Ethnobotanical study of wild food plants used by rice farmers in Northeast Thailand

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Dedicated to Paul, my beloved husband and travelling companion during the PhD voyage

Abstract

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Wild food plants have been recognized as an essential component of the world's food basket. Farmer's gathering locations are increasingly from anthropogenic ecosystems given the decline of pristine environments. However, there are neither quantitative studies on the ecological characterization nor on the seasonal gathering of wild food plants in anthropogenic ecosystems; moreover, systematic studies on the seasonal implications of these food plants for households are rare. Therefore, this thesis aimed at contributing to the understanding of wild food plant gathering by rice farmers, by developing a theoretical and analytical framework supported by multi-facetted empirical evidence on the spatial and seasonal complementarity of anthropogenic ecosystems and sub-systems, as well as its implications for the food security and dietary diversity of households from an ethnobotanical perspective.

A theoretical model was developed and field work was conducted in Kalasin, Northeast Thailand. The empirical analysis comprised three principle analytically and methodologically coherent research components: (a) botanical (species level), (b) ecological (ecosystem and sub-system level) and (c) anthropological (household level). This was reflected in the use of research methodologies drawn from (ethno)botany, ecology and anthropology, respectively.

Results showed a total of 87 elicited wild food plant species comprising trees, terrestrial and aquatic herbs, climbers, shrubs, bamboos and a rattan; growing in anthropogenic ecosystems including rice fields, home gardens, secondary woods, upland fields, swamps and roadsides. Most species can be found in different places and more than two thirds of the species have extra uses besides food.

A total of 42 wild food plant species were reported in 102 sampling sites corresponding to seven sub-systems associated to lowland rice production, including shelters, hillocks, ponds and their margins, tree rows, dikes and field margins. Likewise, 20 wild food plant species were observed in 77 sampling sites corresponding to five home garden sub-systems, comprising yards, fenced gardens and their margins, hedgerows and fences constituting household boundaries, and pots. Species density, Shannon and Simpson diversity indexes were calculated per sub-system in the dry and rainy seasons. Whereas rice fields presented more species during the rainy season, their diversity in home gardens was higher in the dry season, because farmers encourage the availability of these plants though management. The findings also showed that communities of wild food plant species are different for each sub-system and season, and consequently all sub-systems, providing different habitats ranging from terrestrial to aquatic, are important for ensuring wild food plant diversity.

The findings of the 12-month study conducted with a sample of 40 households visited every month to conduct 7-day recalls on wild food plant acquisition events, revealed a substantial number of gathered species (n=50), high monthly percentages of families gathering these plants (100% to 93%) and a great number of collection events (n=2196). It was evidenced that all households gathered wild food plants from both paddy fields and home gardens throughout the year, whereas most families gathered from roadsides. Wild food gathering was principally essential for local households during lean months, constituting a 'rural safety net', in particular for the most vulnerable families.

This study highlighted the importance of diversity at species, sub-system and ecosystem level, and confirmed the theoretical model on seasonal and spatial complementarity of anthropogenic ecosystems and sub-systems for provisioning and gathering wild food plants. It was concluded that this complementarity is crucial for household food security and dietary diversity, and has major societal implications for agricultural programs, food policies, biodiversity conservation initiatives and poverty alleviation strategies in the region.

Keywords: Wild food plant, ethnobotany, domestication, anthropogenic ecosystem, rice ecosystem, home garden, gathering, abundance, diversity, seasonality, ecosystem complementarity, multi-functionality, poverty, vulnerability, rice farmers, Thailand, Southeast Asia.

Preface

This thesis is on wild food plant gathering by rice farmers across anthropogenic ecosystems in Kalasin, Northeast Thailand, and the implications for food security and dietary diversity of local households. Wild food plant gathering has long been neglected by agricultural research and decision makers. I sincerely hope that this study will not only further convey the importance of wild food plant diversity in the farming landscape to the scientific community, but also that it can provide a strong basis for an argument to incorporate these food species in future agricultural programmes, food policies, biodiversity conservation initiatives and poverty alleviation strategies, at regional, national and international levels.

During the course of my PhD study I have greatly benefitted from numerous people who have contributed to the successful completion of this work. First of all, I am deeply indebted to my promotor, Prof. Paul Struik, and my co-promotor, Prof. Lisa Price, without their valuable guidance and countless hours of support it would not have been possible to accomplish this study. I very much appreciate the motivating and highly efficient discussions with Prof. Paul Struik, and I am deeply grateful to the wise and inspiring supervision of Prof. Lisa Price. It was a great honour and pleasure to work with both of you and to learn from both of you.

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Gisella S. Cruz García
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Contents

CHAPTER 1

General introduction

This chapter presents the background of the thesis. It has two major parts. The first part starts with a general introduction to the study of human-plant interactions, followed by general information on wild food plants in anthropogenic ecosystems and an overall description of Northeast Thailand. The second part comprises the problem statement, research objective, theoretical framework of the study, research questions and analytical approach. Finally, the chapter closes with the outline and articulation of the organization of the thesis.

This study belongs to the multidisciplinary project 'Wild Vegetables, Fruits and Mushrooms in Rural Household Well-being: An In-depth Multidisciplinary Village Study in Northeast Thailand', funded by the Neys van Hoogstraaten Foundation. This study was carried out with a UNESCO-L'ORÉAL Fellowship for Young Women in Sciences and the economic support of Het Schure-Beijerinck-Popping Fonds from the Royal Netherlands Academy of Arts and Sciences (KNAW, The Netherlands). Research was conducted under the auspices of the Weed Sciences Group of the International Rice Research Institute (IRRI, Philippines). Data collection was carried out with the authorization of the National Research Council of Thailand (NRCT) and in adherence to the International Society of Ethnobiology Code of Ethics (2006). All informants who participated in the study did it so freely and with consent.

The research was designed from the perspective of ethnobotany, the scientific discipline that explores the dynamic relationships between people and plants from an interdisciplinary approach starting from the *emic* or local cognitive and value systems. Ethnobotany allowed combining quantitative and qualitative research methodologies drawn from anthropology, botany and ecology. This thesis presents a multi-facetted scientific study on wild food plant gathering by rice farmers in Northeast Thailand, aimed at understanding the seasonal and spatial complementarity of anthropogenic ecosystems and sub-systems, as well as their implications for the food security and dietary diversity of local households.

THE STUDY OF HUMAN-PLANT INTERACTIONS

Historical perspective

Throughout history scientists have made many interrelated attempts to contribute to our knowledge of the interaction between humans and nature (Rasmussen and Arler

2010). Most classical, post-classical and Renaissance Western authors, influenced by arguments of Christian theologians asserting that man was superior to other living beings, dichotomized man and nature. This perception continued until the early nineteenth century, with a few exceptions such as Alexander von Humboldt who stressed the ways people have influenced nature and *vice versa*, proposing the concept of man 'in' nature (Harris 1996).

Environmentalism (or environmental determinism), which can be traced back to ancient Greek philosophers and was further developed by Enlightenment thinkers (Ellen 1982), explained that human social and cultural behaviour is causally determined in an unidirectional way by environmental factors. Emphasis of subsequent approaches is usually a response to discontent with previous ones (Ellen 1982). In this way, possibilism stated that: human behaviour is affected, rather than determined, by environmental limiting factors; social organization can be explained by cultural and historical factors; and environment might be affected by humans (Ellen 1982; Weinstock 1986). Later on, cultural ecology, which is currently criticized, searched for generalizations determining human behaviour, proposing an evolutionary continuum from hunter-gatherers to industrial societies where the behaviour and social organization of hunter-gatherers is more influenced by the environment than these of societies on the other extreme of the continuum (Steward 1955). In the last decades, ecological anthropology and human ecology incorporated the ecosystems approach to the study of human-nature relationships, proposing that natural and social systems are a functional whole (Scoones 1999) in 'complex networks of mutual causality' (Ellen 1982, 94). In agricultural sciences, this clearly contributed to the emergence of farming systems research (Weinstock 1986), where human ecology focuses on the different interactions between structure and function of agro-ecosystems and social systems, involving the transfer of materials, energy and information in a constant process of co-adaptation (Marten and Saltman 1986). The study of human-nature relationships by human ecologists, however, is not free of criticisms. Bennett (1976) pointed out the weaknesses of importing ecological concepts into social sciences. Likewise, Ellen (1982, 92) argued that 'the complexities of intra-specific exchange, the dominance of cognition and value together suggest that social structure has a dynamic of their own which is not described adequately or accurately in ecosystem terms…. the biological model cannot just be expanded to incorporate the complexity of modern social systems'. Ellen (1982) also emphasises that the implications of social systems for ecological systems and *vice versa*, should be understood rather than just conflated. Finally, ethnobotany has an interdisciplinary approach as a hallmark of focusing on dynamic human-plant relationships using as a starting point local cognitive and value systems of nature (Cotton 1996), permitting a 'dialogue between ontologies' (Rist and Dahdouh-Guebas 2006, 467), because the way humans categorize and classify their environment will profoundly affect the way they interact with it. This study was conducted from the standpoint of ethnobotany, which allowed for the combination of botanical, ecological and anthropological methods for developing a multi-facetted study of wild food plants gathered by rice farmers across anthropogenic ecosystems; where the species belonging to the cultural domain 'wild food plants' were elicited by *Isaan* farmers from the Thai Northeast (thus not pre-established by researchers).

Understanding the 'wild'

Wild and domesticated plants have been dichotomized in the past in the same way as human and nature have. This dichotomy was challenged in 1868 by Darwin, who proposed in his book 'The variation of animals and plants under domestication' that domestication is a dynamic process. However, scientists did not show much interest on domestication processes until the 1960s, with the advent of ecological concepts and systems theory, when scholars such as Binford, Flannery, Harris, Higgs and Jarman, among others, started to develop gradualistic models explaining the transition of hunting-gathering to agriculture (Harris 1989; Harris 1996). This brought an important transformation to the study of early agriculture, blurring the classic dichotomy between hunter-gatherers and agricultural societies (Harris 1989). In the 1980's, Rindos (1984) included domestication within the concept of co-evolution and Ford (1985) provided relevant insights to the study of domestication. Human-plant interactions regarding human action with wild, semi-domesticated and domesticated plants are best contextualized in the continuum model, with ecological and evolutionary assumptions, presented by Harris (1989) for agricultural systems and Wiersum (1997b) for forest systems. In this continuum, plant exploitative activities, ecological effects of these activities, food-yielding systems and socio-economic trends are placed along a gradient of increasing input of human energy per unit area of exploited land. The continuum is not unidirectional neither deterministic, the levels of interaction with plants are not pre-ordained steps, and it does not involve that societies are unavoidably succeeding from one level of interaction with plants to the next one.

Wiersum (1997a) gave extra attention to the way the bio-physical environment is controlled by people, which was clearly reflected on the three phases of domestication he proposed: (a) social control regarding the use of valuable species, (b) social-oriented practices of management aimed at increasing the productive potential of valuable species, and (c) cultivation of selected crops with a modified genetic make-up for specific uses and environments. In this way, he emphasized that domestication not only involves modification of a species' biological characteristics and bio-physical environment, but also 'acculturalization of a crop to a social management environment' (1997a, 426) involving the establishment of access norms and regulations on extraction practices. Depending on the degree of human intervention on the ecology of plants, the biological fitness of these species that respond opportunistically might increase (Harris 1996), which can be reflected in their phenotypic and genotypic characteristics, thus involving changes in their morphology, phenology, physiology, life cycle or reproductive structures (Casas *et al.* 1996). The same authors hypothesized the role of culture in domestication processes (1996, 476):

> 'The types of plants managed and the ease of management, the requirements satisfied by those plants, the morphologic features of plants used by humans and the ease of artificial selection, as well as the preferences for particular colours, flavours, odours, shapes, or textures, are all aspects modulated by culture and therefore influence the degree of intensity of the human-plant interaction. Changes affecting human culture may also influence domestication trends through time'.

On the other hand, authors have also explored how wild food plants come under a system of management and protection. In this regard, Cunningham (1995) states that any society will establish intentional management controls not only for those resources that have a value, but also for those perceived to be vulnerable to over-exploitation and have short supply. In the same way, it has been hypothesized by a number of authors (Cunningham 1995; Price 1997; Stoffle *et al.* 1990) that intensive management of wild plant food species in anthropogenic systems occurs when species have multiple use value and are perceived as rare; whereas González-Insuasti *et al.* (2007; 2008) demonstrated, from a study conducted in Tehuacán-Cuicatlán (Mexico), that management intensity depends on a species' biology and cultural importance, and that these factors, together with land ownership, substantially influence farmer's decisions to intensify management practices. Price (1997) concluded from her research in Northeast Thailand that rice farmers increasingly manage rare wild food plant species with a high market value, and bring valued plants into a system of privatization that affects species specific gathering rights. She also explained that gathering rights are not only related to market value, but also to land tenure, taste desirability, perceived abundance and ease of collection.

Wild food plants in this study include species that are not locally domesticated, ranging from truly wild to wild protected, cultivated and semi-domesticated plants that may be locally promoted, protected, tolerated, cultivated *in situ* or *ex situ* (Casas *et al.* 1997; González-Insuasti and Caballero 2007). A wild plant may be cultivated without becoming a domesticated species (Price 2005) and for most species the transition from cultivation to domestication does not fully occur (Harlan 1975). Management practices can be selective or not selective, and a plant species may be managed simultaneously in different ways (González-Insuasti and Caballero 2007), for instance, varying with respect to household, location or socio-cultural group.

This study presents an ethnobotanical analysis of wild food plants gathered by rice farmers across anthropogenic ecosystems in Kalasin, Northeast Thailand, with a major focus on the spatial and seasonal complementarity of ecosystems and sub-systems, especially regarding rice paddies and home gardens. While species specific management, factors influencing management decisions, species' market value, taste desirability, perceived abundance, ease of collection and social access to gathering, are not the focus of this study, the underlying assumptions based on the literature reviewed for this research are: (a) the patterns of distribution of wild food plants in the farming landscape are affected by farmers' practices (including management of individual wild food plant species to different degrees across the landscape and practices associated to rice cultivation), values (including use value and market value), perceptions of abundance, ease of collection and preferences; (b) species specific gathering rights and prohibitions, which are socially regulated, will affect household gathering of wild food plants, depending on the ownership of the gathering location, gathering purposes and gathering quantities.

WILD FOOD PLANTS IN ANTHROPOGENIC ECOSYSTEMS

There is increasing evidence that wild food plants are an essential component of the global food basket (Bharucha and Pretty 2010), making a major contribution to the food security and dietary diversity of hundreds of millions of people around the world (Heywood 1999). These plants are critical to the subsistence system of farmers (Ogle *et al.* 2003; Prasad Aryal *et al.* 2009), improving the nutritional quality and micronutrient content of the rural diet (Grivetti and Ogle 2000; Heywood 2011) and providing secondary metabolites such as essential oils, alkaloids and phenolics (Heywood 1999; Johns 2007). Moreover, these plants are remarkable sources of medicine, fuel, animal feed and timber, and have multiple domestic and ritual uses.

Farmer's main wild food plant gathering locations are increasingly from anthropogenic ecosystems rather than pristine environments, given the evident decline in forest areas. Ogle and Grivetti (1985) named this phenomenon the 'botanical-dietary paradox' and explained that farmers depend on agricultural weeds when forests decline. Certainly, collection and consumption of wild food plants from anthropogenic ecosystems, such as agricultural fields and home gardens, have increasingly been demonstrating the use and importance of these plants among farming households all over the world (Bharucha and Pretty 2010; Heywood 1999; Ogle and Grivetti 1985; Scoones *et al.* 1992). This is the case of rice paddies that are multi-resource ecosystems (Grandstaff *et al.* 1986) containing a great biodiversity (Schoenly *et al.*

1998) with over 100 associated useful plant species (IRRI 2004). Likewise, it is well-known that home gardens, which are diverse agro-ecosystems, play an essential role in plant genetic resource conservation (Eyzaguirre and Linares 2010; Galluzzi *et al.* 2010; Torquebiau 1992).

Wild food plants constitute an essential resource for the most vulnerable households, such as families with chronically ill members (Barany *et al.* 2001; Johns and Eyzaguirre 2006) and the poor (Daniggelis 2003). Surely, the higher the diversification within agro-ecosystems, the greater the self-sustainability and self-reliance of the most vulnerable groups (Heywood 2011). These plants are also indispensable to farming families during periods of scarcity and lean months, constituting a household coping strategy and 'buffers against shortages' (Daniggelis 2003; Heywood 1999; Scoones *et al.* 1992), complementing the seasonal availability of crops (Adaya *et al.* 1997).

Despite growing evidence of the importance of wild food plants for farming societies, the conservation of these food plants has received little attention from genetic resource agencies and seed-banks (Heywood 2011). Wild food plants are largely ignored by rural extension, agricultural programmes (Ogle *et al.* 2003; Prasad Aryal *et al.* 2009) and in land-use planning (Cunningham 2000). Their important role for household food security and nutritional diversity is constantly overlooked in food systems and policy research. While these foods are to a certain extent gaining attention in international development circles, this attention is still in its infancy (Aphane *et al.* 2003; Heywood 1999; Scoones *et al.* 1992). Within the scientific arena, wild plants and semi-domesticated species are not common in agricultural research (Chweya and Eyzaguirre 1999). Consequently, these plants are erroneously called 'minor' or 'supplementary' plant resources, as well as 'unconventional' or 'under-utilized' species (Ogle 2001). Wild food plants were labelled as the 'hidden harvest' by Scoones *et al.* (1992) and 'hidden plant genetic resources' by Daniggelis (2003).

