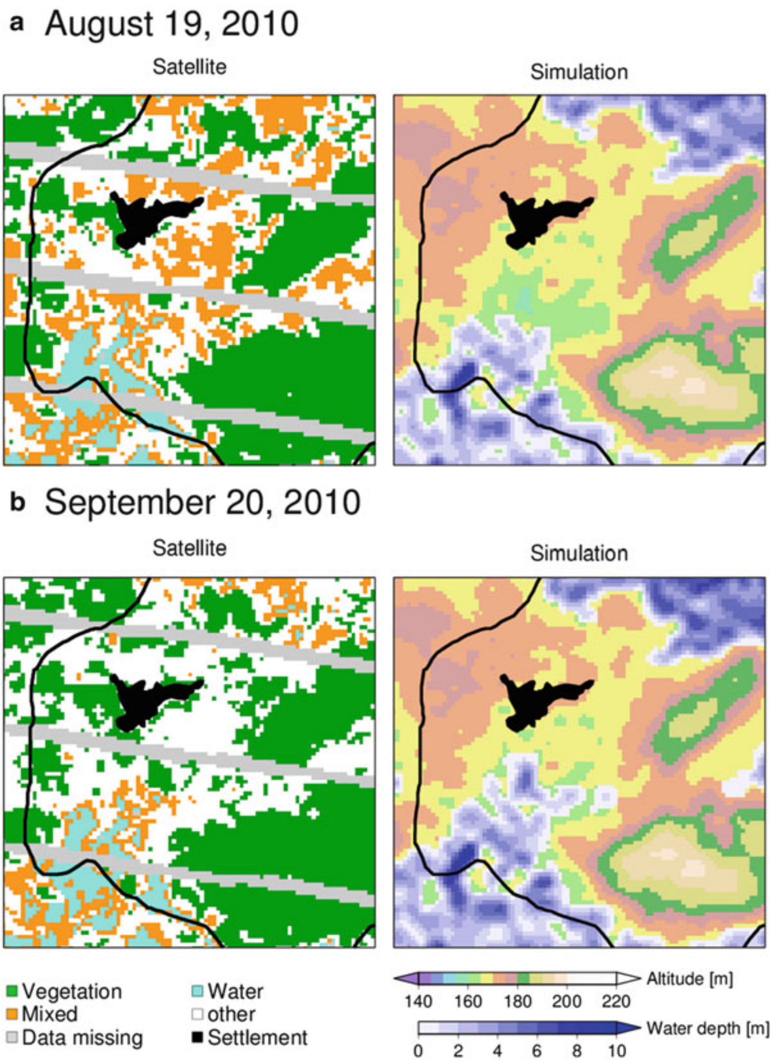

Fig. 7.11 Land use classification image (*left*) and flood map (*right*) in the southern village area (Area 1) on (**a**) August 19, 2010 and (**b**) September 20, 2010

captured the water area. The difference of water area between simulation and satellite is shown on September 20, 2010. The water area was generally captured by the simulation; however, that area tended to be farther northward compared with the satellite estimation. The overestimation of water area is in a small basin (see elevation in Fig. 7.11). Once water area is stored by river flow or local precipitation, water removal processes are not strong. The current model only includes the simple infiltration process of water into the soil. The evaporation process also discharges water and can be simply estimated by atmospheric parameters. Dong Khuai Village is near Vientiane, where a weather station observes surface parameters. One suggested future improvement to the flood model is to introduce the evaporation process.

7.5 Discussion and Conclusion

We investigated the relationship between change of paddy fields in Dong Khuai Village and massive flooding there in 2011. A GPS survey showed a decrease in cultivation area of floating rice and rain-fed paddy fields from 2006 to 2012. The 2011 floods caused the loss of rice seeds, and prevented villagers from continuing floating rice cultivation. We developed a flood model to estimate the 2011 flooding distribution. The model result showed that the flood area corresponds to the paddy field area decrease in the southwest part of Dong Khuai. This suggests a close relationship between the floods and paddy field change in 2011.

Satellite images were analyzed to evaluate the flood map obtained from the flood model simulation. Land-use classifications were successfully captured from satellite images. Flood maps produced by the flood model were generally consistent with the satellite estimation; however, the simulation results tended to be sensitive because of the small basin. An improvement of the current model is to incorporate the evaporation process for discharging stored water.

This study was part of the Clinical Environmental Studies of the Nagoya University Global COE Program. In clinical environmental studies, it is important to provide not only a diagnosis of environmental problems but also to suggest a treatment. A general treatment for mitigating flood risk might be river improvement. Using flood model simulation, we made a tentative assessment of Mak Hiao River improvement (Sect. 3.2.3). The improvement simulation assumed dredging of 2 m. The assessment implied that dredging can drastically reduce the flood area. However, a decrease in flood area could prevent villagers from undertaking livelihood activities such as fishing. To maintain rain-fed rice and floating rice cultivation and harmonize it with other livelihood activities, we must create alternative plans rather than launch conventional development. One such alternative could be paddy-use planning, which takes into account the characteristics of micro-landforms.

Figure 7.12 shows an alternative treatment for flood risk, i.e., land use improvement. We propose converting a part of current wasteland to floating rice fields (Fig. 7.12). In addition, we recommend establishing a sharing system of floating rice seed to reduce the risk of seed loss. We suggest using a buffer zone of low-cost rain-fed paddy fields, because flooding could supply nutrient-rich soil and water there. To apply our proposed treatment to Dong Khuai Village, we need to estimate flood risk based not only on altitude but also on the positional relationship between paddy field and river. The present study established four land-use categories (rain-fed rice, floating rice, low-cost rain-fed rice, and waste land) based on our flood simulation (Fig. 7.13). In our model, we respectively used the 2011 massive flooding, flooding

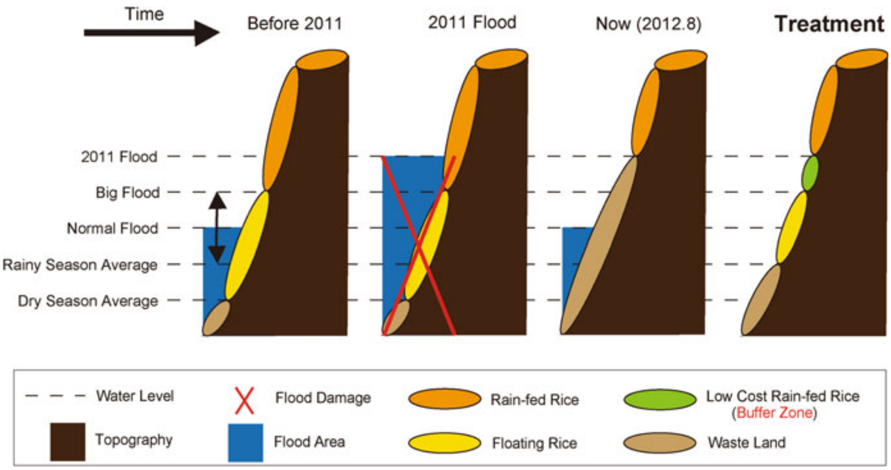

Fig. 7.12 Diagram of our diagnosis and treatment. Horizontal and vertical axes respectively represent time and water level in flood area

