Title	Plant Diversity in Paddy Field Landscape in Savannakhet Province, Laos(Dissertation_全文)
Author(s)	Kosaka, Yasuyuki
Citation	Kyoto University (京都大学)
Issue Date	2006-03-23
URL	http://dx.doi.org/10.14989/doctor.k12433
Right	
Type	Thesis or Dissertation
Textversion	author

A Thesis Submitted for the Degree of Doctor of Area Studies

Plant Diversity in Paddy Field Landscape in Savannakhet Province, Laos

ラオス・サワンナケート県の水田地帯における植物多様性

Yasuyuki KOSAKA

March 2006

Doctor of Area Studies

A Thesis Submitted for the Degree of Doctor

of Area Studies

Plant Diversity in Paddy Field Landscape in Savannakhet Province, Laos

ラオス・サワンナケート県の水田地帯における植物多様性

Yasuyuki KOSAKA

小坂　康之

Graduate School of Asian and African Area Studies
Kyoto University

March 2006

Summary

The approach to nature conservation has been changing over time. Previously, it was widely suggested that protected area should be established to exclude human activities from untouched wilderness. On the other hand, as pervasive human impact has recently been recognized, more concern has been turned to biodiversity which remains in human-managed ecosystems. The purpose of this study is to clarify how agricultural practices support multiple plant resources in paddy field landscape in central Laos. In addition, although it is necessary to refer the overall floristic condition as well as the targeted species to examine the plant resource management, there have been few studies on vegetation in Laos. Therefore, this study also aims to create an inventory of vegetation in central Laos.

Field surveys were carried out in Champhone District, Savannakhet Province, central Laos. The study villages were selected to cover all the vegetation types and land-use types in the region: Dongmakngeo, a newly established village with an abundance of adjacent forest; Bak, an old village with adjacent forest; and Nakhou, an old village without any adjacent forest.

The paddy field in this study site was characterized by the existence of various trees in itself. Therefore, the species composition, distribution and management of trees in paddy fields were firstly studied in the three villages. At Dongmakngeo village, 23 species, mostly remnants from the original forest, were observed in paddy fields. At Bak village, few trees were found in the paddy fields because villagers had ample access to resources in the surrounding large forest. On the other hand, 119 species, 27 of which were planted, were recorded at the forest-deprived Nakhou village; the scarcity of forest resources at Nakhou was compensated for by the utilization and management of trees located among the fields, resulting in tree species changing from remnant to ruderal over time.

Secondly, herbaceous species occurring in paddy fields were investigated from rainy season to dry season, with 78 quadrats distributing in four paddy types classified by local people, in Bak village and Nakhou village. The result is that a total of 184 wild herbaceous species (including 43 exotic species) were recorded. The number recorded in only two villages was large compared with other areas in Asia. Of the recorded species, 19 were used by local people, four were rare species, and three were major weeds. The factors contributing high species diversity were: (1) the presence of species unique to different paddy types; (2) the presence of remnant species from original vegetation; (3) the impact of agricultural practices.

Thirdly, the survey on land-use patterns and plant use were carried out in Bak village and Nakhou village. Bak village was located in an upland topographical position with land-use composed of extensive forest area, fallow fields, shifting cultivation fields, grassland, waterside, and paddy fields. The forest area supplied the largest number of useful plants. Nakhou village was, by contrast, in a lowland setting and land-use was characterized by small areas of remnant forest, grassland, waterside, and extensive paddy fields. Paddy fields contained the largest number of useful plants, followed by forest. Villagers compensated for

the lack of forest resources in Nakhou village by maintaining and managing a diversity of trees within the paddy fields land-use class. In addition, residents of the surrounding villages made the most of locally available plant resources and supplemented each other's resources through trading. Analysis of local plant use at different geographical scales showed that the relationship between humans and plants at this study site was flexible and was influenced mainly by topography and land-use and partly by socio-economic conditions and invasion by naturalized species.

Thus, although paddy fields are primarily used for the monoculture cultivation of rice, multiple species of plants coexist in the landscape under human use and management. Recently, progress has been made on a biological conservation program in Laos involving the establishment of protected areas where human activities are limited. However, the results of this study indicate that it is also important to incorporate the activities of local people into natural resource management.

Table of contents

List of tables

List of figures

Acknowledgments

This is a dissertation submitted to Graduate School of Asian and African Area Studies, Kyoto University in December 2005.

I wish to express my profound gratitude to Dr. Shinya Takeda, Professor Koji Tanaka, Dr. Akihisa Iwata, and Professor Shigeo Kobayashi, for their instructive suggestion since I entered the Graduate School and reading the entire part of text in the dissertation. The memory of the honorary Professor Hisao Furukawa, with whom I had once an opportunity to conduct field survey in Laos, also encourages me to complete the dissertation.

This study also owes much to the helpful comments from the former Professor Norio Ishida, Professor Kozo Hiramatsu, Dr. Kazuo Ando, Dr. Masayuki Yanagisawa, Dr. Shinsuke Tomita, Dr. Nobuhiro Onishi, Dr. Fumikazu Ubukata, Dr. Reiji Suzuki, Dr. Tetsuya Shimamura, Mr. Takayoshi Yamaguchi, Dr. Mitsuru Sonoe, and colleagues in ASAFAS.

My special thanks are due to Mr. Anoulom Vilayphone, Mr. Soulaphone Inthavong, and Mr. Souksompong Prixar, who improve my language skill and knowledge on Lao culture in the daily conversation in the laboratory. Comments and suggestions on botanical viewpoints from Professor Makoto Kato, Dr. Kuniyasu Momose, Dr. Yukino Ochiai, Dr. Khamleck Xaydala, and Dr. Wichan Eidthong were very helpful.

I would also like to thank Mr. Etsuo Mushiake, Ms. Weomany Nampanya, Ms. Yuka Kiguchi, Mr. Yoshiyuki Masuhara, Mr. Kenichiro Yamada, Mr. Hisaya Oakada, Dr. Yayoi Fujita, Ms. Junko Yano, Ms. Yoko Matsushima, Mr. Susumu Nakatsuji, Mr. Isao Hirota, Ms. Kiyoko Yasui, and students in Faculty of Forestry, National University of Laos, for their valuable advice and information on field survey and living in Laos. Especially, I owe much to the kindness and hospitality of the Watsanas, the host family during my stay in Vientiane in 2001.

Gratitude is extended to Mr. Soukkongseng Saignaleuth, Mr. Houngpheth Chanthavong, Mr. Thavy Phimminith, Mr. Khamkhong Phengchanthamaly, Mr. Daovorn Thongphanh, Mr. Thananh Khotpathum, Mr. Kham Phomkhe, and Mr. Bountem Sondavanh in Faculty of Forestry, National University of Laos, and the staff in Provincial Agriculture and Forestry Office and District Agriculture and Forestry Office in Savannakhet Province, Laos, whose helpful support enables my field survey. I would also like to thank Mr. Saysana Sithirajvongsa, whose wit and care often save me from the difficulties in the field trip. This research would never have been completed without the generous hospitality of the villagers in Dongmakngeo village, Bak village and Nakhou village.

There are many other people who helped in this study. Without their cooperation, the compilation of this study would not be possible. Thank you very much.

The field survey was supported in part by Toyota Foundation, the 21st Century COE Program "Aiming for COE of integrated Area Studies" (Project of the Japanese Ministry of Education, Culture, Sports, Science and Technology), and Kobayashi Fellowship from Fuji

Xerox Corporation.

Chapter 1. General introduction

1-1. Background of this study

The main aim of this study is to clarify how biodiversity is conserved in human-managed ecosystems. Further, the final goal is to provide basic data on the relationships between humans and plants. First, let me explain the term "biodiversity," which is the key concept of this study.

The term "biodiversity," which is the abbreviation of "biological diversity," has been used since the 1960s in ecological studies (Hidaka, 2005). The term gained popularity in the 1980s with the recognition of biodiversity conservation and global warming as the most important environmental issues and has been used ever since (Hidaka, 2005). Broadly speaking, four values of biodiversity—intrinsic value, utilitarian value, bequest value, and functional value—can be conveniently recognized, although different authors often use different terminology (Swift et al., 2004). The intrinsic value comprises cultural, social, aesthetic, and ethical benefits. The utilitarian value includes subsistence and commercial benefits of a species or its genes. The bequest value is a belief about something that can take place in the future and does not exist in the present, for example, the presence of a species with currently undiscovered genetic potential for industrial products. The functional value of biodiversity arises from its contribution to an ecosystem's life support functions and the preservation of ecological structure and integrity. Although the rationality of biodiversity conservation is still disputed (Baskin, 1994), this dissertation is based on the opinion that biodiversity is important and should be conserved because of the values mentioned above.

Biodiversity, particularly in human-managed ecosystems, has recently attracted considerable attention. This is closely related to the fact that the approach to biological conservation has changed from establishing protected areas that exclude human activities to one that involves management of human activities on the basis of local knowledge and techniques (Figure 1-1). One reason behind this trend is that many studies revealed that the environment in and around human settlements provided diverse organisms with important habitats (Pimentel et al., 1992). Another reason is that it is very expensive to implement biological conservation programs for all the targeted species in a protected area (Heywood and Iriondo, 2003). In view of these factors this study deals mainly with biodiversity in human-managed ecosystems.

Although there are a variety of organisms in human-managed ecosystems, this study focuses on plants in paddy fields because of the following reasons; (1) the paddy field land-use system is dominant in most of Asia and is also the principal alternative land-use where shifting cultivation is being phased out, (2) plants are the foundation of various types of ecosystem processes such as primary producers, and (3) studying plants in agricultural land will lead to important discussions on the balance between agricultural productivity and

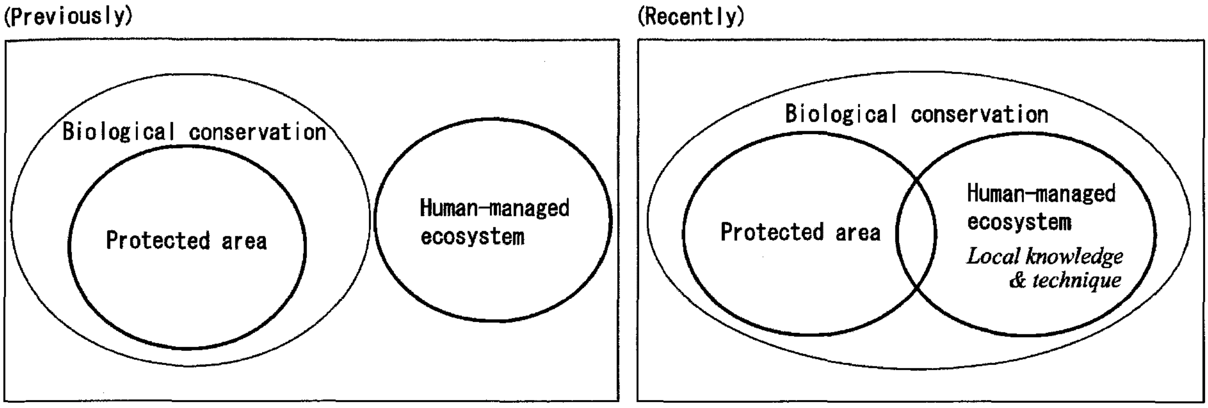

Figure 1-1. Change in the approach to biological conservation.

biodiversity. In paddy fields, weed species compete with the rice plants. Recently it has been observed that with an increase in productivity due to agricultural modernization, there is a corresponding decrease in the species richness in the farmlands. However, it has been suggested that balancing agricultural productivity with biological diversity should be the ultimate goal of the analysis of paddy farming (Tomita et al., 2003a). This study will contribute to a series of studies on agricultural productivity and biological diversity by providing basic data on the relationships between human and plants in subsistence-level rice cultivation areas.

Field surveys were conducted in a paddy field landscape in central Laos which is characterized by the following points: (1) people rely on subsistence rice cultivation without large-scale plantation of cash crops, which results in a landscape showing a mosaic of several land-use types, i.e., a diversity of habitats for plants, (2) wild plants as well as cultivated plants are used on a daily basis in their lives, which results in an abundance of local knowledge and techniques on plant use and management, and (3) the topography, climate, flora and fauna (Heckman, 1974), language, and culture of this place (Evans and Sengdala, 2002) are similar to those of northeast Thailand, and therefore the two can be compared with each other. Although only subsistence farming has been conducted thus far in this study site, a comparison with the cases in northeast Thailand implies that the relationships between humans and plants will change in the near future due to agricultural modernization involving the introduction of pesticides, chemical fertilizers, agricultural machinery, and irrigation and drainage systems.

The background of biological conservation in Laos is summarized here. In Laos, deforestation is calculated at 70,000 ha per year (NOFIP, 1992). In order to control public access to land and forest resources, the government has reviewed its natural resource management policies several times since 1989. In November 1993, the government issued the Prime Ministerial Decree on Management and Use of Forest and Forest Land. Subsequently, in November 1996, the government promulgated a new Forestry Law, which integrated the contents of the former Decree (UNEP, 2001). Reformations in the methods of forest management included community control of forest lands, zoning, and provision of incentives to manage forests sustainably within the concessions provided (UNEP, 2001). In addition, the Government has been developing a national protected area system with the technical assistance of international agencies. Consequently, a total of 20 areas covering approximately 12.5% of the land area of the country were decreed as National Biodiversity Conservation Areas, and 10 other areas remain under consideration (IUCN, 1999).

However, several problems such as conflict between customary resource use system and content of law, lack of understanding by local people, and shortage of staff and budget to enforce the law have emerged (Hyakumura, 2001). In addition, except for cutting trees, there are no regulations on plant use in paddy fields. Therefore, this dissertation examined the resource use and management not from an institutional perspective but from the viewpoint of local knowledge and techniques. The results of this study will contribute to effective biological conservation in Laos, particularly when reinforced by the studies conducted from an institutional perspective, as reported by Hyakumura (2001), Namura and Inoue (1998), and Yokoyama (2004).

1-2. Objective of this study

Considering the background mentioned above, this study aims to examine how plant diversity remains in paddy field landscape in central Laos from a viewpoint of local knowledge and technique.

This study has three unique points. First, the human impact on the paddy fields is positively assessed in terms of plant species diversity. Although several preceding studies (e.g., Shimoda, 2003) have also shown that traditional agricultural activities enhance plant diversity in paddy fields, those were conducted in Japan where the close relationships between human and plants had already been lost. On the other hand, abundant local knowledge of plants and the important roles of multiple wild plants in local life in central Laos motivated me to conduct this study. Second, vegetation and plant use were investigated in the paddy field landscape, which includes not only the paddy fields but also the surrounding land-use classes such as forest lands, shifting cultivation fields, grasslands, water bodies, and homesteads. Since little attention has been paid to the importance of the mosaic of farmland habitats in the conservation of native plant species (Heywood and Iriondo, 2003), the whole paddy field landscape has been recognized as an important habitat for multiple plant species in this study. Third, although it is necessary to consider the overall floristic composition as well as the targeted species to evaluate plant resource management, there have been few studies on vegetation in Laos. Therefore, this study also aims to create an inventory of the vegetation in central Laos. The importance of this inventory is particularly clearer when we consider the rapidly changing natural environment in central Laos.

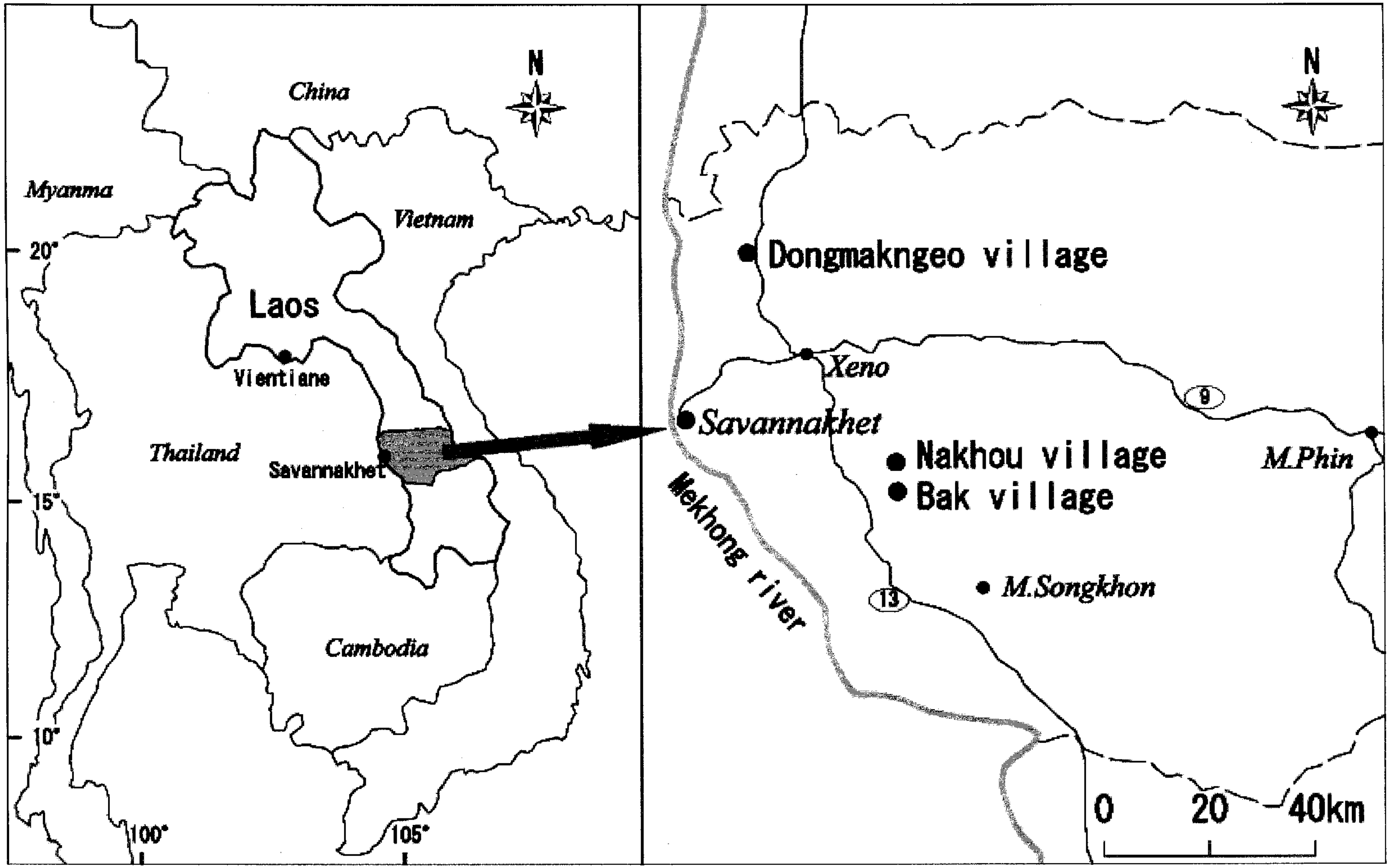

Figure 1-2. Map of the study site in Savannakhet Province, Laos.

Thus, the objective of this study is to clarify (1) species composition, distribution, and management of trees in paddy fields, (2) plant diversity in paddy fields in relation to agricultural practices, and (3) relationships between plant use and land-use patterns along with creating an inventory of vegetation in the villages.

1-3. Overview of dissertation

This dissertation consists of an introductory part (Chapter 1), three case studies (Chapters 2 to 4), and a general discussion and conclusion (Chapter 5). The key question that is addressed in this study is how a diversity of plants persists in human-managed ecosystems.

Chapter 1 states the background, rationality and objective of this study.

Chapter 2, Chapter 3, and Chapter 4 deal with the species composition, distribution, and management of plants in paddy field landscape in the selected three villages— Dongmakngeo (16° 49′ N, 104° 54′ E; 180 m a.s.l.: DM village), Bak (lat 16° 27′ N, long 105° 09′ E; 160 m a.s.l.: BK village), and Nakhou (lat 16° 29′ N, long 105° 09′ E; 140 m a.s.l.: NK village) — in Savannakhet Province, central Laos (Figure 1-2). Chapter 2 examines the factors influencing tree species composition and distribution in the paddy fields, which characterizes the land-use in this region (Kosaka et al., in press a). Chapter 3 examines the relationships between paddy vegetation and agricultural practices by focusing on herbaceous species in the paddy fields (Kosaka et al., in press b). Chapter 4 examines the relationships between land-use classes and plant use both at the landscape level, i.e., land-use class level within villages, and at the regional level, i.e., district level in this study site (Kosaka et al., in press c).

Chapter 5 discusses the importance of human activities in supporting plant diversity in paddy field landscape. In conclusion, biological conservation in human-managed ecosystems will be successfully achieved not only by establishment of protected areas but also by incorporating the activities of local people into natural resource management.

The terminology used throughout this dissertation is summarized here. The term "land-use" is often expressed by similar terms such as "land-use system," "land-use type," or "land-use class." "Land-use system" is used when it indicates one type of farming system. "Land-use type" is one category of the lands, which represents a landscape and ecosystem that differs from the others. "Land-use class" is used in Chapter 4 as a component of "land-use patterns," i.e., forests, grasslands, or paddy fields. "Ruderal species" in Chapter 2 is derived from the CSR model for plant functional types (Grime, 2001). Although the model was hypothesized and tested using studies on herbaceous species, this dissertation uses the term "ruderal" for some woody species in the paddy fields. This is because species growing predominantly in open and disturbed human-managed ecosystems are rarely found in forests, which suggests a distinction among "ruderal species," "pioneer species," and "light-demanding species" in the process of forest succession.

Although a complete description of the study sites is included in Chapters 2, 3, and 4 respectively, the general characteristics of the study sites are summarized in this chapter.

Savannakhet Province is located in central Laos. The mean annual temperature is 26.5℃, and the mean minimum and maximum temperatures are 21.6℃ and 31.3℃, respectively. The mean annual rainfall is 1473 mm, and the rainfall in the mean rainy season (May–October) and the mean dry season (November–April) is 1299.2 mm and 173.8 mm, respectively (Figure 1-3). Statistics for Savannakhet Province suggest that the proportions of the area composed of various land-use types are 55.5% in current forests, 23.8% in potential forests (including shifting cultivation fields and fallow forests in early successional stages), 8.8% in other wooded areas (mainly open woodlands), 9.1% in permanent agricultural land (mainly paddy fields), and 2.8% in other non-forest land such as urban areas, grasslands, or wetlands (NOFIP, 1992). In total 80% of the households are engaged in paddy cultivation (UNDP, 1998).

The statistics mentioned above were compiled in the 1990s. The natural environment and socio-economic conditions in Savannakhet Province are now rapidly changing due to deforestation and a transition toward a market-oriented economy. These changes will be accelerated by the construction of a bridge over the Mekong. It will connect Savannakhet on the Lao side and Mukdahan on the Thai side and will be completed by 2006. Therefore, this dissertation will be an important record of the current status of vegetation and plant use in the villages in Savannakhet Province.

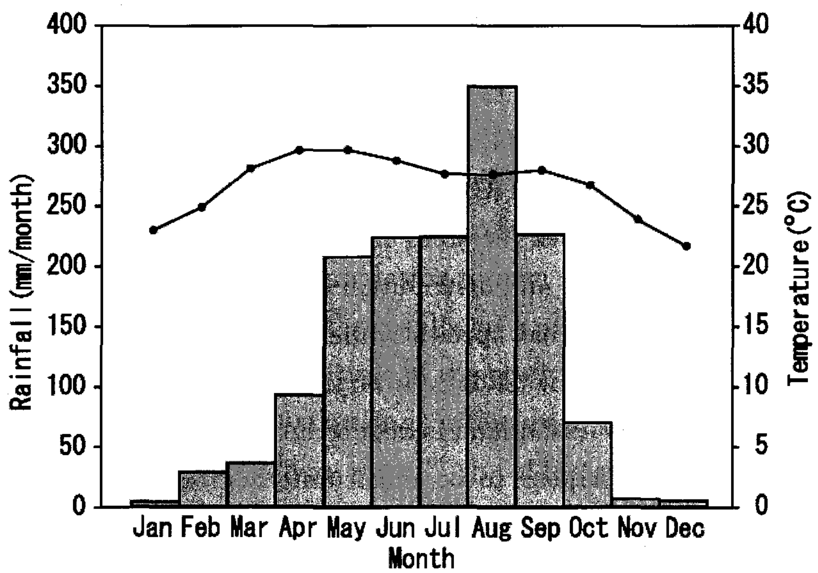

Figure 1-3. Mean temperature (solid line) and rainfall (bars) in Savannakhet Province, Laos (1990-2000).

Chapter 2. Species composition, distribution and management of trees in paddy fields

2-1. Introduction

The role of trees in tropical agricultural landscapes has been studied from various perspectives, such as the improvement of productivity and sustainability (e.g. Kwesiga et al., 2003), subsistence and food security (e.g. Wezel et al., 2003), and conservation of biodiversity (e.g. Harvey and Haber, 1999). The presence or absence of trees has also been shown to sometimes play a role in securing or maintaining rights of use or tenure, and certain trees or wooded areas can be of cultural or religious importance (Arnold, 1995). Analyses of the tree component of agricultural landscapes with these types of narrowly focused perspectives are unlikely to provide a satisfactory picture of why farmers do or do not grow trees unless there is recognition of the broader framework within which the farm trees are located (Arnold, 1995). Consequently, research interest has switched to a more holistic and dynamic approach. The paddy field land-use system is dominant in tropical Asia. Importantly, it is also the principal alternative land-use where shifting cultivation is being phased out (e.g. Lao PDR RD Program, 1998). Throughout central Laos and northeast Thailand, widespread undulating plains display a distinctive landscape of trees standing singly or in small groups amongst a mosaic of rain-fed paddy fields, levees, and residential plots or clusters. Previous studies have shown that trees in the paddy landscape supply wood, food, medicine and other supplementary resources, offer shade to both humans and livestock (Grandstaff et al., 1986; Watanabe et al., 1990; Prachaiyo, 2000), mitigate land degradation (Vityakon, 1993; Vityakon, 2001), and provide habitat for wildlife (Grandstaff et al., 1986).

Despite the wide range of uses for trees in the paddy landscape in central Laos and Thailand, the species composition and distribution of trees differs from place to place. Some fields have a high density of forest species while others have little more than a sparse distribution of planted species; some fields have no trees at all. Prachaiyo (2000) reported that species composition in northeast Thailand is dependent on major topographic variations and soil type. Other factors also appear to be important. For example, tree distribution and growth seems to vary with micro topography or time since conversion from forest to paddy field. In addition, the extent to which local people utilize trees within the surrounding environment seems to affect the tree distribution in paddy fields. For example, the availability of forest resources is likely to influence how people manage trees within the paddy system (Grandstaff, 1986). However, there have been no systematic surveys to confirm the extent to which these various factors influence tree use and distribution in the paddy field land-use system in tropical Asia.

This study was therefore undertaken to better understand what factors determine tree distribution and species composition in paddy landscapes in central Laos. An examination of forest surrounding the villages was an important feature of the study for two reasons. Firstly, because paddy fields have been converted from forested land, so the trees present in the fields will exhibit some influence from the pre-existing forest (Watanabe et al., 1990). Inferences about changes in species composition with time require knowledge of the state at time zero as a reference. Secondly, people extract plant resources from both paddy fields and surrounding forests (Prachaiyo, 2000), so the management of trees within the agricultural landscape is likely to be influenced by the abundance, proximity, and types of forest resources available.

The study examined the following three hypotheses:

(1) That species composition and distribution varies with micro and macro topography in paddy fields.

(2) That species composition and distribution changes over time after forest is converted to paddy field due to the change in environment.

(3) That as tree resources become increasingly scarce, local people respond by intensive tree management.

To test these hypotheses, I conducted field surveys of tree and species distribution, utilization, and management in three villages: a new village with adjacent forest, an old village with adjacent forest, and an old village without access to forest.

2-2. Site description and Methods

Site description

The field survey was conducted at Dongmakngeo village, Outhomphone District, Bak village and Nakhou village, Champhone District in Savannakhet Province, Laos. The original forest vegetation types of the study site are dry dipterocarp forest (DDF), dry evergreen forest (DEF), and mixed deciduous forest (MDF) on undulating terrain formed on Mesozoic red sandstone.

The characteristics of the selected three villages are listed in Table 2-1. Dongmakngeo village was established in 1960. At the time of the study it had a population of 897 people, mostly Lao-Theung people of the Austroasiatic ethnolinguistic family (Sisouphanthong and Taillard, 2000), in 140 households. There were 271 ha of forest measured within the 528 ha of village land. Ninety percent of households were reported to engage in paddy cultivation and 10% in cutting trees. Small patches of shifting cultivation fields were observed within the forest areas. Bak village is said to have more than 200 years of history and had a population of 1852 people in 327 households during the study, mostly Lao-Lum people of the Tai-Kadai ethnolinguistic family (Sisouphanthong and Taillard, 2000). There were 454 ha of forest recorded within the 1405 ha of village land. Ninety percent of households were engaged in paddy cultivation and about 10%, mainly older people, in shifting cultivation. Nakhou village is adjacent to Bak village and was established more than 100 years ago. Its population during the study was 1594, mostly Lao-Lum people, in 252 households. The village area had only

Table 2-1. Characteristics of the study site in central Laos

Vil	Year	Ethnic	Popul	House	Land	Forest	Subsistence
DM	44	LT	897	140	528	271	Paddy cultivation, Shifting cultivation, Cutting, NTFP collection.
BK	>200	LL	1852	327	1405	454	Paddy cultivation, Shifting cultivation, NTFP collection.
NK	>100	LL	1594	252	n/a	a few	Paddy cultivation, Salt making, Mat weaving.

Vil: Village name, Year: Years after village establishment, Ethnic: Ethnic groups; LT: Lao theung people, LL: Lao lum people, Popul: Population (people), House: Number of households, Land: Area of village land (ha), Forest: Area of forested land (ha), Subsistence: Main subsistence at village, NTFP: non-timber forest products.

several hectares of forest. All households were engaged in paddy cultivation. Pollarded trees were observed in paddy fields (Figure 2-1).

Analysis of aerial photographs showed that the land-use of all three villages could be mostly classified as forest, grassland, paddy fields, or homesteads. Three types of cropping pattern exist within the study area: (1) Rainy season crop only. Most paddy fields are rain-fed and are cultivated only in the rainy season. After rice harvesting, no crops are cultivated in paddy fields with the exception of some corn and sweet potatoes along riversides where water is available. (2) Second crop in the dry season. A few hectares of paddy fields in Bak village are irrigated with water from springs permitting a second crop in the dry season. This second cropping did not occur in Dongmakngeo village and Nakhou village. (3) Dry season crop only. In Nakhou village, some lowland paddy fields were flooded in the rainy season and could only be cultivated in the dry season when the water level fell.