According to Howard (2003), one of the reasons wild food plants are undervalued and underestimated by outsiders is the fact that their management and conservation is primarily localized within women's domestic realm. Additionally, Heywood (1999; 2011) explains that these plants are neglected because of:

- lack of reliable methods to measure their contribution to rural households,
- overlook of the role traditional agriculture plays for food production due to a major bias towards large-scale agricultural production,
- lack of information about their economic value and importance for rural economies,
- lack of world markets, irregular supply and international quality standards,
- lack of storage and processing techniques for most of their products, and

- presence of substitutes.

Certainly, the major values of wild food plants are use values and cultural values, rather than monetary values (Howard 2003). While this study is not providing a direct solution to any of these problems, it does provide a multi-facetted analysis of wild food plants that can surely be utilized to persuade outsiders to re-valorise and incorporate this resource into their programs. Moreover and importantly, this study offers a theoretical and analytical framework to the study of wild food plants from anthropogenic ecosystems including an analysis of their implications for farming households, which certainly can be applied in different regions across the world.

NORTHEAST THAILAND: STUDY SITE AND POPULATION

This study was conducted in Kalasin Province, Northeast Thailand (Figure 1), where it has been reported that wild food plants gathered from anthropogenic ecosystems constitute an essential part in the local diet (Grandstaff *et al.* 1986; Lyndon and Yongvanit 1995; Moreno-Black and Price 1993; Moreno-Black and Somnasang 2000; Price 1997; Price 2005). Rice is the main staple in this region and paddies are a main wild food plant gathering area (Price 1997; Somnasang *et al.* 1988). Paddy rice fields possess various useful species of trees (Grandstaff *et al.* 1986; Vityakon 2001) and other plants growing across aquatic and terrestrial habitats, such as water ponds and shelters. Home gardens, which have possibly been the first manifestation of agriculture in Southeast Asia (Wiersum 2006), are equally important in providing wild food plants to local families in the Thai Northeast (Moreno-Black *et al.* 1996; Price 2005; Wester and Yongvanit 1995). In this region wild food plants are managed to different degrees in order to assure their availability (Chanaboon *et al.* 2005; Price 1997).

The geography of Northeast Thailand is determined by the Korat Plateau, which forms a shallow depression with dispersed swamps and hills, ranging from 100 to 300 m asl (Parnwell 1988). This region is characterized by the presence of heavily leached fine sandy loamy soils. Soils have poor drainage, low fertility and high salinity (Parnwell 1988; Wijnhoud 2007). Northeast Thai vegetation is classified as dry dipterocarp forest (Prachaiyo 2000), but deforestation has alarmingly been taking place with a forest extension covering 90% of the territory in the 1930s and less than 14% in 2004 (Vityakon *et al.* 2004; Wijnhoud 2007).

The climate in Northeast Thailand is classified as Tropical Savannah (Köppen ‘Aw’) (Tomita *et al.* 2003) with monthly average temperatures ranging from 32°C to 19°C (Hijmans *et al.* 2005). From May through October the southwest monsoon is responsible for 90% of the annual rainfall in the Thai Northeast (over 200 mm per month), which is essential for lowland cultivation of glutinous rice (or sticky rice) consumed as the staple and sold for the generation of income. Although 70% of the

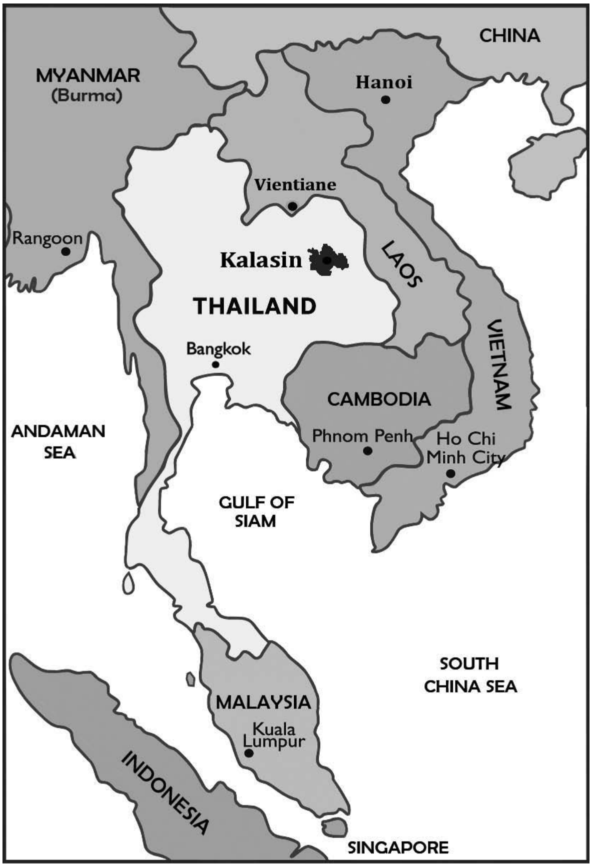

Figure 1. Location of Kalasin Province, Northeast Thailand.

arable land is utilized for rice production, this region has the lowest rice yields in Thailand (Wijnhoud 2007). During the dry season, occurring from November to April with an average monthly rainfall is 20 mm (Hijmans *et al.* 2005), farmers cultivate direct seeded rice, vegetables or mushrooms only when irrigation is available. Upland fields sustain cash crops as sugar cane and cassava.

The total population of Kalasin Province is almost one million inhabitants with a density of 132.3 inhabitants / km^2, most of whom are living in rural areas engaged in agriculture. On average, families have four members and the population has 6.5 years of education (National Statistical Office of Thailand 2001). The main religion in Northeast Thailand is Theravada Buddhism. Northeasteners, who are ethnically of Lao origin, are one of the largest minority groups in Thailand. The language in this region is called *Isaan* and despite the fact it is written with the Thai script, it is a dialect of

Lao with some Thai influences. Northeast Thai society is characterized by having a pattern of matrilocal residence and customary inheritance of land through women (Price and Ogle 2008). The traditional matrilocal stem family cycle is currently being affected by the high rate of out-migration, because remittances have come to play a major role in the rural household economy (Prapertchob 2001).

PROBLEM STATEMENT AND RESEARCH OBJECTIVE

As shown in the previous sections, up to the current time most scientific attention in the study of wild food plants has been given to: (a) the study of domestication (or co-domestication) processes as an ecological and evolutionary continuum in relation to the extent the bio-physical environment is controlled by people; (b) the management of wild plants at species level, including phenotypic and genotypic changes as well as social and cultural aspects related to decision making surrounding species specific management practices; and (c) general social relevance of wild food plants, especially regarding their overall implications for food security and dietary diversity for farming households.

Michon and De Foresta (1997), who conducted research in Indonesian 'agroforests', argued that the linear evolution of current models on domestication does not embrace the complexity of smallholder farmers' practices, resource utilization and diverse ecosystems. There is a need to systematically 'zoom' into the current theoretical model of domestication in order to understand the complexities related to the complementarity of anthropogenic ecosystems and sub-systems belonging to different plant-food production categories, given that in many places these co-exist. Explaining these complementarities is imperative given that it has been widely recognized that locations of wild food plant gathering are increasingly from different anthropogenic ecosystems due to the decline in forests areas, phenomenon called the 'botanical-dietary paradox' (Ogle and Grivetti 1985). Furthermore, it is necessary to understand the implications that this complementarity has for the food security and dietary diversity of farming households.

Rice farming communities provide an ideal setting for conducting such study. Approximately 80 million families (cultivating 60 million hectares) are reliant on rice production in Asia, and live in unfavourable environments characterized by low yields. These families are among the poorest in the world (IRRI 2005). The research location of this study, Northeast Thailand, is one of the areas with significant documentation of the importance wild food plant gathering in the farm areas. Although the utilization of wild food plants has been reported for many countries in Asia and through the world, there has been no systematic study on their spatial and seasonal gathering and distribution across the farming landscape prior to the study of this thesis. Such a study not only may contribute to the scientific understanding of the complementarity of ecosystems and sub-systems with respect to wild food gathering, but also may provide insights to enable the development of more productive lowland farming systems without jeopardizing the seasonal provisioning of these food species that are so important for the vulnerable households in this region. The results of such study may also have practical implications for the more holistic planning of future agricultural programmes, food policies, and biodiversity conservation initiatives world-wide.

The general objective of this study was to contribute to the understanding of wild food plant gathering by rice farmers, by developing a theoretical and analytical framework supported by multi-facetted empirical evidence on the spatial and seasonal complementarity of anthropogenic ecosystems and sub-systems, as well as their implications for the food security and dietary diversity of households.

THEORETICAL FRAMEWORK

Although authors acknowledge the existence of a continuum from natural ecosystems to man-made habitats (Casas *et al.* 1996), models explaining gathering across anthropogenic ecosystems are not common. Anderson and Sinclair (1993, 78) presented a continuum of species diversity and land occupations along gradients of ecological and socio-economic drives. This continuum, later on slightly modified by Abebe (2005, 2), ranges from rain forests to mono-cropping, including intermediate agricultural systems, such as home gardens, other agroforestry systems and inter-cropping systems. On one hand, the socio-economic drive is lower for rain forests, corresponding to hunting and gathering, and higher towards mono-crops, involving commercial production systems. On the other hand, the ecological drive is higher for rain forests and lower towards mono-crops, reflected in the decrease in species diversity, lack of external inputs and openness of the system.

This model, however, does not capture the complexities of smallholder farmer's ecosystem management and resource utilization. This is reflected in three major critical issues:

- Farmers may practice more than one socio-economic activity and use different ecosystems at the same time.
- Hunting and gathering activities should not be mainly related to areas with a high ecological drive, such as rain forests, because farmers with commercial mono-cropping systems may be actively practicing hunting and gathering.
- The position of intermediate agricultural systems along the continuum is not fixed and may change depending on the study site or even the household.

A new model is proposed (Figures 2 and 3), based on the spatial and seasonal complementarity of anthropogenic ecosystems and sub-systems for farming

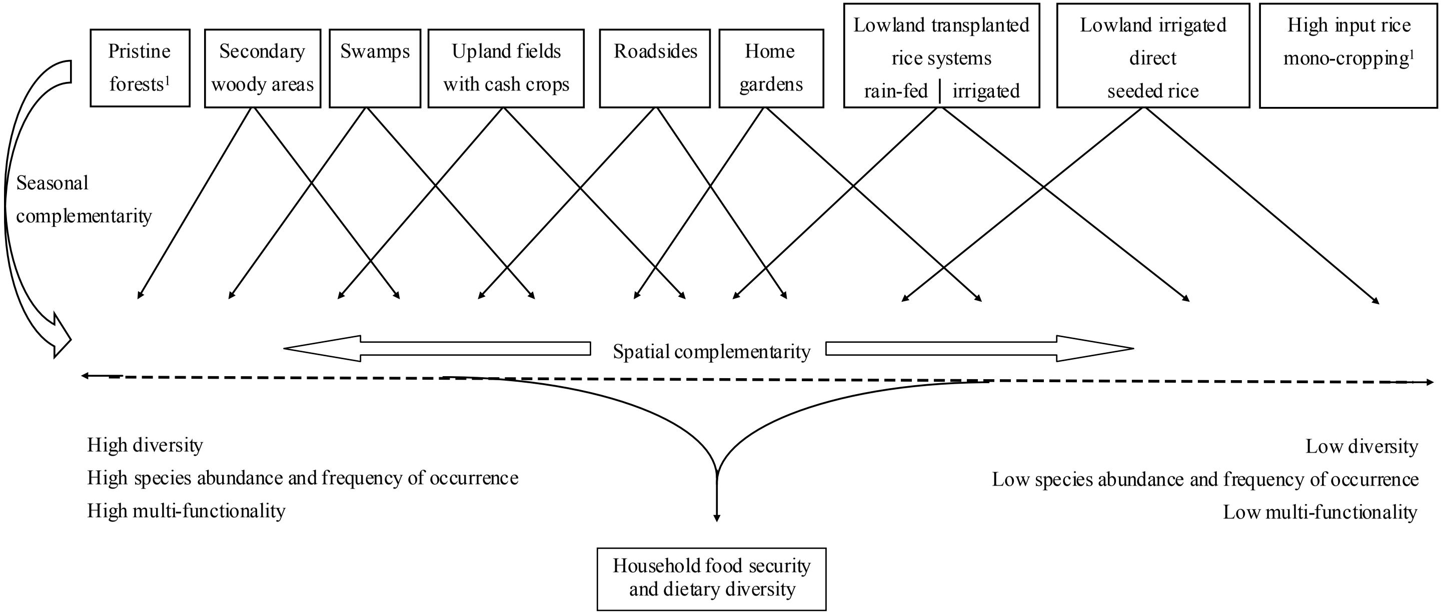

Figure 2. 'Zooming 1'. Theoretical model on spatial and seasonal complementarity of ecosystems. The case of rice farmers' landscape in Northeast Thailand.

[1] Not present in this study.

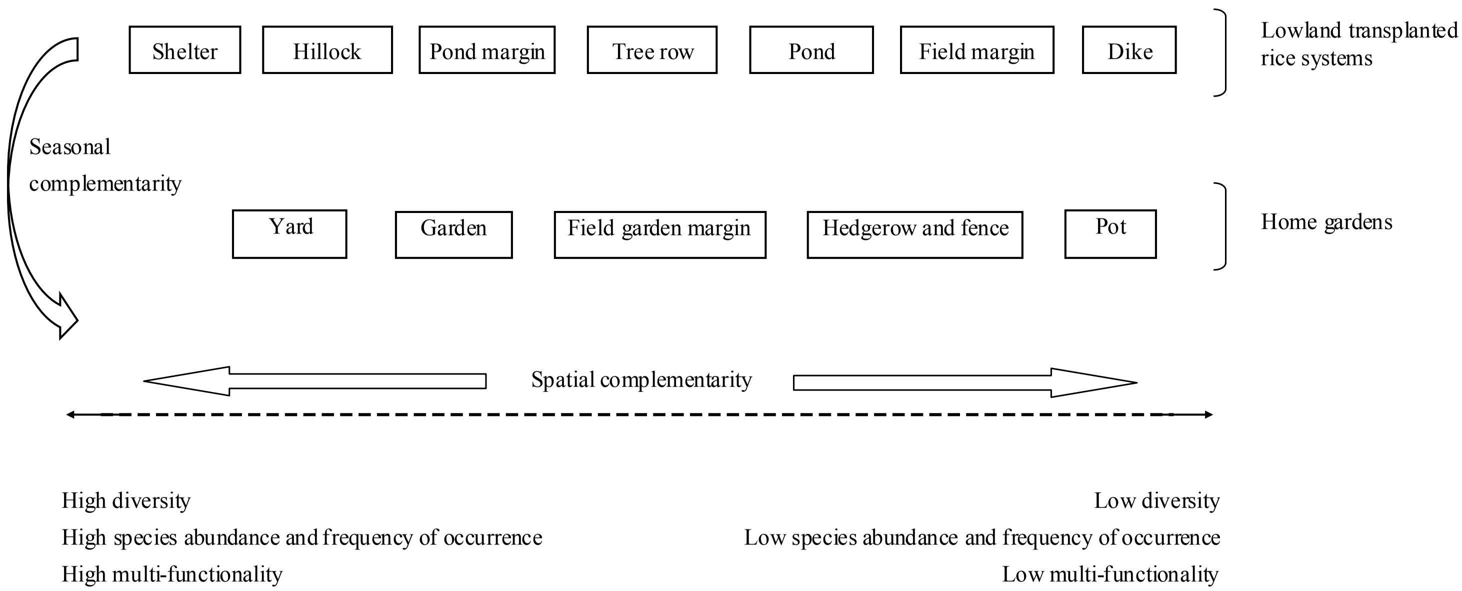

Figure 3. 'Zooming 2'. Theoretical model on spatial and seasonal complementarity of sub-systems. The case of lowland transplanted rice systems and home gardens in Northeast Thailand.

households with respect to wild food plant gathering. This model 'zooms' into the current continuum model of domestication (Harris 1989; Wiersum 1997a; b) aiming at understanding the complexities at ecosystem and sub-system level of different co-existing (and simultaneously used) plant-food production categories. This model has two levels of 'zooming': level 1 corresponding to the ecosystem continuum (Figure 2) and level 2 to the sub-system continuum (Figure 3). However, more intermediate levels of 'zooming' may occur. In both cases, the continuum goes from higher to lower (a) diversity, (b) species abundance and frequency of occurrence, and (c) multi-functionality. Like the domestication continuum (Harris 1989; Wiersum 1997a; b), this new model is neither unidirectional nor deterministic, and neither involves the presence of pre-ordained steps nor do that ecosystems go from one level to the other.

'Zooming 1' (Figure 2) presents a continuum of spatial and seasonal complementarity of ecosystems, in this case, those constituting the landscape of rice farmers in Northeast Thailand. Use of ecosystems may change positions along the continuum, which is indicated with a dotted line, depending on the season and household. Farmers may gather simultaneously wild food plant species from different ecosystems along the continuum.

'Zooming 2' (Figure 3) presents a continuum of spatial and seasonal complementarity of sub-systems, using lowland transplanted rice systems and home gardens as illustrative example. Use of sub-systems may change positions along the continuum, which is also shown in the dotted line. This model shows that at sub-system level may be an overlap among sub-systems corresponding to rice fields and home gardens, thus at this level it might not be possible to assure which ecosystem is more diverse and multi-functional. Rice field's shelters may be more diverse than home garden's fences, whereas rice field's dikes may be less diverse than home garden's yards. Moreover, shelters in rice ecosystems may have fenced gardens and pots. This clearly shows that smallholder farmers deal with a high level of ecological complexity that cannot be compartmentalized. This complexity is related to farmer's control and management of their landscape and species, which is influenced by social, cultural and economic factors. Furthermore, ecosystem and sub-system complementarity is intrinsically related to household's coping strategies for achieving food security and dietary diversity.