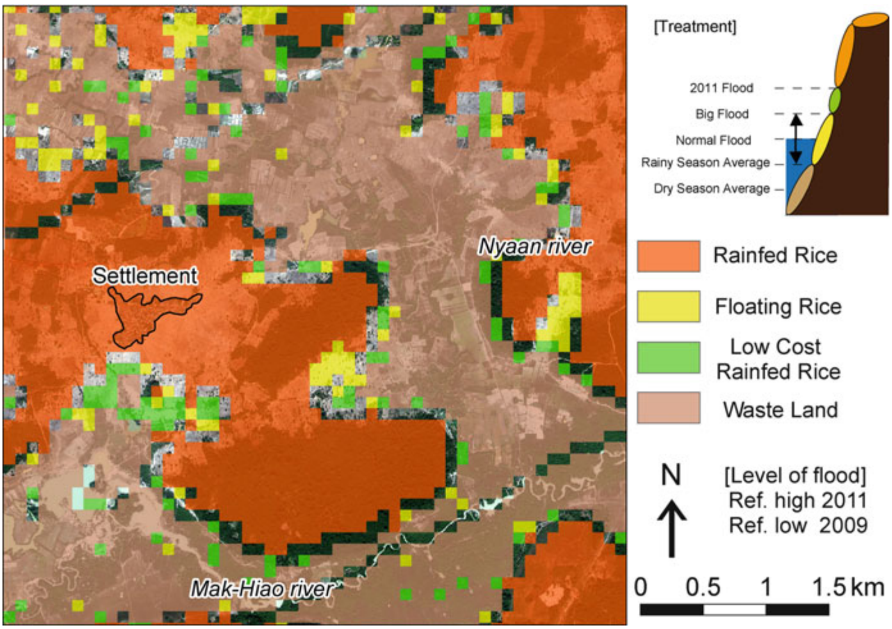

Fig. 7.13 Distributions of rain-fed rice (*orange*), floating rice (*yellow*), low-cost rain-fed rice (*green*), and waste land (*brown*) estimated by our flood simulation

(range within natural fluctuation), and rainy season average levels as the maximum level in 2011, maximum level in 2009, and average level in 2009.

We developed a flood model to estimate flood risk. However, our model has some discrepancies between water regions as estimated by satellite imagery. These discrepancies may be associated with evaporation and infiltration processes. We should therefore continue to improve the model.

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Chapter 8
Influence of Human Activity on Water and Soil Conditions of Agricultural Land in Laos

Yoichi Watanabe, Makoto Shimomura, Xuesong Guo, Rezza Muhammad, Tetsuji Suzuki, and Chisato Takenaka

Abstract The central and southern regions of Laos are the more intensively cultivated areas than the northern and eastern regions of the country, consists of fairly high altitude mountainous. This chapter focuses on the influence of human activities on cultivated area in Laos and evaluates traditional agricultural practices with a view towards long-term sustainability. In case of Paksuun Village, where various land use change patterns can be readily observed, we found that changes due to swidden agriculture, or land use changes from secondary forest to plantation

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forest, did not appear to change soil physical properties. That is, soil property changes resulting from those land use variations are reversible. On the other hand, it was found that a change from secondary forest to paddy field, and then to pasture, might result in irreversible soil property changes, especially in soil density. For traditional rice production in rain-fed paddy field, the examples in Dong Khuai Village were introduced from viewpoints of surface water quality and effect of termite mounds. Through an investigation into various factors impacting the rice production, we found that the application of chemical fertilizer was not always effective for increasing rice yields in rain-fed paddy fields. Other factors such as water flow or floodwater cover as natural phenomena could be important controlling factors for rice yields. From our study, it was suggested that termite mounds could provide useful sources of fertilizer. From the viewpoints of land use change and the qualities of water and soils, we concluded that the present circumstances related to agricultural fields in the central regions of Laos, where traditional agricultural practice remain, would provide a sustainable method of food production.

Keywords Land use change • Rain-fed paddy field • Soil property • Termite mound • Water quality

8.1 Introduction

Three quarters of the land area of the Lao People's Democratic Republic (LPDR), primarily in the northern and eastern regions of the country, consists of fairly high altitude mountainous terrain. In contrast, the central and southern regions of the nation are occupied by the low-lying plains of the Mekong River and its tributaries, and are; therefore, the more intensively cultivated areas of the country. This chapter focuses on the influence of human activities on cultivated area in Laos and evaluates traditional agricultural practices with a view towards long-term sustainability.

Accounting for approximately 48 % of the nation's gross domestic product (GDP), agriculture is the most important sector of the Lao national economy. Indeed, the agriculture sector accounts for 80 % of the nation's employment, and at least 5 million ha (4 % of total area of Laos' total land area of 23,680,000 ha) are suitable for cultivation (Bouahom 2010). It should also be noted that an increase in agricultural activity is usually accompanied with land use changes.

In 1986, in hopes of increasing foreign exchange earnings and stimulating economic growth, the Lao government launched the New Economic Mechanism by opening its doors to foreign investors and adopting the global market system. Since that time, there has been an increasing flow of investment capital into Laos. This trend was especially notable in 2000, which saw dramatic growth in foreign agriculture investments involving rubber, maize, sugarcane, jatropha, along with tree plantations such as Eucalyptus and Acacia. However, while domestic and foreign company investments play a significant role in the nation's agricultural growth, there have been concerns that they could threaten the regional eco-system and endanger local livelihoods.

Accordingly, in order to clarify the impact of increased activity in the agriculture sector, we studied the effects of land use changes on the physic-chemical properties of regional soils, which are considered to be a good indicator of productivity, after which we focused our attention on various factors affecting rice yields. In the central and southern regions of Laos, rain-fed rice cultivation is more common than irrigation-based cultivation. In the case of irrigation-based cultivation, geology, vegetation, amounts of rainfall, and human activities in watershed areas determine water quality, so farmers need only manage the quantity of irrigation water obtained from rivers.

In contrast, the water used in rain-fed paddy fields is affected directly by the surrounding local environments through the activity of villagers, such as livestock dung accumulation, direct inflow of sewage, and other factors that accompany paddy field inundation during the rainy season.