Data collection

Field surveys were carried out in September and November 2001, May and June 2002, and March 2003. To assess tree distribution in paddy fields, plots were randomly set in fields of different age (years since conversion from forest) in each village: 1 year, 5 years, 10 years, and 30 years at Dongmakngeo village, 50 years and 100 years at Bak village, and 10 years, 50 years, and 100 years at Nakhou village. The plots varied in area as they corresponded to the complete block of the respective paddy owner. Species name, habitat, DBH, and height of trees (> 1m in height; including shrubs and woody lianas) were recorded and specimens collected at each plot. Habitats of trees were classified into four types: paddy surface, paddy levees, termite mounds on paddy surface, and termite mounds on paddy levees. Species names of seedlings (young individuals without second order branching) and saplings (well established individuals with identifiable crown due to emergence of second and third order branches) were also recorded when observed in the plots.

Figure 2-1. Pollarding of *Peltophorum dasyrrhachis* for firewood collection at Nakhou village.

To examine the wider range of tree distribution, a belt-transect survey was conducted in Nakhou village. The transect was established in paddy fields along both sides of the village road (3 km long and 200 m wide), where 1971 trees were left. The preliminary field observation had shown that tree distribution in the paddy fields was not influenced by the presence of the village road. All tree measurements were the same as for the plot survey, except that the location of each tree was also recorded using GPS (Garmin GPS Ⅲ Plus).

Vegetation survey was conducted to determine general floristic characteristics of surrounding forests. Plots (20 meters square) were set within representative areas of DDF, DEF, MDF, *Peltophorum dasyrrhachis* dominant forest (PTF), swamp forest with *Syzygium* spp. (SWF), and gallery forest with *Dipterocarpus alatus* Roxb. ex G. Don along streams (GLF). Species name, DBH, and height of trees (> 1.5m in height or > 3cm DBH) were recorded at each plot. Species names of seedlings and saplings were also recorded when observed in the plots.

Interview surveys were performed to ascertain former vegetation, method of forest conversion into paddy fields, and the local name and use of tree species. One key informant and several other persons engaged in agricultural activities in paddy fields were consulted at each village. In Nakhou village, 15 households were also interviewed about the use and management of trees in paddy fields in detail.

Data analysis

Density, basal area, number of species, percentage of the three dominant species, percentage of large trees (>30cm DBH), and mean DBH were calculated from the tree distribution data for paddy plots of different ages. Regeneration patterns (naturally regenerated, planted, or not regenerated) of tree species in forest habitat (forested land where human disturbance was not intensive), woods habitat (forested land where human disturbance was intensive), and village habitat (cultivated land, grassland, or homegarden) were estimated by field observation of seedlings and saplings. The probable agent of seed dispersal was determined on the basis of fruit types and available literature (Gardner et al., 2000; Van der Pijl, 1982).

The data collected by GPS were analyzed with geographical information system software *ArcView* version 3.1 (ESRI), topographic maps (published in 1983), and aerial photographs (taken in December, 1997).

The collected plants were identified in the Faculty of Forestry, National University of Laos, Vientiane, Laos, and in The Forest Herbarium, Royal Forestry Department, Bangkok, Thailand (BKF). Nomenclature of sampled plant species followed Gardner et al. (2000), Ho (1999-2000), Santisuk and Larsen (1997-2002), and Smitinand and Larsen (1970-1996).

2-3. Results

Forest vegetation and conversion

When Dongmakngeo village was established in 1960, dry evergreen forest covered the entire area. However, only half of the land is now covered by forest following conversion to paddy fields. The vegetation survey showed that three types of forest, DEF, DDF and MDF, extend over the lowland to upper land on undulating terrain of the village. Conversion had progressed upslope beginning in the lowland. More recently, DDF on the slightly higher land had been targeted. When the forest was cleared, trees were cut selectively in two ways. One method was cutting directly with ax and saw. The other was cutting after girthing, i.e., killing trees by removing a ring of bark and sapwood around the trunk. Normally, trees with a large straight trunk were left standing due to their timber value or labor requirement for removal.

Bak village was located on slopes with forest covering 32% of the land. Forests consisted of secondary forest dominated by *Dialium cochinchinensis* Pierre. and *Peltophorum dasyrrhachis* (PTF) on the upper slope, SWF surrounding water bodies on the foot slopes, and the village sacred forest with large trees of *Dipterocarpus alatus* and *Lagerstroemia* sp. (DEF) on the flood terrace. Paddy fields were mostly established more than 50 or 100 years ago on lower land facing SWF and DEF.

Aerial photography of Nakhou village showed that most of the land was covered by paddy fields. Older residents mentioned that there had been many stands of *Dipterocarpus alatus*, *Lagerstroemia* sp., and *Pterocarpus macrocarpus* around the village in the past, but few remained as a result of felling. Old paddy fields of more than 50 years were located on the lower land along streams in the east or around houses. On the other hand, new fields were established on the higher land in the west by clearing PTF. Remaining forested land was only small patches of PTF and GLF.

Species composition and distribution

A total of 137 woody species (including 17 shrubs and 7 woody lianas) were recorded in paddy fields at the three villages.

Figure 2-2 shows the characteristics of tree distribution in paddy fields of different ages. The results for Dongmakngeo village show lower tree density after conversion, but only minor change in basal area, implying that trees with large trunks have been preferentially left. The dominant species in each plot were *Dipterocarpus tuberculatus* Roxb., *Shorea obtusa* Wall. ex Blume, and *Terminalia alata* Heyne ex Roth, the indicator species of DDF. Although 12 species were recorded in 1-year paddy fields, only the three dominant species existed in 30-year fields. The percentage of the three dominant species, percentage of large trees (> 30cm DBH) and mean DBH increased in the older fields. There were 23 tree species observed in paddy fields at Dongmakngeo village (Appendix 1). Among them, 20 were common DDF species. Of the other three species, only a few individuals existed, and these had all been planted. No species were found to regenerate in the paddy areas.

In Bak village, there were no trees in paddy fields, but a few individuals of *Syzygium gratum* (Wt.) S.N.Mitra var. *gratum* and *Lepisanthes rubiginosa* (Roxb.) Leenh. occurred on termite mounds. In addition, one shrub, *Melastoma saigonese* (Kuntze) Merr., grew in rows along some paddy levees. In grassland around paddy fields, *Crateva adansonii* DC., *Pandanus* sp., *Tamarindus indica* L., and some large stumps of *Dipterocarpus alatus* were scattered. Interview survey showed that trees that had formerly existed in paddy fields had since been felled.

In Nakhou village, it was notable that although tree density decreased, some trees still remained in older fields (Figure 2-2). Two study plots were used to characterize 50-year paddy field at Nakhou village because species composition differed considerably. The dominant species of each plot differed considerably as follows: *Peltophorum dasyrrhachis*, *Morinda tomentosa* Heyne, and *Leucaena leucocephala* (Lam.) de Wit in the 10-year field, *Streblus asper*, *Borassus flabellifer* L., *Ceiba pentandra* (L.) Gaertn in one of the 50-year fields, *Azadirachta indica* var. *siamensis*, *Tamarindus indica*, and *Streblus asper* in the other 50-year field, and *Mitragyna rotundifolia* (Roxb.) O.Ktze., *Ceiba pentandra*, *Streblus asper* in the 100-year field. The number of species in each plot was 23, 20, 9 and 6 species respectively, of which 7, 9, 6 and 2 species respectively were planted. The number of individuals was much greater than in Dongmakngeo village. The percentage of the three dominant species and percentage of large trees (> 30cm DBH) increased in older fields. However, mean DBH did not change owing to the recruitment by regeneration and planting.

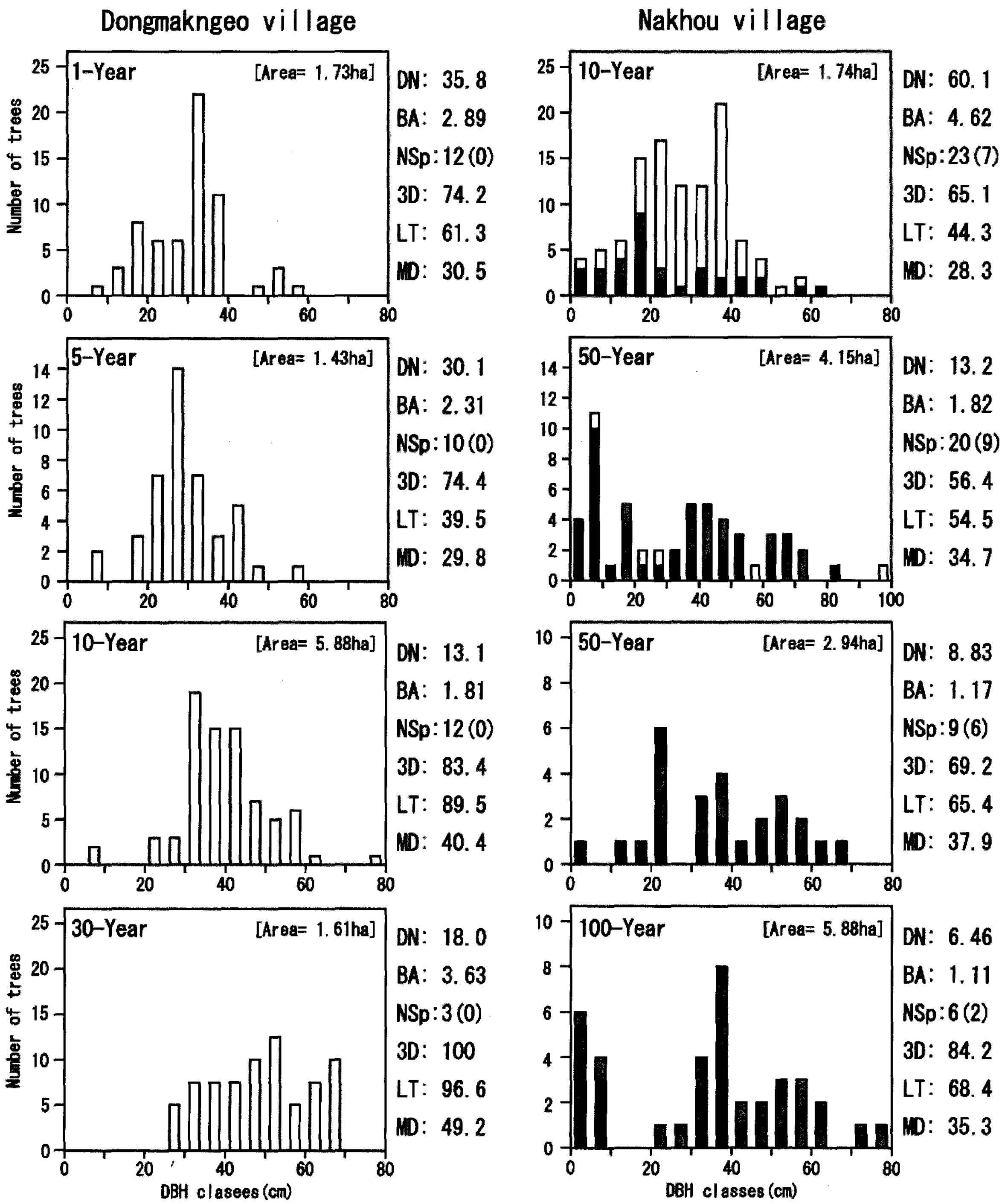

Figure 2-2. Distribution of DBH classes for trees in paddy fields at Dongmakngeo village and Nakhou village.

White bars indicate remnant species, gray bars ruderal species, and black bars planted species. DN: Density (individuals/ha), BA: Basal area (m^2/ha), NSp: Number of species (number of planted species), 3D: Percentage of three dominant species, LT: Percentage of large trees (>30cm DBH), MD: Mean DBH (cm).

The typical distribution pattern of six major species in the belt-transect at Nakhou village was as follows: *Irvingia malayana* and *Peltophorum dasyrrhachis* tended to occur in clusters on higher land in the west. Although *Mitragyna rotundifolia* was widespread, it formed pure stands on lowland along streams in the east. *Streblus asper*, *Azadirachta indica* var. *siamensis*, and *Diospyros mollis* were widespread in older fields (Figure 2-3, Figure 2-4, Figure 2-5).

Figure 2-6 shows the distribution of trees by micro-topographic element in paddy fields for the 20 most common species at Nakhou village. It indicates that species composing pure stands, such as *Irvingia malayana*, *Peltophorum dasyrrhachis* and *Mitragyna rotundifolia*, tended to occur on paddy surface or on paddy levees. On the other hand, species distributed widely within older fields, such as *Streblus asper*, *Azadirachta indica* var. *siamensis*, and *Diospyros mollis*, tended to be on termite mounds. Planted species were found only in rather old paddy fields. Their distribution was primarily determined by micro-topography. Considering the fact that *Jatropha curcas* L. was planted only on paddy levees to form live fences, or that villagers took the trouble to broaden paddy levees to plant *Ceiba pentandra*, the distribution of these species was highly dependent on the intentions of paddy owners.

There were 119 tree species observed at Nakhou village, including 27 planted species (Appendix 1). Among them, 25 species were found to regenerate in paddy area. It should be noted that species composing pure stands on paddy surface had few saplings in paddy area, whereas species scattered on termite mounds were regenerating (Figure 2-7). As to the 27 planted species, the most common ones were *Leucaena leucocephala*, *Tamarindus indica*, *Annona squamosa* L. and *Borassus flabellifer*. They included naturally growing species, such as *Millingtonia hortensis* L.f., which was sometimes planted as a medicinal or ornamental tree. Although most planted species were protected from livestock grazing when they were small, seedlings and saplings of *Leucaena leucocephala* and *Borassus flabellifer* seemed to grow naturally as an escaped plant.

Human use and management

Trees in paddy fields were found to supply various kinds of products in Dongmakngeo village. Trunks of the most abundant species, *Dipterocarpus tuberculatus* and *Shorea obtusa*, are large and straight with high timber value. Oleoresin (Ankarfjard and Kegl, 1998) collected from *Dipterocarpus* spp., called *namman nyang*, is used for fuel in traditional torches. Resin from *Shorea* spp., called *khi sii*, is used in coating handmade water containers. Both are not only self-consumed, but are a source of income that compensates for shortages in rice yield. Charcoal making is conducted in the dry season when there is no farm work. Charcoal is made from *Dipterocarpus tuberculatus*, *Dipterocarpus obtusifolius*, *Terminalia alata*, and *Terminalia mucronata* Craib & Hutch. Fruits of *Schleichera oleosa* (Lour.) Oken, *Syzygium* spp., *Dillenia ovata* Wall. ex Hk.f. & Th., *Phyllanthus embrica* L. and seeds of *Parinari*

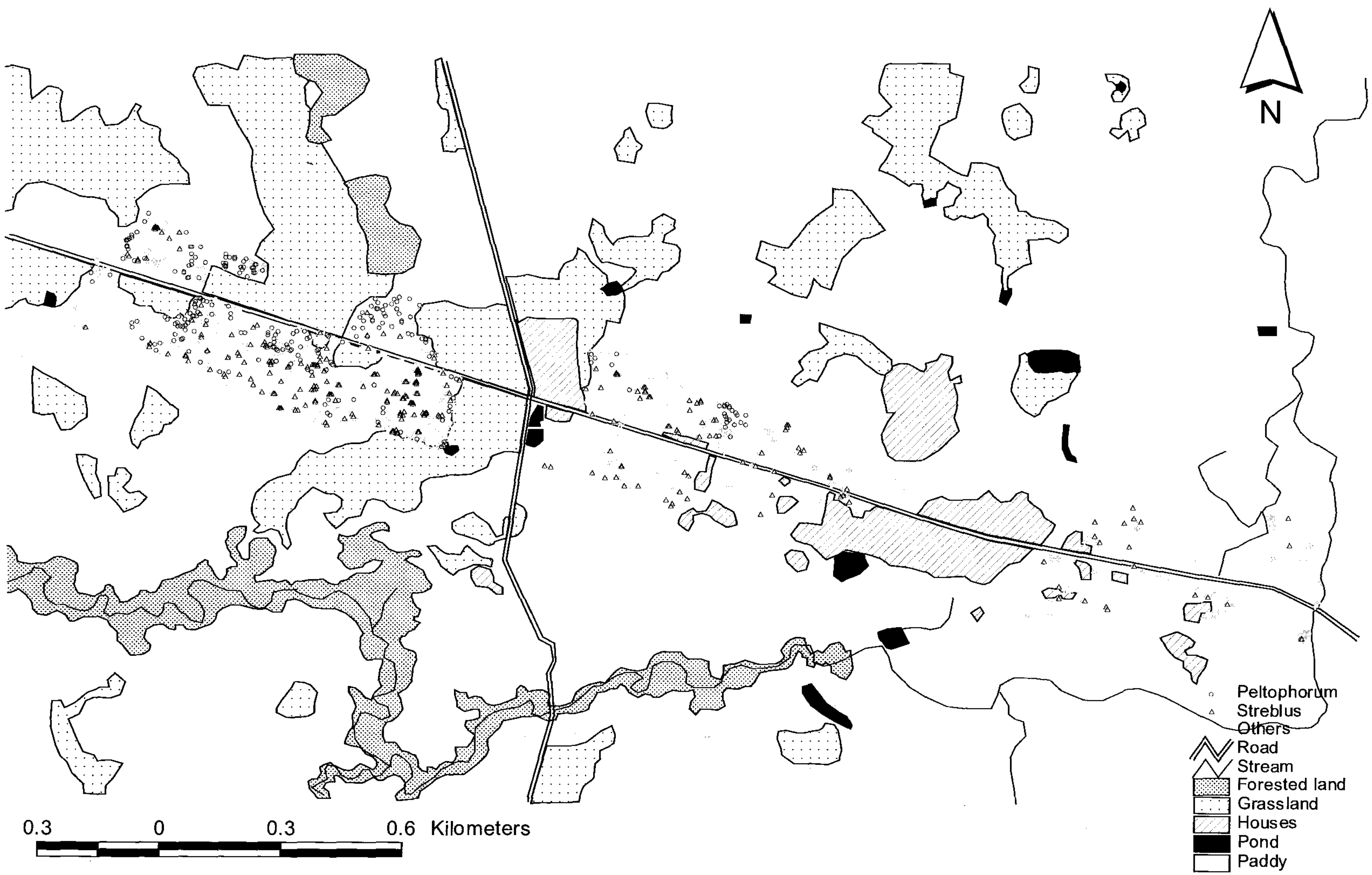

Figure 2-3. Tree distribution (*Peltophorum dasyrrhachis* and *Streblus asper*) in belt-transect survey plot at Nakhou village.

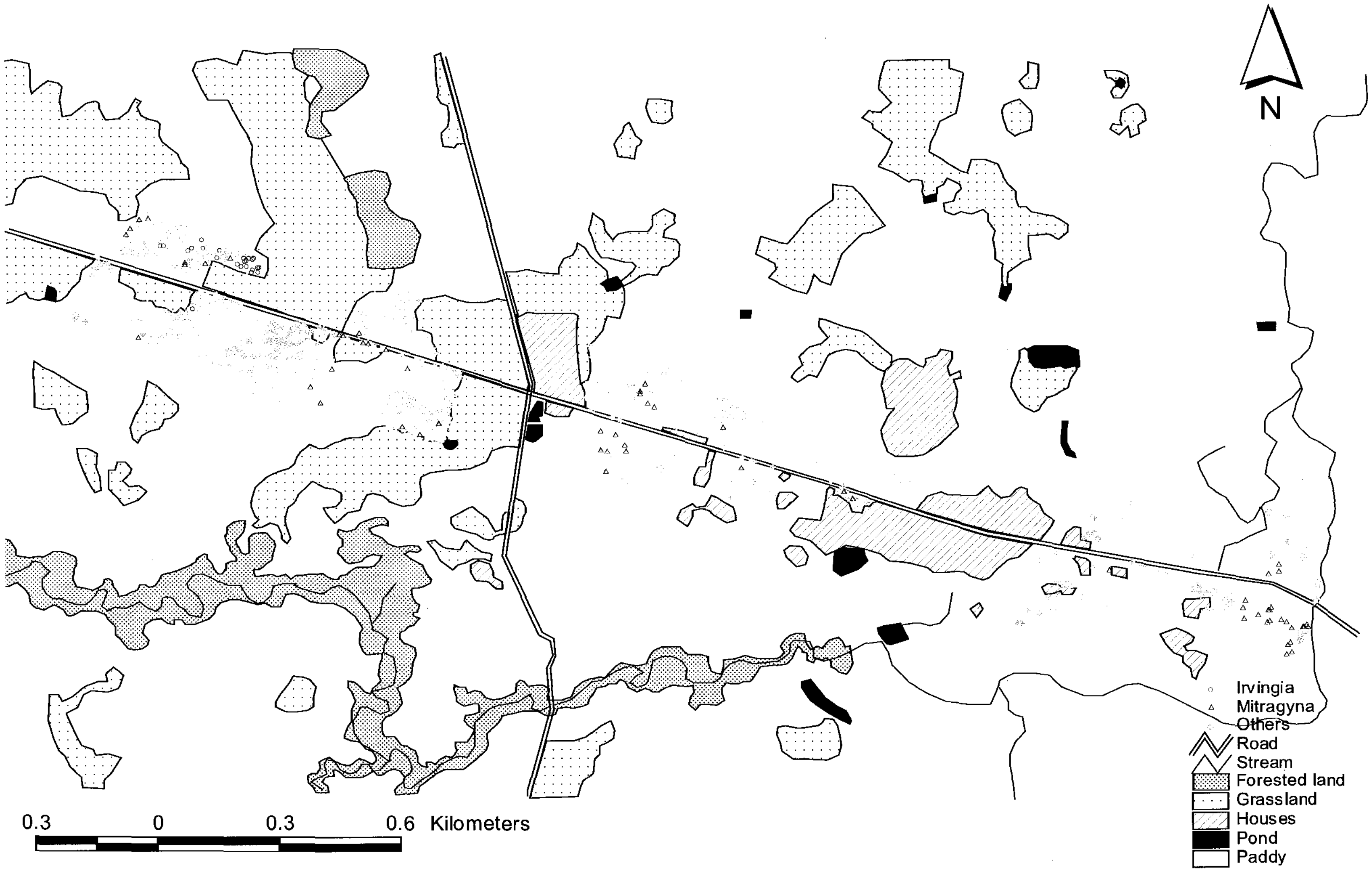

Figure 2-4. Tree distribution (*Irvingia malayana* and *Mitragyna rotundifolia*) in belt-transect survey plot at Nakhou village.

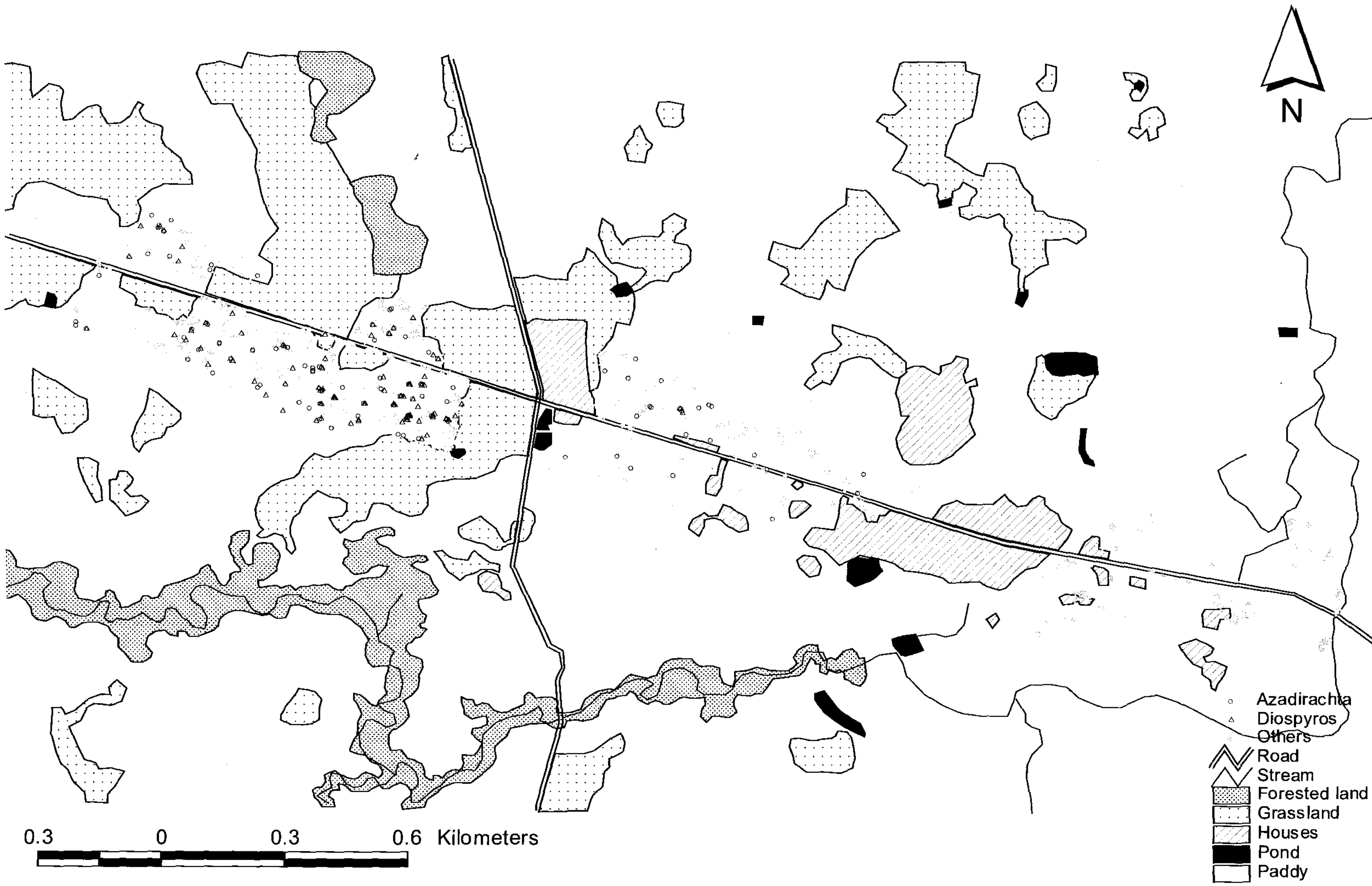

Figure 2- 5. Tree distribution (*Azadirachta indica* and *Diospyros mollis*) in belt-transect survey plot at Nakhou village.

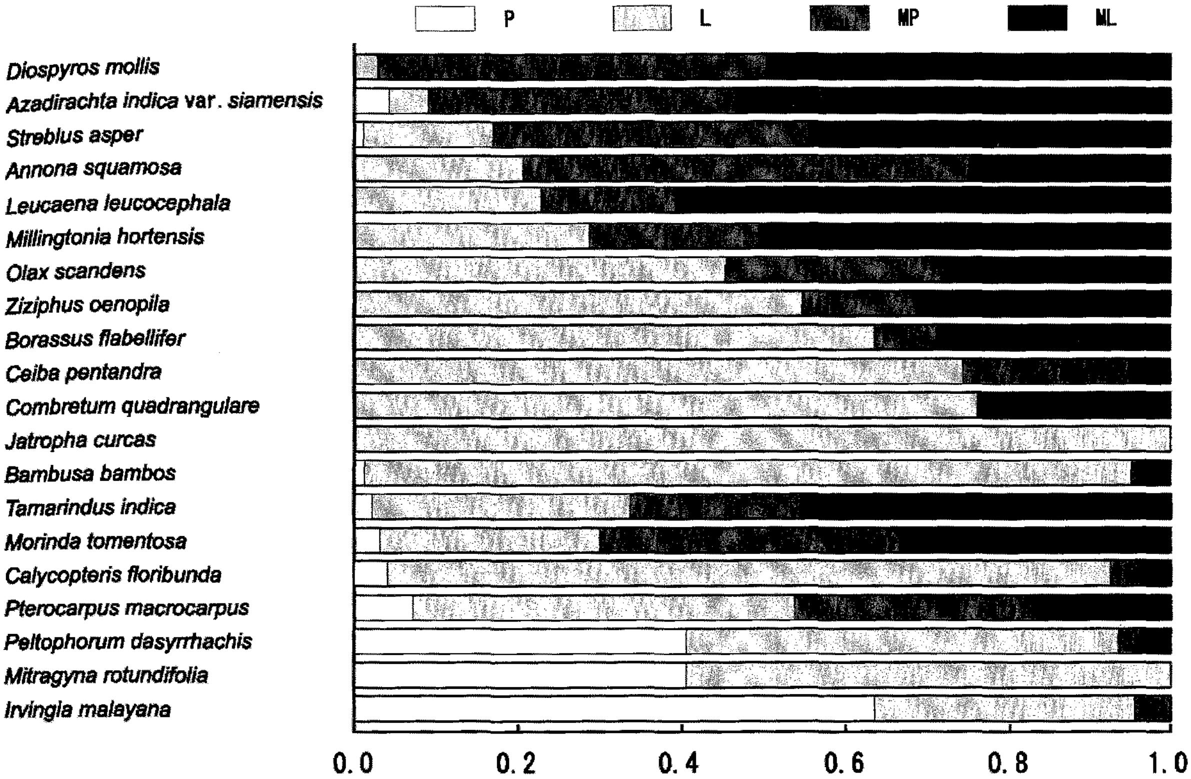

Figure 2-6. Distribution of trees by micro-topographic element in paddy fields in Nakhou village.

Data show the proportion of all individuals occurring on paddy surface (P), paddy levees (L), termite mounds on paddy surface (MP), and termite mounds on paddy levees (ML).

anamense Hance, leaves of *Syzygium gratum* var. *gratum* and *Lophopetalum wallichii* Kurz are edible. The fruit of *Schleichera oleosa* is especially popular for its sour taste and forms an income source when in season. Among planted species, *Oroxylum indicum* (L.) Kurz produces edible fruits and flowers. Cotton-like aril of *Ceiba pentandra* is used for stuffing pillows or mattresses. The fruit of *Tamarindus indica* is one of the most popular foods and seasonings in the country. In addition, villagers were found to recognize the fallen leaves of *Telminalia alata*, *Shorea* spp., *Morinda tomentosa* and *Syzygium* sp. as good fertilizer for paddy soil. To the contrary, *Dipterocarpus tuberculatus* leaves are not used as such owing to their resistance to decomposition. Interviews with several paddy owners showed that despite their recognition of trees in paddy fields as useful resources, trees had been felled since conversion and are rarely protected.