The empirical analysis of this theoretical model with respect to wild food plants was conducted from the perspective of ethnobotany. In this regard, before presenting the results of the fieldwork conducted in Northeast Thailand, this thesis contains two theoretical chapters: Chapter 2 providing a detailed overview of the discipline of ethnobotany, and Chapter 3 presenting a more detailed explanation of the current perspectives on wild food plants.

RESEARCH QUESTIONS AND ANALYTICAL APPROACH

Grounded on the theoretical framework, the following research questions permitted the operationalization of the general objective, serving as a guide for the empirical research conducted in Kalasin, Northeast Thailand:

- To what extent do anthropogenic ecosystems complement each other with respect to wild food plant provisioning and gathering, as well as in relation to rice farming activities?
- To what extent do different sub-systems, comprising rice ecosystems and home gardens, seasonally complement each other in terms of diversity and functionality (regarding multiplicity of uses of wild food plant species)?
- How does wild food plant diversity in rice ecosystems and home gardens differ seasonally, regarding the abundance and frequency of occurrence of individual gathered plant species?
- Does wild food plant gathering have implications for the food security and dietary diversity of households, especially the most vulnerable and during lean months?

It is clear from the research questions that there are three principle analytically and methodologically coherent research components:

- Botanical identification and ethnobotanical characterization of wild food plant species, including the different anthropogenic locations where they grow in and the multiplicity of uses they have;
- Quantification of wild food plant seasonal diversity, abundance and frequency of occurrence in rice's and home garden's sub-systems; and
- Analysis of household seasonal gathering of wild food plants.

Figure 4 summarizes the analytical framework used for examining the spatial and seasonal complementarity of anthropogenic ecosystems and sub-systems with respect to wild food plant gathering by rice farmers, and their implications for the food security and dietary diversity of households. This framework clearly reflects the relations among the three research components and emphasizes the main concepts utilized in this study. The major features of the analytical framework are the following:

- Gathering, use and management of wild food plants, in this case, constitute the link between anthropogenic ecosystem diversity and farming households. However, this is a simplification of the complexity of relations among ecosystems and households, which involves multiple social, cultural and economic aspects. This simplification was done with the purpose of facilitating field work by establishing boundaries. While this study focused on gathering and multiple uses of wild food plants, species management was not fully analysed. Nevertheless, it is important to acknowledge the role of species management in the framework.

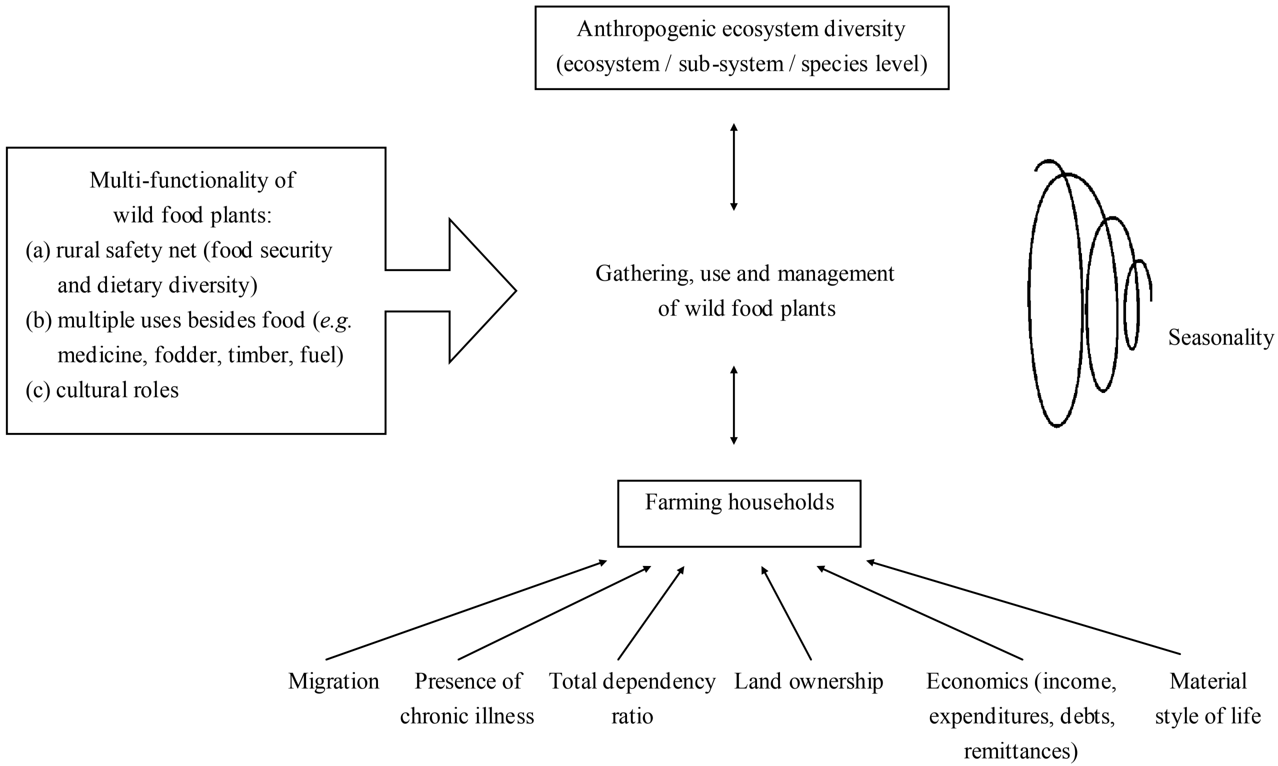

Figure 4. The analytical frame: wild food plant species, anthropogenic ecosystems and households in the ethnobotanical study of wild food plants.

- Diversity of anthropogenic systems, occurring at ecosystem, sub-system and species level, is affected and affects gathering, use and management of wild food plants. This diversity underlines the complementarity of ecosystems and sub-systems. There are more levels of diversity, but these are the most relevant in this case, given that this study 'zooms' into ecosystems.
- Migration, presence of chronic illness, total dependency ratio, land ownership, economics (in terms of income, expenditures and remittances) and material style of life are important demographic and socio-economic variables that may affect household gathering of wild food plants.
- Multi-functionality of wild food plants will influence their gathering, use and management. Multi-functionality of wild food plants is important for a household's rural safety net (with respect to food security and dietary diversity), for the additional uses of these plants besides food (for instance as medicines, animal fodder and fuel), and for their cultural roles.
- Gathering, use and management of wild food plants, ecosystem diversity and household strategies will vary with respect to seasonality. The complementarity of ecosystem and sub-systems is also seasonal.

In a broader time perspective, social and environmental change also influence the different parts of the analytical framework; and, on an even wider time frame, these interactions may lead to co-domestication.

(Ethno)botanical, ecological and anthropological research methods were used in order to conduct data collection and analysis for each of the three analytically and methodologically coherent research components (a, b and c respectively). Further analysis was conducted across these components in order to answer the research questions. The following paragraphs comprise the description of each of these components, including the definitions of the main concepts (when needed) and the indicators or variables utilized for data collection and analysis. Methods of data collection and analysis are explained with detail in Chapter 4 (botanical and ethnobotanical), Chapter 5 (ecological, regarding rice ecosystems), Chapter 6 (ecological, regarding home gardens) and Chapter 7 (anthropological).

Botanical research component (wild food plant species level)

Although it has been recognized that wild food plants play an essential role for farmers' livelihoods in Northeast Thailand (Moreno-Black and Somnasang 2000; Price 1997), there is no single study presenting a detailed list of these species including their botanical and cultural characteristics, which is certainly crucial as a baseline for this study. Michon and De Foresta (1997) claimed that the classification of particular species as 'wild' or 'domesticated' is not always the same for scientists and local people. This certainly implies the need of using the local cognitive classifications of wild plants as starting point, because the way local people categorize a species will certainly affect their interaction with the species and its environment. Therefore, in this study the inventory of wild food plants comprises plants that are classified as 'wild' by local people, and elicited species were botanically identified by local taxonomists. The ethnobotanical characterization of wild food plants included describing their growth form, life cycle, growth location and cultural characteristics, such as edible parts and multiple uses. Growth location refers to the ecosystems where wild food plants grow either naturally or transplanted. The definition of wild food plants used in this study has already been discussed and explained in this Chapter.

Ecological research component (ecosystem and sub-system level)

Despite it is well-known that the diversity, distribution and abundance of wild food plants in anthropogenic ecosystems will affect their availability for domestic consumption, their ecological characterization remains a challenge (Bambaradeniya and Amerasinghe 2003). On one hand, the diversity and abundance of wild food plants has not been systematically quantified for rice ecosystems of Northeast Thailand. Additionally, many of these species are regarded by rice scientists as weeds that need to be eradicated because of their competition for water and nutrients with the crop (Bambaradeniya and Amerasinghe 2003; Chandrasena 1988). On the other hand, wild food plants have not received enough scientific attention in home garden research (Chweya and Eyzaguirre 1999), although it has been documented that they are a major component of home gardens in the Thai Northeast where farmers actively cultivate and preserve these species (Moreno-Black *et al.* 1996; Price 2005; Wester and Yongvanit 1995). Therefore, it was necessary to develop an innovative research strategy for quantifying seasonal abundance and spatial diversity of wild food plant diversity in rice ecosystems and home gardens of Northeast Thailand. Seven sub-systems of rice ecosystems (field margins, shelters, tree rows, hillocks, ponds, pond margins and dikes), and five sub-systems of home gardens (yards, household boundaries, fenced gardens, fenced garden margins and pots) were sampled in both dry and rainy seasons with respect to absolute abundance and frequency of occurrence of wild food plant species. In addition, species richness and diversity indexes were calculated per sub-system and per season.

In this study, 'ecosystems', which might also be composed of several sub-systems, comprise a nested hierarchy of organisms, populations and communities (Conway 1985). The term 'field' refers to 'rice ecosystems' when discussing about rice fields and paddy fields in a general way with a plural connotation; whereas the term 'field' in 'field margins' refers to the borders of the rice plots, which constitute a sub-system of the rice ecosystem. On the other hand, the term 'home gardens' as used in this study refers to multi-layered and diverse ecosystems surrounding the homestead of families and maintained with family labour (Fernandes and Nair 1986). Home gardens usually consist of small-scale production units of food, medicine and fodder, among other products, with the purpose of self-consumption and, in some cases, sale (Kumar and Nair 2004).

Anthropological research component (household level)

The role of wild food plants in the food security and dietary diversity of vulnerable households has extensively been acknowledged (Barany *et al.* 2001; Daniggelis 2003; Johns and Eyzaguirre 2006), especially regarding their crucial role during periods of food shortage and as seasonal complements to crop availability (Grivetti and Ogle 2000; Heywood 1999; Scoones *et al.* 1992). However, their seasonal consumption has only been studied by a few researchers (Herzog *et al.* 1996; Mertz *et al.* 2001; Nordeide *et al.* 1996) and no study has quantified the seasonal complementarity of different anthropogenic ecosystems regarding wild food gathering. Moreover, systematic studies on the seasonal implications of this resource for vulnerable families are scarce. Consequently, an innovative research strategy for analysing seasonal gathering of wild food plants in anthropogenic ecosystems by households had to be developed for Northeast Thailand. A sample of households was visited every month to conduct 7-day recalls over a 12-month period on wild food plant acquisition events (which comprise gathering events), including information on the place (or ecosystem) where the plant was obtained. The seasonality of gathering was analysed per month with respect to number of gathering events in each ecosystem, number of species gathered in each ecosystem and number of households gathering wild food plants in each ecosystem. This information was compared to the local cropping calendar. In addition, the influence of demographic and socio-economic factors on household gathering was examined using the following variables: number of gathering events, number of species gathered, migration, presence of chronic illness, total dependency ratio, land ownership, economics (income, expenditures, debts and remittances) and material style of life.

In this study, a 'household' is defined as a 'family-based co-residential unit' sharing daily activities, most resources and caring for the primary needs of its members (Niehof 2004, 323). Migrants, however, are regarded as household members given that they might economically contribute through remittances. The analysis had an emphasis on the implications of wild food plant gathering for 'vulnerable households', which are those unable to maintain, possess or create enough assets for satisfying their basic needs. Moreover, vulnerable households are unable to successfully cope with risks, stress and change (Niehof and Price 2001). Household vulnerability was assessed in relation to presence of chronic illness, total dependency ratio, land ownership and economics.

OUTLINE OF THE THESIS

This thesis is organized in eight main chapters (Figure 5). Following this introduction, Chapters 2 and 3 are review papers aiming to present a contemporary overview of the main aspects of ethnobotany and wild food plants, respectively. In this regard, Chapter 2 starts with a description of the history of ethnobotany, followed by the main areas of research, ethnobotanical research methods, finalizing with a discussion on the major issues and imperatives of the discipline. Chapter 3 presents the scientific debate on the conceptualization of 'wild food plants' in relation to human interaction with the 'wild', and describes four main contemporary issues related to wild food plant use, knowledge and valuation.

Chapters 4, 5, 6 and 7 are based on the results of the field work conducted in Kalasin, Northeast Thailand. Chapter 4 starts with a comprehensive discussion of the botanical-dietary paradox and the essential role of anthropogenic areas in providing wild food plants. Afterwards, it presents a complete botanical inventory of these species for the region including their diversity of growth forms, the different anthropogenic locations were they grow and the multiplicity of uses they have.

Chapter 5 and 6 present the quantitative analysis of the seasonal diversity of wild food plants in rice ecosystems and home gardens, respectively, through a detailed investigation of the abundance and frequency of occurrence of individual gathered plants across sub-systems, as well as a discussion of Shannon and Simpson diversity indexes. Chapter 5 also compared the negative binomial rank abundance curves calculated per sub-system and per season. Chapter 6 offers a novel approach to the study of home garden structure.

Chapter 7 reports the findings of a 12-month study on the seasonal complementarity of anthropogenic ecosystems with respect to wild food plant gathering and the implications for vulnerable households. This chapter explains how wild food plants constitute a 'rural safety net' acting as a buffer against food shortage and constituting a vital component of local food security.

Chapter 8 presents the general discussion of the study, starting with a reflection on the theoretical model on spatial and seasonal complementarity of ecosystems and sub-systems for farming societies, followed by an overview of the major empirical findings in relation to the research questions. Afterwards, this chapter includes a reflection on critical scientific issues in ethnobotany and an examination of the practical implications of the results; to finalize with a reflection on the analytical approach and recommending areas for future research.

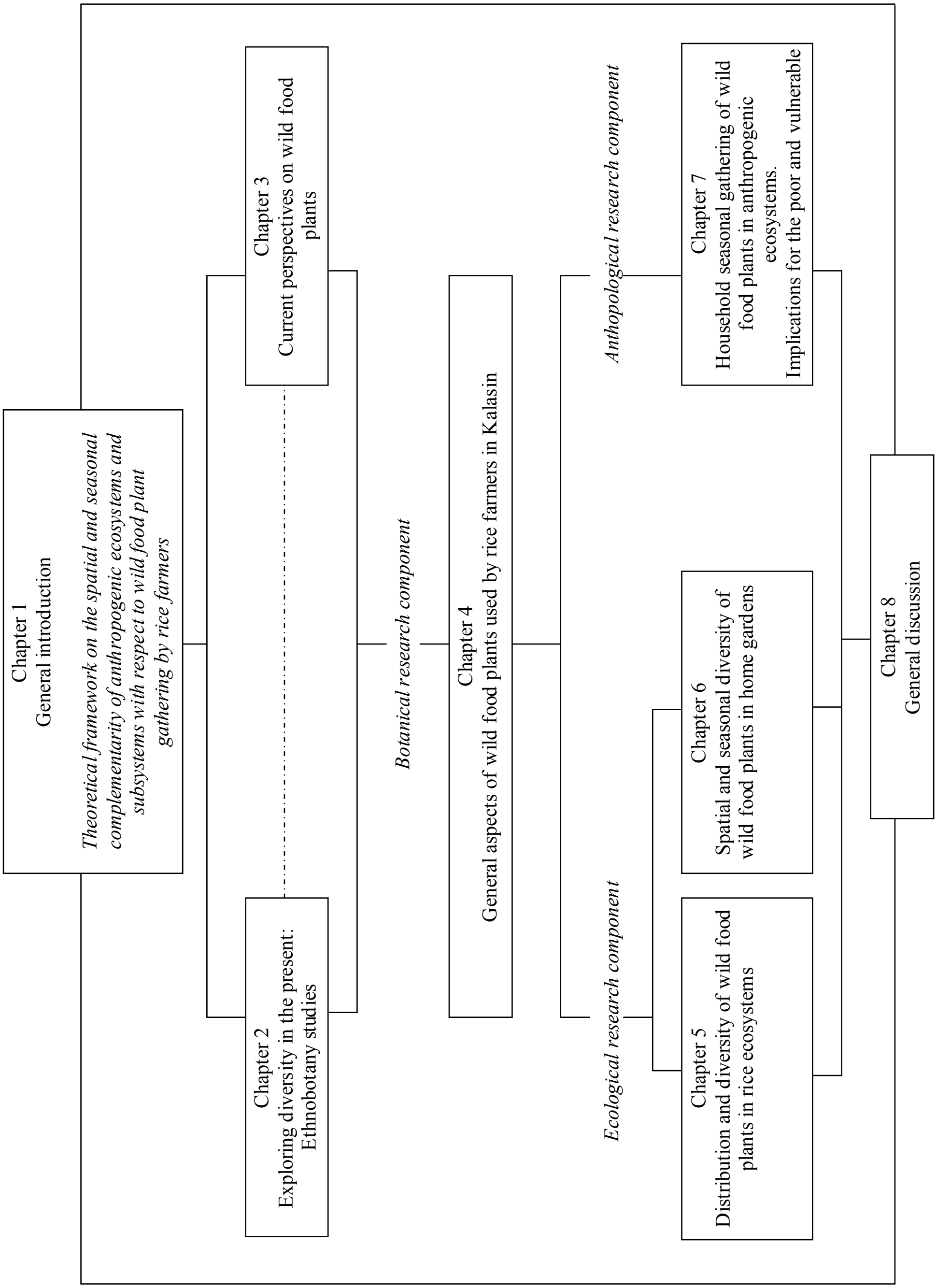

Figure 5. Structure of the thesis.