Furthermore, a significant portion of the nation's plain field watershed area adjacent to the Mekong River is also flooded during the rainy season due to insufficient government flood control activities, and even though such flooding is a natural phenomenon, such floodwaters often contain various contaminants derived from human activity. Therefore, it is important to discuss the effects of human activities, including those related to such flooding, on rice productivity in rain-fed paddy fields. In addition, as an effective contributor to rice productivity, the termite mounds found in paddy field areas were examined and considered as natural fertilizer sources.

8.2 Influence of Land Use Change to Soil Condition

8.2.1 Introduction

Paksuun Village was selected as an appropriate sample region for our study of the impacts of land use change, because this village has a specific verifiable history of land use changes. Prior to 1945, the area's villagers resided in Xieng Khouang Province on northern side of the Kadding River, where they engaged in shifting cultivation as well as rice paddy cultivation. However, between 1945 and 2005, area inhabitants began migrating to the opposite side of the Kadding River due to the deterioration of public security situation in their previous residential area, and by 2005, nearly all had settled in Paksuun Village.

In the years that followed, those former residential areas have been put to use as Eucalyptus plantation forests and pasturelands for cattle and buffalo. Therefore, the results of various land use change patterns, such as from cultivated field to plantation forest, from paddy field to pasture, from secondary forest to cultivated land, and so on, can be readily observed in this village.

Table 8.1 Description on land use history for each site

Site name	Land use category	Description
SF	Secondary forest	Used by villagers to get forest products such as medical plants, insects, and also for grazing
PF	Plantation forest	Eucalyptus trees have been planted since 2007. Soils were plowed at the plantation
Paddy	Paddy field	Rice has been cultivated since 2007. Before rice, cassava was cultivated
Fallow	Fallow	Keep as a fallow land
Bean	Longbean field	Secondary forest was converted to longbean field recently
Pas	Pasture	After paddy field was abandoned, the land has been used for grazing as pasture

Based on information obtained from village leaders and Sustainable Forestry and Rural Development (SUFORD) Project reports from 2010, we found that the Paksuun Village currently covers approximately 30 ha of residential land and has about 1,276 ha of suitable agricultural land under cultivation, which includes 100 ha of lowland rice paddy fields, 813 ha of pasturage, a 640 ha Eucalyptus plantation area, as well as 500 and 681 ha secondary and conservation forest area, respectively. The conservation forest in this village has been kept as unutilized forest to conserve its nature and biodiversity. The total of the six land use types amounts to approximately 3,940 ha. In the remainder of this section, we will discuss examples of the effects resulting from land use changes on the various soil properties of Paksuun Village.

8.2.2 Collection and Analysis of Soil Samples

Soil sampling sites were selected based on interviews conducted with the residents of Paksuun Village in relation to area land use changes. The sites included a continuous secondary forest (SF) area that had arisen from cultivated field, a Eucalyptus plantation forest (PF), an area that had changed from Cassava field to paddy field (Paddy) use, a secondary forest area cultivated as a bean field (Bean) use, fallow (Fallow) field areas, and a paddy field area that had been converted to pasture (Pas) use. Table 8.1 shows detailed descriptions of each site.

In each area, samples were taken from the surface soil layer (0–5 cm) using a core sampler. The metal core cylinder of the sampler works to keep the structure of the soil samples intact to allow for addition physical measurements. Three samples were taken from each site, except for the secondary forest (six samples) and plantation areas (four samples).

Soil characteristics selected for analysis included three-phase distribution, characteristic soil water curve, and total carbon and nitrogen content. Three-phase distribution refers to the balance of vapor, liquid and solid portions of the soil. This physical parameter explains the conditions under which plants and microorganisms develop.

The characteristic soil-water curve is defined as the relationship between volumetric water content (θ) and matric suction (ψ), and reflects the water retention ability of the soil. Total carbon and nitrogen contents are parameters of the soil's fertility.

In order to determine this characteristic soil water curve, θ was measured when the soil was saturated and ψ was measured in the laboratory at 30, 100, 300 and 1,000 cm H_2O, using a pF gauge (DIK-3420; Daiki Rika Kogyo, Tokyo, Japan). The volume of the metal core cylinder of the sampler used for determining matric suction was 100 ml. The characteristic soil water curve was derived as follows (van Genuchten 1980),

$$\theta = \theta_r + \frac{\theta_s - \theta_r}{\left[1 + (\alpha\psi)^n\right]^{1-\frac{1}{n}}} \tag{8.1}$$

where θ_s is the saturated soil water content (%), θ_r is the residual soil water content (%), and α and n are constants. The constants were calculated using the non-linear least-squares method using the gnuplot command-line driven graphing utility on a Linux operating system (OS) by minimizing the standard error between the measured and predicted value of θ.

To measure total carbon and nitrogen content, oven-dried samples were first sieved with 2.0 mm mesh, after which the sieved soil was ground by using mortal and parcel until it became powdery. A CN corder (MT-700; Yanaco New Science, Kyoto, Japan) was then used to measure the total carbon and nitrogen contents of the prepared samples. During the statistical analysis phase, Tukey–Kramer tests were performed to compare each parameter using Statcel Ver. 2 operating on Microsoft Office Excel.

8.2.3 Results and Discussion

8.2.3.1 Water Retention Ability

Figure 8.1 shows the soil-water curve for each land use. Here, the differences between the land uses are readily apparent. If it is assumed that the natural conditions of all soil samples would be similar to the secondary forest soil, it can be seen that land use changes have significant effects on the characteristics of the soil-water curves. Specifically, the soil-water curve of the Paddy and Fallow samples shifted toward higher soil water content levels in comparison with the other samples, thus indicating that those two land uses retains more water in the soil, which caused them to become more clayish.

Table 8.2 shows the parameters explaining the characteristic soil water curve for each land use. The n reflects the curvature. If the n is high, the soil water content rapidly decreases when the metric suction reaches a certain point and the soil becomes sandier. In contrast, the soil water content decreases gradually with a low n. We found that the Paddy and Pas samples had low n when compared to the SF, PF and Bean samples.