In Bak village, although the fruit and young leaves of *Syzygium gratum* var. *gratum*, and fruit of *Lepisanthes rubiginosa* are popular foods, they are collected in forest, where they are more abundant. Fruits of *Tamarindus indica* are also essential and are collected mostly in home gardens for the same reason.

On the other hand, trees in paddy fields were found to supply various kinds of products in

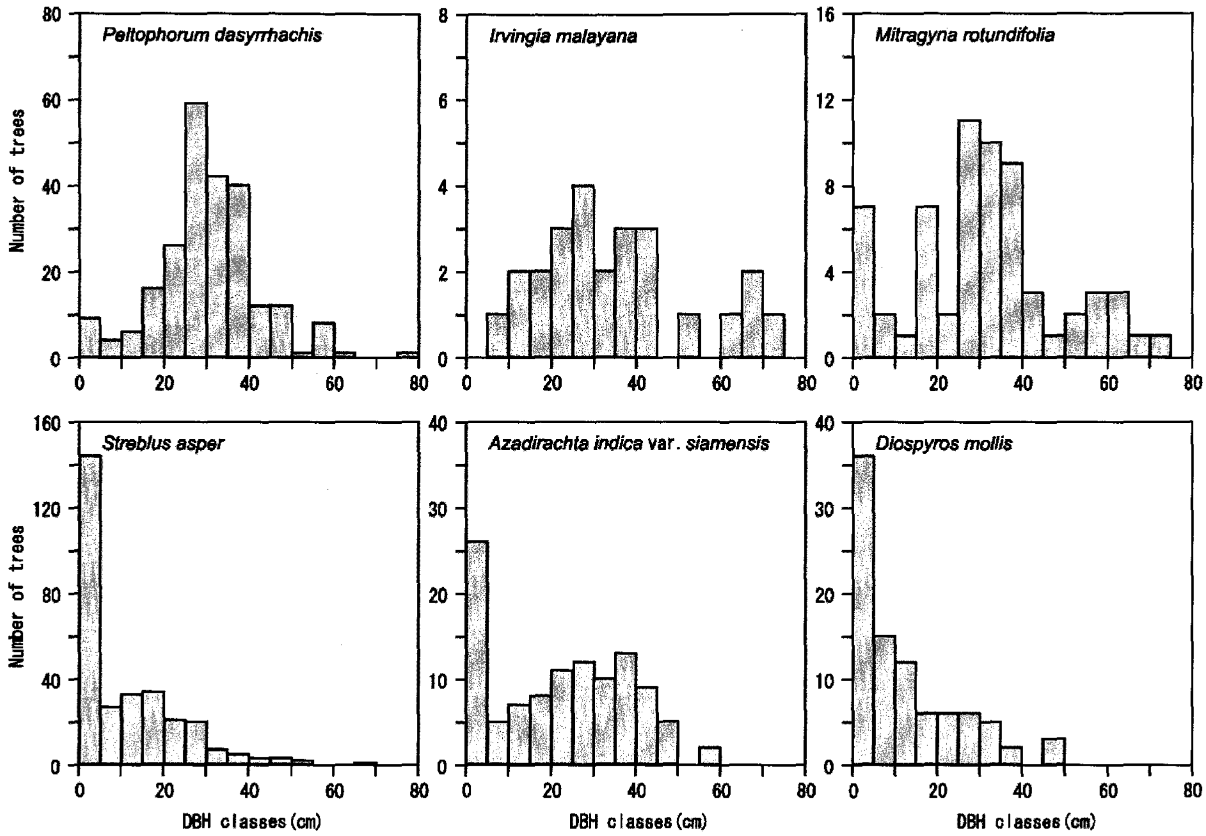

Figure 2-7. Distribution of DBH classes for six major species in paddy fields at Nakhou village.

Nakhou village. Of the 119 species, 86 species (72 %) were directly used by villagers. Most of the useful species had multiple purposes. Figure 2-8 shows the percentage of species used in each use categories at Nakhou village. Multi-purpose species were counted as one species in all the use categories to which they were referred. Among 59 wild useful species, major uses were for food (25 species; 42.4 %), for timber (21 species; 35.6 %), and for firewood (18 species; 30.5 %). Among 27 planted species, major uses were for food (15 species; 55.6 %), for making handicrafts (5 species; 18.5 %), and for medicine (4 species; 14.8 %). For example, leaves and flower buds of *Azadirachta indica* var. *siamensis*, *Bambusa bambos* (L.) Voss shoots, fruits and young shoots of *Leucaena leucocephala*, and seeds of *Irvingia malayana* are important foods. *Annona squamosa*, *Borassus flabellifer*, *Tamarindus indica*, and *Ziziphus mauritiana* Lam. are popular planted fruit trees. Although many species were found to be used for charcoal or firewood, *Irvingia malayana* yields the best quality charcoal. *Streblus asper* and *Samanea saman* (Jacq.) Merr. are used as fodder. *Ceiba pentandra* was preferably planted for cotton-like aril, which is an income source for the villagers. Villagers recognize the fallen leaves of *Peltophorum dasyrrhachis*, *Mitragyna rotundifolia*, *Memecylon* spp., *Samanea saman*, and *Senna siamea* (Lmk.) Irwin & Barn. as good fertilizer for paddy soil. *Jatropha curcas* is planted as a live fence as it is not palatable to buffaloes and cattle. Apart from the direct uses shown in the Appendix 1, almost all species mentioned by villagers provide a

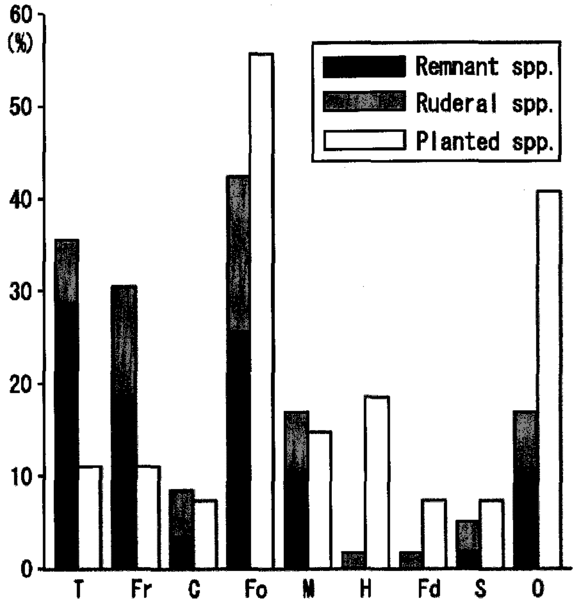

Figure 2-8. Percentage of species used in each use categories at Nakhou village.
T: Timber, Fr: Firewood, C: Charcoal, Fo: Food, M: Medicine, H: Material for handicraft, Fd: Fodder, S: Soil improvement, O: Others.

pleasant shade for both human and livestock and protect rice plants from strong sunshine. Interviews with 15 households showed reluctance of villagers to cut trees in the paddy fields because of their usefulness, except in newly established fields where the tree density is too high.

Impact of forest resources availability

Figure 2-9 indicates the tree density in paddy fields of different ages in the three villages. Trees were still standing in newly established paddy fields in Dongmakngeo village. In fact, because of the time and labor required, villagers often mentioned that tree cutting was not worth the trouble compared with rice cultivation. The number of planted species was quite small in contrast to the high tree density in the paddy fields. Instead, various kinds of forest products were collected in the surrounding forest and, as a result, the villagers were not concerned about the trees in the paddy fields.

At Bak village there were few trees in the paddy fields because their presence was not needed after conversion. The large area of surrounding forest provided ample firewood and timber for daily use.

On the other hand, people in Nakhou village buy firewood or charcoal from nearby villages owing to the scarcity of forested land. However, they were found to make the most of trees in paddy fields. In particular, the branches of *Peltophorum dasyrrhachis* and *Miragyna rotundifolia* are recognized as being quick to regenerate and are pollarded for firewood

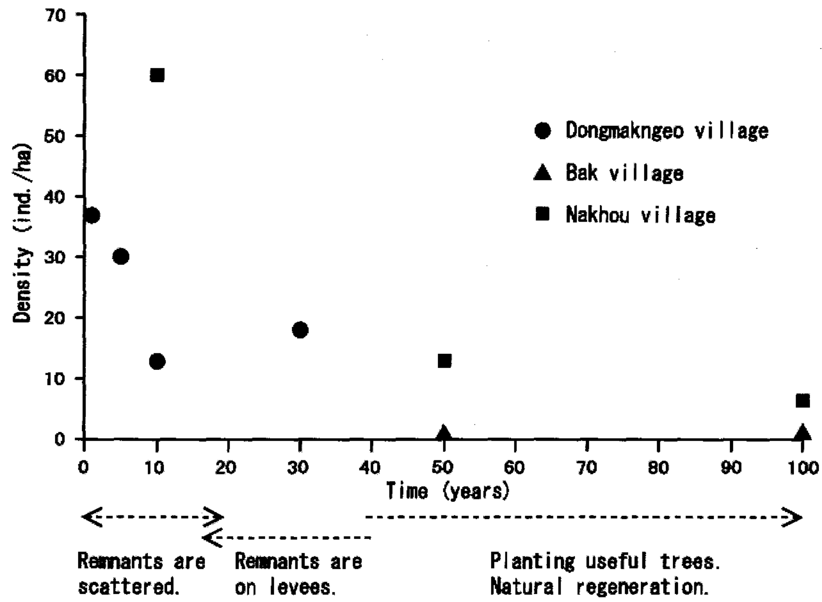

Figure 2-9. Tree density in paddy fields of different ages at the three villages.

collection at a height of 2-3 meters every two years (Figure 2-1). Figure 2-10 shows the effec of human management on tree growth. *Dipterocarpus tuberculatus* showed no significan difference in DBH-height ratio between paddy field and forest. On the other hand *Peltophorum dasyrrhachis* in paddy field had shorter and thicker trunks than in shifting cultivation field, obviously due to pollarding.

2-4. Discussion

According to studies on trees in paddy fields in northeast Thailand, Grandstaff et al. (1986) recorded 54 species (including shrubs), Watanabe et al. (1990) recorded 17 species with a density of 30-148.7 individuals/ha, and Prachaiyo (2000) recorded 28 species with a density of 14.9 individuals/ha. Despite the difficulty in making comparisons with these studies due to differences in various conditions of the study plots, I recorded a high diversity of woody species.

However, this species diversity may decrease in the future. Of the 137 woody species in my study sites, only 47 were naturally regenerated or planted (Appendix 1). Human interference and livestock grazing around paddy fields appears to induce high seedling mortality, as Hocking and Islam (1995) pointed out. It is important to note that the customs of the local people determined whether a species was naturally regenerated or planted. Several natural occurring species in this study site, such as *Azadirachta indica* var. *siamensis*, *Bambusa bambos*, *Combretum quadrangulare* Kurz, *Spondias pinnata* (L.f.) Kurz and *Sreblus asper*, are planted in northeast Thailand (Grandstaff et al., 1986). This means that the presence of trees in paddy fields was much influenced by people's management.

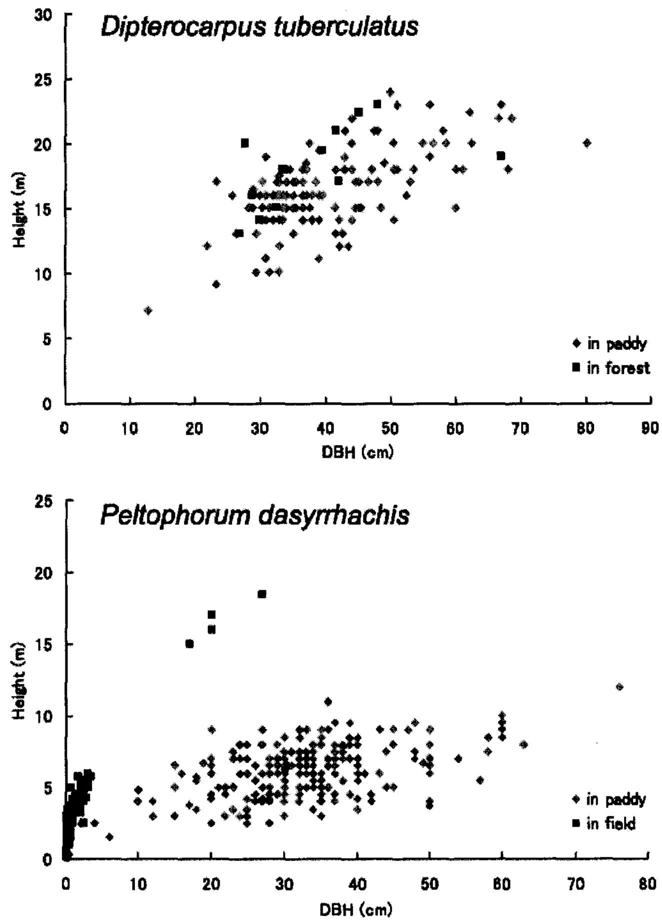

Figure 2-10. DBH and height for *Dipterocarpus tuberculatus* in paddy field (n=133) and dry dipterocarp forest (n=13) at Dongmakngeo village and for *Peltophorum dasyrrhachis* in paddy field (n=225) at Nakhou village and shifting cultivation fields (n=113) at Bak village.

The results at Nakhou village implied that the range of tree species in paddy fields changed from one of predominantly forest vegetation to ruderal vegetation as time passed. Seedlings could not survive such a highly disturbed setting as paddy surface, thus pure stands of species such as *Irvingia malayana*, *Peltophorum dasyrrhachis* and *Mitragyna rotundifolia* on paddy surfaces (Figure 2-6) would be remnants of the original forest. Except for *Mitragyna rotundifolia,* these species had few saplings in the paddy area, so the number of individuals will decrease (Figure 2-7). Although many seedlings of remnant species, e.g., *Peltophorum dasyrrhachis*, were observed on paddy levees at the beginning of the rainy season, none survived to become saplings. The only exception was a pure stand of *Mitragyna rotundifolia*, including saplings, which occurred in frequently flooded low-lying fields. This species adapted to a disturbed area where other species could not grow. The probable decline in remnant species in agricultural landscapes has also been reported for trees in pasture

(Harvey and Haber, 1999), where no regeneration occurred in the study site from trees retained from the primary forest. On the other hand, species scattered on termite mounds in older paddy fields (Figure 2-6), such as *Streblus asper*, *Azadirachta indica* var. *siamensis*, and *Diospyros mollis*, were rarely found in surrounding woods, but occurred in paddy areas. This indicates that they were ruderal species (Grime, 2001) adapted to the disturbed paddy field environment and seeming to increase in number. Their probable mode of dispersal (Van der Pijl, 1982) is by birds and bats (Appendix 1).

Some additional uses of the common species recorded in northeast Thailand (Grandstaff et al., 1986) include: sugar making from *Borassus flabellifer;* cultivating valuable edible fungus with *Ceiba pentandra*; and producing red dye and lac from insects on *Samanea saman*. Some of these uses provide sources of cash income and seem to be important to rural development in the study site for the current study in Laos.

The relationship between humans and trees varied with the environmental conditions, such as forest resources availability (Table 2-2). Grandstaff et al. (1986) hypothesized that tree management in paddy fields gradually evolves from a state of high tree density with little human care to one of low tree density with intensive human intervention. The results of this study supported that hypothesis. At Nakou village, where forest resources were scarce, tree density was high in the newly established fields, and trees still remained in older fields (Figure 2-9). This fact reflected the villagers' care for trees in paddy fields. Paddy fields converted from original forest, therefore, play a similar role to forest in supplying resources (Grandstaff et al., 1986; Watanabe et al., 1990; Prachaiyo, 2000). On this issue, further analysis over a wider area is important to consider both forest resources management and villagers' livelihood at the regional level.

Table 2-2. Summary of forest resources availability at the three villages

	Forest		Paddy fields	
DM	○	DDF: Timber, firewood, resin, food, medicine were collected. MDF: Timber, food, medicine were collected. DEF: Village sacred forest. Food and resin were collected.	○	Trees were left standing in the young paddy fields, though villagers were not consciously observing any tree protection requirements. The trees provided timber, resin, charcoal, and food.
BK	○	PTF: Timber, firewood, food and other NTFPs were collected. SWF: Village protected forest. Food was collected. DEF: Village sacred forest. Food was collected.	×	Trees were absent owing to previous cutting. Villagers with access to rich resources in adjacent forest had no need for plantings on paddy levees.
NK	△	PTF: A little food was collected. GLF: A little food was collected.	△	Trees were intentionally left in paddy fields as supplementary source for daily use. They provided food, charcoal and firewood, fodder, and material for handicrafts.

Firewood, food and timber were considered as the main forest resources for daily livelihood.

○: Adequate supplies for daily use.

△: Insufficient. Supplementary source needed.

×: Absent.

2-5. Conclusion

Species composition and distribution of trees in paddy fields differed considerably between the three study sites owing to three factors: (1) micro and macro topography in paddy fields, (2) years since conversion from forest, and (3) forest resources availability. Remnant species dominant in newly established fields had been replaced with ruderal ones as time passed. Overall tree density depended on villagers' management practices, such as the rate of cutting trees and planting of useful trees. In addition, these management practices were influenced by forest resource availability in the village. The need for trees in paddy fields was greater in the village without forested land. Thus, paddy fields do not form a homogenous landscape, but embody various species compositions and tree distributions owing to micro and macro topography under human management.

In Laos, inventories in 1982 and 1989 showed that deforestation was occurring at 70,000 ha per year, mainly due to shifting cultivation, logging, and collection of firewood (NOFIP, 1992). Although the forest law that became effective in 1996 placed restrictions on logging and shifting cultivation to some extent, 97% of the households in the country still use wood or charcoal for cooking fuel (LWU, 2001). Wood consumption is estimated to be 1 cubic meter/person/year (LWU, 2001). My study shows that the interaction between humans and trees occurs continuously through a process where forest is progressively transformed into cultivated land. The farmer–paddy field system may be important for reestablishing efficient resource use in the country if the people begin to manage trees in the rice fields for their own use (Prachaiyo, 2000). In other words, it is possible that small-scale tree management by villagers, which is not revealed in national forestry statistics, could contribute to relieving deforestation at the national level.

Chapter 3. Plant diversity in paddy fields in relation to agricultural practices

3-1. Introduction

Agricultural landscapes have attracted increasing attention in line with the general rise in concern about the conservation of biodiversity (e.g., Gall and Orians, 1992; Pimentel et al., 1992). The predominant agricultural land-use throughout much of Asia is paddy farming for the monoculture cultivation of rice, and some studies have examined plant biodiversity in paddy fields (e.g., Bambaradeniya, 2004).

Although subject to repeated human disturbance, such as flooding, plowing, or weeding, many plant species persist within the paddy landscape. Shimoda (2003) revealed high plant diversity in a paddy field compared with vegetation in an abandoned field. Ikeda and Miura (2002) showed that many endangered wetland plants survived in paddy fields subject to traditional agricultural practices in Japan. However, the composition of weed species assemblages in paddy fields is rapidly changing due to factors such as increased use of herbicides, changes in plowing and fertilizer practices, changes in cropping systems (especially autumn plowing and off-season crop are no longer practiced), and environmental change by creation of well-drained paddy fields (Shimoda, 2003).

Weeds are a major constraint on crop production, yet as one of the primary producers they may be regarded as an important component of the agroecosystem (Marshall et al., 2003). In addition, many plants in paddy fields are useful. Datta and Banerjee (1978) reported that of 158 paddy weed species collected in West Bengal, 124 were regarded as useful according to available literature. Yamaguchi and Umemoto (1996) focused on weeds on paddy levees and pointed out their various functions for food, medicine, prevention of soil erosion, livestock feed, landscaping, and aesthetic plants. Moreover, the ecology and conservation of wetlands has received much attention (Gopal and Sah, 1995). Thus, there is an urgent need to carry out floristic surveys in paddy fields, which harbor many wetland plants, especially in regions where the flora is not well documented.

There have been several reports published on the herbaceous species composition of paddy fields in mainland Southeast Asia. Heckman (1974) reported the seasonal succession of species in Laos. Tomita et al. (2003a; 2003b) found differences in weed vegetation in response to cultivation method and watering regime. However, overall floristic composition and species richness associated with paddy fields and paddy levees has received little attention. In this context, the plant diversity of an area is not merely a measure of the number of species occurring, but also reflects the dependence of the indigenous communities on that plant resource (Jain, 2000).

This study was performed on the flood plain of the Mekong River in central Laos, where paddy fields are the predominant land use. Significant wetland habitat forms an integral and fundamental part of the agricultural and natural landscape of this region (Daconto, 2001: 1).

The local people do not use herbicides and still collect various plants from paddy fields for use in their daily lives. The purpose of this study was: (1) to create an inventory of and classify paddy vegetation and (2) describe relationships between paddy vegetation and agricultural practices.

3-2. Site description and methods

Site description

The field survey was carried out at Nakhou village and Bak village, Champhone District, Savannakhet Province, Laos. Both villages are located on different parts of the same contiguous slope, with paddy fields beginning in the lowlands of Nakhou village and extending upslope to central Bak village. Shifting cultivation is performed on the higher land of Bak village. Some springs were found in Bak village on the boundary between the paddy field zone and the shifting cultivation zone.

Selection of the survey plots

The local people at the study site classify paddy fields into four types: hillside (*na khok*), home-side (*na tin ban*), lowland (*na tham*), and wet paddy (*na beung*). This classification is based on the topography and location of the fields: hillside paddy on lower and upper slopes; home-side paddy on flat land and lower slopes adjacent to houses; lowland paddy on flood terraces; and wet paddy on valley bottoms and foot slopes.

According to the preliminary interview survey, all types of paddy field are plowed in May, with transplanting occurring in June and harvesting in October. Manure, rice husks, and chemical fertilizer are applied for soil improvement. After rice is harvested, cattle and buffaloes are grazed in paddy fields, except in some lowland and wet paddy fields that are also cultivated in the dry season. The survey also found that home-side paddy is the most fertile because nutrient-rich water flows into it from surrounding houses. Lowland and wet paddy is moderately fertile, while lowland paddy along streams is at risk of flood. Hillside paddy was found to be generally less fertile, and the rice yield from this paddy type is usually low unless fertilizer is applied. The rice yield within the study site was found to be 1–3 t/ha, but subject to considerable variation with land quality, fertilizer application, and weather.

A total of 26 sample plots were selected in paddy fields representing all four paddy types. In June 2003, one quadrat (1 m×1 m) per plot was established for a preliminary survey. Subsequently, three quadrats per plot (including the initial quadrats) were established for a total of 78 quadrats (Figure 3-1), which were assessed for plant species presence and abundance in July, September, October, December 2003, and March 2004 as described in the following section on data collection.

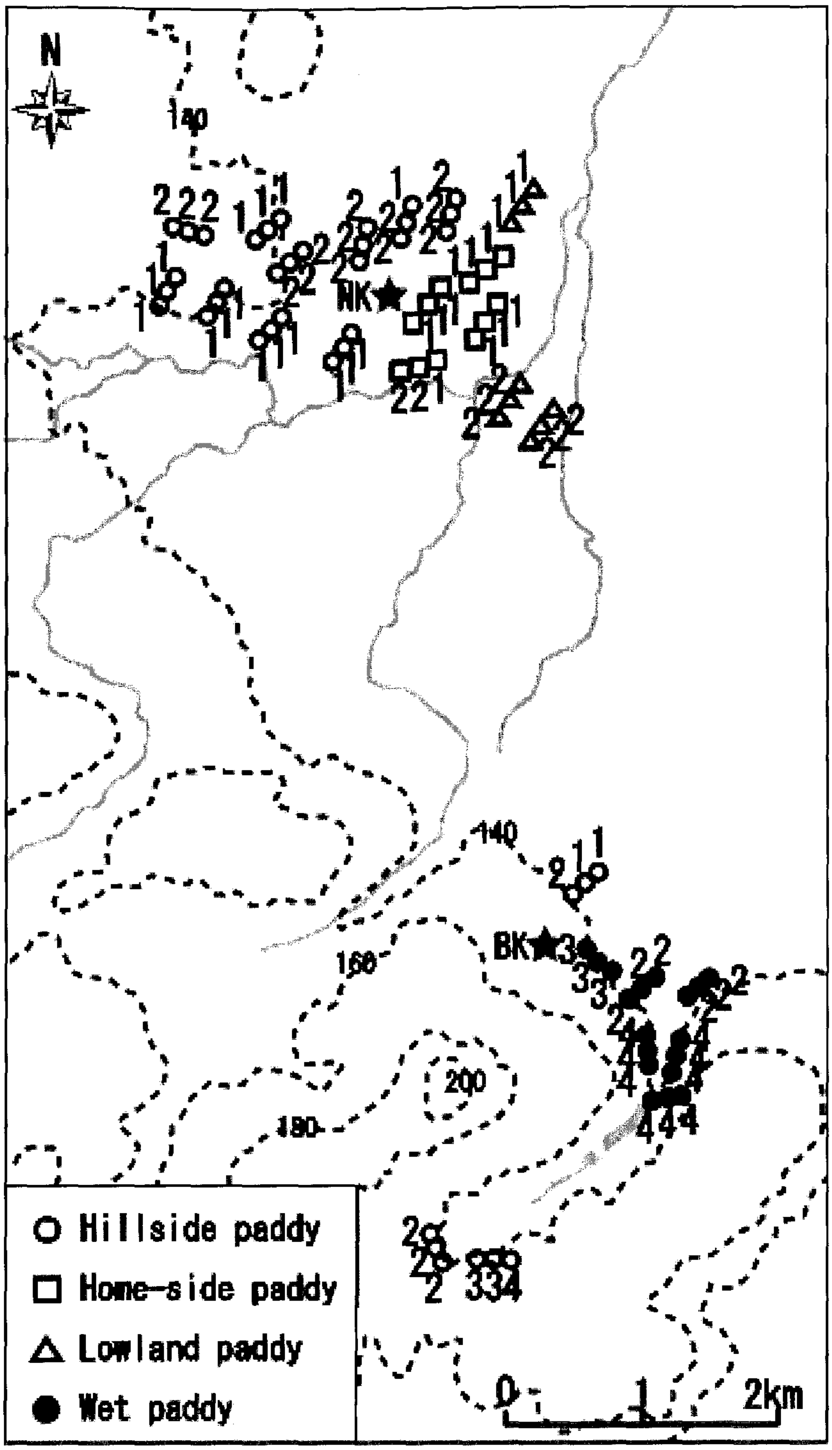

Figure 3-1. Distribution of 78 quadrats and their vegetation types at Nakhou (NK) village and Bak (BK) village.

Numbers (1-4) represent vegetation types obtained by TWINSPAN classification of species assemblages within quadrats.

Data collection

The rice agroecosystem can be divided into three broad habitat types, namely the field, the levee, and the ditch (Chandrasena, 1988). In this study, herbaceous species (spermatophytes and pteridophytes) in fields and on levees were targeted.

The quadrat method was used to determine the composition and coverage of wild species in fields. Coverage (%) and height (highest individual in quadrat) of each species, and water depth (average of several measurements in quadrat) were recorded in each quadrat. In addition, when unrecorded species were observed outside the quadrats during the survey period, their names were also added to the inventory. For wild species on levees, semi-quantitative data (few, scattered, or abundant; Heckman, 1974) were obtained by direct observation at several places in each paddy type because the various micro-habitats (shore, flat part, and grassland; Yamaguchi and Umemoto, 1996) prevented me from establishing quadrats. The name and habitat of cultivated species were recorded when observed. The collected plants were identified in the Faculty of Forestry, National University of Laos, Vientiane, Laos, and in The Forest Herbarium of the Royal Forestry Department, Bangkok, Thailand (BKF). Nomenclature of sampled plants followed Ho (1999-2000), Santisuk and Larsen (1997-2002), and Smitinand and Larsen (1970-1996).

I interviewed one key informant and several farmers in each village to determine the local names and uses of sampled plants as well as the rice cropping system (cropping seasons, fertilizer application, water management, weed control, yield, grazing after harvest).

Data analysis

The quadrat data for species in fields were subject to two-way indicator species analysis using the computer program TWINSPAN (Hill, 1994) and detrended correspondence analysis (DCA) using the computer program DECORANA (Hill, 1994). The relative abundance value was determined for the species with maximal coverage (%) in each quadrat during the survey period. TWINSPAN split the quadrats dichotomously based on species abundance data and was used to identify patterns in the vegetation classification.

DCA extracts the compositional gradients from the species–quadrats data matrix. Species richness, diversity and dominance were determined for each paddy type by calculating species richness (number of species per quadrat), Shannon diversity index (Shannon and Weaver, 1949), Simpson dominance index (Simpson, 1949), and evenness index (Pielou, 1966). In addition, the number of unique species, i.e., species that were recorded in only one paddy type, was counted. The importance of species was estimated using an index of specific value (ISV; Pinder and Rosso, 1998), defining species with value >0.2 as the dominant species (Tomita et al., 2003b):

$$\mathrm{ISV}i = \frac{\sum_{j=1}^{N} rk_{i,j}}{\sum_{j=1}^{N} rk_{\max j}}$$

where rk_{ij} indicates the rank of species i in quadrat j, N indicates the number of quadrats, and $rk_{\max j}$ indicates the rank of the most abundant species in quadrat j.

All wild species both in fields and levees were categorized by life-form (annual herb or perennial herb) and water adaptability (hydrophyte, hygrophyte, or mesophyte), based on field observation and available literature, such as Chandrasena (1988), Harada, Shibayama, and Morita (1993), HEAR (2004), Ho (1999 - 2000), Kasahara (1959), Ohtaki and Ishido (1980), Santisuk and Larsen (1997 - 2002), Shimizu (2003), Smitinand and Larsen (1970 - 1996), Soerjani, Kostermans, and Tjitrosoepomo (1987), Tomita et al. (2003b), and Weerakoon and Gunewardena (1983). In this paper, the definition of naturalized species follows Pysek (1995), and was determined according to HEAR (2004), Kasahara (1959), and Shimizu (2003). Rare species were determined according to the classification of Santisuk and Larsen (1997 - 2002) and Smitinand and Larsen (1970 - 1996).