CHAPTER 2

Exploring diversity in the present: Ethnobotany studies*

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Abstract

Ethnobotany is the scientific discipline that studies the dynamic relationships between people and plants, incorporating the socio-cultural and economic context, as well as people's perception, conceptualization, values and views. Nowadays, a major focus of ethnobotany is the integration of scientific and traditional (or indigenous) knowledge, exploring products and processes of knowledge systems, for instance how a group of people classifies and organizes their knowledge about the environment. This chapter starts with a description of the history of this discipline starting from prehistory up to the post-classical period. Ethnobotany has an ample scope, providing a platform for the convergence of diverse scientific disciplines. The main areas of research are explained in this chapter, comprising ethnoecology, traditional agriculture, cognitive ethnobotany, material culture, paleoethnobotany and archaeobotany, environmental history, ethnomedicine and traditional phytochemistry. Afterwards, the most common research methods are described, from cultural domain analysis, to methods drawn from anthropology, botany, ecology, linguistics, paleoethnobotany and archaeobotany. Finally, the major ethnobotanical issues and imperatives are discussed, including intellectual and theoretical necessities, the role of the discipline in conservation and sustainable development, as well as main ethical considerations.

Keywords: Ethnobotany, knowledge systems, cultural domain, anthropological methods.

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WHAT IS ETHNOBOTANY?

Ethnobotany is the scientific discipline that studies the dynamic relationships between people and plants. The term ethnobotany comes from Harshberger who defined it in the late 1890's as 'the use of plants by aboriginal peoples' (Cotton 1996, 3). Today it is considered that ethnobotany not only refers to the use and management of the plants, but also incorporates the socio-cultural and economic context, as well as people's perception, conceptualization, values and views (Alcorn 1995; Balick and Cox 1996). Ethnobotany, which is part of the discipline of ethnobiology, incorporates two main inter-related approaches: anthropology and botany. Nevertheless, due to its interdisciplinary nature (Prance 1995), it constitutes an interface of several other disciplines such as ecology, economics, linguistics, geography, agriculture and pharmacology (Cunningham 2000; Martin 2004), in addition to archaeology, nutrition, ecology, bioinformatics and mathematical biology (Ethnobiology Working Group 2003).

Nowadays, a major focus of the ethnosciences is the integration of scientific and traditional (or indigenous) knowledge (Rist and Dahdouh-Guebas 2006). Ethnobotany explores products and processes of knowledge systems, such as their creation, acquisition, transformation and transmission (Ellen 2006; Ethnobiology Working Group 2003). Ethnobotany studies how a group of people (ethnic, cultural or linguistic group) classifies and organizes their knowledge about the environment (Price 2001a), given that the way humans classify the world surrounding them influences the way they interact with it. This aspect of ethnobotany has often been overlooked in the past, when this discipline used to have a more utilitarian approach to research.

HISTORY OF ETHNOBOTANY

The roots of human culture are entwined with plants. The study of people-plant interactions has been very important throughout human history, since all human cultures are dependent on plant resources for their subsistence. Plants have profoundly influenced the course of civilization, starting with the use of plants in pre-history by hunter-gatherers and the development of agriculture later on (Balick and Cox 1996). Cross-cultural interest in plant use is clearly seen in the spread of several agricultural crops throughout the world. For instance, maize, cassava and potato from the New World are nowadays staples in the Old World, whereas wheat and rice are basic foods in the New World (Minnis 2000).

At an initial stage, ethnobotany was generally focused on the utilitarian study of useful plants by botanists (Ford 1978). Greek, Roman and Islamic societies were interested in the study of plant use. In the year AD 77, one of the first studies, called 'De Materia Medica' by the Greek Pedanius Dioscorides of Anazarbus, was published, consisting of a compilation of useful flora from the Mediterranean (Pardo-de-Santayana *et al.* 2010). Ethnobotanical explorations were carried out not only by ancient Egyptians in Syria and Somalia, but also had a long history in China (Minnis 2000). During the Medieval and Renaissance periods, numerous European naturalists, such as the Swedish botanist Linnaeus, conducted botanical explorations around the world (Pardo-de-Santayana *et al.* 2010). Botanical gardens were established in Renaissance Europe, as well as by the Incas in South America and the Aztecs in Mesoamerica. Ethnobotanical research was intensified after European colonization (Minnis 2000).

The pre-classical period, according to Clément (1998), began in the nineteenth century when the foundations and branches of ethnobiology were established. A botanist called J.M. Harshberger, who studied ancient plant remains in southwest North America, coined the term ethnobotany in 1896. Other important scholars of this period were Fewkes, Palmer, Powers, Barrow and Hough (Minnis 2000). The diversity of scholars and ethnobotanical reports increased in the following decades. At this time, ethnobotany was mainly focused on making inventories of flora with their respective uses and preparations that could be used by Western civilization (Ellen 2006; Ethnobiology Working Group 2003; Prance 1995). Indigenous peoples were thought not to have any form of scientific knowledge (Clément 1998).

In the 1950s, the classical period of ethnobiology began with the shift from an *emic* to an *etic* approach (*emic* and *etic* are explained later in this chapter). Marked by the work of Conklin, importance was given to local perceptions, vernacular nomenclature and systematic classification of plants (Clément 1998; Ellen 2006). From the 1980s onwards, the post-classical period was characterized by the emergence of cooperation between ethnobotanists and indigenous communities (Clément 1998). The acknowledgement of the importance of traditional knowledge by Western scientists increased along with much of the expansion and diversification of ethnobotany (Cotton 1996). The increasing attention to indigenous communities by scholars occurred once scientists recognized the increasing loss of traditional knowledge of indigenous and folk cultures, as well as the destruction of natural ecosystems and diversity, due to the encroachment of development (Prance 1995). Nowadays, ethnobotany is becoming more technological, experimental and participative, while indigenous peoples are being more empowered to collaborate in defining research, conservation and development priorities (Ethnobiology Working Group 2003). Furthermore, ethnobotany goes beyond the study of indigenous or traditional societies to the investigation of people from any cultural tradition in the world (Ellen 2006; Ford 2000). Table 1 presents a summary of the most important events in the development of ethnobotany.

Table 1. Important events in the development of ethnobotany.

Year	Events in the development of ethnobotany[a]
1492	The discovery of the New World initiates the identification of several plants of considerable economic value and is based on observation of native people.
1663	John Josselyn begins his study of the natural history of New England, later publishing his text on native herbal medicine, New England realities Discovered.
1785	Withering's publications on ethnopharmacology trigger the development of this field in Europe.
1800s	Pre-classical period of ethnobiology.
1803	Ehrenberg reports fossil pollen preserved in sedimentary rocks, initiating a rapid development in the field of palynology in Europe, powerful tool used by paleoethnobotanists.
1871-78	Seminal work by botanists Palmer and Powers is published, period dominated by economic botanists.
1893	Anthropological interest in aboriginal botany leads to increasing emphasis on the cultural significance of plants.
1895	Harshberger introduces the term 'ethnobotany'.
1896	Fewkes introduces the term ethnobotany in anthropological literature.
1898	Ethnology Department of US National Museum endeavours to document all useful plants of North American Indians.
1900	The first PhD in ethnobotany is awarded to David Barrow for his doctoral dissertation in ethnobotany.
1919	Traditional people's resource management is pioneered by Gilmore.
1930	Castetter establishes a masters program in ethnobotany at the University of New Mexico.
1947	Foundation of the Society for Economic Botany.
1950s	Begins the classical period of ethnobiology.
1950-1970	Linguistic concepts and classifications is gaining interest, while Conklin highlights the practical significance of understanding folk classification systems. Paleoethnobotany emerges and archaeobotanical techniques improve.
1977	Establishment of the Society of Ethnobiology.
1980s	Starts the post-classical period of ethnobiology.
1981	The Society of Ethnobiology publishes the first issue of its Journal of Ethnobiology.

Table 1. (continued)

1988	The 'Declaration of Belem' was signed in the First International Congress of Ethnobiology in Brazil. The International Society of Ethnobiology was founded with the objective to understand the complex relationships which exist between human societies and their environments, recognizing Indigenous peoples as critical players in the conservation of biological, cultural and linguistic diversity.
1990s	Both post graduate and undergraduate program in ethnobotany become increasingly available, while many research projects focus on practical applications of plant knowledge. Establishment of 'People and Plants' initiative of WWF, UNESCO and the Royal Botanical Gardens Kew, aiming to increase the capacity for community-based plant conservation worldwide.
2000s	The Journal Ethnobotany Research and Applications and the Journal of Ethnobiology and Ethnomedicine were born.
2006	The Code of Ethics for Ethnobiological research was adopted by all the members of the International Society of Ethnobiology.

[a] Adapted from Cotton (1996), with references also from Clément (1998), Cunningham (2000), the International Society of Ethnobiology (2010), the Society for Economic Botany (2011) and the Society of Ethnobiology (2011).

MAIN AREAS OF RESEARCH

Ethnobotany has an ample scope, characterized by both academically-driven and practice-driven research, providing a platform for the convergence of diverse scientific disciplines (Ellen 2006). The most popular areas of ethnobotanical research are ethnoecology, traditional agriculture, cognitive ethnobotany, material culture, paleoethnobotany and archaeobotany, environmental history, ethnomedicine and traditional phytochemistry.

Ethnoecology is focused on understanding local people's constructions according to their own ethnoscience categories (Frake 1962). Ethnoecology recognizes human-environment interactions as ecological (Minnis 2000). The study of traditional ecological knowledge (or traditional environmental knowledge) is a main component of ethnoecological research, including issues such as traditional vegetation management, ethnopedology and ethnoclimatology. Another important area is landscape ethnoecology, comprising the study of cultural views of the landscape, local classifications of its components in ethnoecological systems, and their significance for local people (Johnson and Hunn 2010).

Traditional agriculture, also called ethnoagronomy, refers to the study of resource management and subsistence economies (Pieroni *et al.* 2005), as well as understanding the cultural, economic and genetic reasons underlying agriculture (Ford 2000). Traditional agriculture is aimed at investigating traditional knowledge about crop varieties and agricultural resources, as well as the environmental impact of variety selection (Cotton 1996). In parallel, ethnobotany also contributes to the understanding of the ecological relationships and human management involved in plant domestication (Alcorn 1995; Casas *et al.* 1997; Minnis 2000). For example, Casas *et al.* (1996) studied the management and domestication of plants among the Nahua and the Mixtec in Mexico from an ethnobotanical perspective, including wild, weedy and domesticated plants.

Cognitive ethnobotany is focused on researching the organization of knowledge systems or folk classifications, which is also called ethnotaxonomy (Cotton 1996), considering how people view their own environment (Minnis 2000). Brent Berlin (1992) proposed a set of principles to describe the traditional systems of ethnobiological classification (modified from his previous results from 1972). Cognitive ethnobotany also deals with traditional perceptions of the natural world (symbolism, ritual and myth).

Material culture deals with traditional knowledge of plants in art and technology. Material culture refers to the ‘artefacts’ or objects made by existing traditional societies. These artefacts include tools, shelter, clothing, boats, containers, as well as decorative arts and craft, such as toys and ornaments. In many societies, not only is timber essential to the construction of houses, shelters, furniture and fences, but also non-timber plant products derived from leaves, pigments, fibres and resins are remarkably important (Cotton 1996).

Paleoethnobotany and archaeobotany investigate past interactions of peoples and plants, based on the interpretation of archaeobotanical remains. This field is very important for documenting people-plant interactions that occurred before the advent of writing, five thousand years ago (Minnis 2000).

Environmental history is focused on the understanding of prehistoric human action on the environment (Stahal 1996), such as the study of ancient crops and respective agricultural techniques (Minnis 2000).

Ethnomedicine is the study of the cultural interpretation of disease, illness and health, healing systems and traditional health care (Pieroni *et al.* 2005).

Traditional phytochemistry studies traditional knowledge about plant chemicals, for instance, for medicine or pest control (Cotton 1996). Ethnopharmacology is aimed at understanding the pharmacological and cultural scopes of the uses of medicinal plants

(International Society for Ethnopharmacology 2011). Ethnopharmacy and ethnopharmacognosy are also important related fields.

METHODS IN ETHNOBOTANICAL RESEARCH

The first step in ethnobotanical research is to define the 'domain' (mental category) or subject of interest (for example, a *domain* could consist of the 'wild food plants' consumed by a certain indigenous group). Borgatti (1999, 115) calls it 'cultural domain' and defines it as 'a set of items or things that are all of the same type or category'. The study of people's interpretation of domains is called 'cultural domain analysis' (Bernard 2002). Cultural domain analysis involves not only investigating the structure and arrangement rules of the domain, but also the relations among its components, their associated values and variability. Cultural domain analysis aims to understand knowledge systems in addition to their similarities and differences among or within groups of people (Puri and Vogl 2004). Knowledge systems could certainly be affected by inter-cultural factors (livelihood strategies, natural resources, level of external contact or acculturation, ethnicity, religion) and intra-cultural factors (age, gender, class, education, literacy, occupation, migration, kinship, language ability).

The study of the components of a domain, also called categorization, involves two approaches: (a) *etic* approach related to the researcher's perception and classification of the study object, (b) *emic* approach referred to the classifications of local people based on the way they perceive the world in their own language (Cotton 1996; Martin 2004). In both cases, it is important to start with an *emic* perspective, for example, referring to the local names of plants and understanding their local classification systems (Martin 2004).

Given that ethnobotany is at the interface of several disciplines, there is a wide variety of research methods (Ethnobiology Working Group 2003). The most common ethnobotanical methods, drawn from anthropology, botany, ecology, linguistics, paleoethnobotany and archaeobotany, are described in this section. Nevertheless, given the interdisciplinary nature of ethnobotany, research studies might also require the use of more specialized methods such as art history, molecular biology, economic anthropology, development studies, environmental economics, ethics and law or communication and education, among others (Cotton 1996). Ethnobotanists usually combine different methods according to their specific research needs.

Anthropological methods

Different methods used in anthropological research might be applied to ethnobotany. These methods could be qualitative or quantitative. Qualitative methods are used to have an in-depth understanding of human behaviour through general ethnographic accounts, whereas quantitative methods consist of a systematic empirical investigation of measurable verbatim answers allowing the use of statistical methods (Martin 2004; Verschuren *et al.* 1999). Both qualitative and quantitative methods are important and complement each other, permitting to a certain degree triangulation of sources as well as greater depth (Verschuren *et al.* 1999). The most common anthropological methods for ethnobotanical data collection are basically grouped in interviews and observation. Additionally, special cognitive and linguistic analytical tools, which are specific semi-structured interview techniques (Borgatti 1999), are widely used to facilitate quantification, cross-verification and choosing participants for specific projects (Cotton 1996).

According to the level of control of the researcher on the interview, interviews are classified in structured, semi-structured, structured and informal. Structured interviews are based on a set of instructions and questions (or questionnaire) allowing to conduct quantitative analysis. Semi-structured interviews are more flexible, as the researcher follows an interview guide but allows respondents to express their opinions and ideas in their own way. In unstructured interviews the researcher has a clear plan in mind, but both researcher and respondent can follow new leads. Informal interviews are characterized by a total lack of structure and control, producing qualitative data. In general, questions could be closed-ended, when respondents have to choose from a list of options provided in the interview; or open-ended, when respondents are free to give the answer in their own words. Specific kinds of interviews are key informant interviews and focus group discussions. Key informant interviews are carried out with experts on the research topic, whereas focus groups are discussions where a group of people has a joint interview session (Bernard 2002).

Observation could be participant or non-participant, depending on the researcher's involvement in the daily life activities of the people in the study area. Participant observation is usually carried out over a long period of time, taking part not only in community life, but also in local events and processes (Bernard 2002; Cunningham 2000; Kottak 2008; Martin 2004).

Analytical tools, mostly developed by linguistic and cognitive anthropologists in the 1960s, are important for assessing the empirical knowledge and cultural preferences of the informants. Many of these tools were incorporated in response to the need for systematic data collection methods to understand people's perceptions and classification of the world (Martin 2004). The most commonly used analytical tools in cultural domain analysis are freelistings, triadic comparisons, paired comparisons, pile sorting, ratings and rankings.