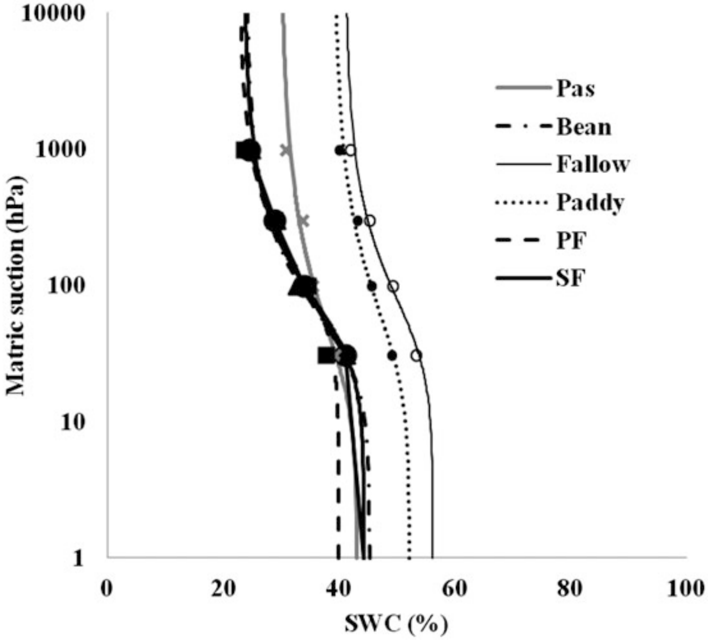


Fig. 8.1 Characteristic soil water curve of each land use. Each line was calculated based on the Eq. (8.1) (van Genuchten 1980) using the actual measured points (*open circle*)

Table 8.2 Values of each parameter in the Eq. (8.1) (van Genuchten 1980) for soils of each land use

	α	n	θr (%)	θs (%)
SF	0.02	1.81	23.6	44.4
PF	0.01	1.88	22.8	40.0
Paddy	0.03	1.58	39.1	52.2
Fallow	0.02	1.71	41.1	56.3
Bean	0.03	1.80	24.0	45.3
Pas	0.04	1.55	29.9	43.1

Since the Paddy and Pas areas are or have been cultivated for rice production, the soil of those areas was well paddled. It was thought that this human activity might have changed the soil texture, which would then change their water retention characteristics. Although the curvatures are similar between Paddy and Pas samples, some differences in soil water content were noted. Soil compaction may explain these differences because it affects the surface soil water content (Canarache et al. 1984). The *n*s of the PF and Bean samples were similar to that of SF. However, since the bean field was recently reclaimed from secondary forest and the plantation area had only entered cultivation when the eucalyptus forest was planted, the similar trends of the PF, Bean, and SF samples suggest that the effects of human activities on the soil samples' water retention abilities might depend on the intensity and duration of such activities.

Table 8.3 Three phase distribution of soils from each site

	Three phase distribution (%)		
Site	Vapor	Liquid	Solid
SF	14.2 ± 2	30.2 ± 2.0	55.6 ± 1.5a
PF	14.4 ± 1	26.0 ± 1.3	59.6 ± 1.9a
Paddy	6.7 ± 3	45.4 ± 2.6	47.9 ± 0.7b
Fallow	9.2 ± 1	47.0 ± 1.1	43.8 ± 0.5b
Bean	23.7 ± 4	21.7 ± 4.2	54.7 ± 1.0a
Pas	14.3 ± 1	28.8 ± 0.5	56.9 ± 0.4a

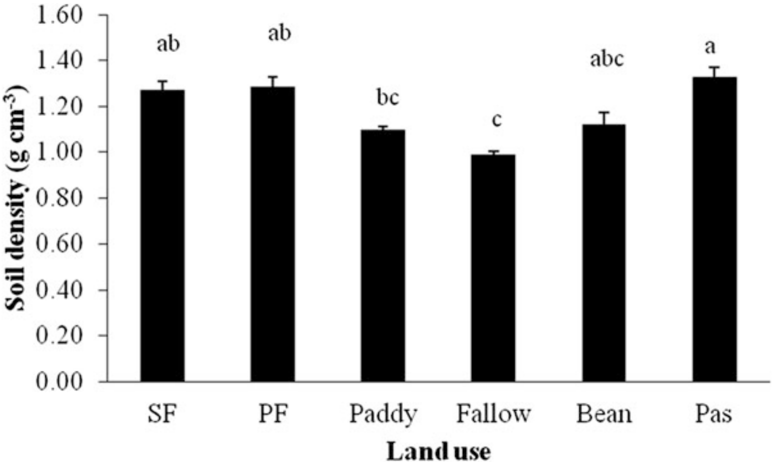


Fig. 8.2 Soil density of each land use. Same letters indicate no statistical significant difference between land use categories by $p < 0.05$ with Tukey–Kramer method (n = 3–6)

8.2.3.2 Three Phase Distribution

Table 8.3 and Fig. 8.2 show the three-phase distribution and soil density of each land use. Here it can be seen that Paddy and PF have significantly lower solid phase distribution and soil density. In contrast, Pas has the highest soil density. Since the soil density can reflect the compaction level of the land use (Shafiq et al. 1994), the differences in solid phase distribution and soil density suggest the effects of human activities. More specifically, once people start using the land for cropping (Paddy, Pas), the land is cultivated and becomes less compacted, which results in a better physical soil profile for plant growth. In contrast, once people stop using the land, the soil can become more compacted (Pas) than its original condition, possibly due to the tread power of cattle and surface soil erosion. All the soil samples show relatively high solid phase distribution compared to the soils in Japan (<40 %; Kawada 1989).

Three-phase distribution generally influences soil biota, and soil compaction significantly reduces root growth, possibly through the increase of solid phase (Rahman and Ito 1996). Therefore, the high solid phase distribution resulting

Table 8.4 Total carbon, total nitrogen and C–N ratio of soils from each land use

	Content (%)		
	Total carbon	Total nitrogen	C–N ratio
SF	1.02 ± 0.17 bc	0.16	6.34
P1	0.57 ± 0.07 c	0.11	5.14
Paddy	1.61 ± 0.12 b	0.25	6.43
Fallow	2.62 ± 0.11 a	0.32	8.33
Bean	0.99 ± 0.09 bc	0.16	6.21
Rice2Past	0.88 ± 0.09 c	–	–

Total carbon and total nitrogen were measured by CN corder
Same letters indicate no statistical significant difference in each column by $p < 0.05$ with Tukey-Kramer method ($n = 3 \sim 6$ for total carbon, $n = 0 \sim 2$ for total nitrogen)

from soil compaction (e.g., Pas) prevents plants from resettling the land. All the land use areas, except for Bean, had low vapor phase distribution, probably because of the rain occurring during the sampling period.

8.2.3.3 Soil Fertility

The Fallow area was found to have significantly high total carbon content among the land use areas measured (Table 8.4). Although the number of samples was small for determining total nitrogen content, we noted that the Fallow and Paddy samples both have higher total carbon and nitrogen content levels, which indicates higher fertility for these land uses. Such fertility can be maintained and improved by application of nutrients such as chemical and natural fertilizers (manure). However, according to our interviews with the villagers, neither of the two land use areas had received such additive nutrients.

Therefore the following two ideas can be proposed. One is that crop and grass residuals may be decomposed in the field, thus maintaining the soil fertility. The other is that the Paddy and Fallow areas may be more naturally suitable for crop production. It should be noted that both the Paddy and Fallow areas are occasionally inundated by river floodwaters, which means the transfer of nutrients from upstream areas may also contribute to their fertility levels. In addition, the effects of long ago slash-and-burn cultivation might have had some affect, although the villagers could not state clearly whether the Paddy and Fallow areas had been subject to slash-and-burn cultivation previously.