3-3. Results

General characteristics of sampled plants

A total of 184 wild species, representing 116 genera and 47 families, was recorded (Table 3-1). Among them, 25 species representing 23 genera and 17 families were observed only in fields, 97 species representing 78 genera and 37 families were observed only on levees, and 62 species representing 42 genera and 22 families were observed in both fields and levees (in common). There were 11 hydrophyte species in fields, none only on levees, and 2 in common (13 in total). Poaceae (6 spp.), Cyperaceae (2 spp.), and Lythraceae (2 spp.) were the dominant families represented by species occurring only in fields. Cyperaceae (18 spp.), Poaceae (12 spp.), and Scrophulariaceae (10 spp.) were the dominant families represented by species occurring only on levees. Poaceae (11 spp.), Scrophulariaceae (11 spp.), Cyperaceae (10 spp.) were the dominant families represented by species in common. Cyperaceae (30 spp.), Poaceae (29 spp.), and Scrophulariaceae (22 spp.) were the dominant families overall. Rare species recorded were *Drosera indica* L. (on levees), *Stylidium kunthii* Wall. (on levees), *Stylidium tenellum* Sw. ex Kunth. (in common), and *Stylidium uliginosum* Sw. ex Willd. (on levees). Among the wild species, a total of 43 species were naturalized species from Africa, America, Australia, India, or Madagascar.

In addition, a total of 17 cultivated species representing 17 genera and 13 families were recorded (Table 3-1).

Table 3-1. Floristic characteristics of herbaceous species in fields and on levees at Nakhou village and Bak village

	In fields	On levees	In Common	Total
Wild species				
No. of family	17	37	22	47
No. of genera	23	78	42	116
No. of species	25	97	62	184
No. of hydrophytes	11	0	2	13
Cultivated species				
No. of family	7	6	0	13
No. of genera	10	7	0	17
No. of species	10	7	0	17
No. of hydrophytes	0	0	0	0

"In fields" and "on levees" indicates the species that occur only in each of those habitats. "In common" means species that occurred both in fields and on levees.

Characteristics of paddy field types

Diversity and other characteristics of the four paddy types are shown in Table 3-2. Of the wild species in fields, the number of species was greatest in hillside paddy (52) and least in wet paddy (27), with each paddy type including several unique species. Species richness (the number of species per quadrat) was greatest in home-side paddy (17.2 ± 3.8), least in wet paddy (7.8 ± 3.8), and intermediate in hillside and lowland paddy. Hillside, home-side, and lowland paddy showed similar values for Shannon diversity index and Simpson dominance index, whereas wet paddy had a lower Shannon diversity index and higher Simpson dominance index. The evenness index was greatest in lowland paddy, least in wet paddy, and intermediate in hillside and home-side paddy. The highest proportion of hydrophytes in wet paddy corresponded to the highest water level in this paddy type, which was flooded almost throughout the year. Dominant species (ISV>0.2) were: *Limnophila geoffrayi* Bonati, *Rotala indica* (Willd.) Koehne, *Ludwigia hyssopifolia* (G. Don) Exell., *Fimbristylis miliacea* (L.) Vahl, and *Cyperus haspan* L. in hillside paddy; *Fimbristylis miliacea, Rotala indica, Ludwigia hyssopifolia, Centipeda minima* (L.) A. Br. & Aschers., *Lindernia viatica* (Kerr ex Barnett) Philcox, *Limnophila geoffrayi, Adenosma javanica* (Bl.) Koord., and *Marsilea crenata* Presl in home-side paddy; *Fimbristylis miliacea, Glinus hernarioides* (Gagn.) Tard., *Cyperus haspan, Rotala indica, Melochia corchorifolia* L., and *Digitaria fuscescens* (Presl) Henrard. in lowland paddy; and *Monochoria vaginalis* (Burm. f.) Presl, *Blyxa japonica* (Miq.) Maxim. ex Aschers., *Limnophila villifera* Miq. ssp. *gracilipes* (Craib ex Hoss.) Yamazaki, *Utricularia aurea* Lour. in wet paddy. Of the wild species on levees, the number of species was greatest in hillside paddy, which included multiple unique species.

Table 3-2. Plant diversity and other characteristics of hillside, home-side, lowland and wet paddy fields at Nakhou village and Bak village

Paddy type	Hillside	Home-side	Lowland	Wet
Mean water depth	0-4 cm	0-4 cm	0-3 cm	6-18 cm
Wild species in fields				
No. of family	23	23	18	17
No. of genera	39	42	32	24
No. of species	52	49	38	27
No. of unique species	8	9	5	7
Species richness*1	11.5±4.8[b]	17.2±3.8[a]	13.4±2.8[b]	7.8±3.8[c]
Shannon's index	3.03	3.03	3.01	2.53
Simpson's index	0.07	0.07	0.06	0.11
Evenness index	0.75	0.77	0.82	0.74
Wild species on levees				
No. of family	37	21	21	18
No. of genera	81	48	44	41
No. of species	125	62	57	59
No. of unique species	49	2	9	11

*1 Entry of species richness (number of species per quadrat) is mean ± standard error. Numbers in the same row followed by the same letter are not statistically different (α=0.05).

Classification and ordination of sample quadrats

From the analysis of wild species in fields, we obtained four vegetation types from the classification of the 78 quadrats (Figure 3-2). At the first level division, group A and B corresponded to water regime. All quadrats in group A were subject to a long dry period during the year, whereas group B was composed of quadrats flooded almost throughout the year. The indicator species was *Limnophila geoffrayi* (hygrophyte) for group A and *Blyxa japonica* (hydrophyte), *Limnophila villifera* ssp. *gracilipes* (hygrophyte), and *Monochoria vaginalis* (hydrophyte) for group B.

At the second level division in group A, most quadrats in home-side paddy were placed into subgroup A-1, whereas all quadrats in wet paddy were placed into subgroup A-2. Quadrats in hillside and lowland paddy were placed into both subgroups. Indicator species for A-1 were *Ludwigia hyssopifolia* (hygrophyte), *Lindernia viatica* (mesophyte), *Centipeda minima* (mesophyte), and *Adenosma javanica* (mesophyte), indicating rather dry conditions. A-2 quadrats were characterized by the existence of *Xyris indica* L. (hygrophyte) and *Eriocaulon* sp. (hydrophyte), indicating wet conditions. In group B, most quadrats in wet paddy were placed into subgroup B-2, characterized by *Monochoria vaginalis* (hydrophyte) and *Hymenachne acutigluma* (Steud.) Gilliland. (hydrophyte), indicating a longer period of

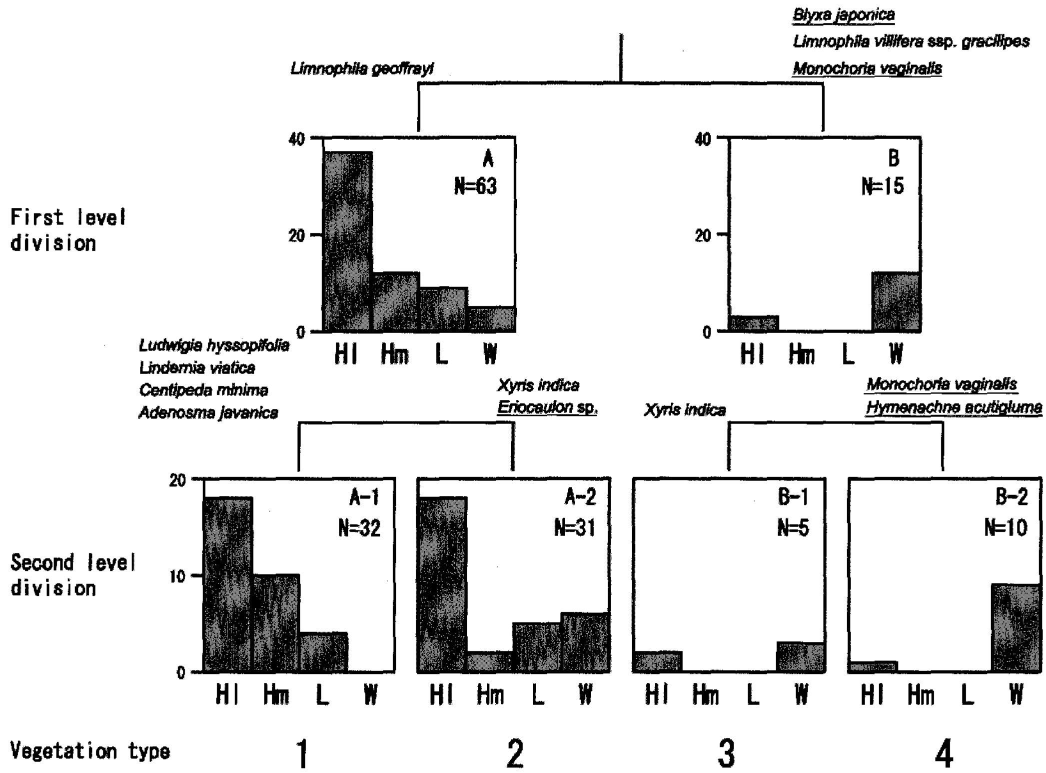

Figure 3-2. TWINSPAN classification of 78 vegetation quadrats at Nakhou village and Bak village.

Plant names represent the indicator species for each division. Species with underlines are hydrophytes. Bars indicate the number of quadrats in the respective paddy types, such as hillside paddy (Hl), home-side paddy (Hm), lowland paddy (L), and wet paddy (W).

flooding in B-2 than in B-1, which was characterized by *Xyris indica* (hygrophyte).

The four vegetation types obtained by the TWINSPAN classification were arranged along DCA axis 1 in order from type 1 to type 4 (Figure 3-3). In addition, there was a gradient in paddy types across axis 1 (Figure 3-3a). Home-side and lowland paddy scored lower, whereas wet paddy scored higher. Hillside paddy was distributed widely along axis 1 in an order corresponding to the water regime (Figure 3-3b). Quadrats with a long dry period had the lowest scores and those flooded almost throughout the year had high scores.

Seasonal change in species composition

Table 3-3 shows the seasonal change in frequency of the 17 most common wild species in fields in each vegetation type obtained by the TWINSPAN classification. Species were listed in order of classification, with species strongly associated with type 1 at the top of the list, and those associated with type 4 at the bottom of the list. The frequency of the respective species (i.e., the number of quadrats in which they were recorded) is shown for July (the beginning of

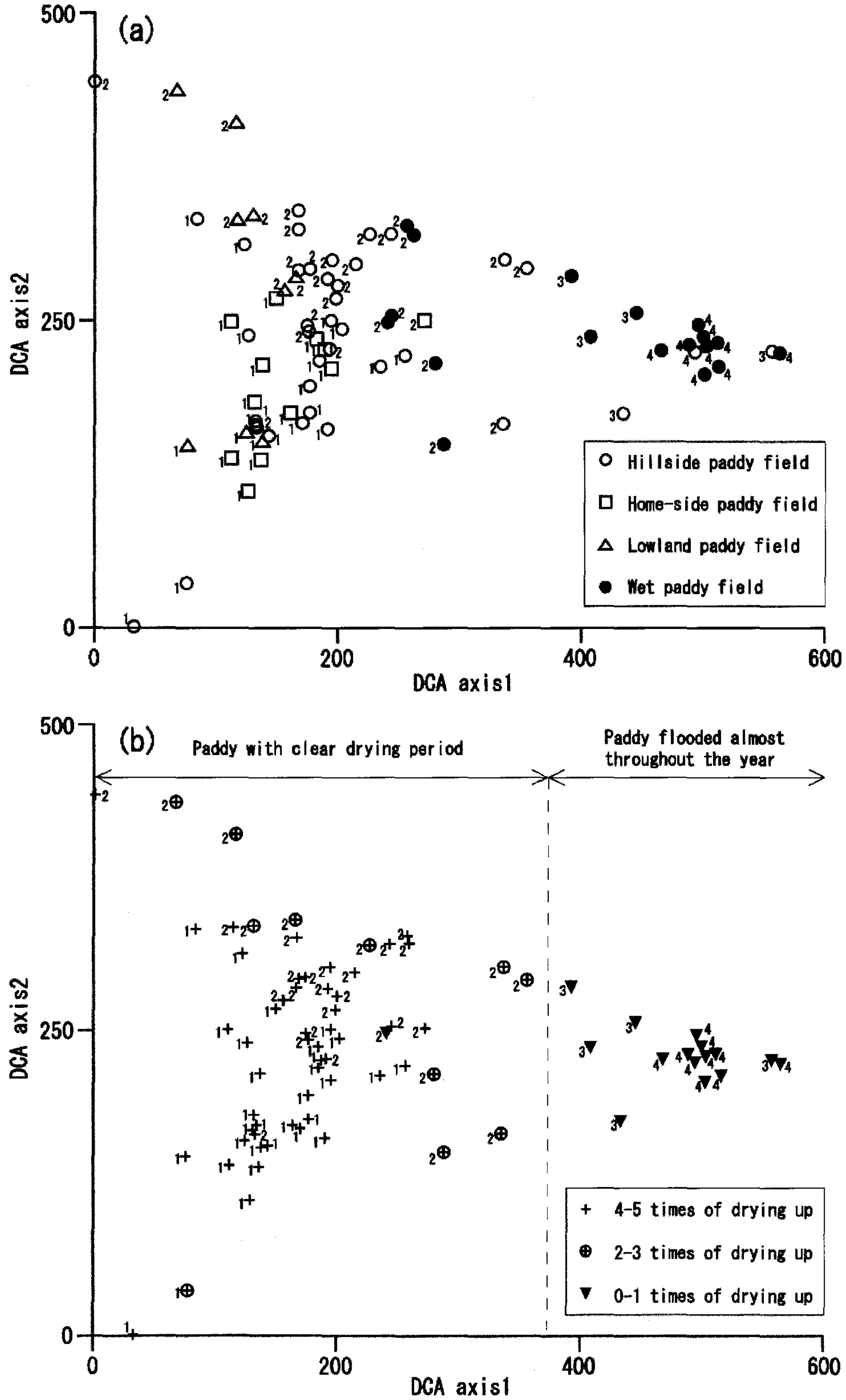

Figure 3-3. Scatter diagram of the first two axes of DCA ordination of 78 vegetation quadrats for (a) paddy type and (b) hydroperiod (represented by the frequency of drying up during the survey period) at Nakhou village and Bak village.

Numbers 1, 2, 3, and 4 correspond to vegetation type obtained by TWINSPAN classification.

Table 3-3. Seasonal change in frequency of the most common wild species in fields for each vegetation type at Nakhou village and Bak village

Vegetation type	1					2					3					4				
No. of quadrats	31					32					5					10				
Month	7	9	10	12	3	7	9	10	12	3	7	9	10	12	3	7	9	10	12	3
Lindernia viatica *	2	4	1				1	1												
Centipeda minima *	1		1	2	4	1			2	2										
Glinus hernarioides					1	1				1										
Fimbristylis milicea	4	5	2	1	1	2	3	2		1						1	1			
Glinus oppositifolius				1	1				1	1										
Melochia corchorifolia	1	1	1	1	3	1	1			2										
Grangea maderaspatana				1	1				1	1										
Limonphila geoffrayi *		3	4	1			4	5	3	1		2								
Panicum repens	1	1	1	1	1	1	2		1	1	2									
Rotala indica	1	2	4	3		1	1	4	4	1				3						
Ludwigia hyssopifolia *	5	5	5	3	4	3	3	2	2	3						1		1		
Xyris indica *			1	1			2	3	3	1				3				1		
Cyperus haspan	2	2	2	1	3	2	2	4	3	4				2		2		1		
Marsilea crenata	1	2	1	1	1	1	1		1	1						3		2	2	1
Monochoria vaginalis *		1				1	1	1	1	1	2			2		5	3	5	5	5
Blyxa japonica *							1						3		4	3	4	1		2
Limnophila villifera ssp. *gracilipes* *						1		1	1	1	5	4	4	4	2	4		3	2	4

Species are listed in order of TWINSPAN classification. Species with an asterisk are the indicator species for the classification. Numbers represent the frequency (1: 0 - 20%, 2: 20 – 40%, 3: 40 – 60%, 4: 60 – 80%, 5: 80 - 100%).

Table 3-4. Seasonal change in frequency of the representative wild species in levees for each vegetation type at Nakhou village and Bak village

Vegetation type	1					2					3					4				
Month	7	9	10	12	3	7	9	10	12	3	7	9	10	12	3	7	9	10	12	3
Bacopa monnieri	S	S	S	F	F															
Adenosma javanica		S	S	A	F		S	S	S	F										
Coldenia procumbens				F	S				F	S										
Grangea maderaspatana					F				F	S										
Nosema cochinchinense							S	S	F											
Osbeckia cochinchinensis							F	S	F											
Drosera indica *						F	F	F												
Stylidium kunthii *								F	F											
Adenosma elsholtzioides						S	A	A	F				S	F						
Limnophila villifera ssp. gracilipes											A	A	A	A	S	A	A	A	A	A
Lindernia anagallis											S	S	S			S	S	S	F	F
Desmodium heterophyllum	S	A	S	F	F	S	A	S	F	F								S	F	F
Murdannia medica	S	S	S	F		S	A	S	F									S	F	
Burmannia coelestis						F	S	S			F	S	S			F	S	S	F	
Fimbristylis pauciflora						S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Lindernia parviflora			S			S	S	S			S	S	S	F	F	S	S	S	S	F
Hedyotis diffusa	F	S	S			F	S	S			F	S	S			F	S	S		
Sacciolepis indica	S	S	S	F		S	S	S	F		S	S	S	F		S	S	S	F	
Chrysopogon aciculatus	S	S	S	F		S	S	S	F		S	S	S	F		S	S	S	F	

Species with an asterisk are rare species. F, S, and A represent the frequency (F: few, S: scattered, A: abundant).

the rainy season; just after transplanting of rice plants), September (the peak of the rainy season), October (the end of the rainy season; during harvest), December (the beginning of the dry season), and March (the peak of the dry season).

The results showed that some species had clear seasonal periods during which they were abundant and actively growing. Thus, species were classified into four types according to their growing period as follows: (1) The early rainy season annual herbs: Species such as *Cyperus haspan*, *Fimbristylis miliacea*, *Lindernia viatica*, *Ludwigia hyssopifolia*, and *Melochia corchorifolia* began to germinate just after plowing and transplanting, blossomed in the middle of the rainy season, and died at the end of the rainy season. Several seedlings of *Cyperus haspan*, *Fimbristylis miliacea*, *Ludwigia hyssopifolia*, and *Melochia corchorifolia* were found after occasional showers in March; however, they did not seem to survive until the beginning of the rainy season. (2) The late rainy season annual herbs: Species such as *Limnophila geoffrayi*, *Rotala indica*, and *Xyris indica* germinated at the peak of the rainy season, blossomed at the end of the rainy season, and died at the beginning of the dry season. (3) The dry season annual herbs: Species such as *Centipeda minima*, *Glinus hernarioides*, *Glinus oppositifolius* (L.) DC., and *Grangea maderaspatana* (L.) Poir. germinated at the beginning of the dry season, blossomed in the middle of the dry season, and died at the beginning of the rainy season. (4) Species occurring throughout the year: The annual herb *Monochoria vaginalis* was common in wet paddy fields, where water was always plentiful. The perennial herb *Panicum repens* L. occurred throughout the year, blooming in the peak of the rainy season.

Species composition on levees also changed periodically during the year. Table 3-4 shows the seasonal change in frequency of the 19 representative wild species on levees in each vegetation type: (1) The early rainy season annual herbs were *Hedyotis diffusa* Willd., *Sacciolepis indica* (L.) Chase, and *Chrysopogon aciculatus* (Retz.) Trin. (2) The late rainy season annual herbs were *Adenosma javanica*, *Nosema cochinchinensis* (Lour.) Merr., and *Osbeckia cochinchinensis* Cogn. (3) The dry season annual herbs were *Coldenia procumbens* L. and *Grangea maderaspatana*. (4) The species occurring throughout the year included annual herbs, such as *Limnophila villifera* ssp. *gracilipes*, *Lindernia anagalis*, and *Lindernia parviflora* (Roxb.) Haines on the shore of wet paddy fields, and perennial herbs such as *Fimbristylis pauciflora* R. Br.

This periodical change in species composition is closely related to human use and management of paddy vegetation as described below.

Agricultural practices and its impact

Paddy vegetation was strongly influenced by agricultural practices. Some kinds of human impacts affected plant distribution at a broad scale. For example, flooding and plowing caused a clear difference between field habitat and levee habitat. Among the 184 wild species recorded, 25 species (13.6%) grew only in fields, 97 species (52.7%) only on levees, and 62 species (33.7%) both in fields and levees (Table 3-1). In addition, species composition varied with micro-habitat on the levees, such as near the waterline, on the flat crown, and side-slope. Although many species tended to grow near the waterline and grassland, only a few species, such as *Desmodium heterophyllum* (Willd.) DC. and grasses, survived on the flat crown, which was subject to continuous trampling. Moreover, the effect of livestock grazing after harvesting was pronounced. According to the interview survey and field observation, buffaloes and cattle grazed almost all herbaceous species.

Other kinds of impacts occurred site-specifically with different frequency and intensity. *Fimbristylis miliacea*, *Ludwigia hyssopifolia*, and *Limnophila villifera* ssp. *gracilipes* were recognized as the most harmful weeds by villagers. *Fimbristylis miliacea* and *Ludwigia hyssopifolia*, however, were removed by uprooting manually only during the peak of the rainy season when growth is most vigorous. On the other hand, *Limnophila villifera* ssp. *gracilipes* often covered wet paddy fields throughout the off-season of rice cultivation. Such fields were first weeded with hoes before plowing, consuming much time and labor. Repairing of paddy levees also seemed to affect species composition. For example, perennial herbs such as *Osbeckia chinensis* L., *Sida rhombifolia* L., and *Waltheria indica* L. grew on levees made of laterite, which require infrequent repair, whereas annuals were dominant on levees made of erodible sandy soil, which require frequent repair.

Useful plants

A total of 19 wild species were directly used by villagers for food and other purposes (Table 3-5). We recorded 11 edible species: *Amaranthus viridis* L., *Blyxa japonica*, *Colocasia esculenta* (L.) Schott., *Glinus oppositifolilus*, *Justicia balansae* Lind., *Kaempferia galanga* L., *Limnophila geoffrayi*, *Lygodium* sp., *Marsilea crenata*, *Monochoria vaginalis*, and *Smilax* sp. Of these, *Limnophila geoffrayi* and *Marsilea crenata* were not only dominant in paddy fields, but were also found to be important herbs in the local diet and were sold in markets. *Limnophila geoffrayi* has a fragrant smell and is an essential herb for the popular Lao food, *keng noomai* (bamboo shoot soup). Dried plants are kept for the dry season when live plants are not available. *Glinus oppositifolius* was sold in markets in the dry season, when other wild edible plants were scarce.

Local people used five species for medicines. A decoction of *Amorphophallus* sp. tubers was used for malaria. A decoction of leaves and roots of *Elephantopus scaber* L. was consumed orally for stomachache. A paste of fresh leaves of *Eupatorium odoratum* L. was applied on wounds as an astringent. A decoction containing *Scoparia dulcis* L. roots, *Sida rhombifolia* roots, and *Imperata cylindrica* (L.) Beauv. var. *major* (Nees) Hubb. (which was not found in paddy field areas in this study site) roots was consumed orally for irregular menstruation. *Adenosma javanica* and *Ludwigia hyssopifolia* were used as pig feed. *Cyperus pilosus* Vahl

Table 3-5. Local name of useful wild species at Nakhou village and Bak village

Scientific Name	Family	Local Name	Use
Justicia balansae Lind.	Acan	Phak ka taa	Food
Amaranthus viridis L.	Amar	Phak hom	Food
Amorphophallus sp.	Arac	Ka bouk paa	Medicine
Colocasia esculenta (L.) Schott.	Arac	Kok bon	Food
Elephantopus scaber L.	Ast	Khi fai nok khoum	Medicine
Eupatorium odoratum L.	Ast	Nya kiu / Nya falang	Medicine
Cyperus pilosus Vahl	Cyp	Pheu naa	Mat weaving
Blyxa japonica (Miq.) Maxim. ex Aschers.	Hydr	Nee poua	Food
Sida rhombifolia L.	Mal	Nya khat	Medicine
Marsilea crenata Presl	Mars	Phak ven	Food
Glinus oppositifolius (L.) DC.	Moll	Phak dang khom	Food
Ludwigia hyssopifolia (G. Don) Exell.	Onag	Kok kadian	Feed
Monochoria vaginalis (Burm. f.) Presl	Pont	Phak i hin	Food
Lygodium sp.	Schi	Phak kout kapom	Food
Adenosma javanica (Bl.) Koord.	Scr	Nya pheun	Feed
Limnophila geoffrayi Bonati	Scr	Phak ka nyeng	Food
Scoparia dulcis L.	Scr	Nya khai hao	Medicine
Smilax sp.	Smil	Kheua kheuang	Food
Kaempferia galanga L.	Zin	Van toup moup	Food

Family: Acan, Acanthaceae; Amar, Amaranthaceae; Arac, Araceae; Ast, Asteraceae; Cyp, Cyperaceae; Hydr, Hydrocharitaceae; Mal, Malvaceae; Mars, Marsileaceae; Moll, Molluginaceae; Onag, Onagraceae; Pont, Pontederiaceae; Schi, Schizaeaceae; Scr, Scrophulariaceae; Smil, Smilacaceae; Zin, Zingiberaceae.

was collected at the end of the rainy season and used as the raw material for mat weaving in Nakhou village. Floating plants, such as *Salvinia cucullata* Roxb. and *Salvinia natans* (L.) All., were not directly used, but were considered useful for maintaining lower water temperature in paddies. Moreover, almost all species were utilized as forage for buffaloes and cattle.

Among the 17 cultivated species, 15 were edible plants. *Allium ascalonicum* L., *Anethum graveolens* L., *Arachis hypogaea* L., *Brassica rapa* L. var. *chinensis* (L.) Kitam., *Citrullus lanatus* (Thunb.) Mats. & Nak., *Cucumis sativus* L., *Ipomoea batatas* (L.) Lam., *Vigna unguiculata* (L.) Walp. var. *sesquipedalis* (L.) H. Ohashi, and *Zea mays* L. were planted in home-side and lowland paddy where nearby water was available after rice (*Oryza sativa* L.) harvesting. *Canna edulis* Ker., *Capsicum frutescens* L., *Cleome gynandra* L., *Mentha aquatica* L. var. *aquatica*, and *Ocimum basilicum* L. were planted in small vegetable gardens on broadened paddy levees in the rainy season. At Nakhou village, *Cyperus corymbosus* Rottb. was planted in pools within the homestead and also in small marshes adjacent to paddy fields. It was collected twice a year for use in mat weaving. *Hymenocallis littoralis* (Jacq.) Salisb.

was an important species; used in Buddhist ceremonies and for medicine, it was often planted in home gardens and was also found on paddy levees. Straw from rice plants was kept after threshing and used as feed for buffaloes and cattle in the rainy season, a period in which they are excluded from grazing in paddy fields. Rice husks were used as feed for chicken, ducks, and fish.

3-4. Discussion

Characteristics of species composition compared with other areas in asia

The number of wild herbaceous species (87 in fields, 159 on levees and 184 in total) recorded at only two villages was large compared with other areas in Asia. Kasahara (1959) recorded 191 paddy weeds from all over Japan. A study on paddy weeds in west Sri Lanka (658 fields in 329 villages from four districts) reported 136 species (75 in fields and 116 on levees; Chandrasena, 1988). Tomita et al. (2003b) recorded 96 species in fields (78 species were identified) from 179 rain-fed paddy fields with a wide range of rainfall, topography, soil and hydrological conditions in northeast Thailand. The number of naturalized species at the current study site (including prehistoric-naturalized species) whose origins were identified in the literature (HEAR, 2004; Kasahara, 1959) was 43. This compares with 96 in Japan, 39 in west Sri Lanka, and 25 in northeast Thailand.

The three most dominant families represented by wild species in fields, Poaceae (17 spp.), Scrophulariaceae (12 spp.), and Cyperaceae (20 spp.), were also common in other studies in tropical Asia. The corresponding numbers for these three families were 20 spp., 15 spp. and 9 spp. in west Sri Lanka and 21 spp., 20 spp., and 11 spp. in northeast Thailand. The proportion of wild species in fields belonging to these three families was smaller (47.7%) in this study site than in west Sri Lanka (58.7%) and northeast Thailand (54.2%). The number of families represented by wild species in fields was larger in this study site (30) than in west Sri Lanka (22) and northeast Thailand (27).

Many of the common wild species in fields in this study site were also common in northeast Thailand (Tomita et al., 2003b), where paddy fields were classified into seven types: direct dry-seeded fields with rich, medium, and poor water condition, transplanted fields with rich, medium, and poor water condition, and fallowed fields. Dominant species (ISV>0.2) in at least one paddy type were: *Alysicarpus vaginaris* (L.) DC., *Cynodon dactylon* (L.) Pers., *Cyperus difformis* L., *Cyperus pulcherrimus* Willd. & Kunth, *Digitaria ciliaris* (Retz.) Koel., *Digitaria elongata* (Trin) Spring, *Echinochloa colonum* (L.) Link., *Fimbristylis miliacea*, *Ludwigia adscendens* (L.) Hara., *Ludwigia hyssopifolia*, *Melochia corchorifolia*, *Panicum repens*, and *Paspalum scrobiculatum* L. Ten of these species were also recorded in the present study and of these, *Fimbristylis miliacea*, *Ludwigia hyssopifolia*, and *Melochia corchorifolia* were dominant. Considering that *Fimbristylis miliacea* and *Ludwigia hyssopifolia* were found to be dominant in almost all types of paddy fields in northeast Thailand (Tomita et al., 2003b), they seem to be wide-spread from northeast Thailand to central Laos.

On the other hand, other species that were dominant in this study site, (*Adenosma javanica*, *Blyxa japonica*, *Centipeda minima*, *Cyperus haspan*, *Digitaria fuscescens*, *Glinus hernarioides*, *Limnophila geoffrayi*, *Limnophila villifera* ssp. *gracilipes*, *Lindernia viatica*, *Monochoria vaginalis*, *Rotala indica*, and *Utricularia aurea*) were not recorded in northeast Thailand (Tomita et al., 2003b). Although the topography, climate, flora and fauna of the Mekong Valley in Laos and northeast Thailand are similar (Heckman, 1974), this result suggests that some herbaceous species display site-specific dominance.