- Freelistings: informants are asked to list plants that fulfil a particular criterion (such as ‘wild’, ‘food’ or ‘medicine’). Freelistings are used to identify the components of a cultural domain.
- Triadic comparisons: informants are presented the items of the domain in groups of three and asked to pick out of each group the item they perceive as the most different. Picking an item means that they consider the other two similar. Triads are used to discover the arrangements of a cultural domain.
- Pile sorting: informants are asked to sort items of a domain into groups according to how similar they are. This method is also used to discover the arrangements of a cultural domain.
- Paired comparisons: informants are presented pairs of items and asked to indicate which of the two is more related to a specific criterion. This method is important for identifying the arrangement rules of the groups of items in a domain.
- Ratings: informants are asked to place each plant or item of the domain along an abstract scale.
- Rankings: informants are asked to compare plants or items to each other and to list them according to a specific criterion. Both ratings and rankings are used for identifying the arrangement rules of the groups of items in a domain.

  (Bernard 2002; Borgatti 1999; Cotton 1996; Martin 2004; Puri and Vogl 2004; Ryan and Bernard 2000).

The results produced by any of these tools consist of numeric values assigned to each component of the domain (plant or item), allowing not only to compare them and understand the structure of the domain, but also to compare knowledge, values and practices of different groups of informants. For example, from freelistings is possible to obtain a salience index and from rankings a preference ranking index, whereas indexes of agreement can be produced by any tool applied.

- The salience index quantifies the importance of a plant or item based on the assumption that those plants more frequently mentioned and that appear earlier in the lists are more commonly used by a group of people for a particular purpose (Cotton 1996). The most common indexes are Smith’s salience index (Smith 1993) and Sutrop’s cognitive salience index (Sutrop 2001).
- The preference ranking index estimates the preference or importance of a plant in relation to a particular criteria (Cotton 1996), such as taste or availability (Price 1997).
- Indexes of agreement compare the level of agreement between informants with respect to the components and/or structure of a domain (Boster 1985).

In addition, ethnobotanists have also been interested in gaining a deeper understanding of the comparative cultural value of plant species. This is reflected in the development of use-value and cultural significance indexes. These indexes have been modified in the last years: researchers add or change variables, edit formulas and adapt them to their particular research question and study area.

- The use-value index estimates the overall usefulness of a plant in terms of number of uses mentioned by each informant and total number of informants (Cotton 1996; Cunningham 2001; Phillips and Gentry 1993). Data could be obtained not only through interviews, but also by examining utilization surveys, which might involve walking with informants in vegetation transects (Anderson 1991).
- The cultural significance index is defined as 'the importance of the role that [a plant] plays within a particular culture' (Turner 1988, 275). Initially it used to include the quality, intensity and exclusivity of plant use (Turner 1988), but afterwards the contemporary plant use was added (Stoffle *et al.* 1990). Later on, Pieroni (2001) presented the cultural food significance index, including other variables such as quotation index (frequency of citation of a species in a freelisting) and perceived availability. On the other hand, Reyes-García *et al.* (2006) introduced the cultural, economic and practical value indexes, which summed up to equal the total value of a species. Tardío and Pardo-De-Santayana (2008) conducted a comparative study of different indexes of cultural importance and use-value of plants.

Botanical survey

The botanical survey is essential for ethnobotanical research. It consists of collecting voucher specimens of plants and conducting their taxonomical identification (Cotton 1996; Cunningham 2000; Martin 2004). Basic plant characteristics should be registered at the time of specimen collection, such as life-form, height, diameter, colour of flower and fruit and local name (for a detailed explanation about specimen collection, pressing, drying, labelling and preservation, see Martin, 2004). Depending on the objective of the research, other botanical data should be collected, such as stem diameter, height, bark thickness, biomass, volume, leaf measurements (culm length, petiole width, foliage mass, specific leaf area), canopy measurements (biomass, volume, area, density, crown position), dry weight, production of flowers, fruits and seeds, age (of trees, bulbs, corms, stem tubers), phenology, characteristics related to the plant's reproductive biology and yields (Cunningham 2000).

Ecological methods

Ecological surveys are mainly devoted to understanding the distribution, diversity, occurrence, abundance and structure of plant populations and communities, as well as landscape and ecosystem processes. The purposes of carrying out ecological surveys could vary from assessing harvesting quantities, pressures and impact on the vegetation, to commercialization of plant resources, conservation and management. The first step in ecological research is to conduct a general description of the ecosystem(s) in terms of soil, vegetation types, climate, land form, stages of ecological succession and land use zones. The next step is to carry out quantitative research of plant resources (Martin 2004). Most common ecological methods include vegetation surveys, systematic participatory mapping, transect walks, time lines and seasonal calendars.

Vegetation surveys could be conducted at species, population or community level. Systematic surveys of vegetation start with the selection of ecological sampling units (Cotton 1996). Sampling units, or plots sub-divided into quadrants or transects (Martin 2004), should preferably be randomly established and carefully defined regarding their distribution, number, environmental gradients, size and type (see Cunningham 2000; Krebs 1999). Seasonality is important, hence sampling units should be surveyed in different seasons. Most common analysis consists on the calculation of species richness, spatial patterns and dispersion, diversity indexes, rank abundance curves, as well as their comparison across space and through time (Krebs 1999; Magurran 2004).

Participatory mapping assesses the local knowledge of resources, not only in relation to perceived abundance and harvesting patterns, but also to associated social aspects such as access to resources, tenure and territoriality. The complementary use of aerial photographs and satellite images will help to understand the distribution of vegetation, historical change, degree of threat and disturbances in the landscape (Cunningham 2000). They can be compared to the knowledge of the landscape and values attributed to it by local people, as shown in the research carried out by Fagerholm and Käyhkö (2009) in Tanzania and Barrera-Bassols *et al.* (2006) in Mexico.

Transect walks (or 'walks in the woods') are conducted in the research area with local informants, in combination with interviews. Time lines are usually aimed at identifying important historical events, while seasonal calendars illustrate the change of uses, availability and preferences throughout the year (Cunningham 2000).

Linguistic and other symbolic analysis

In ethnobotany, it is necessary to understand how information is communicated within a particular group of people, therefore linguistic and symbolic analyses are important. On the one hand, language is the 'gateway to knowledge and perceptions' (Price 2001a, 159) and on the other hand, much information is transmitted using symbolic representations such as myths, rituals and art (Cotton 1996). Particularly, linguistic analysis is essential for ethnotaxonomical studies that investigate traditional systems of classification. This involves the use of analytical tools and linguistic evidence (see Berlin 1992; Cotton 1996; Martin 2004).

Paleoethonobotanical and archaeobotanical methods

Paleoethonobotany involves the study of botanical evidence found in archaeological sites, analysis of historical texts and interpretation of plants in ancient art. For the study of botanical evidence, it is necessary to apply archaeobotanical techniques. Archaeobotanical evidence includes plant fossils, grain impressions in baked clay and microwear polishes found on tools. In addition to these, other archaeological samples – such as coprolites, phytoliths in grinding tools, residues in pottery – could give information on the uses of the plants, as well as on how they were harvested and processed in the past (Cotton 1996). Paleoethnobotanical research involves sampling and collection in archaeological sites, plant material identification and plant material dating. Dating can be done using pollen profiles, isotope analysis and thermoluminiscence (Cotton 1996; Pearsall 1989).

ETHNOBOTANICAL ISSUES AND IMPERATIVES

Intellectual and theoretical imperatives

Given that ethnobiology is a field that is rapidly growing and creatively expanding, the NSF funded the Biocomplexity workshop aiming to explore recent scientific developments and critical issues of the discipline. As an outcome of this workshop, the report 'Intellectual imperatives in ethnobiology' (2003) listed the main contemporary intellectual and theoretical imperatives of ethnobiology, which can certainly be applied to ethnobotany, in relation to the areas of knowledge systems; medicine, health and nutrition; ecology, evolution and systematics; landscapes and global trends; and the role of social-cultural-political systems in biocomplexity research. Moreover, Cunningham (2000) emphasized that it is also imperative to apply efficiently quantitative methods and predictive models to conservation strategies.

Clearly, important concerns of study are evolution, systematics and ecology, where it is necessary to understand more than purely 'artificial selection'. Ethnobotany incorporates the complexity of human interactions with nature, allowing more thorough research on the management of flora and domestication processes. This is certainly necessary for addressing major intellectual concerns such as:

> 'How does human use and management of biodiversity affect ecological processes and patterns? How have human interactions with taxa - from gathering to domestication - influenced evolution and systematics, and what trends or differences are there within and among taxa? In the evolutionary process, how are

'natural' and 'artificial' selection similar and different?' (Ethnobiology Working Group 2003, 3).

The study of domestication can particularly profit from an ethnobotanical perspective, especially in relation to the 'ability to work cross-culturally' thus uncovering the 'indigenous insight on complex questions' (Ethnobiology Working Group 2003, 4).

Ethnobotanical research can be very useful for revealing 'positive examples of human mediated biodiversity creation and management' (Ethnobiology Working Group 2003, 3), which is also an important intellectual imperative of the discipline. In this regard, Alcorn (1995, 29) emphasises the importance of studying plant management systems, so called ethnobotanical dynamics, and how in traditional agro-ecosystems 'human activities influence both the crops and the natural vegetation occupying the region'.

Ethnobotany, conservation and sustainable development

The inter-relation between biodiversity and human cultures, or the study of bio-cultural diversity, is an important imperative of ethnobotany, as clearly stipulated in the Declaration of Belem (Posey 1988). It was emphasized by the Ethnobiology Working Group (2003, 3) that 'landscape transformations are dependent on distributions of culture, biota, and environments' concluding that 'biodiversity is correlated with human cultural diversity'. Given the on-going problem of loss of biodiversity, as well as the associated loss of traditional knowledge and cultures, it is essential to understand the complex dynamics of human cultures with the environment (Prance 1995). The impacts of ethnobotanical research are important for cultural survival and biodiversity conservation (Ethnobiology Working Group 2003; Prance 1995) and should contribute to the formulation of practices and policies for sustainable development (Prance 1995).

It has been demonstrated in the last decades that many top-down, centralized conservation actions planned by outsiders (policy-makers or urban-based planners) have failed, because they do not include local perceptions and views (Cunningham 2000). Nevertheless, in the last decades, many ethnobotanists have been keen on applying their research results to conservation and development strategies (Cotton 1996; Martin 2004; Rist and Dahdouh-Guebas 2006; Sillitoe 2006). Ethnobotanists have much to offer to policy-makers (Alcorn 1995; Sillitoe 2006). Moreover, the incorporation of indigenous insights and indigenous peoples in decision-making and problem-solving has also been demonstrated to be important (Balick and Cox 1996; Cunningham 2000; Ethnobiology Working Group 2003; Rist and Dahdouh-Guebas 2006). There are many examples of such initiatives, such as community projects, establishment of markets for non-timber forest products (Cotton 1996; Martin 2004), conservation of wild crop relatives and endangered plants, healthcare, social forestry, educational programs for the young, popular workshops and publications, ecotourism, and so on (Martin 2004). Sillitoe (2006) also explains the importance of ethnobiology for development, for instance, through the promotion of participatory initiatives, the facilitation of local solutions to development and the support to alternative development strategies, as a response to the critiques of development as an exported capitalist concept.

Results from paleoethnobotanical research could also be applied for effective resource management. Paleoethnobotanical evidence gives us lessons to be learned from the past, such as those drawn from the ancient Mayan agricultural fields or 'chinampas' in Mexico, which proved to be economically and ecologically sustainable (Cotton 1996).

Ethical considerations

Bio-prospecting – or searching for new products from nature with commercial objectives – led in the mid-1990s and early 2000s to the exploitation of these resources (and their associated traditional knowledge) without any compensation to indigenous or local peoples. Furthermore, third parties accessed ethnobotanical information published by researchers without the consent of the local knowledge-holders (Bannister 2007; Cotton 1996; Ethnobiology Working Group 2003; Posey 1990). In this perspective, Bannister (2007, 16) emphasizes that 'indigenous communities across the world, consequently, have been put in the position of contesting patent applications related to their traditional plant uses, copyright over associated stories, and trademarks over use of indigenous names and designs'. Today, unintended consequences of scientific research can no longer be ignored by ethnobotanists. There are global debates going on regarding indigenous rights and cultural misappropriation (Bannister 2007; Martin 2004), as well as over-exploitation of plant resources and loss of biodiversity (Balick and Cox 1996; Cotton 1996).

Nowadays there is much emphasis in the international arena on benefit-sharing, prior informed consent, intellectual property rights (Bannister 2007; Ethnobiology Working Group 2003) and the importance of returning the research results to the community (Ethnobiology Working Group 2003; Martin 2004). Professional societies have developed codes of ethics, professional standards and research guidelines (Ethnobiology Working Group 2003). For example, the International Society of Ethnobiology (2006) promotes a Code of Ethics which provides a framework of conduct for ethnobiological (including ethnobotanical) research and a framework for decision-making.

This study

The preceding sections argued that among the main issues and imperatives of ethnobotany are the study of domestication processes from an *emic* perspective, human management of biodiversity, bio-cultural diversity and the role of ethnobotanical research in conservation and sustainable development. The theoretical model, analytical framework and empirical research developed in this study certainly contribute towards the understanding of these critical issues, as discussed in the following chapters presenting the results of fieldwork conducted in Northeast Thailand (Chapters 4, 5, 6 and 7) and rounded-up in the final discussions of the study (Chapter 8).

This study profited from different ethnobotanical areas of research, which was necessary in order to answer the research questions. The starting point is the *emic* elicitation of wild food plants by local people that is related to cognitive ethnobotany (Chapter 4). This study also deals with traditional agriculture aiming to understand the complementarity of ecosystems and sub-systems for farming households, and to contribute to the understanding of the complexity of domestication processes at ecosystem and sub-system level (Chapters 5, 6 and 7). Material culture is another important area touched in this research, especially regarding to the additional cultural values of wild food plants besides food, such as for making handicrafts, home utensils and dying (Chapter 4). The overlapping role of wild food plants as food and medicine is also discussed in this study (Chapter 4), corresponding to ethnomedicine. Accordingly, this study utilized different botanical, ecological and anthropological methods of data collection and analysis, for instance botanical and vegetation survey, freelistings, focus group discussions and interviews.

CHAPTER 3

Current perspectives on wild food plants*

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Abstract
Plant gathering is a deeply rooted, shared aspect of human heritage and millions of people in rural areas are still dependent upon gathered plants for the multiple roles they play in their livelihoods. This chapter starts with a discussion on the conceptualization of 'wild food plants' in relation to human interaction with the 'wild', explaining the continuum model of people and plant interactions at different management intensities: from truly wild to fully managed and cultivated. Then, four main contemporary issues related to wild food plant use, knowledge and valuation are discussed, namely the overlap of the role of wild food plants as food and medicine, their use during famine and food shortages, the role of women, and their stigmatization versus 'revival'.

Keywords: Wild food plant, management intensity, famine foods, medicine, women, social stigmatization.

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INTRODUCTION

Humans have been hunters and gatherers for about 350,000 generations, then mostly agriculturalists for another 600, and quite recently, industrialized agriculture has existed for just two generations† (Pretty 2003). Plant gathering is a deeply rooted, shared aspect of human heritage and millions of people in rural areas are still dependent upon gathered plants for the role they play in their diet, medicine, fuel, construction, crafts, animal husbandry, deterrents of pests, as well as in their religious ceremonies and rituals. From the total of 250,000 to 300,000 known higher plant species, about 5,000 have been managed at certain times, and only 20 to 30 are regarded as staple foods for humanity (Cotton 1996; Heywood 1999). On the other hand, there are thousands of wild and semi-domesticated species used by people, which are cultivated and/or gathered from the wild. This resource has been used by populations in the past and present as shown by multiple archaeobotanical, ethno-historical and ethnobotanical studies‡.

In order to understand the dynamics of wild food plant consumption and gathering as well as their importance for rural livelihoods in the present and the past, it is necessary to combine different disciplines and methodological approaches. People-plant relationships in the present are studied by means of ethnobotanical methods, whereas the past use of plants (prehistory and history) is investigated on the basis of several sources of data, ranging from fossilized plant remains, preserved artefacts, graphic representation, to historical documents, folktales and poems.

Besides the temporal and methodological scope of wild food plant research, the broad geographical scope must also be taken into consideration. Wild food plants are used across all continents, and millions of people depend on this biodiversity of resources for their sustenance. For example, wild food plants are used not only by indigenous societies from in Amazonia (Defour and Wilson 1994) but also in north-western North America (Turner 2003). The use and management of wild edible plants has also been reported in Latin America, for instance, among the Nahua and the

† Pretty (2003) accepts the dates of 7 million years before present (BP) for human divergence from apes, 12,000 BP for the start of agriculture and 20 years for the average generation length.

‡ Further reading on the use of wild food plants is to be found in the book edited by Nina Etkin 'Eating on the wild side' (1994), which presents the pharmacological, ecological and social implications of wild food plant consumption by different societies, not only in the present, but also in prehistory. In addition to this, Cunningham's 'Applied ethnobotany: people, wild plant use and conservation' (2000) as well as Prance and Nesbitt's 'The cultural history of plants' (2005) are important books on this topic. The book series of PROSEA Foundation (Plant Resources of South–East Asia) (2006) documented 6697 plant species from South–East Asia, whereas PROTA (Plant Resources of Tropical Africa) (2010) presents information on about 7000 useful plants, including many wild edible plants. The prehistoric use of wild food plants is illustrated in the articles published by Behre (2008), Bouby and Billaud (2005) and Hastorf (1988), among other authors.