The total carbon and nitrogen levels in the slash-and-burn cultivation areas of northern Laos had previously been reported to be around 2.5 % and 0.2 %, respectively (Watanabe et al. 2004). Since only the Fallow and Paddy areas ranked with those values (Table 8.4), this tends to suggest the contribution of long ago old slash-and-burn cultivation practices to the fertility of those sites.

Contrastingly, the PF and Pas areas show relatively low total carbon content (Table 8.4). In the plantation area, understory vegetation is periodically removed to maintain healthy growth of the eucalyptus trees. This human activity may explain the reduced carbon content. Although the Paddy area was thought to be relatively fertile since it had been used for grazing and had thus received significant amounts of livestock dung, the actual carbon content was low and it was thought that the high soil density (Fig. 8.2) might be preventing water and nutrients from penetrating into the soil (Shafiq et al. 1994). High soil density might also enhance surface water and nutrient outflow from the area.

All the carbon–nitrogen ratio values were low, which suggests a higher rate of decomposition in the region as microorganisms decompose organic matter (carbon) while nitrogen tends to remain in the soil.

Human activities affect soil profiles in areas such as water retention, three-phase distribution, soil density, and even fertility, and may even improve soil profiles for plant growth in terms of three-phase distribution and fertility. Nevertheless, this study suggests that the intensity and period of human activities have significant effects. If the intensity of such activities is sufficiently low (e.g. only one type of plantation cultivation, as in the case of PF), the soil profile can be maintained. Additionally, if the impact period is short, such as in the case of land recently reclaimed from secondary forest (Bean), the soil profile will not have had time to change.

However, it is also clear that even if people stop using the land after intense and long-tem cultivation, it may not readily revert to its original conditions (Pas). Therefore, the effects of human activities resulting from land usage should be considered from a longer time scale so that the land can be maintained in conditions that are suitable for future cultivation.

8.3 Various Human Activities and the Other Factors Relating to Rice Production in Rain-fed Paddy Fields

8.3.1 Introduction

Dong Khuai Village is located in Vientiane Prefecture of the Lao PDR and is situated on the Vientiane Plain in an area that is often inundated by Mac Hiaw River waters during the rainy season. The Mac Hiaw River is a tributary branch of the Mekong River.

In this village, rice production has historically been conducted in rain-fed paddy fields. Adachi et al. (2010b) reported that the rice yield spatially fluctuates in the village, with notably better yields reported near the residential and low land areas. However, the reason for these yield distribution differences had not been determined previously.

Factors that can potentially affect on rice yields include fertilizer applications, the inflow of nutrient-rich surface water from residential areas, or various natural conditions. In terms of natural factors, paddy field inundation from river floodwaters and the presence of trees and termite mounds in the area seem to significantly affect rice production. Miyagawa et al. (2010) suggested that the yields reported in paddy fields near trees were higher than fields located in open terrain due to the presence and development of termite mounds around the trees because the termite mounds provide a natural source of fertilizer.

In this section, we show how various factors, including human activities and natural conditions, affect surface water quality in relation to rice crop yields, and discuss the possibility that termite mounds provide a source of natural fertilizer. It is expected that the information contained herein might help facilitate understanding and maintain the natural and sustainable traditional agriculture practices used in Laos.

8.3.2 Methodology

This portion of the study was conducted at Dong Khuai Village, which is a typical rain-fed, rice-growing village situated on the Vientiane Plain. Annual precipitation is from 1,500 to 2,000 mm and annual mean temperature is from 26.5 to 27.5 °C (Lao Department of Statistics, 2010). Soil was alluvium deposited by inundation and meandering of the Mekong River. The village covers an area of 2,528 ha, which includes 820 ha of paddy fields (Adachi et al. 2010a).

In our study, a distribution of nutrient concentrations in surface water was mapped to investigate the relationship between nutrients and the rice production. The field survey was conducted on August 9–11, 2012. The sampling points were chosen to include flooding and no-flooding area within approximately 1 km distance from settlements. The flooding area was defined based on geo-spatial mapping by a flood simulation conducted during the same survey period. The surface waters of paddy fields, streams and ponds were collected and brought back to a laboratory in Japan for testing.

The concentrations of total nitrogen (TN) and total phosphorus (TP) in the water samples were then determined by spectrophotometry using TNP-10 (DKK-TOA Corp., Tokyo, Japan). The topographical elevation was measured by the triangulation using TruPulse360 (Hanshin Commercial Co., Ltd., Osaka, Japan), and the altitude was estimated by Aster GDEM data. The information on rice yields and fertilizer usage (amounts and type) for the last several years was obtained by interviewing the owners or farmers of 11 paddy fields.

In order to determine the potential and effects of termite mounds on rice growth, we collected soil samples from the surface and interior of a number of termite mounds as well as the surface soil of paddy fields where rice growth was evaluated. For the rice growth evaluation, we established two 1-m^2 quadrats (visually high and low growth) in each parcel, and measured the number and height of stubble and the number of tiller for each stubble in each quadrat.

The collected soil samples were dried at room temperature, and measured for pH (H_2O), nitrate nitrogen (extracted by water and measured with ion chromatography), and available phosphate via the Truog method (Truog 1930).