Effect of water regime on paddy vegetation

The results of the classification and ordination indicated that the water regime of paddy fields influenced the paddy vegetation in this study site. It has been pointed out that wetland vegetation is influenced not only by hydroperiod, but also by water chemistry, availability of moisture in the soil during the dry season, and soil fertility (Goslee, Brooks, and Cole, 1997; Pinder and Rosso, 1998). In this study, water and soil quality were not investigated. Despite this limitation, it will be important to conduct provisional classification of paddy vegetation and subsequent identification of indicator species. The identification of more indicator species could lead to the development of a useful tool for wetland research and management because hydrological monitoring is often both expensive and time-consuming (Goslee, Brooks, and Cole, 1997).

Factors contributing to high species diversity

The mosaic distribution of different types of paddy fields was considered the most important factor contributing to species diversity. Higher species diversity at the field scale was associated with fields receiving less water, i.e., home-side, lowland, and hillside paddy (Table 3-2). A general reduction in plant diversity with increasing hydroperiod has also been reported from studies of wetlands (Pinder and Rosso, 1998; Robertson, Weaver, and Cavanaugh, 1984). However, wet paddy also contributed to the overall species richness in this study site because the species composition was different from other types of paddy fields. Consequently, the existence of various species unique to the different paddy types enhanced the local species diversity (Table 3-2). However, paddy fields are artificial wetlands (Lu, 1995), and the water regime is managed by humans. As is often the case with paddy fields in Japan (Shimoda, 2003), the paddy field flora will be simplified by the homogeneity of the water regime resulting from irrigation and drainage.

The presence of remnant species from the original vegetation also contributed to species diversity. For example, *Elephantopus scaber*, *Habenaria rostellifera* Reichb. f., *Kaempferia* *galanga*, and *Smilax* sp. are forest species, and *Drosera* spp., and *Utricularia aurea* occur in natural wetlands. These species may be regarded as temporary weeds, i.e., they occur in newly established fields but gradually decline and eventually disappear (Kasahara, 1954). However, the paddy fields in this study site contained fields aged from 10 years to more than 100 years, and remnant species were recorded even on the levees of the older fields.

Human impacts were considerable. Human-made habitats contributed to the high species diversity, e.g., by harboring many species specializing in either field or levee habitat (Table 3-1). Livestock grazing and the various activities relating to rice cultivation appeared to prevent the paddy vegetation from undergoing succession to meadows of grasses or sedges. Shimoda (2003) revealed the high plant diversity in paddy fields by comparing herbaceous vegetation in paddy with that of abandoned fields. The study also showed that succession to meadows in abandoned fields can be prevented by human management such as mowing and maintenance of ditches (Shimoda, 2003). Although mowing was not carried out in this study site, it is considered that the grazing of buffaloes and cattle played a similar role to mowing.

Some rare species were recorded in this study site. It is considered that even a slight change in the paddy environment may lead to their extinction because their habitat or the number of individuals was limited. Even the currently common species in paddy fields could drastically decrease in number if herbicide use is adopted (Smitinand and Larsen, 1985). Some of the common wetland species in this study site, *Blyxa japonica*, *Ceratopteris thalictroides* (L.) Brongn., and *Salvinia natans*, are regarded as important for conservation in Japan, where herbicides are widely used in paddy fields (Ikeda and Miura, 2002). Although wetlands have disappeared at alarming rates throughout the world (Mitsch and Gosselink, 2000), it is apparent that herbicide-free paddy fields play a role in providing habitat for various wetland plants.

Biodiversity and agricultural productivity

It has been suggested that harmonizing agricultural productivity with biological diversity should be the ultimate goal of the analysis of paddy vegetation (Tomita et al., 2003a). In this study, an overall species inventory was conducted first as the basic groundwork. The relationship between paddy vegetation and subsistence livelihoods was described by identifying exploited (and cultivated) species, beneficial species, rare species, and harmful species (major weeds). This kind of provisional classification assists in the analysis of the interactions between agricultural practices and organisms (Gall and Orians, 1992). However, these interactions were not always confined within neat definitions. For example, even weed species harmful to rice production were useful as feed for livestock. In addition, agricultural intensification and innovation has begun to affect this study site, a place where previously only subsistence agriculture had been conducted. For example, irrigation with electric pumps was introduced to some of the lowland paddy fields at the beginning of 2004, enabling a second crop each year. The number of households using chemical fertilizer and powere tillage equipment will increase, although it is now still small. These changes will lead t increases in rice yield. However, the relationship between paddy vegetation and people livelihoods may also change, though to what extent is unclear. Maintaining biologica diversity is essential for productive agriculture, and ecologically sustainable agriculture i essential for maintaining biological diversity (Pimentel et al., 1992). Therefore, further stud on paddy vegetation is necessary to provide the knowledge required to maintain bot agricultural productivity and biological diversity.

3-5. Conclusion

In this study site, paddy fields were not just a homogenous landscape merely producing rice but also harbored many plant species, including exploited species, beneficial species and rar species. The water regime varied with different types of paddy field from shorter to longe hydroperiod, influencing the paddy vegetation. The presence of species unique to the differen paddy types (hillside, home-side, lowland, and wet paddy) was considered the greatest facto contributing to the high species diversity. The presence of remnant species from the origina vegetation, such as forest species or natural wetland species, was also significant. Moreover agricultural practices influenced the species composition. Human-made habitats contributed to high species diversity by harboring many species specializing in field or levee habitat Human activities such as flooding and plowing, weeding, repairing paddy levees, and livestock grazing prevented paddy vegetation from making the succession to homogenous meadows of grasses or sedges. Thus, multiple plant species coexisted in paddy fields under various agricultural practices, and some of these species were essential as local food or for subsistence livelihoods. This kind of evaluation on the interaction between the vegetation in agricultural land and agricultural practices makes an important contribution to the understanding of biological diversity in human-managed ecosystems.

Chapter 4. Land-use patterns and plant use

4-1. Introduction

With the recent rise in concern for biodiversity, indigenous people have been identified as an important source of knowledge on useful plants (e.g., Etkin, 2002; Jain, 2000). Culturally appropriate conservation can be achieved only by understanding the complexities of indigenous knowledge of the landscape and the principles of resource utilization (Etkin, 2002). I conducted the study reported herein to determine to what extent this assumption applies in rural Laos.

In Laos, 83% of people aged 10 years and above are engaged in agriculture and/or fishing/aquaculture activities for subsistence (MAF, 2000), and 97% of households use wood or charcoal as a cooking fuel (LWU, 2001). In addition, numerous timber and non-timber forest products are collected and play a key role in the daily life of local communities (Lehmann et al., 2003; Xaydala, 2003). However, the rate of deforestation is estimated to be 70,000 ha per year, mainly due to shifting cultivation, logging, and collection of firewood (NOFIP, 2000). Accordingly, several conservation programs have prepared local natural resource inventories (UNEP, 2001).

Earlier descriptions of plant use in Laos generally fall into one of three types: (1) inventories of the useful plants of particular regions (e.g., Vidal, 1962; Xaydala, 2003), (2) inventories of useful plants of particular land-use classes (e.g., Lehmann, 2003), and (3) full descriptions of particular useful plants (e.g., Ankarfjard and Kegl, 1998; Evans and Sengdala, 2002). However, the use of plants in subsistence livelihoods is influenced by several factors, such as the location and environmental conditions of the village (e.g., Pieroni, 1999), previous land-use (e.g., Fu et al., 2003), and socio-economic conditions (e.g., Wezel, 2003). Thus, descriptions of the factors influencing plant use in local communities will support conservation and rural development in Laos, especially when reinforced by previous inventories of useful plants.

The study of natural resource use and conservation is well-suited to the landscape and regional spatial scales (Zimmerer and Young, 1998). In central Laos, where this field survey was carried out, the landscape is made up of a mosaic land-use pattern on undulating terrain. These landscapes, in turn, aggregate to form regions at a broader spatial scale. The purposes of this study were: (1) to describe land-use and plant use at the landscape level, (2) compare land-use and plant use at the regional level, and (3) examine the factors influencing plant use in Lao villages.

4-2. Site description and methods

Site description

The field survey was conducted at Bak village and Nakhou village, Champhone District in Savannakhet Province, Laos.

Forest resources are declining rapidly in Laos. During the 1940s, the forest cover represented about 70% of the total area, but this has fallen to 47% at present (UNEP, 2001). In order to control public access to land and forest resources, the government has reformed its natural resources management policies several times since 1989. In this study site, forest demarcation was applied in Bak village in 2000 according to the Forestry Law, but not in Nakhou village because it only has small areas of forest.

Methods

Field surveys were conducted in the following periods: May and June 2002; June, July, September, October, and December 2003; and March 2004. Land-use was classified for both villages by analysis of aerial photographs and field observation. Data collection on plant species occurrence and their use was conducted for each land-use class separately.

Useful plants were collected as voucher specimens with the help of key informants, one at Nakhou village (a male paddy cultivator aged in his early forties and knowledgeable about plants) and two at Bak village (one was a male village soldier aged in his mid forties, knowledgeable about plants of the forest, fallow fields, shifting cultivation fields, and grassland; the other was a male paddy cultivator in his early forties who was knowledgeable about plants from paddy fields, waterside, and homesteads). Other villagers were also consulted at both villages while they were going about collecting, processing, or using plant resources. These people were also interviewed with respect to the history and current status of land-use classes, agricultural activities, local names and uses of plants, and trading of plant resources between neighboring villages. Useful plants were ranked in importance according to a three level classification: 1) species essential for livelihood or as a source of cash income (this category included several timber species and other species of economic value, i.e., sold in local markets or to traders); 2) species sometimes used for self-consumption but not essential to livelihood; and 3) species recognized as useful but rarely used at present.

Vegetation surveys were conducted to describe the general floristic characteristics of each land-use class, which emphasizes the fact that a mosaic of vegetation types existed within individual villages. The surveys carried out for each land use class were as follows:

(1) In forest and fallow fields, every tree was measured (> 1.5 m in height or > 3 cm DBH) by recording DBH and height in plots (20m × 20m). Plots were selected within typical forest types, such as dry evergreen forest (DEF), *Peltophorum dasyrrhachis* dominant forest (PTF), and swamp forest with *Syzygium* spp. (SWF) at Bak village, and gallery forest (GLF) with *Dipterocarpus alatus* and PTF at Nakhou village. At Bak village there were two plots in DEF,

three in PTF, and one in SWF; in Nakhou village there was one plot in GLF and two in PTF. The definition of forest included, in addition to current protection forest, previous shifting cultivation areas that had been left to regenerate for at least 10 years. Fallow was defined as former shifting cultivation fields that had been left dormant for four to nine years since burning; this time frame was adopted because a three-year cropping cycle for shifting cultivation fields was common in Bak village.

(2) In shifting cultivation fields, the names of both cultivated and wild species present were recorded in several fields in Bak village. Shifting cultivation was not practiced in Nakhou village, so the land-use class did not exist there.

(3) In grassland, only the names of species observed were recorded, since the number of species was very small.

(4) In waterside land, only species names and their habitats were recorded, since the number of species was very small. Water bodies beside which the waterside class existed included irrigation dams, small marshes around paddy fields, ditches, ponds, and streams.

(5) In paddy fields, different methods were used for recording herbaceous species than for recording woody species. For herbaceous species, species names and their habitats (field or levee) were recorded during the rainy season (in June, July, September, October 2003) and the dry season (in December 2003 and March 2004) at both villages. At Bak village, only the names of observed woody species (>1 m height, including shrubs and woody lianas) and their habitats (field, levee, or termite mound) were recorded because the number of individuals and species was very small. At Nakhou village, where many trees were observed, the species name, habitat, DBH, and height were recorded in a belt-transect survey plot (3 km long and 200 m wide).

(6) In the homestead land-use class, species names were recorded when observed at both villages. This class means a general category of land-use consisting of homes and adjoining land occupied by families.

The collected plants were identified at the Faculty of Forestry, National University of Laos, Vientiane, Laos, and in the Forest Herbarium, Royal Forestry Department, Bangkok, Thailand (BKF). Nomenclature of sampled plants followed Ho (1999 - 2000), Santisuk and Larsen (1997 - 2002), and Smitinand and Larsen (1970 - 1996).

4-3. Results

History and current status of landscape

Figure 4-1 shows current land-use patterns in Bak village and Nakhou village. Both villages are located on different parts of the same contiguous slope, with shifting cultivation being performed on the higher land of Bak village and paddy fields widespread over the lowlands beginning in central Bak village and extending to Nakhou village. Some springs were found in

Bak village on the boundary between the shifting cultivation zone and the paddy field zone.

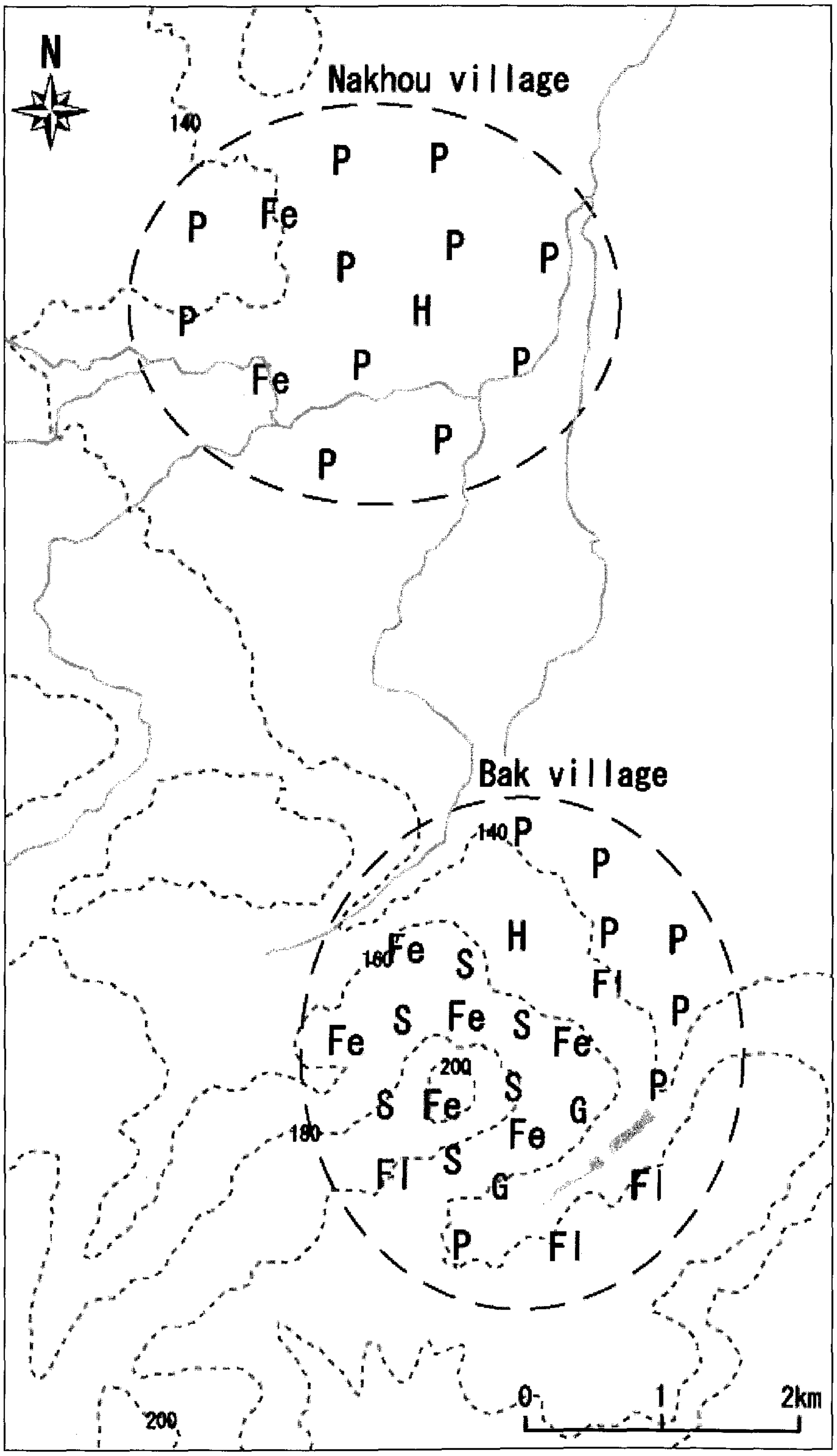

Figure 4-1. Current land-use patterns in Bak village and Nakhou village.
Fe:Early successional forest and fallow fields, Fl:Late successional forest, G:Grassland, H:Homestead, P:Paddy fields, S:Shifting cultivation fields.

(1) Bak village

In Bak village, both shifting cultivation and paddy cultivation have been the main sources of subsistence since village establishment. However, most households have become devoted to paddy cultivation since the revolution in 1975. Late successional forest with large trees such as *Afzelia xylocarpa*, *Anisoptera costata*, *Dipterocarpus alatus*, *Pterocarpus macrocarpus*, and *Xylia xylocarpa* var. *kerrii* was distributed all over the higher land in the past. The trees were logged by the government to generate revenue in 1976 and 1977. The current landscape of Bak village is a mosaic of late successional forest (DEF and SWF), early successional forest (PTF), shifting cultivation fields, grassland, waterside, paddy fields, and homesteads.

In my surveys, DEF was observed in sacred forests, crematory forests, and some protection forests. The main species of the canopy layer were *Dipterocarpus alatus* and *Hopea odorata*.

PTF mainly occurred in fallow fields and other early successional forest. The main species of the canopy layer were *Dialium cochinchinense* and *Peltopholum dasyrrhachis*. Those of the understory layer were *Amomum villosum*, *Calamus* sp., *Holarrhena pubescens*, and *Streblus taxoides*.

SWF was distributed around water sources as village traditional conservation forest. The main species of the canopy layer were *Syzygium* spp. Those of the understory layer were *Ardisia* spp.

In shifting cultivation fields, *Ananas comosus* (pineapple), *Carica papaya* (papaya), *Cucumis melo* (melon), *Cucumis sativus* (cucumber), *Morus alba* (mulberry), *Musa* sp. (banana), *Oryza sativa* (rice), *Sesamum indicum* (sesame) were cultivated. Seedlings of *Calamus* sp., *Peltophorum dasyrrhachis*, and other forest tree species were found growing among these crops.

Grassland was distributed in patches between the shifting cultivation zone (including fallow fields) and waterside. This vegetation occurred where shifting cultivation had been abandoned due to invasion of *Imperata cylindrica* var. *major*. In this vegetation, *Imperata cylindrica* var. *major* dominated, and some shrubs, such as *Helicteres hirsuta*, *Melastoma malabathricum* ssp. *malabathricum*, and scattered seedlings of forest trees were observed.

Waterside was classified into three separate habitats based on the type of water body: irrigation dams, small marshes around paddy fields, and ditches. They harbored different species compositions as follows: *Nelumbo nucifera* and *Nymphoides indica* predominated in irrigation dams; *Blyxa japonica*, *Neptunia oleracea*, and *Utricularia aurea* were predominant in small marshes around paddy fields, and *Monochoria vaginalis* and *Polygonum* sp. occurred in ditches.

In the paddy field land-use class, the herbaceous species composition varied with habitat. In field habitat, *Blyxa japonica*, *Cyperus haspan*, *Fimbristylis miliacea*, *Limnophila villifera* ssp. *gracilipes*, and *Monochoria vaginalis* were dominant in addition to paddy rice. In levee habitat, *Chrysopogon aciculatus*, *Desmodium heterophyllum*, *Fimbristylis pauciflora*, *Limnophila villifera* ssp. *gracilipes*, *Lindernia parviflora*, and *Sacciolepis indica* were dominant. Only a few woody species were observed: trees such as *Lepisanthes rubiginosa* and *Syzygium gratum* var. *gratum* occurred on termite mounds, while a shrub, *Melastoma saigonese*, grew on some levees.

In the homestead land-use class, wild vegetation could not be seen except for some weeds, but many useful trees, shrubs, lianas, and herbs were planted.

(2) Nakhou village

In Nakhou village, paddy cultivation has been conducted since village establishment. Late successional forest consisting of *Dipterocarpus alatus*, *Lagerstroemia* sp., and *Pterocarpus macrocarpus* existed in the past. However, it was converted to paddy field. The current landscape of Nakhou village is a mosaic of early successional forest (GLF and PTF), grassland, waterside, paddy field, and homestead land-use classes.

GLF was observed to occupy the private forest along streams. The Main species observed in the canopy layer was *Dipterocarpus alatus*. In the understory layer, the main species were *Cratoxylum cochinchinense* and *Memecylon scutellatum*. *Bambusa bambos* was also widespread.

PTF occurred as sacred forest, crematory forest and private forest. The presence of several stumps and large gaps in the canopy implied intensive human disturbance. The main species of the canopy layer were *Dialium cochinchinense*, *Peltopholum dasyrrhachis*, and *Xylia xylocarpa*. In the understory layer the main species were *Dipspyros filipendula* and *Oxyceros horridus*. Bamboos, such as *Bambusa bambos* and *Gigantochloa albociliata*, were also widely observed.

Paddy fields were surrounded by grassland with scattered trees such as *Peltopholum dasyrrhachis*. The herbaceous species composition was similar to that of paddy levees mentioned below. Although this grassland is currently used as pasture during the rainy season, it may be converted to paddy field, pond, or homestead in the future.

Waterside was classified into three habitats: stream, pond, and small marshes around paddy fields. These habitats harbored different species as follows: *Combretum quadrangulare*, *Pandanus* sp., and *Phyllanthus taxodiifolius* predominated along streams; *Ipomoea aquatica* and *Nymphaea pubescens* were the most abundant species in ponds; and *Cyperus pilosus* in small marshes around paddy fields.

In paddy fields, the herbaceous species composition varied with habitat. In field habitat, *Fimbristylis miliacea*, *Limnophila geoffrayi*, *Lindernia viatica*, *Ludwigia hyssopifolia*, and *Rotala indica* were dominant in addition to paddy rice. In levee habitat, *Adenosma javanica*, *Adenosma elsholtzioides*, *Chrysopogon aciculatus*, *Corchorus aestuans*, and *Desmodium heterophyllum* were dominant. In addition, many woody species were observed, such as

Azadirachta indica var. *siamensis*, *Diospyros mollis*, and *Streblus asper* on termite mounds and *Irvingia malayana* and *Peltphorum dasyrrhachis* both in fields and on levees.

Around homesteads, wild vegetation could not be seen except for some weeds, but many useful trees, shrubs, lianas, and herbs were planted.

Plant use in respective land-use patterns

The characteristics of plant use in Bak village and Nakhou village were compared for each land-use class separately (Table 4-1). Useful species were placed into the following use categories: food, timber, fuel (fuelwood and charcoal), material for handicrafts, medicine, and others. The total number of species placed into these categories exceeded the overall number of useful plants recorded, because many species were utilized in multiple ways and therefore counted more than once. The habitat, importance, and uses of the major useful plant species are listed in Table 4-2 and Table 4-3. It was noted that both villages had traditional rules on the collection of useful plants. Wild fruits, shoots or greens could be collected anywhere in the villages except protected areas. On the other hand, wild trees were only allowed to be cut with the traditional owner's permission. In addition, no parts of cultivated plants were allowed to be collected other than by their owners.

(1) Forest

In Bak village, forest supplied the largest number of useful plants. Of the 104 species used by villagers, seven species were planted and 25 species had economic value (sold in local market or to traders). They were mainly used as food (47 spp.), timber (39 spp.), or fuel (52 spp.). Plant products that were often sold as food in local markets were *Dendrocalamus strictus* shoots, *Nephelium hypoleucum* fruits, *Syzygium gratum* var. *gratum* shoots. Late successional trees such as *Dipterocarpus alatus* and *Pterocarpus macrocarpus* produce high quality timber, but they were found to be largely unavailable at present because their main habitats are designated as protected area. Instead, *Dialium cochinchinense* and *Peltophorum dasyrrhachis* were indicated as the main timber species. Charcoal made of *Irvingia malayana* had the best quality. Abundant *Calamus* sp. and *Dendrocalamus strictus* were utilized as raw materials for basketry. Formerly, oleoresin from *Dipterocarpus alatus* had been one of the main income sources. It had been sold to traders as a raw material for varnish, lacquer, and paint. However, only small amounts were observed to be collected currently owing to population decrease, and the main use for the material that is collected is the making of traditional torches. *Amomum villosum* and *Tinospora crispa* were important medicinal plants. *Amomum villosum* seeds were used for stomach ache in the village, and Thai traders occasionally came to buy them. Alcohol in which *Tinospora crispa* stems had been steeped was used as a medicine for lumbago. This species was sometimes collected and transplanted

Table 4-1. Number of useful plant species in each land-use class in Bak village and Nakhou village

Village	Land	No.Used	Plant.	(%)	Econ.	(%)	Food	(%)	Timber	(%)	Fuel	(%)	Hand.	(%)	Medic.	(%)	Others	(%)
BK	Forest	104*	7	(7)	25	(24)	47	(45)	39	(37)	52	(49)	3	(3)	4*	(4)	7	(7)
	Fallow	31	1	(3)	11	(35)	18	(58)	11	(35)	13	(42)	1	(3)	2*	(6)	1	(3)
	Field	16	16	(100)	13	(81)	15	(94)	0	(0)	0	(0)	0	(0)	0	(0)	2	(13)
	Grass	5	0	(0)	1	(20)	1	(20)	0	(0)	0	(0)	2	(40)	0	(0)	2	(40)
	Water	5	1	(20)	2	(40)	3	(60)	0	(0)	0	(0)	0	(0)	0	(0)	2	(40)
	Paddy	18	9	(50)	12	(67)	17	(94)	0	(0)	0	(0)	0	(0)	0	(0)	5	(28)
	Home	39*	39	(100)	27	(69)	27	(69)	1	(3)	0	(0)	2	(5)	2*	(5)	15	(38)
NK	Forest	48	0	(0)	9	(19)	20	(42)	8	(17)	25	(52)	1	(2)	6*	(13)	6	(13)
	Grass	3	0	(0)	0	(0)	0	(0)	1	(33)	1	(33)	0	(0)	2*	(67)	0	(0)
	Water	4	1	(25)	3	(75)	2	(50)	0	(0)	0	(0)	2	(50)	0	(0)	0	(0)
	Paddy	116	40	(34)	40	(34)	62	(53)	24	(21)	26	(22)	8	(7)	20*	(17)	34	(29)
	Home	31*	31	(100)	19	(61)	21	(68)	2	(6)	0	(0)	6	(19)	4*	(13)	9	(29)

Useful plant species were placed into use categories by the authors.

Land: Land-use class (field: shifting cultivation field; grass: grassland; water: waterside; paddy: paddy field; home: homestead), ***No.Used:*** Number of species used in the village, ***Plant.:*** Number of planted (cultivated or transplanted) species, ***Econ.:*** Number of species with economic value (sold in local markets or to traders). ***Food, Timber, Fuel, Hand., Medic., Others:*** Number of species used for food, timber, fuelwood and charcoal, material for handicrafts, medicine, and for other purposes. Number with an asterisk indicates only main species.

Table 4-2. Major plant species used in Bak village

Speceis	Local	Habitat		I	Use	Note
Diptererocarpus alatus *Roxb. ex G.Don*	*Mai nyang*	W	DEF	3	T,O	Formerly, oleoresin was main income source.
Nephelium hypoleucum Kurz	Mak ngeo	W	DEF	3	Fo,T,C	Fruits eaten raw.
Syzygium gratum *(Wight) S.N.Mitra var.* gratum	*Phak samek*	W	DEF, SWF	3	Fo	Essential vegetable for popular Lao dish.
Tinospora crispa (L.) Hook.f. & Th.	Kheua khao ho	T	DEF, Home	3	M	Medicine for lumbago. Transplanted to homesteads.
Amomum villosum Lour.	Mak neng	W	PTF	3	M	Medicine for stomachache. Thai traders came to buy.
Baccaurea ramiflora Lour.	Mak fai	W	PTF	3	Fo	Fruits eaten raw.
Cratoxylum formosum (Jack) Dyer	Phak tiu	W	PTF	3	Fo	Essential vegetable for popular Lao dish.
Dialium cochinchinense Pierre	Mai kheng	W	PTF	3	Fo,T	Fruits eaten raw. Producing high quality timber.
Irvingia malayana Oliv. ex Benn.	Mai bok	W	PTF	3	C,Fo,	Seeds eaten raw. Best quality charcoal was made.
Peltophorum dasyrrhachis *(Miq.) Kurz*	*Kok aran (safang)*	W	PTF	2	T,C	Fast growing pioneer tree.
Tiliacora triandra *(Colebr.) Diels*	*Kheua ya nang*	W	PTF	3	Fo	Essential ingredient for popular Lao dish.
Dendrocalamus strictus (Roxb.) Nees	Mai sang phai	C	PTF	3	Fo,H,	Planted in forest as living fence. Shoots edible.
Calamus sp.	Waai	W	PTF	3	Fo,H	Shoots cooked as vegetable. Fruits eaten raw.
Ananas comosus (L.) Merr.	Mak nat	C	Field	3	Fo	Fruits eaten raw.
Morus alba L.	Kok moon	C	Field, Home	3	Fe	Leaves used for sericulture.
Imperata cylindrica (L.) Beauv. var. *major* (Nees)Hubb.	Nya kha	W	Grass	3	O	Used for roofing.
Thysanolaena maxima (Roxb.) O.Ktze.	Kok khem	W	Grass	2	H	Spikes used as material for broom.
Nelumbo nucifera Gaertn.	Dok boua	W	Dam	3	Fo	Young seeds eaten raw.
Pandanus sp.	Kok teuy	T	Dam, Marsh	2	O	Transplanted from marsh for dam protection.
Neptunia oleracea Lour.	Phak kaset	W	Marsh	3	Fo	Cooked as vegetable.
Limnophila geoffrayi Bonati	Phak ka nyeng	W	Paddy	3	Fo	Essential herb for popular Lao dish.
Lygodium sp.	Phak kout kapon	W	Paddy	2	Fo,O	Edible fern. Stems used as string.
Marsilea crenata Presl	Phak ven	W	Paddy	3	Fo	Eaten raw as vegetable.
Mentha aquatica L.	Phak suumlao	C	Paddy	3	Fo	Cultivated in paddy levees. Important herb.
Ocimum basilicum L.	Phak i tou	C	Paddy	3	Fo	Cultivated in paddy levees. Important herb.
Oryza sativa L.	Khao	C	Paddy, Field	3	Fo,Fe	Staple diet. Straw and husk was feed for livestock.
Annona squamosa L.	Mak khiap	C	Home	3	Fo	Fruits eaten raw.
Chrysophyllum cainito L.	Mak nam nom	C	Home	3	Fo	Fruits eaten raw.
Pentace burmanica Kurz	Kok si siet	T	Home, DEF	3	O	Used for betel chewing. Transplanted to homesteads.