Mixtex (Casas *et al.* 1996), in the Bolivian Andes (Vandebroek and Sanca 2007) and Cuba (Volpato and Godinez 2007). The importance of wild vegetables in Africa has been highlighted by Chweya and Eyzaguirre (1999) and their consumption has been reported for the Sambaa in northeast Tanzania (Vainio-Mattila 2000), in the Kingdom of Swaziland (Ogle and Grivetti 1985), and in the Hadejia-Nguru wetlands of Nigeria (Adaya *et al.* 1997), among others. In Asia, the use of wild food plants is also widespread, for instance farmers in northeast Thailand, Laos and Vietnam depend on this resource for their food and nutritional security (Price 1997, Price and Ogle 2008), whereas wild edible plants are also gathered in Turkish Central Anatolia (Ertuğ 2000; Ertuğ 2003b), and by the Rai and Sherpa forager farmers in Nepal (Daniggelis 2003). With respect to Europe, these plants are consumed not only in Sicily (Galt and Galt 1978) and by Arberesh people in Lucania (Pieroni 2003), but also in Spain and Portugal (Pardo-de-Santayana *et al.* 2007; Tardio *et al.* 2006), as well as Poland (Luczaj 2008; 2007). Regarding the vast Australasian area, Tim Low's book 'Wild food plants of Australia' (1991) presents a detailed description of this resource in the country.

To start this section, it is necessary to conceptualize 'wild food plants' in relation to human interaction with the 'wild'. Then, four main contemporary issues related to wild food plant use, knowledge and valuation are discussed. Firstly, the overlap of the role of wild food plants as food and medicine; secondly, their use during famine and food shortages; thirdly, the role of women; and finally, their stigmatization versus 'revival'. This Chapter finishes with a reflection on the implications of the previous sections for this study.

HUMAN INTERACTION WITH THE 'WILD'

Ethnobotanical studies, as well as new data from archaeobotanical research, have caused fundamental revisions of earlier concepts and definitions of 'agrarian' societies. Terms such as 'hunter-gatherer' and 'agriculturalist' were once used by archaeologists as mutually exclusive. However, ethnobotanical research has demonstrated that hunter-gatherers may undertake agricultural practices, and that agriculturalists persist in gathering activities (Adaya *et al*. 1997; Harlan 1975; Ogle and Grivetti 1985). Indeed, wild food plants from agricultural ecosystems provide a critical component to the subsistence system of farmers[§].

[§] The consumption of wild plants from agricultural ecosystems is the main point of Scoones, Melnyk and Pretty's publication called 'The hidden harvest: wild foods and agricultural systems: a literature review and annotated bibliography' (1992), as one of outputs of the Hidden Harvest international programme, which presents a compilation of literature regarding several aspects of this resource. The importance of this resource for farmers is explained by Ertuğ (2000), Guijt *et al.* (1995), Ogle and Grivetti (1985), Bharucha and Pretty (2010), Heywood (1999) and Price (2005, 1997), among other authors.

The word 'wild' does not imply the absence of human management. Wild resources are actively managed (including transplanting, promoting, protecting, among other practices) by traditional communities (Cotton 1996). Local management practices are important not only for the diversity, but also for assuring the long-term availability of plant species, especially in times of seasonal unavailability, famine and stress. Thus it is possible to cultivate wild plants, while cultivated plants are not always domesticated. Furthermore, many of the food plants we grow have not been totally domesticated: for most species the transition from cultivation to domestication does not occur (Harlan 1975). Certainly, Harlan (1975, 63) argues:

> 'Since domestication is an evolutionary process, there will be found all degrees of plant and animal association with man and a range of morphological differentiations from forms identical to wild races to fully domesticated races. A fully domesticated plant or animal is completely dependent upon man for survival'.

In this sense, Harris (1989) and Wiersum (1997) present a continuum model of people and plant interactions at different management intensities: from truly wild to fully managed and cultivated. This continuum model helps us to better conceptualize human-plant interactions, regarding human action with wild, semi-domesticated and domesticated plants. The management of a plant species changes in time and space, but the model is neither unidirectional nor deterministic. Hence, some cultivated wild plants are moving towards domestication, whilst some plants that used to be intensively managed in the past are only tolerated or slightly protected in the present (Harris 1989). Moreover, a plant species can be managed simultaneously in various ways and at different management degrees in some regions, and, at the same time, may not be managed at all in others (González-Insuasti and Caballero 2007; Ogle 2001).

Different degrees of management allow grouping plants in three main categories to facilitate their study: (1a) gathered plants, (1b) plants under incipient management and (1c) cultivated plants. Furthermore there is a gradient within incipient management: (2a) tolerance, (2b) protection, (2c) promotion, and (2d) ex-situ cultivation. Gathering can also be considered as incipient management by changing the order of gathering locations and restricting harvesting. Furthermore, it is necessary to assess the presence or absence of selectivity when researching the management of a species. Selectivity, aimed at improving the desirable quality of the products, involves higher management intensity, and over a long-term period could result in the domestication of the species. (Casas *et al*. 1997; González-Insuasti and Caballero 2007). On the other hand, in order to better understand management and domestication, it is necessary to recognize the socio-cultural aspects involved in the use and value of the species (Casas *et al*. 1996).

The values attributed by local people to the plant species will affect their incentives to manage them (Guijt 1998) and to continue their use (Ogle 2001).

In this study, when we refer to wild food plants, we refer to non-domesticated plants, including wild plants that are not managed at all (‘truly’ wild), wild and semi-domesticated plants that may be tended in some way through encouragement, including clearing surrounding vegetation to reduce competition or selective cutting of perennials. Many of these plants may also be classified as ‘weeds’ by local people, agronomists and even by scientific literature. While we include in our definition ‘naturalised’ and ‘introduced’ plants, domesticated species, namely cultivars are excluded.

Weeds, defined as ‘pioneers of secondary succession’ (Bunting 1960) or ‘general unwanted organisms that thrive in habitats disturbed by man’ (Harlan and de Wet 1965) – have evolved by adapting to disturbed ecosystems. As we are dealing with evolution, we will have many intermediate states: some plants will be weedier than others, some plants will be more resilient to environmental disturbances, and some plants with weedy tendencies may be encouraged while others are despised (Harlan 1975). Many useful wild plants grow as ‘weeds’ in the context of cultivation. Interestingly, Ogle and Grivetti (1985) in their study in Swaziland, presented the botanical-dietary paradox: although the most intensively cultivated area (Middleveld) experienced the highest species diversity loss, it turned out to have the highest consumption of wild vegetables, mostly weeds (Ogle and Grivetti 1985, 59).

FOOD, MEDICINE AND FAMINE

Plants’ edible parts may include fruits[**], seeds, flowers, roots, rhizomes, bulbs and tubers, stems and leaves. Wild food plants can be eaten fresh or may need to be prepared or processed before being consumed. There are a myriad of ways to consume these plants, for example, Tardío and Pardo-de-Santayana classified wild plants from Spain in six food-use categories: vegetables, beverages (liqueurs and infusions), fruits, seasonings, preservatives and sweets (Forthcoming). Processing, which involves grinding, soaking, drying, heating or parching, is not only important for removing highly toxic secondary compounds or bitter qualities, but also for storage purposes (Cotton 1996). Wild plants are not only consumed alone, but also prepared in numerous combinations of plants and plant-processed products constituting different dishes, which provide an important nutritional benefit (Messer 1972).

The consumption of wild resources as food is essential as a means to ensure food diversity and secure food intake in non-industrialized rural societies, contributing to a balanced diet. Indeed, one of the most important aspects of wild vegetables and fruits

[**] Fruit refers either to the botanical part of the plant or a food-use category.

is their important role in nutrition: wild food plants are a very important source of vitamins and minerals, as well as secondary metabolites such as alkaloids, phenolics and essential oils (Heywood 1999; Johns 2007). This role was amply documented in Ogle's publication entitled 'Wild vegetables and micronutrient nutrition' (Ogle 2001), which presents a compendium of studies done around the world on dietary intake of micronutrients from wild plants and chemical analysis of their micronutrient content. The nutritional importance of wild food plants usually overlaps with their frequent use as medicine and their role in disease prevention[††]. In this way, Etkin and Ross (1982) report 'food as medicine and medicine as food' when referring to wild food plants, and Ogle (2003) emphasizes the disease-preventing role and presence of health-promoting mechanisms in such plants due to bioactive substances. Some substances, such as flavonoids, tannins, pectins and saponins, have antioxidant activities that stimulate the immune system, or antibacterial, antifungal or antiviral activities. Likewise, Pieroni and Quave (2005) discuss the high antioxidant activity of these plants. Nevertheless, very little is known about the health benefits of regular consumption of small quantities of medicinal foods and the contribution of wild foods with small quantities of trace minerals and vitamins (Etkin and Ross 1982; Etkin and Ross 1994; Ogle *et al.* 2003; Price 2005). Furthermore, the overlap of their role as food-medicine is not yet fully understood (e.g. Vandebroek and Sanca 2007), even though this role is extremely important as regards their widely documented use as 'famine foods' among poor rural communities throughout the world.

The use of wild plant foods occurs across a spectrum from routine to more irregular use under conditions of mild to extreme stress, holding several positions in the diet (Price 2005). Accordingly, Turner and Davis (1993) distinguish four categories of famine foods: (a) normally eaten foods that become more important during stress periods; (b) less preferred foods that are seldom consumed during normal circumstances; (c) starvation foods that are consumed only in periods of stress; and (d) hunger suppressants and thirst quenchers. Wild food plants are particularly important as 'buffers against shortages' during major stress and scarcity periods (Daniggelis 2003; Heywood 1999; Scoones *et al.* 1992). For instance, when the harvest of staple foods is finished or when cultivated crops fail, wild foods can thus complement the seasonal availability of crops (Adaya *et al.* 1997). Hence the frequent reference to

[††] The overlap of wild plant roles as food and medicine, as well as the use of these foods for disease prevention is the focus of the book edited by Pieroni and Price 'Eating and healing, traditional food as medicine' (2005), presenting case studies from around the world. This topic is also interestingly discussed in Johns' book 'With bitter herbs they shall eat it. Chemical ecology and the origins of human diet and medicine' (1990). This double role of wild food plants is also central to proceedings of the joint conference of the Society for Economic Botany and the International Society for Ethnopharmacology 'Plants for food and medicine' (Prendergast *et al.* eds. 1998).

them as 'famine foods' or as foods to supplement the diet in periods of shortage or stress (Grivetti and Ogle 2000).

WOMEN AND WILD PLANTS

The role of women is essential in farming and gathering. In many parts of the world, women are the main custodians of the knowledge of wild plant resources, since they are mainly responsible for wild plant food collection, cooking preparation and processing for storage, as well as being home-gardeners, domesticators, herbalists, and seed custodians[‡‡]. Additionally, they are often responsible for household nutrition (Howard 2003a; b; Ogle and Grivetti 1985). Today, rural women are actively engaged in small-scale marketing of wild food and food-medicinal plants in local and sometimes urban markets, which constitutes a significant source of income for them[§§]. These 'women's markets' not only provide cash to the gatherers and sellers, but also have important social implications in that they provide women with social networks beyond their immediate communities as well as access to non-local resources and expertise (e.g. Ertuğ 2003a; Kalyoncu 2002). The important role of women in managing wild resources, cultivation and domestication became more visible after female researchers became actively involved in ethnobotanical studies.

SOCIAL STIGMATISATION VERSUS REVIVAL

The gathering and consumption of wild food plants in some places is locally stigmatised, increasingly associated with poverty and social marginality (Cruz-García 2006; Malaza 2003; Somnasang and G. Moreno-Black 2000). Social stigmatisation of wild food plants is also related to their use as famine foods. For example, Selleger (Forthcoming) states that Dogon people feel uncomfortable talking about wild edible grasses, given that their consumption is associated with difficult periods of famine. In addition, Tardío and Pardo-de-Santayana (Forthcoming) mention that some wild food plants, especially those with a bitter taste, were considered as 'poor people's food'. Price (2005, 85), who conducted research in Northeast Thailand, explains:

> 'The degree to which 'wild' plant foods are incorporated into the diet of agriculturists depends also in part on if there are any social status restrictions on the consumption of these foods (or selected species), that is, if they are considered peasant food or foods of poverty and are infrequently consumed by the more

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[‡‡] The book edited by Howard, 'Women and plants: gender relations in biodiversity management and conservation' (2003c) discusses and presents several case studies from the world related to the role of women as the main custodians of knowledge on wild plant resources.

[§§] More information on the role of women in small-scale marketing of wild food and food-medicinal plants was published by Daniggelis (2003), Ertuğ (2003a), Hanlidou *et al.* (2004), Moreno-Black and Price (1993), Putscher and Vogl (2006), among others.

prosperous. The greater the social stigma the more likely these foods will be used as a buffer in times of stress and shortage rather than daily consumption'.

A judgment on the level of acceptance of a wild food plant species is its presence in local markets and its consumption by 'upper' social classes (Pemberton and Lee 1996; Price 2001b).

On the other hand, wild plants may participate in new highly regarded neo-rural cultural identities by appropriation. As Pieroni (2003) pointed out from his research in Southern Italy, some wild food plants are nowadays re-valorised by urbanites or highly educated people, as typical local varieties or 'specialty' food products. Likewise, Tardío and Pardo-de-Santayana (Forthcoming) affirm that there is a 'revival' in the consumption of some wild food plants in several regions of Spain, related to urban people's need to re-connect with rural life and associated with increasing environmental awareness. It is even possible to suggest that this revival is linked to some Rousseauist nostalgia of an idealized, pre-Neolithic pristine egalitarian, natural society. Tardío and Pardo-de-Santayana also mentioned that certain wild plants are considered as delicacies, recognized for their health benefits and even acknowledged as symbols of regional identity. Similarly, Morales and Gil (Forthcoming) explain that the Canary Island date palm (*Phoenix canariensis* Hort. ex Chabaud), has been the botanical emblem of the Canary Islands since 1991, constituting a newly created component in Canarians' identity. The recognition of some wild food plants as symbols of local identity has recently come to be a frequent phenomenon in Europe (Pardo-de-Santayana *et al.* 2010). Food movements, such as Slow Food or All Nature shops are the vectors of this new contemporary positive perception of 'traditional' food, and therefore also of wild plants. Indeed, recent research about the importance of wild food plants as a source of healthy food, dietary supplements and in medicinal treatments is increasingly fostering their use by contemporary urban people. This is also likely to reflect the trend that 'artisanal' and 'traditional' qualities of foods are important in the marketing and consumption of these products as signifiers of social distinction (Heath and Meneley 2007).

This study

This Chapter presents the current perspectives, including critical intellectual issues, on wild food plants. The first section explains the on-going debate of human interaction with the 'wild', comprising a brief description of the domestication continuum (Harris 1989; Wiersum 1997a; b), followed by an examination of wild species management. Certainly, as discussed in Chapters 4 and 8, this study further contributes to the definition of 'wild', and provides a theoretical framework supported by empirical evidence (Chapters 4, 5, 6 and 7, rounded-up in Chapter 8) that facilitates 'zooming' into the continuum of domestication in order to uncover the complexities of the relationships among people, plants and their environment, at ecosystem level. This Chapter also emphasises the necessity to combine different methodological approaches for investigating wild food plant consumption and gathering, which is clearly reflected in the methodological interdisciplinarity of this study.

The overlapping roles of wild food plants as food and medicine were also reported in the study site in Northeast Thailand (Chapter 4); and the role of these plants as famine foods during lean months is examined with respect to household seasonal gathering (Chapter 7). Although this study did not touch the gender aspects related to wild food plants, only women were interviewed during fieldwork given that results from previous research conducted in the same region demonstrated that gathering and management of wild food plants is part of women's domain (Price 2003). Finally, the issues of culinary and cultural identity related to these plants are discussed in Chapter 8 (general discussion).

CHAPTER 4

General aspects of wild food plants used by rice farmers in Kalasin, Northeast Thailand*

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Abstract

Wild food plants are a critical component in the subsistence system of rice farmers in Northeast Thailand. One of the important characteristics of wild plant foods among farming households is that the main collection locations are increasingly from anthropogenic ecosystems such as agricultural areas rather than pristine ecosystems. This paper provides selected results from a study of wild food conducted in several villages in Northeast Thailand. A complete botanical inventory of wild food plants from these communities and surrounding areas is provided including their diversity of growth forms, the different anthropogenic locations were these species grow and the multiplicity of uses they have. Data was collected using focus groups and key informant interviews with women locally recognized as knowledgeable about contemporarily gathered plants. Plant species were identified by local taxonomists. A total of 87 wild food plants, belonging to 47 families were reported, mainly trees, herbs (terrestrial and aquatic) and climbers. Rice fields constitute the most important growth location where 70% of the plants are found, followed by secondary woody areas and home gardens. The majority of species (80%) can be found in multiple growth locations, which is partly explained by villagers moving selected species from one place to another and engaging in different degrees of management. Wild food plants have multiple edible parts varying from reproductive structures to vegetative organs. More than two thirds of species are reported as having diverse additional uses and more than half of them are also regarded as medicine. This study shows the remarkable importance of anthropogenic areas in providing wild food plants. This is reflected in the great diversity of species found, contributing to the food and nutritional security of rice farmers in Northeast Thailand.

Keywords: Wild food plant, ethnobotany, rice ecosystem, edible part, use, growth location, growth form, gathering, Thailand, Southeast Asia.