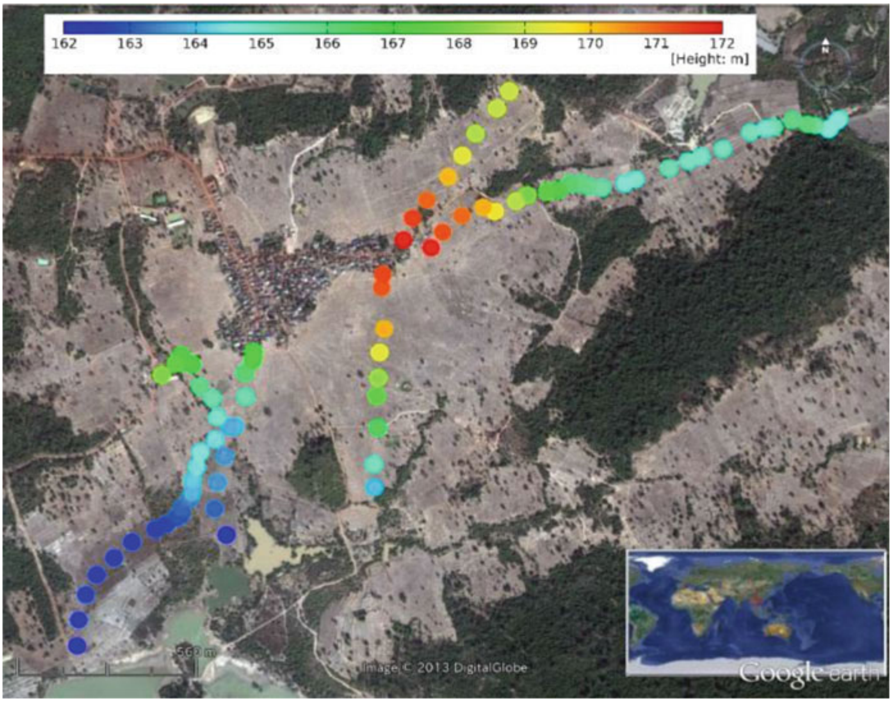


Fig. 8.3 Topographical profile around the village

8.3.3 Result and Discussion

8.3.3.1 Effects of Surface Water

The topographical profile of Dong Khuai Village is shown in Fig. 8.3. The settlements are located at a 165–172 m altitude and 10 m above a pond located in the south. In the area around the settlements, the maximum slope was less than 1° and the paddy fields were located on very flat land. Figure 8.4 shows the analytical results of *pH* and *EC* (*Electric Conductivity*) levels measured in the various water samples referenced to the village map. As can be seen in the figure, the pH values were lowest in the rainwater samples and highest in the stream water flowing in the south of the settlements. The EC value in the stream water flowing in south of settlements was highest. The values of both *TN* (*Total Nitrogen*) and *TP* (*Total Phosphorus*) in the surface waters of the paddy fields were too low to measure.

In contrast, the values of TN and TP in the stream waters were relatively high. This suggests that human activity, such as effluent outflow from households or husbandry affects the quality of surface water, because the TP values in waters downstream from the settlements and pig farms were especially high.

Information on rice yields and fertilizer usage for each paddy field, which were obtained via interviews, are mapped in Fig. 8.5. From those interviews, we found

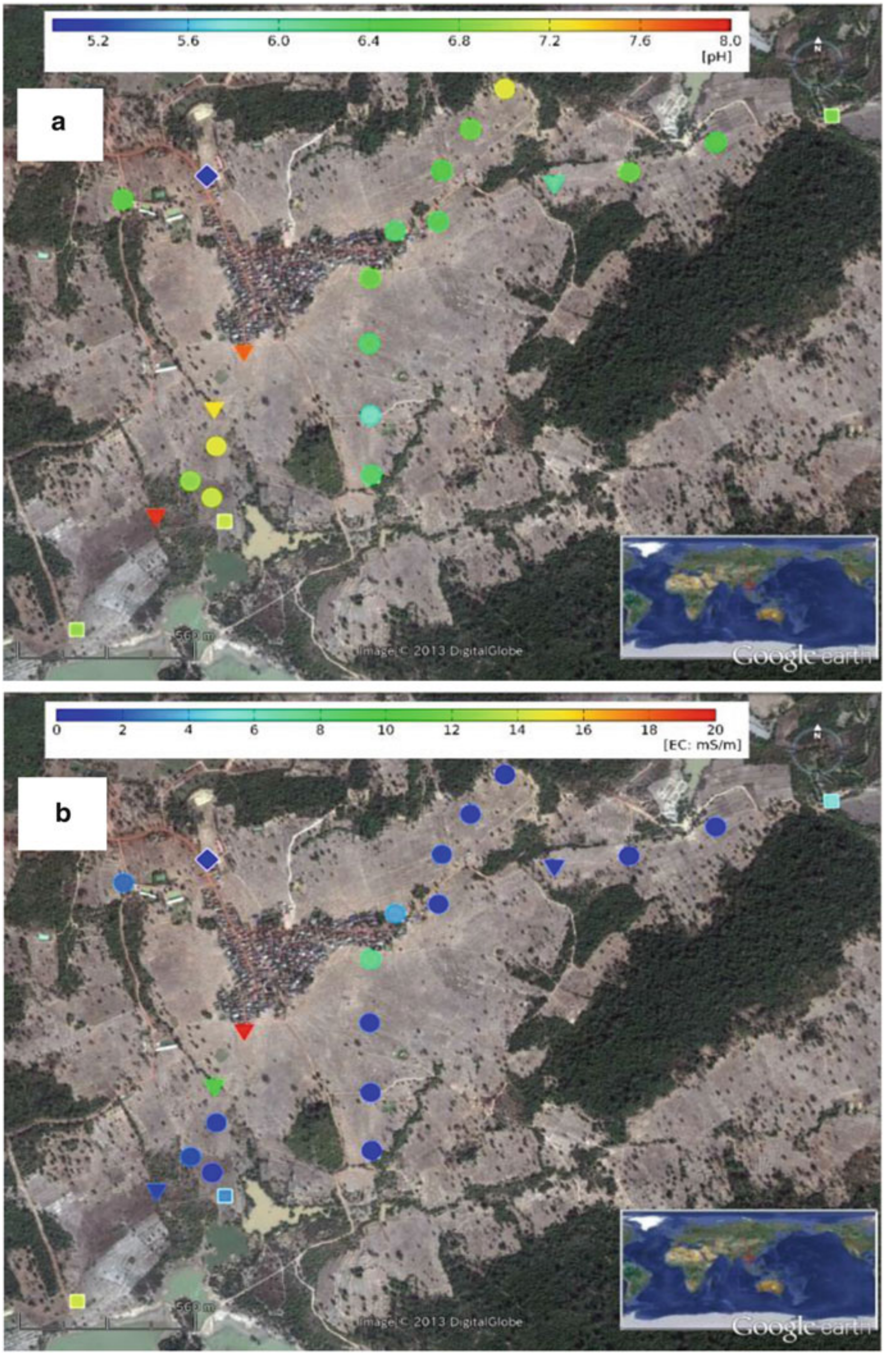


Fig. 8.4 Distribution of (**a**) pH and (**b**) EC in the surface water. (Legend; *filled circle*: paddy field, *inverted triangle*: stream, *filled square*: pond, *diamond*: rain-water)