Local: Local name, Habitat (C: Cultivated, E: Cultivated and escaped, W: Wild, T: Transplanted, DEF: Dry evergreen forest, PTF: *Peltophorum* dominant forest, SWF: Swamp forest, Field: Shifting cultivation field, Grass: Grassland, Home: Homestead, Paddy: Paddy field), I: Importance (3: Essential for daily livelihood or source of cash income, 2: Sometimes self-consumed but not essential, 1: Recognized as useful but rarely used at present), Use (C: Charcoal, Fe: Feed, Fo: Food, Fr: firewood, H: Material for handicraft, M: Medicine, O: Other uses, T: Timber).

Table 4-3. Major plant species used in Nakhou village

Speceis	Local	Habitat		I	Use	Note
Bambusa bambos *(L.) Voss*	*Mai phai paa*	W	PTF,	3	Fo,O	Shoots edible.
Gigantochloa albociliata *(Munro) Kurz*	*Mai lai*	W	PTF	3	Fo,H	Shoots edible. Also used as a material for handicrafts.
Lepisanthes rubiginosa *(Roxb.) Leenh.*	*Mak houat*	W	PTF	3	Fo	Fruits eaten raw.
Croton crassifolius Geisel	Kan khii	W	Grass	2	M	Medicine for stomachache.
Alloteropsis sp.	Nya phek	W	Marsh	3	O	Used for roofing.
Cyperus pilosus *Vahl*	*Pheu nong*	W	Marsh	3	H	Material for mat weaving.
Ipomoea aquatica Forssk.	Phak bong	W	Pond	3	Fo	Cooked or eaten raw as vegetable.
Nymphaea pubescens Willd.	Dok boua nooi	C	Pond	2	Fo	Flower stalks eaten raw.
Azadirachta indica A.Juss. var. *siamensis* Valeton	Kok ka dao	W	Paddy	3	Fo,T,M	Essential vegetable for popular Lao dish.
Careya arborea Roxb.	Kok ka don	W	Paddy	3	Fo,M,O	Essential vegetable for popular Lao dish.
Diospyros mollis Griff	Mak keua	W	Paddy	1	O, Fo	Formerly, fruits were used for dyeing.
Elephantopus scaber L.	Khi fai nok khoum	W	Paddy	2	M	Medicine for stomachache.
Glinus oppositifolius (L.) DC.	Phak dang khom	W	Paddy	3	Fo	Cooked as vegetable.
Limnophila geoffrayi Bonati	Phak ka nyeng	W	Paddy	3	Fo	Essential herb for popular Lao dish.
Mitragyna rorundifolia (Roxb.) O. Ktze.	Kok thom	W	Paddy	3	C,T	Pollarded every two years for fuelwood.
Peltophorum dasyrrhachis (Miq.) Kurz	Kok aran (safang)	W	Paddy,	3	T,C,Fr	Pollarded every two years for fuelwood.
Pterocarpus macrocarpus Kurz	Mai dou	W	Paddy,	3	T	Producing best quality timber.
Streblus asper Lour.	Kok som pho	W	Paddy,	2	Fr,Fe,M,Fo	Dominant tree in paddy field, used in multiple ways.
Ipomoea batatas (L.) Lam.	Man dang	C	Paddy	3	Fo	Tubers eaten cooked.
Oryza sativa L.	Khao	C	Paddy	3	Fo,Fe	Staple diet. Straw and husk was feed for livestock.
Zea mays L.	Mak sa li	C	Paddy	3	Fo	Fruits eaten cooked.
Borassus flabellifer L.	Kok taan	E	Paddy,Ho	3	Fo,T, O	Young seeds and inner stem edible.
Cassia fistula L.	Mai khoun	E	Paddy,Ho	2	T,O	Flowers for ornamental.
Leucaena leucocephala (Lam.) de Wit	Kok ka thin	E	Paddy,Ho	3	Fo,C	Fruits and young shoots eaten raw.
Millingtonia hortensis L.f.	Kok kang khong	E	Paddy,Ho	2	M,O	Medicine for a cough.
Tamarindus indica L.	Mak kham	E	Paddy,Ho	3	Fo	Fruits eaten raw.
Ziziphus mauritiana Lam.	Mak ka than	E	Paddy,Ho	3	Fo	Fruits eaten raw.
Ceiba pentandra (L.) Gaertn.	Kok ngiu	C	Home,Pad	3	H	Cotton-like aril was used as stuffing of pillow.
Cyperus corymbosus Rottb.	Pheu itok	C	Home,Pad	3	H	Material for mat weaving.

Local: Local name, Habitat (C: Cultivated, E: Cultivated and escaped, W: Wild, T: Transplanted, DEF: Dry evergreen forest, PTF: *Peltophorum* dominant forest, SWF: Swamp forest, Field: Shifting cultivation field, Grass: Grassland, Home: Homestead, Paddy: Paddy field), I: Importance (3: Essential for daily livelihood or source of cash income, 2: Sometimes self-consumed but not essential, 1: Recognized as useful but rarely used at present), Use (C: Charcoal, Fe: Feed, Fo: Food, Fr: firewood, H: Material for handicraft, M: Medicine, O: Other uses, T: Timber).

within homestead areas.

In Nakhou villge, forested land other than sacred forest and crematory forest produced a total of 48 useful plants. However, the amount of plant resources was small owing to the limited area of forest. They were mainly used as food (20 spp.) and fuel (25 spp.). *Bambusa bambos* and *Gigantochloa albociliata* shoots were important foods. *Lepisanthes rubiginosa* produced popular fruits. *Gigantochloa albociliata* was also used as a raw material for making handicrafts.

(2) Fallow fields

Fallow fields in Bak village harbored 31 useful species including several of the most popular edible species, *Baccaurea ramiflora*, *Calamus* sp., *Cratoxylum formosum*, *Dialium cochinchinense*, and *Tiliacora triandra*. The leaves of *Tiliacora triandra* leaves are the main ingredient of a popular Lao dish, *keng noomai* (bamboo shoot soup), and *Cratoxylum formosum* shoots are an essential companion vegetable to another popular Lao dish, *laap* (spicy salad of pork, beef, or fish). Pineapple plants persisted in fallow fields and their fruit continued to be harvested through the fallow.

(3) Shifting cultivation fields

In Bak village, 16 cultivated species were recorded, including 13 species with economic value. Fifteen of the 16 species were used for food crops. Although upland rice had previously been the primary crop, pineapples have become the most popular crop and income source since the 1990s. Mulberry trees were planted for sericulture in Bak village, but not Nakhou. Regenerated seedlings of *Peltophorum dasyrrhachis*, a fast growing pioneer tree, were preferentially retained in the field to promote vegetation recovery in the fallow period.

Shifting cultivation was not being practiced in Nakhou village.

(4) Grassland

In Bak village, the dominant species, the leaves of *Imperata cylindrica* var. *major*, was an important roofing material. This grass was harvested in December. Shrubs and saplings of forest trees were removed at the same time to prevent the grassland from reverting to secondary forest. Small groups of people would harvest the plants by sickle, remove shrubs and saplings using a spade, and bind the harvested plants into bundles using twine made of *Trachelospermum asiaticum* or *Lygodium* sp. A thatched roof would last for three years. In addition, material from *Thysanolaena maxima* was collected and used for making brooms.

In Nakhou village, the medicinal plant *Croton crassifolius* was found only in grassland around paddy fields. A decoction of the roots, often mixed with *Casearia grewiaefolia* roots, was used as a medicine for stomach ache. *Eupatorium odoratum* leaves were applied externally as a styptic for wounds.

(5) Waterside

In Bak village, among the five useful species, *Nelumbo nucifera* fruits and *Neptunia oleracea* shoots were popular foods often sold in markets. *Pandanus* sp. was transplanted from marsh to irrigation dams for the dam's protection.

In Nakhou village, although the number of useful species was small, those that were available were essential to livelihood. *Ipomoea aquatica* shoots and *Nymphaea pubescens* flower stalks were major foods often sold in markets. *Alloteropsis* sp. was harvested in December for use as a roofing material. The thatch from this species was regarded as being of better quality than that from *I. cylindrica*, lasting as long as five years. *Cyperus pilosus* was used as material for mat weaving.

(6) Paddy fields

In Bak village, of the 18 useful species recorded in paddy fields, 14 were herbaceous species and four were woody species. The majority (17 spp.) were edible. *Limnophila geoffrayi* and *Marsilea crenata* were the major greens often sold in local markets. Especially, *Limnophila geoffrayi* had a fragrant smell, and was an essential herb for *keng noomai* (bamboo shoot soup). Plants were dried and kept for the dry season, when it was otherwise not available. *Monochoria vaginalis*, one of the dominant paddy weeds, was also edible. *Mentha aquatica* and *Ocimum basilicum* were essential culinary herbs and were cultivated in small vegetable gardens on paddy levees in the rainy season.

In Nakhou village, paddy fields contained the largest number of useful plants. Of the 116 useful species found in paddy fields, 30 were herbaceous species and 86 were woody species. Among them, 40 species were planted, and 40 species had economic value. They were mainly used as food (62 spp.), timber (24 spp.), and fuel (26 spp.). Regarding herbaceous species, besides *Limnophila geoffrayi* and *Marsilea crenata* mentioned above, *Glinus oppositifolius* was used as an edible green. This species was collected in the dry season when other wild edible plants were scarce. *Ipomoea batatas* (sweet potato) and *Zea mays* (corn) were cultivated after the harvesting of paddy rice in lowland paddy fields, where nearby water was available even in the dry season. *Elephantopus scaber* growing on paddy levees was used as a medicinal plant. A decoction of leaves and roots was prepared and consumed orally for stomach ache. The major foods sold in local markets derived from woody species included shoots and flower buds of *Azadirachta indica* var. *siamensis*, fruits of *Borassus flabellifer*, shoots of *Careya arborea*, fruits and shoots of *Leucaena leucochephala*, fruits of *Tamarindus indica*, and fruits of *Ziziphus mauritiana*. *Mitragyna rotundifolia* and *Peltophorum* *dasyrrhachis* were recognized as fast growing species and were pollarded for fuelwood at a height of 2-3 meters every two years. *Pterocarpus macrocarpus*, a remnant tree of original forest, was recognized as providing the highest quality timber of local species. *Diospyros mollis* fruits were once used for dyeing. Alcohol or water in which the bark of *Millingtonia hortensis* had been soaked was used as a medicine for coughs. A decoction of *Streblus asper* roots was consumed orally for stomach ache or as an antifebrile.

Moreover, almost all plants in paddy fields had indirect utility in both villages. Cattle and buffaloes were grazed in the paddy fields after rice harvesting. Trees in paddy fields provided shade for both humans and livestock. Villagers in Nakhou village said that shade from the trees protected rice plants from strong sunshine, or that fallen leaves from the trees fertilized paddy soil.

The average rice yield was 1-3 t/ha in both villages; however, the yield varied considerably with land quality, amount of fertilizer input, and weather. Most of the grain produced was for self-consumption.

(7) Homestead

In Bak village, mulberry leaves were used for sericulture and *Pentace burmanica* bark was used for betel chewing. Although *Pentace burmanica* was previously extracted from the forest, it had become scarce and was planted around homesteads in recent years. *Annona squamosa* (sugar apple) and *Chrysophyllum cainito* (star apple) were also planted in Nakhou village, but more frequently in Bak village.

A special product of Nakhou village was mats woven from culms of *Cyperus corymbosus*, which was planted in small pools dug within homestead areas and harvested twice a year. *Ceiba pentandra* was also planted in Bak village, but more frequently in Nakhou village. The cotton-like aril of this species (kapok) was used for stuffing pillows and as an income source.

In addition, many common species were planted in both villages. For example, *Mangifera indica* (mango) and *Psidium guajava* (guava) were planted for their fruit, *Bambusa blumeana* for edible shoots and handicrafts, *Cocos nucifera* (coconut palm) for fruit and handicrafts, *Alpinia galanga* (great galangal), *Capsicum frutescens* (bush red pepper), *Citrus hystrix* (kaffir lime), and *Cymbopogon citratus* (lemon grass) for essential spices, *Jatropha curcas* as a live fence, *Muntingia calabura* for shade, *Hymenocallis littoralis* for medicine and Buddhist ceremonies, and *Plumeria rubra* as an ornamental.

Plant use at regional scale

Plant use in Bak village and Nakhou village was also influenced by plant resource production in surrounding villages. Figure 4-2 shows production and distribution of plant resources in the region around Bak village and Nakhou village. Kenkok village is the center of Champhone

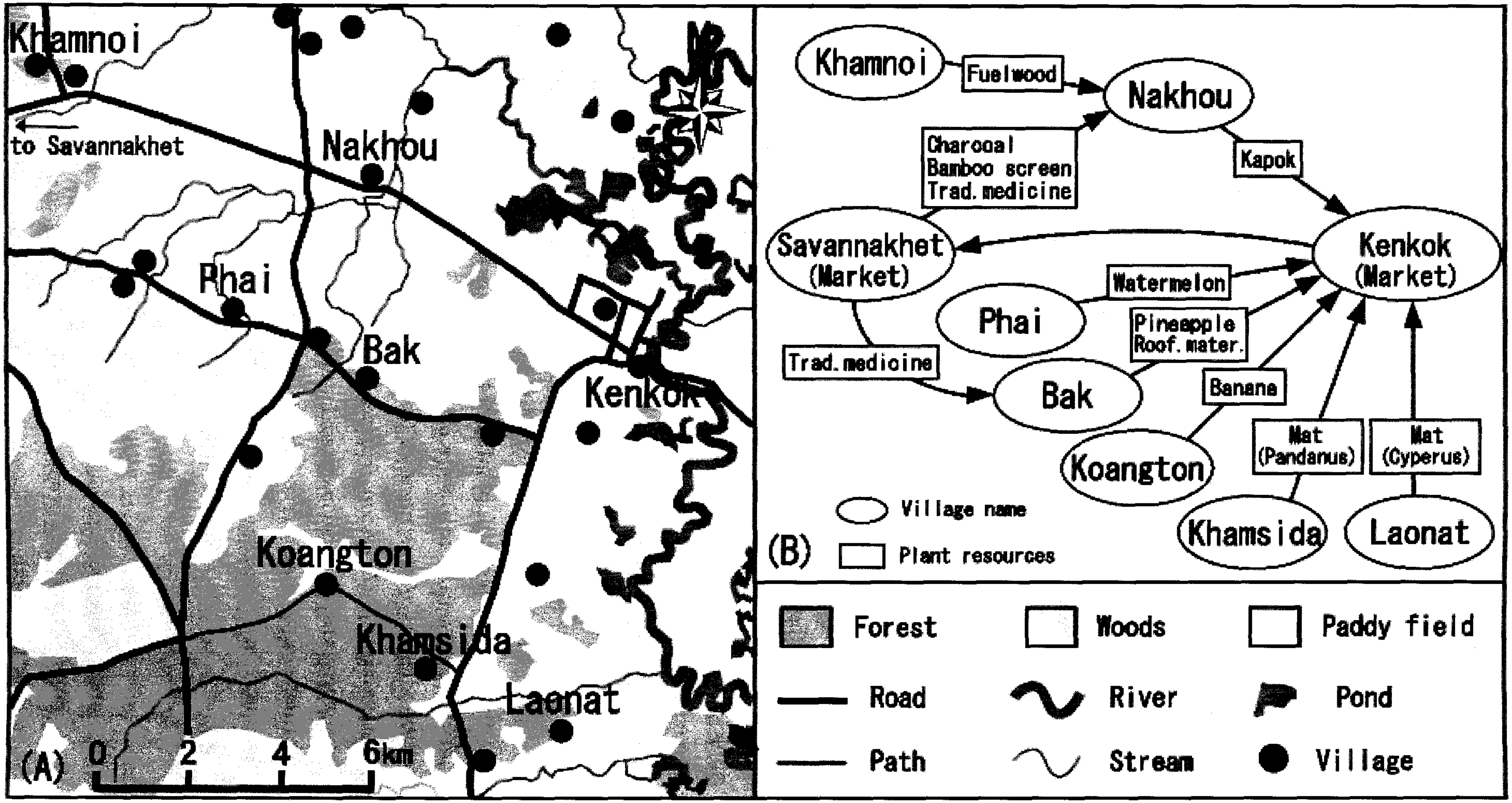

Figure 4-2. Production and distribution of plant resources in the region around Bak village and Nakhou village.
(A)Map of the study site (Adapted from Republique Democratique Populaire Lao: Service Geographique D'Etat 1982). (B)Production and distribution of plant resources.

District and has a local market every morning and evening. Fresh vegetables, fruits, fish, meat, and other products are brought from nearby villages and sold. In Figure 4-2, however, the "market" designation for Kenkok village is nominal, indicating only that resources were distributed; sometimes plant resources were exchanged or traded directly between villagers.

Plant resources sold from Bak village were pineapple and *Imperata* thatching. Bananas were sold from Koangton village and watermelon from Phai village. Koangton village and Phai village are adjacent to Bak village on the upper hillslope. The people of both villages were engaged in shifting cultivation as well as paddy cultivation. Although bananas and watermelons were also cultivated in Bak village, they were only used for self-consumption. The main plant resource sold from Nakhou village was kapok. Although *Cyperus* spp., was used for mat weaving in Nakhou village, the mats produced were for self-consumption. Within the general region, most mats of *Cyperus* spp. supplied for trade came from Laonat village, and mats of *Pandanus* sp. were from Khamsida village. Owing to the limited area of forested land in Nakhou village, fuelwood supply from village resources was insufficient, especially for distillation of alcohol, cremation, or salt making by boiling. The Nakhou villagers therefore bought fuelwood from Khamnoi village, which had a large area of forest.

Other plant resources were distributed on a larger geographical scale by trade. Bak village bought traditional medicine, and Nakhou village bought traditional medicines, bamboo screens, and charcoal from the market in a central town in Savannakhet Province about 50 km northwest of both villages. Although some types of medicinal plant were available in both villages, others were also needed for the preparation of traditional medicines. They were obtained from other villages in Savannakhet Province or Vientiane Province (about 400 km northwest of Savannakhet Province). The best quality bamboo screens were made of *Schizostachyum zollingeri* and were used for house walls and floors. This bamboo was mainly produced in Khammouane Province (about 120 km north of Savannakhet Province), but was seldom produced in Savannakhet Province. Charcoal was also sold in the market at Kenkok village, but people preferred buying it in bulk from Savannakhet, where the price was lower.

4-4. Discussion

To consider the wider applicability of the results of this case study, I discuss the factors influencing plant use in local communities with reference to three broad categories: geographical factors, socioeconomic factors, and the role of naturalized species. Finally, I discuss the implications of our findings for management and conservation of plant resources.

Geographical aspects of plant use

There was a clear difference in plant use between Bak village and Nakhou village, mainly as a result of topography and land-use patterns and their affect on the actual vegetation present

(Figure 4-1, Table 4-1).

Previous studies on topography and land-use patterns in northeast Thailand ar comparable to this study. The topography, climate, flora, and fauna of the Mekong Valley i Laos are similar to those of northeast Thailand (Heckman, 1974), as are the language an culture (Evans and Sengdala, 2002). Northeast Thailand is more densely populated and wa largely deforested long before areas on the Lao side of the Mekong (Evans and Sengdal 2002). In northeast Thailand, the land was transformed from forest to cultivated fields b pioneering farmers, beginning in the lowland (prime areas for paddy fields) and the expanding into the uplands (Vityakon et al., 2004). However, this land transformation did no lead to a rapid loss of forest until the economy transformed from a subsistence base to a mor commercial orientation, leading to the expansion of cash crop cultivation in the 1950 (Vityakon et al., 2004). In this study, forest cover was also found to remain in upland area where subsistence agriculture was conducted, as observed in Bak village. On the other hand Nakhou village was located in the lowlands, so only small areas of forest had survived th past clearing for paddy cultivation. However, many trees were left or planted in paddy fields and this compensated for the lack of forest resources. The presence of trees in paddy fields is characteristic of the landscape throughout northeast Thailand (Grandstaff et al., 1986 Prachaiyo, 2000; Takaya and Tomosugi, 1972; Watanabe et al., 1990) and central Lao (Kosaka et al., in press).

Plant resource utilization in each village made the most of the natural environment. Th results of this study suggested that the main crop species grown for income were not commor to most adjacent villages (Figure 4-2). It was also shown that plant resources were no uniformly distributed among surrounding villages or even provinces and, therefore, adjacen villages or provinces supplemented each other in the resources that they lacked. This kind o resource distribution is important at this study site where the rice yield is unstabl (Mushiake, 2002).

Influence of socio-economic factors on local plant resources

In Bak village, the number of households engaged in oleoresin extraction from *Dipterocarpus alatus* has decreased due to the reduction in trees by logging during the revolution era. On the other hand, oleoresin is still collected in Laos, and demand for it has risen since European perfume manufacturers started to use it as a fixative in perfumes (Ankarfjard and Kegl, 1998) The adoption of dipterocarp oleoresin as a component in perfumes is an encouraging example of a long-used non-timber forest product finding new markets after the traditional use has declined in importance (Ankarfjard and Kegl, 1998).

Diospyros mollis, which grows in the paddy fields in Nakhou village, used to be used by the villagers as a dye. However, this practice has disappeared with the availability of colored clothing, cloth, and fibers at a low price at nearby markets. On the other hand, many dye plants, including *Diospyros mollis*, are still used in some area of Laos and are becoming especially important for export as the worldwide demand for natural dyes is expanding due to increased environmental awareness (Hayashi et al., 2002).

Plant resources in Laos occasionally become an income source through access to new external markets. However, local communities do not always receive an enduring profit from such discoveries. In the past, some useful species have tended to be over harvested. This clearly occurred in northern Laos soon after Chinese traders made a contract with villagers to buy *Coscinium fenestratum* (personal observation). Further study on useful species is necessary to investigate appropriate use and management that contributes to rural development (Evans and Sengdala, 2002).

Remarks on naturalized species

In Nakhou village, *Leucaena leucocephala* was not only planted on paddy levees, but was also growing wild as an escaped plant. Although this species was introduced from South and Central America (Smitinand and Larsen, 1985), the fruits and shoots are currently one of the major vegetables in Laos. *Leucaena leucocephala* has been introduced into many areas in the tropics as a feed crop or cover crop, whereas its rapid expansion sometimes affects indigenous vegetation negatively (Yoshida and Oka, 2000).

Imperata cylindrica var. *major*, which is used for roofing in Bak village, is also a naturalized species. Although it has been locally collected and traded for use as a roofing material, building house walls, and other uses for centuries in Southeast Asia, it is one of the world's worst weeds (Potter, 1997).

Eupatorium odoratum, introduced into Laos in the 1930s, has become the most abundant weed and fallow species occurring in shifting cultivation fields (Roder et al., 1995). In Bak village and Nakhou village, it was observed more at the edges of forest, along roadsides, on paddy levees, and in grassland than in shifting cultivation fields. The use of this species was not documented in the inventory of Vidal (1962); however, its widespread medicinal use as a styptic for wounds in Laos was recorded in our field surveys. In addition, its many favorable attributes as a fallow species were pointed out by Roder et al. (1995).

Care needs to be taken with the introduction of non-native species, even if they seem to be useful. The threats posed by some invasive species are so severe that reducing the rate of introduction of non-indigenous species needs to become a greater conservation priority (Primack, 2002). For example, *Mimosa pigra* was once introduced into Thailand as a cover crop for riverbank protection but is now a serious problem along water bodies because it disrupts fishing activity (Harada et al., 1996). *M. pigra* was not observed at this study site, but its distribution is spreading through many other regions of Laos (personal observation).

Human management of plant resources

The use and management of plant resources in the study area has played a role in their conservation. In Bak village, plants of *Pentace burmanica* and *Tinospora crispa* were transplanted from forest to homestead areas owing to their population decline in forest. Over-harvesting may alter population size, growth rates, and reproductive capacity of harvested species, leading to a reduction in the quantities of NTFPs (Hall and Bawa, 1993). Accordingly, moving plants from the wild to protected house gardens may be a way of conserving economically important species in the region (Evans and Sengdala, 2002; Fu et al., 2003). Pollarding, which was conducted in Nakhou village, has recently been re-evaluated as a practice that allows conservation of species diversity (Orians and Millar, 1992). In addition, sacred forest, crematory forest, and traditional conservation forest in the villages were also found to contribute to forest resources management. Shifting cultivation produces an extensive area of ecologically and economically valuable fallow vegetation, although it is being phased out throughout mainland Southeast Asia (Schmidt-Vogt, 2001). Moreover, several land-use classes under human management in Bak village and Nakhou village contained many specific useful plants, and surrounding villages had their own products with otherwise limited availability, resulting in a variety of available useful plant species both at the landscape level and the regional level.

Thus, traditional botanical knowledge is neither static nor uniform as is often assumed, but is generated, maintained and modified according to local ideology, external social or practical influences, and changing resource availability (Cotton, 1996). In Laos, uniform application of the Forestry Law will cause a conflict between traditional land-use systems and newly established forest demarcation (Hyakumura, 2001; Namura and Inoue, 1998; Yokoyama, 2004). In such cases, re-evaluation of indigenous knowledge, use, and management of natural resources may provide clues to mitigate the problem.

4-5. Conclusion

Plant use at this study site was influenced mainly by topography and land-use and partly by socio-economic conditions and invasion by naturalized species. Bak village was located on an upper hillslope and still had a large area of forest. There were abundant forest products and specific useful plants in several other land-use classes. On the other hand, Nakhou village was located on lower flat land and had few areas of forest because of earlier conversion to paddy fields. However, the villagers coped with the lack of forest resources by use and management of trees in paddy fields in multiple ways. In addition, plant resources in surrounding villages influenced plant use in both villages. Each village utilized specific plant resources by making the most of those locally available and supplementing deficiencies through trade.

Thus, the analysis of local plant use at different geographical scales showed that the relationship between humans and plants in this study site was flexible. Moreover, it was also shown that the number of available useful plant species was enhanced at the landscape level by a mosaic distribution of land-use and also at the regional level by the trading of specific products between villages. Therefore, it is suggested that species inventories and descriptions of the external factors influencing plant use at different geographical scales within a spatially heterogeneous landscape can form an important basis for management and conservation of the plant resources of local communities.

Chapter 5. General discussion and conclusion

5-1. General discussion

This dissertation has dealt with the relationships between humans and plants in the paddy field landscape by focusing on local knowledge and techniques. The local knowledge and techniques in the context of this study includes the methods of utilization and management of plant species, the use and management of agricultural lands, the distribution of plant resources in the region, and a history of the vegetation and land-use patterns. In this chapter, the relationships between human and plants are analyzed from three viewpoints to understand the roles of humans in supporting plant diversity in human-managed ecosystems (Figure 5-1).

First, the various types of human impact on the plant population are listed. According to the results of this study, the human impact on the plant population can be classified into two types— intended human impact (Table 5-1) and unintended human impact (Table 5-2). Although this classification is ambiguous in some cases of human impact, it will be useful when we examine the relationships between humans and plants. Intended human impact means human activities against targeted plants with a clear intention to manage them directly. It is represented by the management of trees in agricultural fields and transplanting or protecting wild species in homestead land-use class. Here, it should be noted that intended plant resource management is conducted in places without any regulations on resource use. However, in some regions of Laos, logging or NTFPs gathering are strictly regulated by government policy or village customary rules in forested lands (Hyakumura, 2003). This is not true for other land-use types. Although permission from the local authority is needed when cutting trees in paddy fields, the ownership of the trees lies with the paddy owner. However, in paddy fields or homestead land-use class, people spontaneously manage and retain useful species that may otherwise decrease in number. Unintended human impact

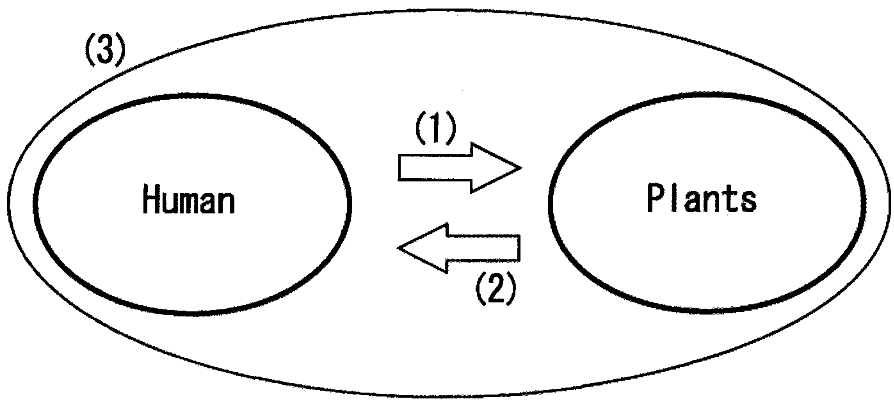

Figure 5-1. Framework of analysis on the relationships between human and plants.

Table 5-1. Intended human impact and probable plants' response

Village	Land-use	Human impact	Plants' response
BK	Forest	*Protected area based on Forestry Law**	Late successional species can survive.
	Field	Tree management (protection), Fallow	*Peltophorum* becomes dominant in the fallow forests.
	Grass	Removing small woody species	*Imperata* becomes dominant.
	Paddy	Removing overgrowing herbaceous species	Multiple plants coexist with *Orzya sativa*.
	Home	Protecting wild species	The targeted species survive in disturbed environment.
		Transplanting wild species	The targeted species get new habitat for their survival.
NK	Paddy	Tree management (protection, pollarding, planting)	Change from remnant to ruderal and planted species.
		Removing overgrowing herbaceous species	Multiple plants coexist with *Orzya sativa*.
	Home	Transplanting wild species	The targeted species get new habitat for their survival.

Items with an asterisk represent human impact caused by institution.

Table 5-2. Unintended human impact and probable plants' response

Village	Land-use	Human impact	Plants' response
BK	Forest	*Village customary protected forest**	Late successional species can survive.
	Field	Fallow	Non-targeted early successional species can grow.
	Paddy	Disturbance by agricultural practices	Multiple herbaceous species occur.
NK	Paddy	Disturbance by agricultural practices	Multiple herbaceous species occur.