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BACKGROUND

The collection and consumption of 'wild' plant foods from agricultural and non-agricultural ecosystems has been documented in multiple cultural contexts, illustrating their use and importance among farming households throughout the world (Bharucha and Pretty 2010; Cruz-Garcia and Ertuğ Forthcoming; Scoones *et al.* 1992). The evidence to date suggests that gathering by farmers occurs in various environments, ranging from intensively farmed areas, to more subsistence oriented horticultural systems, and finally in more pristine areas such as forests. This is certainly the case of rice farmers in Asia (IRRI 2004). For example, Ogle *et al.* (2001; 2003) found that in the Mekong Delta of Vietnam 90% of women eat wild vegetables, uncovering a total of 94 species. Kosaka (2006), in his research on flora from the paddy rice fields in Savannakhet, Laos, recorded 11 edible species from a total of 19 herbaceous useful plants, and 25 food trees out of 86 useful species. The documentation of 'wild' food plant gathering and consumption in mainland Southeast Asia is still growing, however the literature is scattered across numerous disciplines (Price and Ogle 2008).

The research on which this paper is based was conducted in Kalasin Province, Northeast Thailand. Studies conducted in this region provide documentation that 'wild' food plants are a critical component in the subsistence system of farmers (Grandstaff *et al.* 1986; Lyndon and Yongvanit 1995; Moreno-Black and Price 1993; Moreno-Black and Somnasang 2000; Price 2005; 1997). This food resource is extremely important to the rural population comprised of rice farmers, given that the Northeast region is regarded as both Thailand's largest and poorest part of the country. This paper adds to this literature by providing the most comprehensive botanical inventory of these foods to date. Two botanical characteristics are described in this article: growth form and life cycle. Moreover, we present the growth location of the plants. Regarding cultural characteristics, this paper also identifies multiple uses of wild food plants.

Wild food plants in this article refer to non-domesticated plants. These plants exist on a continuum of people and plants interactions in regard to their degree of management. In this way, wild food plants include those from 'truly' wild to wild protected, cultivated and semi-domesticated plants that may be promoted, protected or tolerated in some way locally. Wild food plants can be cultivated, but not all cultivated plants are domesticated. For most species the transition from cultivation to domestication never happens. Human plant management does not necessarily move toward greater intensity and ultimately plant domestication. While some plants are moving towards domestication, other plants that used to be highly managed in the past could be only slightly tolerated and protected under contemporary circumstances (see Cruz-Garcia and Ertuğ Forthcoming). While we include in our definition 'introduced' and 'naturalized' plants, locally domesticated plants are excluded. We use the term 'local' because, since the nature of this study is ethnobotanical, we based our research on these plants that are classified as 'wild' by local people. This is why some food plants that are regarded as 'wild' in Kalasin, might be treated as domesticates in other areas.

The research site

The research for this paper was conducted in four villages in Kalasin Province, Northeast Thailand. The villages are fairly typical for the region. Kalasin is located at 152 m above sea level (asl) in the Korat Plateau, which geographically defines the Northeast region of the country. This Plateau, forming a shallow depression between 100 m and 200 m asl, is generally quite flat with scattered swamps and ponds (some seasonal) and low hills that rise to around 300 m asl (Parnwell 1988).

Soils in this region are mostly heavily leached fine sandy loams, with poor drainage and high salinity. Furthermore they are usually low in phosphate, nitrogen and organic matter (Parnwell 1988). Declining soil fertility is prevalent in the region (Wijnhoud 2007). Nevertheless, the soils in lowland paddy fields are better than in the uplands because they receive nutrient in-flows eroded from the higher areas (Vityakon *et al.* 2004). The natural vegetation of this region is dry monsoon forest, primarily composed by dry dipterocarp forest (Prachaiyo 2000), with *Dipterocarpus tuberculatus* Roxb., *D. obtusifolius* Teijsm. ex Miq., *Shorea obtusa* Wall., *S. siamensis* Miq., *Xylia xylocarpa* (Roxb.) Taub., *Irvingia malayana* Oliv. ex A.M. Bennett, *Cratoxylon formosum* (Jack) Dyer. and *Careya arborea* Roxb. as dominant species (Tipraqsa 2006).

Deforestation has been occurring at a high rate since the early 1950s with the extension of agricultural land due to commercialization of agriculture, as well as population growth. In this way, the forest and wooded areas have decreased from 90% in the 1930s to less than 14% in 2004. The rate of deforestation was likely augmented significantly during the economic crisis at the end of the 1990s (Prachaiyo 2000; Vityakon *et al.* 2004; Wijnhoud 2007). At the same time, soil degradation in the agricultural areas has been increasing and consequently yields have declined (Vityakon *et al.* 2004).

The Northeast covers 170,000 km^2 (Vityakon *et al.* 2004) and has more land dedicated to agriculture than the rest of the country (9.25 million hectares). Around 94% of the region's population live in rural areas (Prapertchob 2001) with the region possessing the highest number of farms in the Nation (2,273,000) (Office of Agricultural Economics 1998). Indeed, in Kalasin province 85.1% of the population depend on agriculture (National Statistical Office of Thailand 2001). The main crop is glutinous rice (also called sticky rice), which is important as the dietary staple and for income generation. Rice production corresponds to 70% of the arable land of the Northeast, but average rice yields are the lowest in the country (1.8 Mg ha^{-1}) (Wijnhoud 2007). Within the traditional rain-fed paddy agricultural system, which is primarily transplanted rice, crops can be damaged by delayed rains when transplanting seedlings, or by droughts and floods (Parnwell 1988; Wijnhoud 2007). The annual monsoon provides 90% of the annual rainfall of the Northeast, averaging over 200 mm from May through October, which is essential for the cultivation of glutinous rice. From November to April, rainfall averages only about 20 mm per month in Kalasin (Hijmans 2005).

The research population

The Northeast is referred to as *Isaan* and is also known for its distinct cultural characteristics. The people who inhabit the region, commonly referred to as *Isaan* people, are ethnically of Lao origin, constituting one of the largest minority populations in the country. Most North-easterners speak a dialect of Lao mixed with some influences from Thai also known as *Isaan*. *Isaan* is written using the Thai script. Thai is learned formally in school and villagers are literate in Thai, except for the very elderly.

Kalasin Province has a population of about one million inhabitants and a density of 132.3 inhabitants / km^2. Households on average have four family members in the rural areas, and 23.6% of them are female headed. Theravada Buddhism is the main religion in this province (99.5% of the population), as in the rest of the country. The population has attained on average 6.5 years of education. Regarding their work status, 51.7% are unpaid family workers and 35.8% are engaged in self-employment, usually in agriculture (National Statistical Office of Thailand 2001). There is a high rate of seasonal or full-time migration to major cities mainly as wage labourers who aim to send remittances to their families that stay in the rural areas (Tipraqsa 2006). Off-farm employment accounts for two thirds of the total income of families in Northeast Thailand (Prapertchob 2001).

There is customary inheritance of land through women and a pattern of matrilocal residence. This system facilitates women having a thorough knowledge of their social and physical environment (Price and Ogle 2008).

General overview of wild food plants in Northeast Thailand

An important yet not widely available study at the national level established that wild food plants play an essential role in the diet in all the rural areas of Thailand (Ngarmsak 1987). This is clearly reflected in the fact that more than 500 different edible natural products have been documented as being sold in the markets around the country (Wanida 1995).

Gathering mainly occurs in anthropogenic ecosystems, such as agricultural lands (including paddy fields), woody areas, (home) gardens, house areas and swamps (Moreno-Black and Somnasang 2000; Price 1997; Somnasang and Moreno-Black 2000). Agricultural lands and home gardens are traditionally owned by women (Moreno-Black *et al.* 1994; Price 2003; Somnasang 1996). In Northeast Thailand, women are the main gatherers, selectors, transplanters and propagators of wild food plants (Moreno-Black *et al.* 1994; Somnasang 1996; Somnasang and Moreno-Black 2000; Somnasang *et al.* 1998; Price 2003; 1993; 2001).

In this region farmers have as their staple glutinous rice accompanied by a variety of wild foods derived from wild, semi-domesticated and domesticated plants, as well as frogs, paddy crabs, insects and fish. During the rainy season wild food can constitute as much as half of the total food consumed in the villages. Wild food plants are mainly consumed as fresh fruits or vegetables eaten raw or steamed, and in local 'curries' or soups (Coomklang *et al.* 2000; Somnasang *et al.* 1988).

In fieldwork conducted in Northeast Thailand in 1990, Price documented 77 species gathered by farmers in a village in Kalasin Province (1997; 2000). Somnasang, Rathakette and Rathanapanya (1988) listed 42 wild vegetables and 7 wild fruits in a paper published in the 1980s. Ten years later, Somnasang, Moreno-Black and Chusil (1998) recorded 66 wild food plants consumed in Northeast Thailand. Furthermore, Sapjareun, Kumkrang and Deewised (2004) published a book, in Thai, entitled 'Local vegetables in *Isaan*' presenting a general description of a number of plants by species, their propagation, ecological importance and uses, as well as the local recipes.

The botanical-dietary paradox

One of the important characteristics of wild plant foods among farming households is that the main collection locations are increasingly from the anthropogenic ecosystems such as agricultural areas rather than pristine ecosystems (Price 1997). Ogle and Grivetti (1985) in their study in Swaziland found that the most intensively cultivated area among their research sites exhibited the highest level of loss of edible species, but, at the same time, the most consumption of wild food plants. They termed this phenomenon the 'botanical-dietary paradox' and proposed that this occurs when people start to rely on eating the weeds of agriculture once a decline in forests occurs. Ultimately, the species that are considered local vegetables change. Price and Ogle (2008) further explain that time constraints are a major factor in the commencement of the botanical-dietary paradox in that as forests decrease and become more remote from the village, gathering from the forests becomes increasingly too time consuming, so farmers shift to gathering in areas closer to home and shift to eating many of the weeds of agriculture and other food plants in the agricultural system. This shift in food resources is evident on Mainland Southeast Asia.

Saowakontha *et al.* (1994) conducted a study on edible forest products in two villages, Ban Moh and Ban Nong Khong, Phu Wiang district, in Northeast Thailand, presenting a list of 34 wild food plants. They found that the degree of dependency on this resource was related to the distance from the village to the forest, thus, the longer the distance to the forest, the higher the dependency on other areas for food gathering. Likewise, Kosaka *et al.* (2006a; b) compared two rice farming villages from Savannakhet Province, Laos, obtaining the same results. Whereas Bak village, located in the uplands with an extensive forest area, showed to be more dependent on forest diversity, farmers from Nakou village, situated in the lowlands with a small area of remnant forest, identified more useful plants from the rice fields than the forest, compensating for the lack of resources by maintaining the tree diversity within the paddy rice fields. Studies conducted specifically on non-timber forest products provide surprising results. For example, in a study conducted in the Lao P.D.R., the researchers discovered that farmers used multiple land types and that 60% of the 'non-timber forest products' were not from the forest at all but were collected from fields (paddy, dry grass areas, and fallow), streams and ponds (Foppes and Ketphanh 1997). The same happened when Shibahara conducted research on hunting and gathering in public forests of Roi Et, Northeast Thailand. Although research was focused on forest areas, a major finding was that farmers relied mainly on wild foods from rice fields rather than forests. Shibahara (2004) also emphasized that most gathering activities occurred on private land instead of public land. The role of private land in food gathering entitlements among Northeast Thai villagers has been documented by Price (1997).

Given the alarming rate of decrease in forest and wooded areas in Thailand (Khumkratok *et al.* 2005) it is becoming increasingly important to also study the wild food plants from anthropogenic areas, as several studies have shown that farmers are becoming more dependent on these places for ensuring their household dietary diversity and food security (Chanaboon *et al.* 2005; Johnson and Grivetti 2002; Moreno-Black and Somnasang 2000; Price and Ogle 2008; Price 1997).

Somnasang, Rathakette and Rathanapanya (1988) found that paddies are a principal place for gathering wild vegetables and fruits in Northeast Thailand. Likewise, Price (1997) estimated that farmers gather more from the fields than from any other place. Indeed, rice fields are not only important in terms of rice production but are biologically diverse (Schoenly *et al.* 1998) and multi-resource agro-ecosystems (Grandstaff *et al.*1986). According to the International Rice Research Institute (2004), paddies possess over 100 useful associated plant species being sources of food, medicine, fibre, construction material, fuel and animal feed.

Anthropogenic ecosystems

Rice fields on the plains of Northeast Thailand and Laos are characterized by having trees in the paddy fields, given their importance for local culture (Kosaka *et al.* 2006a) and their socio-economic and ecological functions (Vityakon 2001). Trees are either planted or remnants from a previous forest, which went through different stages of transformation until becoming a rice field during the historical and on-going process of agricultural expansion (Grandstaff *et al.* 1986; Prachaiyo 2000; Vityakon *et al.* 2004). The transition point was named 'rice production forest' by Takaya and Tomosugi (Miyagawa 2008). Vityakon *et al.* (2004) recognize different transitional historical stages of land use change, which they describe at the regional, community, landscape and field level in their article 'From forests to farm fields: changes in land use in undulating terrain of Northeast Thailand at different scales during the past century'. Prachaiyo (2000) also explains this process in his publication entitled 'Farmers and forests: a changing phase in Northeast Thailand'.

There are a number of studies on the diversity of trees in paddy fields in Northeast Thailand. Grandstaff, Rathakette, and Thomas (1986) recorded 54 species of trees and shrubs, 32 of them used as food and/or medicine, growing in the rice fields. Watanabe *et al.* (1990) recorded 16 useful tree species growing in paddy fields in the region. Additionally, Vityakon (2001; 1993; 2005; 2007) conducted research on the importance of trees for soil fertility in rice fields. She identified 25 species (14 of them used as food and/or medicine) surviving from previous forests, indicating, if applicable, their uses as food and/or medicine (1993). Later on, Prachaiyo (2000) described 28 useful tree species growing in the paddies mainly for timber, latex, food, medicine, oil or fodder. Subsequently, Tipraqsa (2006) emphasized the importance of trees in rice fields in Northeast Thailand, documenting 52 trees found in the diverse farming systems in the rice landscape. Finally, trees in rice fields have also been systematically documented in Laos by Kosaka (2006), and also discussed in the symposium 'Tree-rice ecosystem in the paddy fields of Laos' organized by a Japanese-Thai project on the same topic, where the utilization of some tree species as food was noted (Funahashi and Adachi 2008).

Plant diversity in rice fields not only consists of trees, but also aquatic and terrestrial herbs, climbers and shrubs. However, several herbs, climbers and shrubs are classified as weeds or invasive species by agronomists. Yet, a number of weeds are used as vegetables or medicines in Thailand. Maneechote (2007) documents 59 edible weeds indicating their parts eaten and the habitat where they grow, which corresponds to about 30% of the 150 plant species classified as weeds in the country. Vongsaroj and Nuntasomsaran (1999) conducted a literature review on weed utilization in Thailand reporting 33 weeds used as food, 16 as medicine and 12 as animal feed; some of them were also listed later on in Vongsaroj's (2005). Kosaka *et al.* (2006b) identified 11 edible species, 5 medicinal species and 2 plants used as animal feed, mostly weeds from the paddy fields in Savannakhet, Laos.

Prachaiyo (2000) also listed some herbs used as vegetable or medicinal plants growing in the rice fields of Northeast Thailand. Although weeds have been shown to have diverse uses around the world (Kim *et al.* 2007), they are continuously overlooked in their role as sources of food and medicine (Maneechote 2007). Minor attention is paid to weed utilization in Thailand given that most agricultural research is focused on minimizing their population (Vongsaroj and Nuntasomsaran 1999).

This study

Despite the recognition of the important role that wild food plants play for farmers' livelihoods in Northeast Thailand, information is rather scattered throughout different publications, which are mainly in the Thai language. There is no single article presenting not only an exhaustive list of species but also their local name and, botanical and cultural characteristics. This is certainly necessary as a baseline for future research in this area.

The objectives of this paper are to provide selected results from an ethnobotanical study of wild food plants conducted in Northeast Thailand. A complete botanical inventory of wild food plants used by the study villages and their surrounding areas is provided including their diversity of growth forms, the different anthropogenic locations were these species grow and the multiplicity of uses they have. The research presented in this paper contributes to understanding the importance of different anthropogenic ecosystems where wild food plants grow and provides insights on the multiplicity of uses of these plants.

METHODS

Taxonomic identification and plant naming

Fieldwork was conducted from 2006 to 2010, taking as a baseline the results obtained in research carried out by one of the authors in two adjacent villages located in Kalasin Province, where she identified 77 species classified as 'wild' food plants during focus group elicitations conducted with local farmers (Price 1997). This list was built upon and increased using focus groups and key informant interviews as complementary methods in the same villages. A final list of 87 species of locally classified 'wild' food plants was constructed and local names of plants in the local Thai-Lao vernacular were recorded in the Thai script. Species were botanically identified by taxonomists from the Department of Biology of Chang Mai University and Walai Rukhavej Botanical Research Institute of Mahasarakham University. Herbarium specimens of most of the identified species are on repository in one or more locations in Thailand, including the Bangkok Herbarium of the Department of Agriculture (BK) in Bangkok, Herbarium of Walai Rukhavej Botanical Research Institute (WRBG) in Mahasarakham, and the Herbarium of Khon Kaen University (KKU) in Khon Kaen. Botanical naming of family, genus and species follows 'Flora of Thailand' (Bangkok Forest Herbarium).