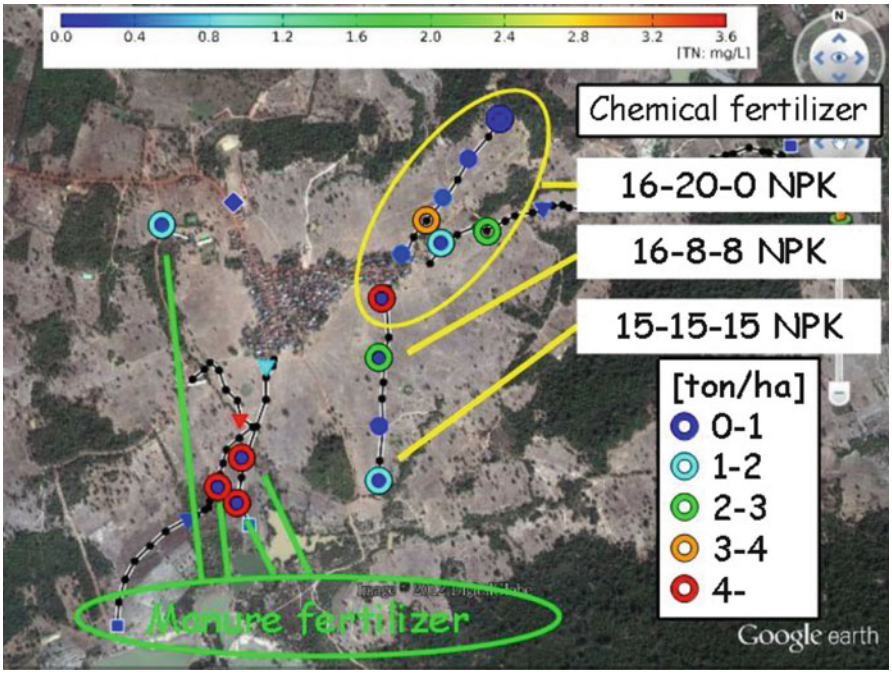


Fig. 8.5 Annual amount of rice yield and fertilizer type, overlaid with TN distribution

that all farmers have used fertilizers of one type or another. Specifically, seven paddy fields were treated with commercial type chemical fertilizer and four paddy fields were treated with manure supplied from cow and pig farmyards. As for commercial chemical fertilizers, 16-20-0 NPK type was most commonly used. However, the application of chemical fertilizer did not always result in good rice yields. Interestingly, the paddy fields located in the south of settlements showed higher yields when compared with the average yields obtained for lowland rice (Haefele et al. 2006). In these paddy fields, manure was applied instead of chemical fertilizer, and the TN and TP concentrations in the stream water supplied to the paddy fields were high.

In addition, we found that the high yield fields in the south area were situated in the flood-prone area (Fig. 8.6), which suggests that the inundating floodwaters had supplied nutrient-rich water and soil to the fields, thus making it possible to increase rice yields.

8.3.3.2 Effects of Termite Mounds

Next, we collected soil samples from 32 points in paddy fields showing high and low yield, and from 13 termite mound points including two points of the interior. The results of our examinations show that the pH of the soils ranged from 4.68 to

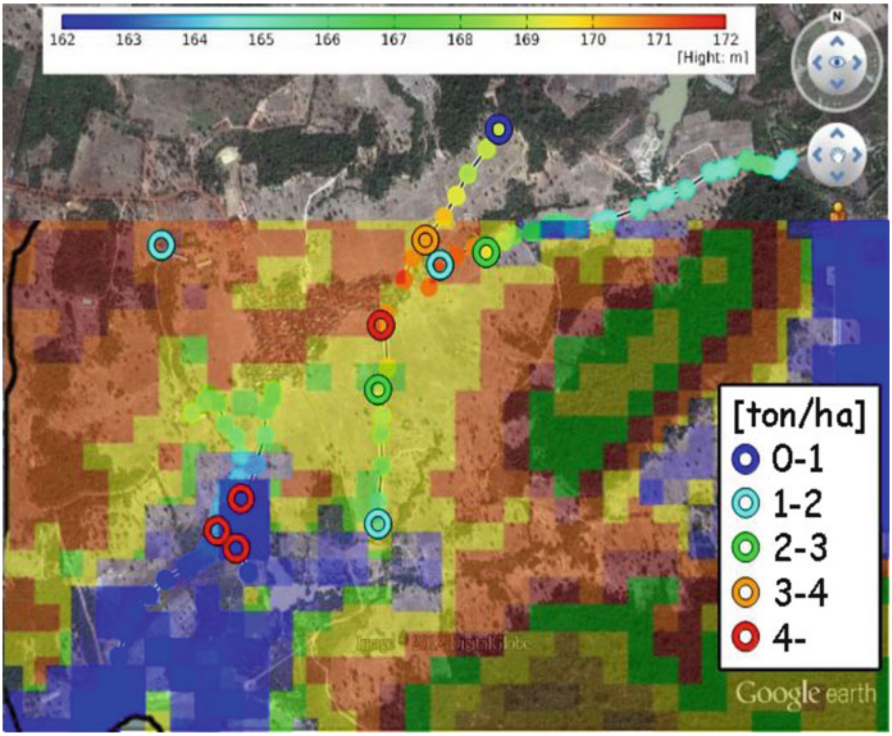


Fig. 8.6 Distribution of flooding area around the settlements, overlaid with altitude and rice yield distribution. (raster with *blue color* shows flooding area on September 23rd, 2011)

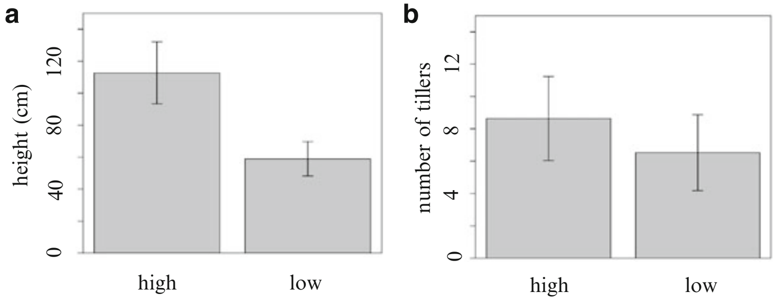


Fig. 8.7 Rice height (**a**) and number of tillers (**b**) in visibly high and low growth paddy fields

8.16 and median values were 5.40, 5.51, and 5.60 at the paddy field high growth, low growth, and termite mound, respectively, thus showing that there were no significant differences among them (Fig. 8.7).