Items with an asterisk represent human impact caused by institution.

means human activities that result in influencing non-target species inadvertently. It includes predictable disturbances caused by periodical agricultural practices such as plowing and water logging in paddy fields and fallowing in shifting cultivation fields. It is also represented by unpredictable disturbances caused by unscheduled agricultural practices such as clearing for creating new paddy fields. This type of unintended human impact should also be emphasized because it is likely to be neglected in natural resource management programs. Many studies have revealed that moderate human disturbance contributes in the maintenance of biodiversity. For example, traditional agricultural practices enhance the regional plant species diversity (e.g., Kitazawa and Ohsawa, 2002), and margins or hedgerows of farmlands harbor biodiversity (e.g., Croxton et al., 2004). Thus, whether or not intended, some kinds of human activities show positive effects on plant diversity. This should be taken into account in biological conservation programs in and around areas with human settlements.

Second, the probable response of plants to human impact is summarized in Table 5-1 and Table 5-2. Plants may grow in the paddy field landscape under various types of human impact not only by resisting intense disturbance, but also by adapting themselves to such circumstances. However, this study was conducted in a qualitative manner to determine how the plants can survive under the human impact. Therefore, a further study is needed to investigate the life cycle and the reproductive strategies of plants quantitatively to analyze how plants survive such disturbing circumstances (e.g., Ghimire et al., 2005; Hall and Bawa, 1993).

Third, the factors influencing the relationships between humans and plants are discussed. The relationships between humans and plants are neither static nor uniform due to local ideology, external social or practical influences, and changing resource availability (Cotton, 1996). This is also true in the case of this study site. For example, trees in paddy fields are managed in forest-deprived villages. In addition, *Imperata*-dominant grasslands are now important places for sourcing roofing material, although it had been cultivated until the amount of *Imperata* grass increased in number. These are cases that demonstrate how local people cope with environmental changes by flexible resource management. Moreover, as shown in Bak village, the number of households engaged in shifting cultivation has decreased with an increase in the proportion of paddy farming. This is largely a result of a government policy. Thus, the history of plant use and land use should be taken into account in order to understand the current relationships between humans and plants in human managed ecosystems.

Thus, the importance of the role of humans in supporting plant diversity in human-managed ecosystems is revealed by the analysis of human-plant relationships from the three viewpoints——human impact on plants, plants' response to human impact, and factors influencing human–plant relationships. This has great implication on the biological conservation in Laos that has been implemented by excluding human activities from protected areas.

5-2. Conclusion

This dissertation has described the relationships between humans and plants in the paddy field landscape in central Laos. The research findings will provide useful information for considering appropriate biological conservation methods in human-managed ecosystems.

Chapter 2 examines the factors influencing tree species composition and their distribution in paddy fields, which characterized land use in this region. A total of 119 species were recorded in the forest-deprived Nakhou village. The scarcity of forest resources at Nakhou was compensated by the utilization and management of trees located among the fields, resulting in tree species changing from remnant to ruderal over time. This result has important implications in the setting up of both landscape-level land-use management plans and local tree management policies for achieving sustainable tropical paddy-dominated silvo-agricultural systems.

Chapter 3 examines the relationships between paddy vegetation and agricultural practices by focusing on herbaceous species. The result is that a total of 184 wild herbaceous species were recorded and some of these species are essential either as local food or for subsistence livelihood. The factors contributing to high species diversity are: (1) the presence of species unique to different paddy types, (2) the presence of remnant species from the original vegetation, and (3) the impact of agricultural practices. These findings have important implications for plant resource management in paddy fields.

Chapter 4 examines the land-use patterns and plant use both at the landscape level and at the regional level. The analysis of local plant use at different geographical scales showed that the relationship between humans and plants at this study site is flexible and is influenced mainly by topography and land use and partly by socio-economic conditions and invasion by naturalized species. It is suggested that a species inventory and descriptions of the external factors influencing plant use at different geographical scales within a spatially heterogeneous landscape can form an important basis for management and conservation of the plant resources of local communities.

The paddy field landscape in this study site has been found to be a human-managed ecosystem that harbors high plant diversity. Recently, the forest conservation program in Laos has been strengthened by establishing protected areas where human use is limited. However, the results of this study indicate that it is also important to incorporate the local people's activities into biological conservation. For achieving this, the possibility of biological conservation based on local knowledge and techniques should be assessed from the three viewpoints——human impact on plants, response of plants to human impact, and the factors influencing human-plant relationships.

Reference

Anderson, E. F. 1993. Plants and people of the golden triangle: Ethnobotany of the hill tribes of northern Thailand. Dioscorides Press, Oregon. 279 pp.

Ankarfjard, R. and Kegl, M. 1998. Tapping oleoresin from *Dipterocarpus alatus* (Dipterocarpaceae) in a Lao village. Economic Botany 52:7-14.

Arnold, J.E.M. 1995. Framing the issues. In: Arnold, J.E.M. and Dewees, P.A. (eds) Tree management in farmer strategies: Responses to agricultural intensification. Oxford University Press, Oxford, pp 3-17.

Bambaradeniya, C. N. B., Edirisinghe, J. P., De Silva, D. N., Gunatilleke, C. V. S., Ranawana, K. B., and Wijekoon, S. 2004. Biodiversity associated with an irrigated rice agro-ecosystem in Sri Lanka. Biodiversity and Conservation 13:1715-1753.

Baskin, Y. 1994. Ecologists dare to ask: How much does diversity matter ? Science 264: 202-203.

Chandrasena, J. P. N. R. 1988. Floristic composition and abundance of rice-field weeds in four low-country wet zone districts of Sri Lanka. Tropical Pest Management 34:278-287.

Cotton, C. M. 1996. Ethnobotany: principles and applications. John Wiley and Sons, West Sussex. 424 pp.

Croxton. P. J., Franssen, W., Myhill, D. G., and Sparks, T. H. 2004. The restoration of neglected hedges: a comparison of management treatments. Biological Conservation 117: 19-23.

Cunningham, A. B. 2001. Applied ethnobotany: People, wild plant use and conservation. Earthscan Publication Ltd., London. 229 pp.

Daconto, G., ed. 2001. Siphandone Wetlands. CESVI, Bergamo, Italy.

Datta, S. C., and Banerjee, A. K. 1978. Useful weeds of west Bengal rice fields. Economic Botany 32:297-310.

Etkin, N. L. 2002. Local knowledge of biotic diversity and its conservation in rural Hausaland, northern Nigeria. Economic Botany 56:73-88.

Evans, T. D., and Sengdala, K. 2002. The adoption of rattan cultivation for edible shoot production in Lao PDR and Thailand – From non timber forest product to cash crop. Economic Botany 56: 147-153.

Fiedler, P. L., and Jain, S. K., eds. 1992. Conservation biology: the theory and practice of nature conservation, preservation, and management. Chapman and Hall, New York.

Fu, Y., Guo, H., Chen, A., Cui, J. & Padoch, C. 2003. Relocating plants from swidden fallows to gardens in southwestern China. Economic Botany 57:389-402.

Gall, G. A. E., and Orians, G. H. 1992. Agriculture and biological conservation. Agriculture, Ecosystems and Environment 42:1-8.

Gardner, S., Sidisunthorn, P., and Anusarnsunthorn, V. 2000. A field guide to forest trees of northern Thailand. Kobfai Publishing Project, Bangkok, 545 pp.

Ghimire, S. K., McKey, D., and Aumeeruddy-Thomas, Y. 2005. Conservation of Himalayan medicinal plants: Harvesting patterns and ecology of two threatened species, *Nardostachys grandiflora* DC. and *Neopicrorhiza scrophulariiflora* (Pennell) Hong. Biological Conservation 124:63-475.

Gopal, B., and Sah, M. 1995. Inventory and classification of wetlands in India. Vegetatio 118:39-48.

Goslee, S. C., Brooks, R. P., and Cole, C. A. 1997. Plants as indicators of wetland water source. Plant Ecology 131:199-206.

Grandstaff, S. W., Grandstaff, T. B., Rathakette, P., Thomas, D. E. & Thomas, J. K. 1986. Trees in paddy fields in northeast Thailand. In: Traditional agriculture in Southeast Asia. (Marten, G. G. ed.), Pp. 273-292. Westview Press, Colorado.

Grime, J.P. 2001. Plant strategies, vegetation processes, and ecosystem properties. John Wiley & Sons Ltd., England, 417 pp.

Hall, P. and Bawa, K. 1993. Methods to assess the impact of extraction of non-timber tropical forest products on plant populations. Economic Botany 47: 234-247.

Harada, J., Shibayama, H., and Morita, H. 1993. Weeds in the Tropics. AICAF, Tokyo, Japan. (in Japanese)

Harada, K. 2005. Dilemma of protected areas: Conflicts between biodiversity and culture. Japanese Journal of Forest Science 87:261-271. (in Japanese with English summary)

Harvey, C. A. and Haber, W. A. 1999. Remnant trees and the conservation of biodiversity in Costa Rican pastures. Agroforestry Systems 44:37-68.

Hayashi, R., Takeda, S. and Watanabe, H. 2002. Utilization and diversity of dye plants in the Lao P.D.R. Forest Research, Kyoto 74: 121-130. (In Japanese with English summary)

HEAR. (Hawaiian Ecosystems at Risk project). 2004. A Global Compendium of Weeds. http://www.hear.org/gcw. Accessed on December 19, 2004.

Heckman, C. W. 1974. The seasonal succession of species in a rice paddy in Vientiane, Laos. Internationale Revue Der Gesamten Hydrobiologie 59: 489-507.

Heywood, V. H. and Iriondo, J. M. 2003. Plant conservation: old problems, new perspectives. Biological Conservation 113:321-335.

Hidaka, T. 2005. Seibutu tayousei wa naze taisetsuka？ Shouwado. 183 pp. (in Japanese)

Hill, M. O. 1994. DECORANA and TWINSPAN, for ordination and classification of multivariate species data: a new edition, together with supporting programs, in FORTRAN77. Institute of Terrestrial Ecology, Huntingdon.

Ho, P. 1999-2000. An illustrated flora of Vietnam. Nha xuat ban tre, Hanoi.

Hocking, D. and Islam, K. 1995. Trees in Bangladesh paddy fields. 2. Survival of trees planted in crop fields. Agroforestry Systems 31:39-57.

Hyakumura, K. 2001. Issues of conservation forest management policy in Lao P.D.R.: For the effective policy to be representing the actual conditions in the region. Journal of Forest Economics 638:22-33. (in Japanese)

Hyakumura, K. 2003. Hogochiiki ni okeru sinrinkanri —Raos nanbu・Savannakhet ken no jirei. Inoue, M. ed. Ajia ni okeru sinrin no syousitsu to hozen. IGES. (in Japanese)

Ikeda, R., and Miura, R. 2002. Tsurugashi nakaikemi no shitsudennoukou to zetsumetsukigu syokubutsu. Noukou no Gijutsu to Bunka 23:43-72. (in Japanese)

Ikeya, K. 2003. Sansai torino syakaishi —Shigenriyou to teritory—. Tohoku University Press. 204 pp. (in Japanese)

Inoue, M. 2001. Shizensigen no kyoudoukanriseido toshiteno commons. Inoue, M. and Miyauchi, T. eds. Commons no syakaigaku. Shinyousya. (in Japanese)

IUCN. 1999. Wildlife in Lao PDR: 1999 status report. IUCN.

Jain, S. K. 2000. Human aspects of plant diversity. Economic Botany 54:459-470.

Kasahara, Y. 1954. Studies on the species of the weeds in Japan and their geographical distribution 5. Nogaku Kenkyu 42:97-113. (in Japanese)

Kasahara, Y. 1959. Studies on the species of the weeds in Japan and their geographical distribution 6. Nogaku Kenkyu 47:123-140. (in Japanese)

Kitazawa, T., and Ohsawa, M. 2002. Patterns of species diversity in rural herbaceous communities under different management regimes, Chiba, central Japan. Biological Conservation 104:239-249.

Kosaka, Y., Takeda, S., Prixar, S., Sithirajvongsa, S., and Xaydala, K. Species composition, distribution and management of trees in rice paddy fields in central Lao, PDR. Agroforestry Systems. (in press a)

Kosaka, Y., Takeda, S., Sithirajvongsa, S., and Xaydala, K. Plant diversity in paddy fields in relation to agricultural practices in Savannakhet Province, Laos. Economnic Botany. (in press b)

Kosaka, Y., Takeda, S., Sithirajvongsa, S., and Xaydala, K. Land-use patterns and plant use in Lao villages, Savannakhet Province, Laos. Tropics. (in press c)

Kwesiga, F., Akinnifesi, F. K., Mafongoya, P. L., McDermott, M. H. and Agumya, A. 2003. Agroforestry research and development in southern Africa during the 1990s: Review and challenges ahead. Agroforestry Systems 59:173-186.

Lao PDR RD Programme 1998. Government document sixth round table follow-up meeting, Vientiane, 74 pp.

Lehmann, L., Greijmans, M. and Shenman, D. 2003. Forests and trees of the central highlands of Xieng Khouang, Lao PDR: A field guide. Lao Tree Seed Project, Vientiane, Lao PDR. 246 pp.

Lu, J. 1995. Ecological significance and classification of Chinese wetlands. Vegetatio 118:49-56.

LWU (Lao Women's Union). 2001. Fuel for life: Women, men, and the fuelwood cycle in the Lao PDR. LWU, GRID Center, Vientiane, Lao PDR. 49 pp.

MAF (Ministry of Agriculture and Forestry). 2000. Agricultural statistics 1975-2000. Lao PDR. 171 pp.

Marshall, E. J. P., Brown, V. K., Boatman, N. D., Lutman, P. J. W., Squire, G. R., and Ward, L. K. 2003. The role of weeds in supporting biological diversity within crop fields. Weed Research 43:77-89.

Mitsch, W. J., and Gosselink, J. G. 2000. Wetlands. John Wiley & Sons, New York.

Mushiake, E. 2002. People and their life in South Laos. 6. Edible plant in the local market of Kengkok. Japanese Journal of Tropical Agriculture 46 Extra issue 1:81-82. (In Japanese)

Namura, T. and Inoue, M. 1998. Land use classification policy in Laos: Strategy for the establishment of an effective legal system. Journal of Forest Economics 44:23-30.

NOFIP. (National Office of Forest Inventory and Planning). 1992. Forest cover and land use in Lao PDR: Final report on the nationwide reconnaissance survey. Lao-Swedish Forestry Co-operation Programme, Lao PDR.

Ohtaki, M., and Ishido, T. 1980. Illustrated Japanese water plants. Hokuryukan, Tokyo, Japan.

Orians, G. H. and Millar, C. I. 1992. Forest lands. Agriculture, Ecosystems and Environment 42:125-140.

Pielou, E. C. 1966. The measurement of diversity in different types of biological collections. Journal of Theoretical Biology 13:131-144.

Pieroni, A. 1999. Gathered wild food plants in the upper valley of the Serchio Riber (Garfagnana), central Italy. Economic Botany 53:327-341.

Pimentel, D., Stachow, U., Takacs, D. A., Brubaker, H. W., Dumas, A. R., Meaney, J. J., O'Neil, J. A. S., Onsi, D. E., and Corzilius, D. B. 1992. Conserving biological diversity in agricultural / forestry systems. Bioscience 42:354-362.

Pinder, L., and Rosso, S. 1998. Classification and ordination of plant formations in the Pantanal of Brazil. Plant Ecology 136:151-165.

Potter, L. M. 1997. The dynamics of *Imperata*: historical overview and current farmer perspectives, with special reference to South Kalimantan, Indonesia. Agroforestry Systems 36:31-51.

Prachaiyo, B. 2000, Farmers and forests: A changing phase in northeast Thailand. Southeast Asian Studies 38:6-178.

Primack, R. B. 2002. Essentials of conservation biology. Sinauer Associates, Massachusetts. 698 pp.

Roder, W., Phengchanh, S., Keoboualapha, B. and Maniphone, S. 1995. *Chromolaena odorata* in slash-and-burn rice systems of northern Laos. Agroforestry Systems 31:79-92.

Santisuk, T., and Larsen, K., eds. 1997-2002. Flora of Thailand. The Forest Herbarium, Royal Forest Department, Bangkok, Thailand.

Schmidt-Vogt, D. 2001. Secondary forests in swidden agriculture in the highlands of Thailand. Journal of Tropical Forest Science 13:748-767.

Shankar, U., Murali, K. S., Shaanker, R. U., Ganeshaiah, K. N., and Bawa, K. S. 1998. Extraction of non-timber forest products in the forests of Biligiri Rangan hills, India. 4.

Impact on floristic diversity and population structure in a thorn scrub forest. Economic Botany 52:302-315.

Shannon, C. E., and Weaver, W. 1949. The mathematical theory of communication. University of Illinois Press, Urbana, Illinois.

Shimizu, T., ed. 2003. Naturalized plants of Japan. Heibonsha, Tokyo, Japan.

Shimoda, M. 2003. Suidennno seibutsu wo yomigaeraseru. Iwanamishoten, Tokyo, Japan. (in Japanese)

Simpson, E. H. 1949. Measurement of diversity. Nature 163:688.

Sisouphanthong, B., and Taillard, C. 2000. Atlas of Laos – The spatial structures of economic and social development of the Lao People's Democratic Republic. The Nordic Institute of Asian Studies (NIAS), Copenhagen, Denmark.

Smitinand, T., and Larsen, K., eds. 1970-1996. Flora of Thailand. The Forest Herbarium, Royal Forest Department, Bangkok, Thailand.

Swift, M. J., Izac, A. M. N., van Noordwijk, M. 2004. Biodiversity and ecosystem services in agricultural landscapes – are we asking the right questions? Agriculture, Ecosystems and Environment 104:113-134.

Takaya, Y. and Tomosugi, T. 1972. Rice lands in the upland hill regions of northeast Thailand – A remark on "rice producing forests" –. Southeast Asian Studies 10:77-85. (In Japanese with English summary)

Tomita, S., E. Nawata, Y. Kono, T. Inamura, Y. Nagata, C. Noichana, and A. Sributta. 2003a. Impact of direct dry seeding on rainfed paddy vegetation in north-east Thailand. Weed Biology and Management 3:68-76.

Tomita, S., Nawata, E., Kono, Y., Nagata, Y., Noichana, C., Sributta, A., and Inamura, T. 2003b. Differences in weed vegetation in response to cultivating methods and water conditions in rainfed paddy fields in north-east Thailand. Weed Biology and Management 3:117-127.

Umezaki, M. 2004. Kankyouhozen to ryouritsu suru seigyou. Shinohara, T. ed. The death of slash-and-burn agriculture on Hainan Island, China. University of Tokyo Press. (in Japanese)

UNDP. 1998. Socio-economic profile of Savannakhet Province. UNDP, Vientiane, Lao PDR.

UNEP. 2001. Lao PDR: State of the environment. UNEP, Pathumthani, Thailand. 81 pp.

Van der Pijl, L. 1982. Principles of dispersal in higher plants. Springer, Berlin, 215 pp.

Vidal, J. 1962. Noms vernaculaires de plantes en usage au Laos. Ecole Francaise D' Extreme-orient, Paris. 197 pp.

Vityakon, P. 2001. The role of trees in countering land degradation. Southeast Asian Studies 39:398-416.

Vityakon, P., Subhadhira, S., Limpinuntana, V., Srila, S., Trelo-Ges, V. and Sriboonlue, V. 2004. From forest to farmfields: Changes in land use in undulating terrain of northeast Thailand at different scales during the past century. Southeast Asian Studies 41:

444-472.

Watanabe, H., Abe, K., Hoshikawa, T., Prachaiyo, B., Sahunalu, P. and Khemnark, C. 1990. On trees in paddy fields in northeast Thailand. Southeast Asian Studies 28:45-54.

Weerakoon, W. L., and Gunewardena, S. D. I. E. 1983. Rice field weed flora of Sri Lanka. Tropical Agriculturist 139:1-14.

Wezel, A. and Bender, S. 2003. Plant species diversity of homegardens of Cuba and its significance for household food supply. Agroforestry Systems 57:39-49.

Xaydala, K. 2003. Field guide book of edible forest product in Sangthong District, Vientiane, Lao PDR. Faculty of Forestry, National University of Laos, Lao PDR. 72 pp.

Yamaguchi, H., and Umemoto, S. 1996. Classification of paddy levees in terms of plant resource complex. Weed Research, Japan 41:286-294. (in Japanese with English summary)

Yokoyama, S. 2004. Forest, ethnicity and settlement in the mountainous area of northern Laos. Southeast Asian Studies 42:132-156.

Yoshida, K. and Oka, S. 2000. Impact of biological invasion of *Leucaena leucocephala* on successional pathway and species diversity of secondary forest on Hahajima Island, Ogasawara (Bonin) Islands, northwestern Pacific. Japanese Journal of Ecology 50: 111-119. (In Japanese with English summary)

Zimmerer, K. S. and Young, K. R. 1998. The geographical nature of landscape change. In: Nature's geography: New lessons for conservation in developing countries. (Zimmerer, K.S. & Young, K.R. eds.), Pp. 3-34. The University of Wisconsin Press, Wisconsin.

Appendix 1. Tree species recorded at paddy fields in Dongmakngeo village and Nakhou village

Dongmakngeo village

No.	Species	Family	Local Name	T.No.	Forest-habitat	Village-habitat	Species Type	Dispersal Agent	Use
1	*Dipterocarpus tuberculatus* Roxb.	Dip	Mai Kun	138	N		Remnant	Wind	T, R, C, O
2	*Shorea obtusa* Wall. ex Blume	Dip	Kok Chik	48	N		Remnant	Wind	T, R, S
3	*Terminalia alata* Heyne ex Roth	Com	Kok Seuak	45	N		Remnant	Wind	S, C, T, M
4	*Aporosa villosa* Baill.	Eup	Kok Meuat	6	N		Remnant	n/a	M
5	*Mitragyna rotundifolia* (Roxb.) O.Ktze.	Rub	Kok Thom	6	N		Remnant	Water?	T
6	*Morinda tomentosa* Heyne	Rub	Kok Nyo	5	N		Remnant	Bats	M, S
7	*Syzygium* sp.	Myr	Kok Waa	5	N		Remnant	Birds	Fo, S
8	*Terminalia mucronata* Craib & Hutch.	Com	Mai Peuay leuat	5	N		Remnant	Wind	C
9	*Parinari anamensis* Hance	Ros	Mai Phok	3	N		Remnant	n/a	Fo
10	*Shorea siamensis* Miq.	Dip	Mai Hang	3	N		Remnant	Wind	T, R, S
11	*Dillenia ovata* Wall. ex Hk.f. & Th.	Dil	Kok Saan	2	N		Remnant	Birds	Fo
12	*Gluta usitata* (Wall.) Ding Hou	Ana	Kok Nam kiang	2	N		Remnant	Wind	
13	*Strychnos nux-blanda* A.W.Hill	Log	Kok Tum kaa	2	N		Remnant	n/a	M
14	*Terminalia chebula* Retz.	Com	Kok Sommo	2	N		Remnant	Birds	
15	*Dalbergia* sp.	Leg	Mai Padong	1	N		Remnant	Ruminants	T
16	*Dipterocarpus obtusifolius* Teysm. Ex Miq.	Dip	Mai Saat	1	N		Remnant	Wind	T, R, C, O
17	*Lophopetalum wallichii* Kurz.	Cel	Kok Sii khok	1	N		Remnant	Wind	Fo
18	*Phyllanthus embrica* L.	Eup	Kok Kham phon	1	N		Remnant	Birds	Fo
19	*Schleichera oleosa* (Lour.) Oken	Sap	Kok Khosom	1	N		Remnant	Birds	Fo

Appendix 1. (cont.)

No.	Species	Family	Local Name	T.No.	Forest-habitat	Village-habitat	Species Type	Dispersal Agent	Use
20	*Syzygium gratum* (Wt.) S.N.Mitra var. *gratum*	Myr	Kok Samek	1	N		Remnant	Birds	Fo
21	*Oroxylum indicum* (L.) Kurz	Big	Kok Linmai	n/a		P	Planted	Human	Fo
22	*Ceiba pentandra* (L.) Gaertn	Bom	Kok Niu	n/a		P	Planted	Human	H
23	*Tamarindus indica* L.	Leg	Kok Kham	n/a		P/N?	Planted	Human	Fo

Of 23 species identified, three species were planted, no species were found to regenerate in the paddy areas.

Nakhou village

No.	Species	Family	Local Name	T.No.	Woods-habitat	Village-habitat	Species Type	Dispersal Agent	Use
1	*Streblus asper* Lour.	Mor	Kok Sompho	301	N	N	Ruderal	Birds	Fr, Fd, M, Fo, O
2	*Peltophorum dasyrrhachis* (Miq.) Kurz	Leg	Kok Sa fang	248	N	(N)	Remnant	Ruminants	T, C, Fr, S
3	*Calycopteris floribunda* (Roxb.) Lamk.	Comb	Kheua Kaden	116	N	N	Ruderal	Wind	Fr, O
4	*Azadirachta indica* A.Juss. var. *siamensis* Valeton	Meli	Kok Ka dao	108	N	N	Ruderal	Bats	Fo, T, M
5	*Diospyros mollis* Griff	Ebe	Kok Keua	81	N	N	Ruderal	Birds	Fr, Fo, (H)
6	*Bambusa bambos* (L.) Voss	Gra	Mai Phai paa	80	N	N	Ruderal		Fo, H
7	*Mitragyna rotundifolia* (Roxb.) O.Ktze	Rub	Kok Thom	66	N	N	Remnant/ Ruderal	Water?	C, T, S

Appendix 1. (Cont.)

No.	Species	Family	Local Name	T.No.	Woods-habitat	Village-habitat	Species Type	Dispersal Agent	Use
8	*Leucaena leucocephala* (Lam.) de Wit	Leg	Kok Ka thin	47		P/N	Planted	Human, Ruminants	Fo, C
9	*Tamarindus indica* L.	Leg	Kok Kham	47		P/(N)	Planted	Human, Ruminants	Fo
10	*Pterocarpus macrocarpus* Kurz	Leg	Mai Dou	41	N		Remnant	Wind	T
11	*Annona squamosa* L.	Ann	Kok Khiap	41		P	Planted	Human	Fo
12	*Olax scandens* Roxb.	Ola	Ton Nyo ngua	37	N	N	Ruderal	Birds	Fo
13	*Borassus flabellifer* L.	Pal	Kok Tan	36		P/N	Planted	Human, Ruminants	Fo, T, O
14	*Morinda tomentosa* Heyne	Rub	Kok Nyo	30	N		Remnant	Bats	Fr
15	*Millingtonia hortensis* L.f.	Big	Kok Khankhon	28	N	P/N	Ruderal/ Planted	Wind	M, O
16	*Ceiba pentandra* (L.) Gaertn	Bom	Kok Niu	28		P/(N)	Planted	Human	H
17	*Combretum quadrangulare* Kurz	Comb	Kok Kee	26	N	N	Ruderal	Water	Fr, O
18	*Irvingia malayana* Oliver ex A.Benn.	Irv	Mai Bok	25	N		Remnant	Ruminants	C, Fo
19	*Jatropha curcas* L.	Eup	Mak Nyao	23		P	Planted	Human	O
20	*Ziziphus oenopila* (L.) Mill.	Rha	Nam Lep meo	22	N	N	Ruderal	Birds	O
21	*Feronia* sp.	Rut	Kok San	20	N	N	Ruderal	n/a	T, C, Fo
22	*Ziziphus mauritiana* Lam.	Rha	Kok Ka than	20		P/N	Planted	Birds	Fo
23	*Maytenus marcanii* Ding Hou	Cel	Kok Ben	19	N	N	Ruderal	n/a	Fo
24	*Cassia fistula* L.	Leg	Mai Khoun	19		P/N	Planted	Human	T, O

Appendix 1. (Cont.)

No.	Species	Family	Local Name	T.No.	Woods-habitat	Village-habitat	Species Type	Dispersal Agent	Use
25	*Salacia chinensis* L.	Cel	Kok Ta kai	19	N		Remnant	Birds	Fr, M
26	*Albizia lebbekoides* Benth.	Leg	Kok Khang houng	18	N		Remnant	Ruminants	T
27	*Naringi crenulata* (Roxb.) D. H. Nicolson	Rut	Kok Kasung	16	N	N	Ruderal	Birds	Fo
28	*Memecylon* sp.	Mela	Kok Meuat ee	16	N	(N)	Remnant	Birds	T ,S
29	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) Nielsen	Leg	Mai Deen	15	N		Remnant	Ruminants?	T, Fo
30	*Acacia harmandiana* (Pierre) Gagnep.	Leg	Kok Phi man	14	N	N	Ruderal	Ruminants	Fr, M
31	*Dipterocarpus intricatus* Dyer	Dip	Mai Sa beng	14	N		Remnant	Wind	T
32	*Crateva adansonii* DC.	Cap	Kok Kam	13	N	(N)	Remnant	n/a	Fr
33	Bignoniaceae sp.	Big	Kok Mou	13	N		Remnant	Wind	Fr
34	*Mangifera indica* L.	Ana	Kok Mouang	13		P	Planted	Human	Fo
35	*Bambusa blumeana* Schult.f.	Gra	Mai Phai ban	13		P	Planted		Fo, T, H
36	Unidentified		Kok Khon tha	12	N		Remnant	n/a	M
37	*Psidium guajava* L.	Myr	Kok Sida	11		P	Planted	Human	Fo, M
38	*Samanea saman* (Jacq.) Merr.	Leg	Kok Samsa	11		P/(N)	Planted	Ruminants	Fd, Fr, C, S, O
39	*Haldina cordifolia* (Roxb.) C. E. Ridsdale	Rub	Kok Khao	10	N	N	Ruderal	n/a	Fr
40	*Ziziphus cambodiana* Pierre	Rha	Nam Khom	9	N		Remnant	Birds	
41	*Cananga latifolia* (Hk.f. & Th.) Fin. & Gagnep.	Ann	Kok Thong nao	9	N	(N)	Remnant	Birds	T, Fr
42	*Syzygium* sp.	Myr	Kok Waa	9	N	N	Ruderal	Birds	C, Fo, T

Appendix 1. (Cont.)