The concentration of the nitrate-N ranged from 0.01 to 2.61 and median values were 0.19, 0.07, and 0.71 at the paddy field high growth, low growth, and termite

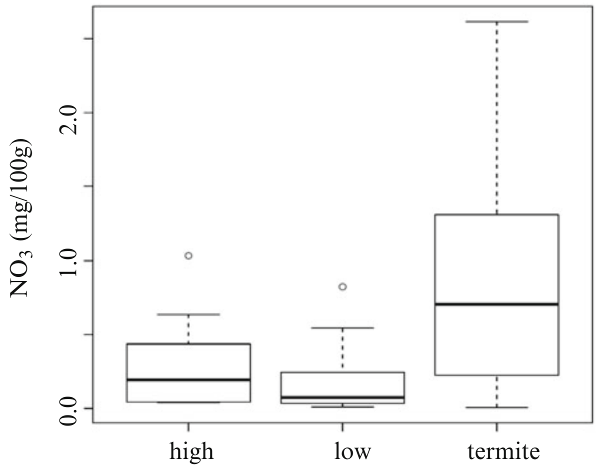


Fig. 8.8 Nitrate-N in the soils from high growth, low growth and termite mound

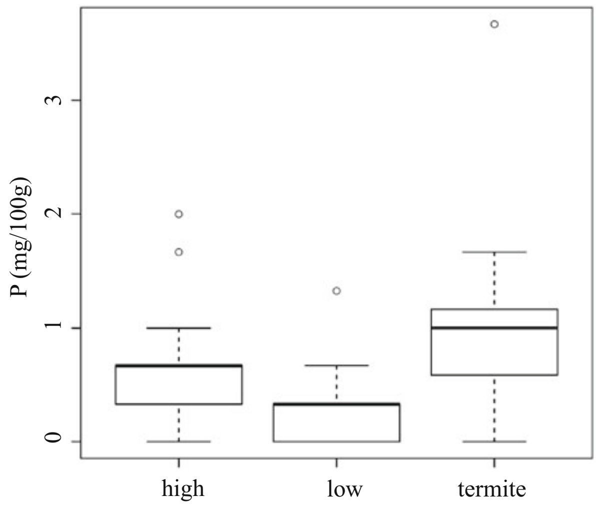
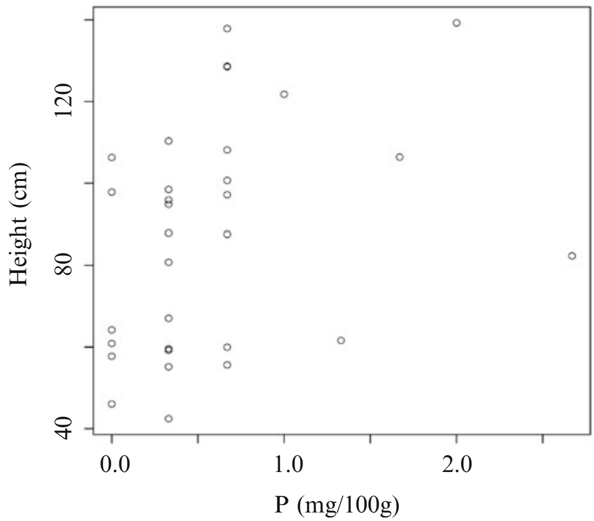


Fig. 8.9 Phosphate contents in the soils from high growth, low growth and termite mounds. The highest value in termite mounds was 41.7 mg/100 g

mound, respectively, which indicates a significant difference between the low growth paddy fields and termite mounds ($P < 0.05$, Fig. 8.8). On the other hand, the concentrations of available phosphate varied from 0.00 to 41.7, with especially high values observed in the interior soils of the termite mounds (11.5 and 41.7 mg/100 g, Fig. 8.9). This is significant because positive relationships have been noted between plant heights and nitrate-N or phosphate concentrations (Fig. 8.10).

Since there was no difference in plant numbers among quadrates, planting densities could be deemed equal as well. Therefore, it is considered likely that the differences in rice yields resulted from other factors. No differences were noted in the pH and nitrate-N were concentration between the high- and low-growth rice fields, although a notable phosphate concentration difference was recorded.

Fig. 8.10 Relationship between phosphate contents and height of rice



This result does not contest the importance of nitrogen on rice growth (Fukai et al. 1999), phosphate levels can also be expected to influence harvesting (crop yields), because it is important component in the synthesis of DNA, especially in the case of flowers and fruits. In any case, it is clear that fertilizer conditions were a very important factor in the high yields that were reported in the low fertility paddy fields (Inthapanya et al. 2000; Inamura et al. 2003).

Termite mounds have shown to contain higher concentration of nitrate-N and phosphate than paddy fields, and from examinations of rice growth particulars, it was found that, in many cases, such mounds existed near or in the same quadrates as the high growth parcels, thus underscoring the possibility that the high phosphate concentrations resulted from proximity to the termite mounds.

This result reinforces previous reports, including studies in Thailand and Africa (Black and Okwakol 1997; Brossard et al. 2007; Miyagawa et al. 2010) that underscore the utility of termite mounds as fertilizer sources. Furthermore, not only is the soil of termite mounds especially useful as fertilizer due to its high phosphate concentrations, such mounds host termite nests constructed with a variety of organic materials collected by the insects, and have surfaces covered with fungi (Photo 2). Indeed, the high phosphate concentrations and nitrogen measurements may result from phosphate fixation caused by the collected organic materials, or by the fungi.

However, it should also be noted that the nitrate-N and phosphate concentrations in the exterior surface soil and interior of the termite mounds showed large variations, which were probably caused by the differences among the termite species examined or different mound development stages. For example, in Dong Khuai Village, there are many different recognized termite species, and considerable variability in their mound sizes (Miyagawa et al. 2011).

8.4 Conclusion

From a survey in Paksuun Village, we confirmed that land use changes caused changes in soil properties such as density, and that the traditional shifting cultivation causes continuous land use changes from secondary forest to crop field, and then back to secondary forest again. It was also found that changes of this type, or land use changes from secondary forest to plantation forest, did not appear to change soil physical properties. That is, soil property changes resulting from those land use variations are reversible.

On the other hand, it was found that a change from secondary forest to paddy field, and then to pasture, might result in irreversible soil property changes, especially in soil density. And, since soil is a valuable resource for human beings, it is important to understand the process and mechanisms of the changes in soil properties caused by land use changes.

Additionally, through an investigation into various factors impacting the rain-fed lowland rice production system in Dong Khuai Village, we found that the application of chemical fertilizer was not always effective for increasing rice yields in rain-fed paddy fields. Other factors include the natural topographical conditions resulting from slopes in the area, such as surface water flows from higher to lower areas of the village and the fact that portions of the Dong Khuai Village paddy fields are sometimes inundated with floodwater from the nearby river during the rainy season. This suggests that water flow and water cover are natural phenomena that could be important controlling factors for rice yields.

Furthermore, from our study, it was suggested that termite mounds could provide useful sources of fertilizer, and that the interior of such mounds could be considered an especially useful source of phosphate. However, termite mounds had disappeared around the village because of exploitation, and Miyagawa et al. (2011) suggested that the disappearance of termite mounds in the vicinity of paddy fields had resulted from their deliberate destruction. It was also noted that living termite mounds around the village were decreasing, even though numerous living termite mounds could be observed in the secondary forests around the village (Saito, unpublished). Accordingly, it is important to conserve secondary forests in order to provide a suitable environment for living termite mounds.

From the viewpoints of land use change and the qualities of water and soils, we concluded that the present circumstances related to agricultural fields in the central regions of Laos provides a sustainable method of food production, and that human activities will not result in negative impacts on the environment, providing that people respect and follow the traditional agricultural practices of each area.

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