No.	Species	Family	Local Name	T.No.	Woods-habitat	Village-habitat	Species Type	Dispersal Agent	Use
43	*Randia* sp.	Rub	Nam Nian paduk	8	N		Remnant	Birds	
44	*Terminalia alata* Heyne ex Roth	Comb	Kok Seuak	8	N		Remnant	Wind	T
45	*Cratoxylum* sp.	Hyp	Kok Tiu	8	N	N	Ruderal	n/a	Fo
46	*Carica papaya* L.	Car	Kok Houng	8		P	Planted	Human	Fo
47	*Eucalyptus* sp.	Myr	Mai Vik	8		P	Planted	Human	O
48	*Acacia* sp.	Leg	Kheua Kachay	7	N		Remnant	Ruminants	
49	*Capparis flavicans* Kurz	Cap	Kok Namten	7	N	N	Ruderal	n/a	
50	*Careya arborea* Roxb.	Lec	Kok Kadon	6	N		Remnant	n/a	Fo, M, O
51	*Diospyros montana* Roxb.	Ebe	Kok Keua kaa	6	N	N	Ruderal	Birds	
52	*Bombax anceps* Pierre	Bom	Kok Niupaa	6	N		Remnant	Wind	
53	*Phyllanthus taxodiifolius* Beille	Eup	Kok Siao	6	N	N	Ruderal	Birds	Fr, S
54	*Cocos nucifera* L.	Pal	Kok Phao	6		P	Planted	Human	Fo, H
55	*Terminalia bellirica* Roxb.	Com	Kok Heen	5	N		Remnant	Birds	T
56	Unidentified		Mai Sa khon don	5	N		Remnant	n/a	Fr
57	*Oxyceros horridus* Lour.	Rub	Kok Khankhao	4	N	N	Ruderal	Birds	M
58	*Memecylon* sp.	Mel	Kok Meuat nyai	4	N		Remnant	Birds	T, S
59	*Casearia grewiaefolia* Vent.	Fla	Kok Paa sam	4	N	(N)	Remnant	n/a	M
60	Combretaceae sp.	Com	Ton Sak paa	4	N		Remnant	n/a	
61	*Plumeria obtusa* L.	Apo	Kok Cham paa	4		P	Planted	Human	O
62	*Delonix regia* (Boj. ex Hook.) Raf.	Leg	Kok Fang nyung	4		P	Planted	Human	Fo, O
63	*Bambusa* sp.	Gra	Mai San phai	4		P	Planted		Fo, T, H

Appendix 1. (Cont.)

No.	Species	Family	Local Name	T.No.	Woods-habitat	Village-habitat	Species Type	Dispersal Agent	Use
64	*Sennna siamea* (Lmk.) Irwin & Barn.	Leg	Kok Khi lek	3		P/N	Ruderal/ Planted	Ruminants	Fo,Fd,Fr,S,O
65	*Lepisanthes rubiginosa* (Roxb.) Leenh.	Sap	Mak Houat	3	N	(N)	Remnant	Birds	Fo
66	*Breynia glauca* Craib.	Eup	Kok Khomma	3	N		Remnant	n/a	
67	*Sindora siamesis* Teysm. ex Miq. var. *siamensis*	Leg	Kok Tee nam	3	N		Remnant	Rodents?	T
68	*Holarrhena curtisii* King & Gamble	Apo	Kok Muk	2	N		Remnant	Wind	
69	Shorea siamensis *Miq.*	Dip	Mai Hang	2	N		Remnant	Wind	T
70	*Lagerstroemia macrocarpa* Kurz var. *macrocarpa*	Lyt	Kok Kakalao	2	N	P	Remnant/ Planted	n/a	Fr
71	*Dalbergia* sp.	Leg	Mai Ka nyung	2	N		Remnant	Ruminants	T
72	Unidentified		Kheua Tumkaa	2	N		Remnant	n/a	
73	*Spondias pinnata* (L.f.) Kurz	Ana	Mak Kok	2	N		Remnant	Bats?	Fo
74	*Glochidion* sp.?	Eup	Mak Duk	2	N		Remnant	n/a	Fo
75	*Gluta usitata* (Wall.) Ding Hou	Ana	Kok Nam kiang	2	N		Remnant	Wind	
76	*Ficus* sp.	Mor	Kok Pho	2	N		Remnant	Birds	
77	*Polyalthia* sp.	Ann	Kok Phi phouan	2	N		Remnant	Birds	Fo
78	*Cratoxylum* sp.	Hyp	Kok Tiu paa	2	N		Remnant	n/a	
79	*Catunaregam tomentosa* (Bl. ex DC.) D. D. Tirvengadum	Rub	Kok Nam theng	2	N		Remnant	n/a	
80	*Croton roxburghii* N.P.Balakr	Eup	Kok Pao	2	N		Remnant	n/a	
81	*Crescentia cujete* L.	Big	Kok Namtao	2		P	Planted	Human	H

Appendix 1. (Cont.)

No.	Species	Family	Local Name	T.No.	Woods-habitat	Village-habitat	Species Type	Dispersal Agent	Use
82	*Morus macroura* Miq.	Mor	Kok Mon	2	N		Remnant	Birds	Fo, O
83	*Butea monosperma* (Lmk.) Taub.	Leg	Kok Chan	1	N		Remnant	Ruminants	
84	*Artocarpus lakoocha* Roxb.	Mor	Mai Haat	1	N		Remnant	Bats	Fo
85	*Ficus* sp.	Mor	Kok Hai	1	N		Remnant	Birds	Fo
86	Unidentified	Leg	Kok Iram	1	N		Remnant	n/a	
87	*Stereospermum* sp.	Big	Mai Kenpoi	1	N		Remnant	Wind	
88	Unidentified		Kheua Maktee	1	N		Remnant	n/a	
89	*Trachelospermum asiaticum* (Sieb. & Zucc.) Nakai	Apo	Kheua Seut	1	N		Remnant	Wind	O
90	Sapindaceae sp.	Sap	Kok Kai lin	1	N		Remnant	n/a	Fo, M
91	*Suregada multiflora* (A.Juss.) Baill.	Eup	Kok La monpaa	1	N		Remnant	n/a	
92	*Antidesma* sp.	Eup	Kok Makmao	1	N		Remnant	Birds	
93	Unidentified		Kok Thun	1	N		Remnant	n/a	
94	Unidentified		Kok Kout	1	N		Remnant	n/a	
95	Unidentified		Kok Lanpuk	1	N		Remnant	n/a	
96	*Ficus* sp.	Mor	Mai Haiheuan	1	N		Remnant	Birds	
97	Unidentified		Kok Mii	1	N		Remnant	n/a	
98	*Lagerstroemia* sp.	Lyt	Mai Peuay	1	N		Remnant	Wind	T
99	*Hura crepitans* L.	Eup	Kok Pho thalee	1	N		Remnant	n/a	Fr
100	*Sterculia pexa* Pierre	Ste	Kok Samhong	1	N		Remnant	n/a	T, M
101	*Derris* sp.	Leg	Kok Tampaa	1	N		Remnant	Ruminants	
102	*Syzygium* sp.	Myr	Kok Waanoi	1	N		Remnant	Birds	Fo

Appendix 1. (Cont.)

No.	Species	Family	Local Name	T.No.	Woods-habitat	Village-habitat	Species Type	Dispersal Agent	Use
103	*Pedilanthus* sp.	Eup	Kok Chinai	1		P	Planted	Human	Fo
104	*Calotropis gigantea* (L.) R.Br. ex Ait.	Asc	Dok Hak	1		P	Planted	Human	O
105	*Phyllanthus acidus* (L.) Skeels	Eup	Mak Nyom	1		P	Planted	Human	Fo
106	Unidentified		Kok Seua	1	N		Remnant	n/a	
107	*Wrightia arborea* (Dennst.) Mabb.	Apo	Kok Muk nyai	n/a	N	(N)	Remnant	Wind	Fr
108	*Asparagus* sp.	Asp		n/a	N		Remnant	Birds	
109	*Terminalia glaucifolia* Craib	Com	Kok Heen	n/a	N		Remnant	Wind	Fr, T
110	*Cassia alata* L.	Leg	Kok Khi lekban	n/a		P	Planted	Human	M
111	*Dialium cochinchinense* Pierre	Leg	Mai Kheng	n/a	N		Remnant	Birds?	T, Fo
112	*Milletia* sp.	Leg	Kok Chak chan	n/a	N		Remnant	Ruminants	Fr, O
113	Leguminosae sp.	Leg	Ton Sa monphai	n/a		P	Planted	Human	M
114	*Urena lobata* L.	Mal		n/a	N	N?	-	n/a	
115	*Ficus* sp.	Mor	Kok Deua	n/a	N	N?	-	Birds	Fo
116	*Maclura* sp.	Mor		n/a	N	N?	-	Birds	
117	*Schleichera oleosa* (Lour.) Oken	Sap	Kok Kho som	n/a	N		Remnant	Birds	Fo
118	*Helicteres hirsuta* Lour.	Ste		n/a	N	N?	-	n/a	
119	*Helicteres lantana* (Teysm. & Binn.) Kurz	Ste		n/a	N	N?	-	n/a	

Of 119 species identified, 27 species were planted, 25 species were found to regenerate in the paddy areas.

No.: Number of individuals occurring in the study plot. "N/a" indicates the species observed out of the plot. *Forest-habitat*: Species predominantly found in forested land where human disturbance was not intensive. *Woods-habitat*: Species predominantly found in forested land where human disturbance was intensive. *Village-habitat*: Species predominantly found in open lands such as cultivated land, grassland, or homegarden. "N" indicates naturally regenerating species, "(N)" indicates species whose seedlings grew naturally but seemed to die before reaching sapling stage, "P" indicates planted species. *Species Type*: Each species were identified as remnant, ruderal, or planted, according to its regeneration habit. *Probable Dispersal Agent*: The probable agent of seed dispersal was determined on the basis of fruit types and available literature. "Ruminants" represent cattle and buffalos. *Use*: The use at each village (C: Charcoal / Fd: Fodder / Fo: Food / Fr: Firewood / H: Material for handicraft / M: Medicine / O: Others / R: Resin / S: Soil improvement / T: Timber).

Appendix 2. List of herbaceous species collected from fields or levees of paddy fields at Nakhou village and Bak village

Spermatophytes

No.	Species	Family	Life-form				Water adapt.			Habitat		Remark
			Ah	Ph	Li	Ep	Hd	Hg	Ms	L	F	
1	*Justicia balansae* Lind.	Aca	X						X	X	X	
2	*Nelsonia campestris* R. Br.	Aca	X						X	X		
3	*Strobilanthes* sp.	Aca		X				X		X		Wetland, Vulnerable
4	*Glinus hernarioides* (Gagn.) Tard.	Aiz	X						X	X	X	
5	*Glinus oppositifolius* (L.) DC.	Aiz	X						X	X	X	Exotic
6	*Trianthema portulacastrum* L.	Aiz	X						X	X		
7	*Alternanthera sessilis* (L.) A. DC.	Amar	X						X		X	
8	*Amaranthus viridis* L.	Amar	X						X	X	X	
9	*Gomphrena celosioides* Mart.	Amar	X						X	X		Exotic
10	*Amorphophallus* sp.	Arac		X					X	X		
11	*Colocasia esculenta* (L.) Schott.	Arac		X			X			X		Wetland
12	*Scindapus oficinalis* (Roxb.) Schott.	Arac			X				X	X		
13	*Hemidesmus indicus* (L.) R. Br.	Asc			X				X	X		
14	*Hoya obovata* Dcne. in DC. var. *obovata*	Asc				X			X	X		
15	*Streptocaulon kleinii* W. & Arn.	Asc			X				X	X		
16	*Centipeda minima* (L.) A. Br. & Aschers.	Ast	X						X	X	X	
17	*Eclipta prostrata* (L.) L.	Ast	X						X	X	X	
18	*Elephantopus scaber* L.	Ast		X					X	X	X	
19	*Emilia sonchifolia* (L.) DC.	Ast	X						X	X		
20	*Eupatorium odoratum* L.	Ast		X					X	X		Exotic
21	*Grangea maderaspatana* (L.) Poir.	Ast	X						X	X	X	

Appendix 2. (Cont.)

No.	Species	Family	Life-form				Water adapt.			Habitat		Remark
			Ah	Ph	Li	Ep	Hd	Hg	Ms	L	F	
22	*Sphaeranthus africanus* L.	Ast	X						X		X	Exotic
23	*Vernonia cinerea* (L.) Less.	Ast	X						X	X		
24	*Coldenia procumbens* L.	Bora	X						X	X	X	Exotic
25	*Heliotropium indicum* L.	Bora	X						X		X	
26	*Burmannia coelestis* D. Don.	Burm	X					X		X		Wetland, Vulnerable
27	*Lobelia sinensis* Lour.	Cam	X					X		X		Wetland, Vulnerable
28	*Commelina diffusa* Burm. f.	Comm	X	X					X	X		
29	*Cyanotis axillaris* L.	Comm	X	X					X	X	X	
30	*Murdannia medica* (Lour.) Hong.	Comm		X					X	X	X	
31	*Murdannia spirata* (L.) Bruckner.	Comm		X				X			X	Wetland
32	*Murdannia versicolor* (Dalz) Bruckner.	Comm		X					X	X		
33	*Argyreia nervosa* (Burm. f.) Boi.	Conv			X				X	X		Exotic
34	*Merremia hirta* (L.) Merr.	Conv			X				X	X	X	
35	*Coccinia grandis* (L.) Voigt.	Cucu			X				X	X		
36	*Bulbostylis barbata* (Rottb.) C.B. Clarke	Cyp	X						X	X		
37	*Cyperus castaneus* Willd.	Cyp	X						X	X	X	Exotic
38	*Cyperus difformis* L.	Cyp	X					X		X	X	
39	*Cyperus haspan* L.	Cyp	X					X		X	X	Exotic
40	*Cyperus iria* L.	Cyp	X						X	X	X	
41	*Cyperus leucocephalus* Retz.	Cyp		X					X	X	X	
42	*Cyperus pilosus* Vahl	Cyp		X				X		X		Exotic
43	*Cyperus rotundus* L.	Cyp		X					X	X		

Appendix 2. (Cont.)

No.	Species	Family	Life-form				Water adapt.			Habitat		Remark
			Ah	Ph	Li	Ep	Hd	Hg	Ms	L	F	
44	*Cyperus tenuispica* Steud.	Cyp	X					X		X		
45	*Cyperus* sp.1	Cyp		N/a					X	X		
46	*Cyperus* sp.2	Cyp		N/a					X	X		
47	*Diplacrum caricinum* R. Br.	Cyp	X						X	X		
48	*Eleocharis retroflexa* (Poir.) Urb. ssp. *chaetaria* (Roem.& Schult.) T.Koyama	Cyp	X					X			X	Wetland
49	*Fimbristylis acuminata* Vahl	Cyp		X				X		X		Wetland
50	*Fimbristylis cinnamometorum* (Vahl) Kunth	Cyp		X				X		X		Wetland
51	*Fimbristylis cymosa* R. Br.	Cyp		X					X	X		
52	*Fimbristylis dichotoma* (L.) Vahl ssp. *dichotoma*	Cyp	X						X	X		
53	*Fimbristylis ferruginea* (L.) Vahl	Cyp		X				X		X		Exotic
54	*Fimbristylis miliacea* (L.) Vahl	Cyp	X					X		X	X	Exotic
55	*Fimbristylis pauciflora* R. Br.	Cyp		X				X		X		Wetland
56	*Fimbristylis schoenoides* (Retz.) Vahl	Cyp		X				X		X	X	Exotic
57	*Fimbristylis umbellaris* (Lam.) Vahl	Cyp		X				X		X	X	Wetland
58	*Fimbristylis* sp.	Cyp		N/a					X	X		
59	*Fuirena ciliaris* (L.) Roxb.	Cyp		X				X		X	X	Wetland
60	*Kyllinga brevifolia* Rottb.	Cyp			X				X	X		Exotic
61	*Lipocarpha chinensis* (Osbeck) Kern	Cyp	X	X				X		X		Exotic
62	*Lipocarpha microcephala* (R. Br.) Kunth	Cyp		X				X		X	X	Wetland
63	*Pycreus polystachyos* (Rottb.) P. Beauv.	Cyp		X					X	X		Exotic

Appendix 2. (Cont.)

No.	Species	Family	Life-form				Water adapt.			Habitat		Remark
			Ah	Ph	Li	Ep	Hd	Hg	Ms	L	F	
64	*Schoenoplectus juncoides* (Roxb.) Palla	Cyp		X				X			X	Exotic
65	*Scleria levis* Retz.	Cyp		X					X	X		Exotic
66	*Drosera burmannii* Vahl	Dros	X					X		X		Wetland, Vulnerable
67	*Drosera indica* L.	Dros	X					X		X		Wetland, Vulnerable
68	*Eriocaulon* sp.	Erio	X				X			X	X	Wetland, Vulnerable
69	*Euphorbia thymifolia* L.	Euph	X						X	X	X	
70	*Phyllanthus niruri* auct. non L.	Euph	X						X	X		Exotic
71	*Phyllanthus urinaria* L.	Euph	X						X	X	X	
72	*Phyllanthus virgatus* Forst. f.	Euph	X						X	X		
73	*Aeschynomene americana* L.	Fab		X					X	X	X	Exotic
74	*Aeschynomene indica* L.	Fab	X						X	X		
75	*Cassia occidentalis* L.	Fab		X					X	X		Exotic
76	*Cassia tora* L.	Fab	X						X	X		Exotic
77	*Crotalaria pallida* Aiton.	Fab		X					X	X		Exotic
78	*Desmodium heterocarpon* (L.) DC.	Fab		X					X	X		
79	*Desmodium heterophyllum* (Willd.) DC.	Fab		X					X	X	X	
80	*Mimosa pudica* L.	Fab	X						X	X	X	Exotic
81	*Neptunia javanica* Miq.	Fab		X					X	X		
82	*Zornia gibbosa* Spanoghe.	Fab	X						X	X		Exotic
83	Papilionoideae sp.	Fab			X				X	X		
84	*Blyxa japonica* (Miq.) Maxim. ex Aschers.	Hydr	X	X			X				X	Wetland, Vulnerable
85	*Hypericum japonicum* Thunb. ex Murr.	Hyp	X					X		X	X	Wetland, Vulnerable

Appendix 2. (Cont.)

No.	Species	Family	Life-form				Water adapt.			Habitat		Remark
			Ah	Ph	Li	Ep	Hd	Hg	Ms	L	F	
86	*Hyptis suaveolens* (L.) Poit.	Lab	X						X	X		Exotic
87	*Leonotis nepetaefolia* (L.) R. Br.	Lab	X						X	X		Exotic
88	*Nosema cochinchinense* (Lour.) Merr.	Lab	X						X	X		
89	*Utricularia aurea* Lour.	Lent		X			X				X	Wetland, Vulnerable
90	*Utricularia bifida* L.	Lent	X					X		X		Wetland, Vulnerable
91	*Utricularia caerulea* L.	Lent	X					X		X		Wetland, Vulnerable
92	*Utricularia minutissima* Vahl	Lent	X					X		X		Wetland, Vulnerable
93	*Mitrasacme indica* Wight.	Loga	X					X		X	X	Wetland, Vulnerable
94	*Mitrasacme pygmaea* R. Br. var. *pygmaea*	Loga	X					X		X	X	Wetland, Vulnerable
95	*Rotala indica* (Willd.) Koehne	Lyth	X				X				X	Wetland
96	*Rotala rosea* (Poiret) Cook.	Lyth	X				X				X	Wetland
97	*Hibiscus vitifolius* L.	Mal	X						X	X		
98	*Sida rhombifolia* L.	Mal		X					X	X		Exotic
99	*Urena lobata* L.	Mal		X					X	X		Exotic
100	*Osbeckia chinensis* L.	Mela		X					X	X		
101	*Osbeckia cochinchinensis* Cogn.	Mela	X						X	X		
102	*Najas graminea* Delile	Naj	X				X				X	Wetland, Vulnerable
103	*Ludwigia adscendens* (L.) Hara	Onag		X			X				X	Wetland
104	*Ludwigia epilobioides* Maxim.	Onag	X					X		X		Wetland
105	*Ludwigia hyssopifolia* (G. Don) Exell.	Onag	X				X			X	X	Wetland
106	*Habenaria rostellifera* Reichb. f.	Orc		X					X	X		
107	*Axonopus compressus* (Sw.) P. Beauv.	Poa		X					X	X		Exotic

Appendix 2. (Cont.)

No.	Species	Family	Life-form Ah	Ph	Li	Ep	Water adapt. Hd	Hg	Ms	Habitat L	F	Remark
108	*Chrysopogon aciculatus* (Retz.) Trin.	Poa	X						X	X		
109	*Cynodon dactylon* (L.) Pers.	Poa		X					X	X		Exotic
110	*Dactyloctenium aegyptium* (L.) Willd.	Poa	X						X	X		
111	*Dichanthium annulatum* (Forssk.) Stapf	Poa		X					X	X		
112	*Dichanthium caricosum* (L.) A. Cam.	Poa		X					X	X		
113	*Digitaria ciliaris* (Retz.) Koel.	Poa	X						X	X	X	
114	*Digitaria fuscescens* (Presl) Henrard.	Poa		X					X	X	X	
115	*Echinochloa colonum* (L.) Link	Poa	X					X		X	X	Exotic
116	*Echinochloa crus-galli* (L.) P. Beauv.	Poa	X					X			X	
117	*Eleusine indica* (L.) Gaertn.	Poa	X						X		X	Exotic
118	*Eragrostis cilianensis* (All.) Lindl.	Poa	X						X	X	X	Exotic
119	*Eragrostis malayana* Stapf	Poa	X						X		X	
120	*Eragrostis unioloides* (Retz.) Nees ex Steud.	Poa	X					X		X	X	
121	*Eragrostis zeylanica* Nees & Mey.	Poa		X					X	X		
122	*Eremochloa ciliaris* (L.) Merr.	Poa	X						X	X		Exotic
123	*Heteropogon contrortus* (L.) P. Beauv. ex R. & Sch.	Poa		X					X	X		Exotic
124	*Hymenachne acutigluma* (Steud.) Gilliland.	Poa		X			X				X	Wetland
125	*Ischaemum barbatum* Retz. var. *lodiculare* (Nees) Jans.	Poa		X					X	X		
126	*Ischaemum rugosum* Salisb.	Poa	X						X	X	X	

Appendix 2. (Cont.)

No.	Species	Family	Life-form				Water adapt.			Habitat		Remark
			Ah	Ph	Li	Ep	Hd	Hg	Ms	L	F	
127	*Leptochloa chinensis* (L.) Nees.	Poa	X	X				X			X	
128	*Narenga porphyrocoma* (Hance) Bor.	Poa		X					X	X		
129	*Panicum maximum* Jacq.	Poa		X					X	X	X	Exotic
130	*Panicum repens* L.	Poa		X					X	X	X	Exotic
131	*Paspalum longifolium* Roxb.	Poa		X				X			X	
132	*Paspalum paspalodes* (Michx.) Scribn.	Poa		X				X		X	X	Exotic
133	*Paspalum scrobiculatum* L.	Poa		X					X	X	X	
134	*Pseudosorghum fasciculare* (Roxb.) A. Cam.	Poa	X	X					X	X		
135	*Sacciolepis indica* (L.) Chase	Poa	X						X	X	X	
136	*Salomonia cantoniensis* Lour.	Poly	X					X		X		Wetland, Vulnerable
137	*Monochoria vaginalis* (Burm. f.) Presl	Pont	X				X				X	Wetland
138	*Portulaca oleracea* L.	Port	X						X		X	
139	*Borreria alata* (Aubl.) DC.	Rub	X						X	X		Exotic
140	*Hedyotis arguta* R. Br.	Rub	X					X		X		Wetland
141	*Hedyotis corymbosa* (L.) Lam.	Rub	X	X					X	X	X	Exotic
142	*Hedyotis diffusa* Willd.	Rub	X						X	X	X	
143	*Hedyotis diffusa* Willd. var. *longipes* Nakai	Rub	X						X	X	X	
144	*Hedyotis* sp.	Rub		N/a					X	X		
145	*Adenosma elsholtzioides* Yamazaki	Scr	X						X	X	X	
146	*Adenosma hirsuta* (Miq.) Kurz	Scr		X					X	X	X	
147	*Adenosma javanica* (Bl.) Koord.	Scr		X					X	X	X	
148	*Bacopa floribunda* (R.Br.) Wettst.	Scr	X					X		X	X	

Appendix 2. (Cont.)

No.	Species	Family	Life-form				Water adapt.			Habitat		Remark
			Ah	Ph	Li	Ep	Hd	Hg	Ms	L	F	
149	*Bacopa monnieri* (L.) Wettst.	Scr		X				X		X		
150	*Buchnera tetrasticha* Wall. ex Benth.	Scr	X	X					X	X		
151	*Limnophila geoffrayi* Bonati	Scr	X					X		X	X	Wetland
152	*Limnophila micrantha* (Benth.) Benth.	Scr	X					X		X	X	Wetland
153	*Limnophila repens* (Benth.) Benth.	Scr	X					X		X	X	Wetland
154	*Limnophila villifera* Miq. ssp. *gracilipes* (Craib ex Hoss.) Yamazaki	Scr	X	X				X		X	X	Wetland
155	*Lindernia anagallis* (Burm.f.) Pennell	Scr	X					X		X		Exotic
156	*Lindernia cephalantha* Yamazaki	Scr	X						X	X		
157	*Lindernia ciliata* (Colsm.) Pennell	Scr	X	X				X		X		Exotic
158	*Lindernia crustacea* (L.) F.v.M. var. *crustacea*	Scr	X						X	X	X	
159	*Lindernia laotica* (Bonati) Bonati	Scr	X					X		X		Wetland
160	*Lindernia parviflora* (Roxb.) Haines	Scr	X					X		X	X	Wetland
161	*Lindernia pusilla* (Willd.) Bold.	Scr	X					X		X		Wetland
162	*Lindernia viatica* (Kerr ex Barnett) Philcox	Scr	X						X	X	X	
163	*Pierranthus capitatus* (Bonati) Bonati	Scr	X						X	X		
164	*Scoparia dulcis* L.	Scr	X						X	X		Exotic
165	*Striga masuria* (Buch.-Ham. ex Benth.) Benth.	Scr	X						X	X		
166	*Torenia violacea* (Azaola ex Blanco) Pennell	Scr	X					X			X	Wetland
167	*Smilax* sp.	Smil			X				X	X		

Appendix 2. (Cont.)

No.	Species	Family	Life-form				Water adapt.			Habitat		Remark
			Ah	Ph	Li	Ep	Hd	Hg	Ms	L	F	
168	*Melochia corchorifolia* L.	Str	X	X					X	X	X	Exotic
169	*Waltheria indica* L.	Str		X					X	X	X	Exotic
170	*Stylidium kunthii* Wall.	Styl	X					X		X		Wetland, Vulnerable
171	*Stylidium tenellum* Sw. ex Kunth.	Styl	X					X		X	X	Wetland, Vulnerable
172	*Stylidium uliginosum* Sw. ex Willd.	Styl	X					X		X		Wetland, Vulnerable
173	*Corchorus aestuans* L.	Til	X						X	X	X	Exotic
174	*Triumfetta bartramia* L.	Til	X						X	X		Exotic
175	*Cayratia trifolia* (L.) Domino.	Vit			X				X	X		
176	*Xyris indica* L.	Xyr		X			X			X	X	Wetland
177	*Xyris pauciflora* Willd.	Xyr		X			X			X		Wetland
178	*Kaempferia galanga* L.	Zin		X					X	X		

Pteridophytes

No.	Species	Family	Life-form				Water adapt.			Habitat		Remark
			Ah	Ph	Li	Ep	Hd	Hg	Ms	L	F	
179	*Azolla pinnata* R. Br.	Azo	X				X				X	Wetland, Vulnerable
180	*Marsilea crenata* Presl	Mars		X			X			X	X	Wetland, Vulnerable
181	*Ceratopteris thalictroides* (L.) Brongn.	Park	X				X				X	Wetland, Vulnerable
182	*Salvinia cucullata* Roxb.	Sal	X				X				X	Wetland, Vulnerable
183	*Salvinia natans* (L.) All.	Sal	X				X				X	Wetland, Vulnerable
184	*Lygodium* sp.	Schi			X				X	X		

Appendix 2. (Cont.)

No.	Species	Family	Life-form				Water adapt.			Habitat		Remark
			Ah	Ph	Li	Ep	Hd	Hg	Ms	L	F	
185	Unidentified sp.1			N/a					X	X		
186	Unidentified sp.2			N/a					X	X		

Family: Aca, Acanthaceae; Aiz, Aizoaceae; Amar, Amaranthaceae; Amry, Amaryllidaceae; Api, Apiaceae; Arac, Araceae; Asc, Asclepiadaceae; Ast, Asteraceae; Azo, Azollaceae; Bora, Boraginaceae; Burm, Burmanniaceae; Cam, Campanulaceae; Cann, Cannaceae; Capp, Capparaceae; Comm, Commelinaceae; Conv, Convolvulaceae; Cruc, Cruciferae; Cucu, Cucurbitaceae; Cyp, Cyperaceae; Dros, Droseraceae; Erio, Eriocaulaceae; Euph, Euphorbiaceae; Fab, Fabaceae; Gent, Gentianaceae; Hydr, Hydrocharitaceae; Hyp, Hypericaceae; Lab, Labiatae; Lent, Lentibulariaceae; Lili, Liliaceae; Loga, Loganiaceae; Lyth, Lythraceae; Mal, Malvaceae; Mars, Marsileaceae; Mela, Melastomataceae; Naj, Najadaceae; Onag, Onagraceae; Orc, Orchidaceae; Park, Parkeriaceae; Poa, Poaceae; Poly, Polygalaceae; Pont, Pontederiaceae; Port, Portulacaceae; Rub, Rubiaceae; Sal, Salviniaceae; Schi, Schizaeaceae; Scr, Scrophulariaceae; Smil, Smilacaceae; Sola, Solanaceae; Str, Sterculiaceae; Styl, Stylidiaceae; Til, Tiliaceae; Vit, Vitaceae; Xyr, Xyridaceae; Zin, Zingiberaceae.

Life-form: Ah, Annual herb; Ph, Perennial herb; Li, Liana; Ep, Epiphyte.

Water adapt., Water adaptability: Hd, Hydrophyte; Hg, Hygrophyte; Ms, Mesophyte.

Habitat: L, Levee; F, Field.

Remark: Exotic, Exiotic species; Wetland, Natural wetland species determined as hydrophytes and hygrophytes except exotic species and so-called paddy weeds; Vulnerable, Vulnerable species to agricultural intensification determined by available literatures.