The villagers use the term *geht eng*, which means 'birth itself' for wild food plants. However they do distinguish between 'birth itself' as a type of plant versus just the verb 'to birth by itself' (without human intervention, such as sowing or transplanting). Some 'birth itself' species can also be transplanted or propagated, as some domesticates such as tomatoes can 'birth themselves' (growing from consumption debris). Domesticates that 'birth themselves' are not considered wild food plants ('birth itself' 'type' of plant). Plant types are further identified by prefixes. The most common prefixes used for naming food plants refer to their edible part, such as *bak* and *maak* that mean fruit (บัก, หมาก), *yod* meaning shoots (ยอด), *bai* (which is a more unusual prefix) referring to leaf (ใบ), and *dok* that means flower (ดอก). A very common prefix for naming wild food plants is *phak* which means vegetable (ผัก) (Price 1997). *Phak* includes shoots, leaves, stems and sometimes whole aerial parts eaten as vegetable. In this way, if a plant has more than one edible part, it will likely have more than one name differing in the prefix used. For example, *Garcinia cowa* has two local names 'phak moong' (ผักโมง) and 'bak moong' (บักโมง) given that it is eaten as both vegetable and fruit. A total of 131 plant names were documented for the 87 plants, giving an average of 1.5 names per plant. Plant names were carefully recorded in the local *Isaan* dialect (capturing both pronunciation and local tone) using the Thai script. Plant names were also transliterated into English. Finally, English names were obtained from Germplasm Resources Information Network (USDA ARS National Genetic Resources Program 2011), Multilingual Multiscript Plant Name Database (Porcher 2011) and Plant Resources of Southeast Asia (PROSEA Foundation 2006).

Ethnobotanical data collection

Growth form and life cycle were determined for each species through field observation and complemented with literature (Smitinand 2001). Growth location and cultural characteristics of the plants, such as edible parts and multiple uses, were assessed through focus groups and supplemented with key informant interviews conducted not only in the research villages but also in two additional nearby villages. The use of different methods permitted, to a certain degree, triangulation and greater depth. These activities were carried out with the aid of local translators who speak the Thai-Lao vernacular of the Lao language (*Isaan*) as it is spoken in the research location and are knowledgeable about the research topic. Finally, a relational data base of wild food plants was built using Microsoft® Access.

Focus groups are particularly useful when the everyday use of language and culture of particular groups is of interest, and when one wants to explore the degree of consensus on a given topic (Morgan and Kreuger 1993). The focus group method has previously been successfully applied to the collection of plant species level information with farmers in Northeast Thailand (Price 1997). Each focus group consisted of six to nine members, following Bernard's recommendations (2002) on the number of participants. Focus group participants were generally middle-age women or slightly older (34 to 66 years old), named by the villagers themselves as knowledgeable about contemporarily gathered plants (Bernard 2002; Pelto and Pelto 1996). A total of 12 sessions were carried out sometimes with different participants, each session lasted two to three hours and was tape recorded. All of who participated in the study did so freely and with consent.

RESULTS AND DISCUSSION

Botanical characteristics of wild food plants

A total of 87 wild food plants, belonging to 47 families, were mentioned by farmers through key informant interviews and focus group discussions in 2006, building up on a previous list of plants documented by Price in 1990. Out of this total, 76 plants were botanically identified to the species level recognizing a total of 75 different species (two plants correspond to different sub-species of the same species), 9 were identified to genus level and for two botanical identification was not possible (Table 1). About 13% of the plants were from the Leguminosae family (6 species belonged to Mimosoideae and 5 to Caesalpinioideae). Other important families were Annonaceae, Myrtaceae, Poaceae, Pontederiaceae, Sapindaceae, Zingiberaceae, with 3 species each.

Two categories of life cycles were considered: annual and perennial. Some 79% of the wild food plants were perennial and 21% annual. For analysing growth form, seven categories were considered: aquatic herb, terrestrial herb, climber, shrub, tree, bamboo and rattan. Figure 1 shows that almost half of the wild food plants were trees (44%). Other important growth forms were terrestrial herb (18%), aquatic herb (15%) and climber (13%). Shrubs only presented five plants, followed by bamboo with three plants and rattan with only one plant. Climber and terrestrial herbs were both annual

Table 1. List of wild food plants indicating botanical family, scientific name, local *Isaan* name(s), English transliteration of local *Isaan* name(s) and English name(s).

Scientific name	English transliteration of local (*Isaan*) name	Local (*Isaan*) name	English name
Aizoaceae			
Glinus oppositifolius (L.) Aug.DC.	Phak kaen khom	ผักแก่นขม	
Amaranthaceae			
Amaranthus viridis L.	Phak hom	ผักหม	green amaranth, pigweed, slender amaranth
Anacardiaceae			
Mangifera caloneura Kurz	Bak muang paa	บักม่วงป่า	
Spondias pinnata Kurz	Bak kawek	บักกอก	common hog plum, Indian mombin, Andaman mombin
Annonaceae			
Polyalthia debilis Finet & Gagnep.	Bak lok kok	บักลกคก	
Polyalthia evecta Finet & Gagnep.	Bak tong leeng	บักต้องแล่ง	
Uvaria pierrei Finet & Gagnep.	Bak pii puwen	บักพิผ่วน	
Araceae			
Amorphophallus sp.	Phak e-loke	ผักอีลอก	
Araliaceae			
Irvingia malayana Oliver	Bak bok Maak bok	บักบก หมากบก	barking deer's mango
Arecaceae			
Borassus flabellifer L.	Bak taan Yod taan	บักตาล ยอดตาล	palmyra palm, tala palm, wine palm
Calamus sp.	Bak waai Waai	บักหวาย หวาย	
Asclepiadaceae			
Telosma minor Craib	Phak kik Dok kik Bak kik	ผักขิก ดอกขิก บักขิก	
Basellaceae			
Basella rubra L.	Phak pang	ผักปัง	Ceylon-spinach, Malabar-nightshade, vine-spinach
Bignoniaceae			
Dolichandrone serrulata Seem.	Kee paa	แคป่า	

Table 1. (continued)

Oroxylum indicum Vent.	Phak lin faa Bak lin faa Yod lin faa Bai lin faa	ผักลิ้นฟ้า บักลิ้นฟ้า ยอดลิ้นฟ้า ใบลิ้นฟ้า	midnight horror, oroxylum
Burseraceae			
Canarium subulatum Guillaumin	Bak luwam	บักเหลื่อม	
Campanulaceae			
Lobelia begonifolia Wall.	Phak luem phua	ผักลืมผัว	
Lobelia sp.	Phak som	ผักส้ม	
Clusiaceae			
Cratoxylum formosum (Jack) Benth. & Hook.f. ex Dyer	Phak tew	ผักติ้ว	
Garcinia cowa Roxb.	Phak moong Bak moong	ผักโมง บักโมง	cowa
Compositae			
Blumea balsamifera DC.	Phak naad	ผักหนาด	
Emilia sonchifolia (L.) DC.	Phak lin pii	ผักลิ้นปี่	emilia, sow thistle
Convolvulaceae			
Cuscuta chinensis Lam.	Phak mai tong	ผักไหมทอง	Chinese dodder
Ipomoea aquatica Forssk.	Phak bung	ผักบุ้ง	Chinese water-spinach, swamp morning-glory
Cucurbitaceae			
Coccinia grandis (L.) Voigt	Phak tam nin Bak tam nin Tam nin	ผักตำนิน บักตำนิน ตำนิน	ivy gourd, little gourd
Momordica charantia L.	Phak sai Bak phak sai	ผักไส่ บักผักไส่	balsam-apple, bitter gourd, bitter melon
Ebenaceae			
Diospyros rhodocalyx Kurz	Maak koo	หมากโก	
Euphorbiaceae			
Phyllanthus acidus (L.) Skeels	Bak yom Yod bak yom	บักยม ยอดบักยม	gooseberry-tree, Indian-gooseberry, star-gooseberry
Fagaceae			
Castanopsis sp.	Bak kaaw	บักก่อ	
Gnetaceae			
Gnetum sp.	Bak muway	บักหม่วย	
Hydrocharitaceae			
Ottelia alismoides (L.) Pers.	Phak hob hep	ผักโหบเหบ	duck-lettuce, water-plantain ottelia

Table 1. (continued)

Hydrophyllaceae			
Hydrolea zeylanica (L.) J.Vahl	Phak ka-liang	ผักกะเหลียง	Ceylon hydrolea
Lauraceae			
Cassytha filiformis L.	Phak mai	ผักไหม	dodder-laurel
Lecythidaceae			
Barringtonia acutangula (L.) Gaertn.	Phak kadon naam Kadon naam	ผักกะโดนน้ำ กะโดนน้ำ	Indian-oak
Careya arborea Roxb.	Phak kadon kok Kadon kok	ผักกะโดนโคก กะโดนโคก	
Leguminosae			
Adenanthera pavonina L.	Phak lam	ผักล่ำ	coralwood, red sandalwood-tree
Cajanus cajan (L.) Millsp.	Bak tua heea Tua heea	บักถั่วแฮ ถั่วแฮ	pigeon-pea, red gram
Cassia siamea Lam.	Phak khee lek Khee lek	ผักขี้เหล็ก ขี้เหล็ก	kassodtree, Thai cassia, Siamese senna
Dialium cochinchinense Pierre	Bak keng	บักเค็ง	velvet-tamarind
Leucaena leucocephala (Lam.) de Wit	Phak kased Bak kased Yod phak kased Kased	ผักกะเสด บักกะเสด ยอดผักกะเสด กะเสด	leadtree, white popinac, leucaena
Neptunia javanica Miq.	Phak kased kok	ผักกะเสดโคก	
Neptunia oleracea Lour.	Phak kased naam	ผักกะเสดน้ำ	water-mimosa
Pithecellobium dulce (Roxb.) Benth.	Bak kaam lian Kaam lian	บักขามเลียน ขามเลียน	blackbead, Manila tamarind, sweet-inga
Senna sophera (L.) Roxb.	Phak let ket	ผักเล็ดเค็ด	Kasondi senna
Sindora siamensis Teijsm. ex Miq.	Bak tee	บักแต้	
Tamarindus indica L.	Bak kaam Bak kaam som Maak kaam Yod kaam	บักขาม บักขามส้ม หมากขาม ยอดขาม	tamarind
Xylia xylocarpa Taub. var *kerrii* (Craib & Hutch) I.C. Nielsen	Bak deeng Maak deeng	บักแดง หมากแดง	
Liliaceae			
Asparagus racemosus Willd.	Phak shi shang Shi shang	ผักชีช้าง ชีช้าง	Indian asparagus
Limnocharitaceae			
Limnocharis flava Buchenau	Phak kanjong Bak kanjong Phak pai	ผักคันจอง บักคันจอง ผักพาย	sawah-flower rush, sawah-lettuce, velvetleaf

Table 1. (continued)

Marsileaceae			
Marsilea crenata C.Presl	Phak waen	ผักแว่น	pepperwort, water clover
Meliaceae			
Azadirachta indica A.Juss. var. *indica*	Phak ki nin	ผักคินิน	sadao India
Azadirachta indica A.Juss. var. *siamensis* Valeton	Phak kadaw Yod kadaw Yod phak kadaw	ผักกะเดา ยอดกะเดา ยอดผักกะเดา	sweet neem, Thai neem
Menispermaceae			
Cissampelos pareira L.	Bai maa noi Maa noi	ใบหมาน้อย หมาน้อย	velvetleaf
Tiliacora triandra Diels	Yaa nang Bai yaa nang	ย่านาง ใบย่านาง	
Menyanthaceae			
Nymphoides indica (L.) Kuntze	Phak kanong ma	ผักกะหน่องม้า	banana-plant, water-snowflake
Moraceae			
Artocarpus lacucha Roxb.	Bak haad Maak haad	บักหาด หมากหาด	monkey-jack, monkeyfruit
Myrtaceae			
Psidium guajava L.	Bak sidaa noi	บักสีดาน้อย	guava
Syzygium cumini (L.) Skeels	Bak waa	บักหว่า	jambolan, Java-plum, Malabar-plum
Syzygium gratum (Wight) S.N.Mitra	Phak mek Maak mek	ผักเม็ก หมากเม็ก	
Nymphaeaceae			
Nymphaea pubescens Willd.	Phak sai bua Sai bua	ผักสายบัว สายบัว	red water-lily
Onagraceae			
Ludwigia adscendens (L.) H.Hara	Phak phee phui	ผักผีพวย	water-primrose
Opiliaceae			
Melientha suavis Pierre	Phak waan paa	ผักหวานป่า	melientha
Passifloraceae			
Adenia viridiflora Craib	Bak saap Phak saap	บักสาบ ผักสาบ	
Passiflora foetida L.	Tam nin farang	ตำนินฝรั่ง	running pop, stinking passionflower, wild water-lemon

Table 1. (continued)

Poaceae			
Bambusa sp.	Naw mai phai huwak	หน่อไม้ไผ่ฮวก	
Bambusa bambos (L.) Voss	Naw mai phai paa	หน่อไม้ไผ่ป่า	giant thorny bamboo, spiny bamboo
Vietnamosasa ciliata (A.Camus) T.Q.Nguyen	Naw jood	หน่อโจด	
Pontederiaceae			
Eichhornia crassipes (Mart.) Solms	Phak katok Phak paud	ผักกะโตก ผักปอด	water-hyacinth
Monochoria hastata (L.) Solms	Phak top Phak top thai	ผักตบ ผักตบไทย	arrow-leaf monochoria, hastate-leaf-pondweed
Monochoria vaginalis C.Presl	Phak e-hin	ผักอีฮีน	oval-leaf monochoria, pickerel-weed
Rhamnaceae			
Ziziphus mauritiana Lam.	Bak tan noi	บักทันน้อย	Indian jujube, Indian plum, Sour jujube
Ziziphus oenoplia (L.) Mill.	Bak lep meuw Maak lep meuw	บักเล็บแมว หมากเล็บแมว	jackal jujube, small-fruited jujube, wild jujube
Rubiaceae			
Oxyceros horridus Lour.	Bai kat kaaw	ใบคัดเค้า	
Rothmannia wittii (Craib) Bremek.	Bak maaw	บักหม่อ	
Rutaceae			
Aegle marmelos Corrêa	Bak tuum Maak tuum Yod maak tuum	บักตูม หมากตูม ยอดหมากตูม	bael, belfruit-tree, golden-apple
Sapindaceae			
Lepisanthes rubiginosa (Roxb.) Leenh.	Bak huat kaa	บักหวดข่า	rusty sapindus
Nephelium hypoleucum Kurz	Bak ngeuw Maak ngeuw	บักแงว หมากแงว	
Schleichera oleosa (Lour.) Oken	Bak kawe Luk kawe Maak kawe	บักค้อ ลูกค้อ หมากค้อ	Ceylon-oak, lactree
Scrophulariaceae			
Limnophila aromatica Merr.	Phak kayang	ผักกะแยง	swampleaf

Table 1. (continued)

Umbelliferae			
Centella asiatica (L.) Urb.	Phak nok	ผักหนอก	Asiatic pennywort, pennyweed, sheep-rot
Oenanthe javanica DC.	Phak shi naam	ผักชีน้ำ	Chinese-celery, Indian pennywort, water-celery
Zingiberaceae			
Alpinia malaccensis C.Presl	Kaa paa	คาป่า	
Curcuma singularis Gagnep.	Dok ka-jeeuw	ดอกกะเจียว	
Curcuma sp.	Dok waun	ดอกหว่าน	
Zygnemataceae			
Spirogyra sp.	Taw	เทา	
Unidentified			
sp. 1	Phak muad	ผักเหมือด	
sp. 2	Phak pe	ผักแป๋	

and perennial, while aquatic herbs were only annual plants. Trees, shrubs, bamboos and rattans were all perennial plants.

Growth location of wild food plants

From an ecological perspective, local farmers provided two major kinds of answers when they were asked where a plant grows. Firstly, (a) they gave general names of what ecologists regard as anthropogenic ecosystems, such as rice field or home garden; and secondly (b) they provided names of specific sub-systems of an anthropogenic ecosystem, such as field margin, tree row or water pond, which all are part of the rice ecosystem. In order to facilitate the analysis, the answers were grouped into six major growth locations: rice field, secondary woody area, home garden, upland field, swamp and roadside, including plants that grow in any of the sub-systems. The analysis of the ethnoecological classification of growth locations (local 'emic' categorization) was not an objective of this paper. The six major growth locations of wild food plants are the following:

- Rice field, containing a diverse range of aquatic, semi-terrestrial and terrestrial niches, is where most wild food plants, roughly 70%, can be found. Only six plants out of 61 are exclusively found in the rice fields (mainly terrestrial herbs regarded as weeds), whereas the rest can also be found in other places, mostly home gardens (64%), secondary woody areas (45%), upland fields (40%) and swamps (20%). In rice fields it is possible to find aquatic herbs such as *Nymphaea* *pubescens* and *Neptunia oleracea*; terrestrial herbs such as *Limnophila aromatica* and *Amaranthus viridis*; trees as *Borassus flabellifer* and *Leucaena leucocephala*; and climbers like *Coccinia grandis*.

- Fifty-five percent of the plants occur in secondary woody areas, which are mainly public areas located outside the farms, near upland fields. Only eight out of 48 plants were noted as growing exclusively in woody areas, whereas the rest grow also in other locations, mainly rice fields (68%) and/or home gardens (65%), some of which having been transplanted by the villagers. Most of the wild food plants growing in the woody areas are trees (65%), such as *Azadirachta indica* (also growing in home gardens and rice fields) and *Canarium subulatum* (found only in woody areas). A culturally important terrestrial herb only gathered in woody areas is *Curcuma singularis*, which is gathered in the rainy season.
- Fifty-two percent of the plants occur in home gardens. There were no plants exclusive to home gardens, all plants could be found in other locations, mainly rice fields (78%), woody areas (58%) and upland fields (49%). Many species growing in home gardens are transplanted from other areas and subject to different degrees of management, such as *Tamarindus indica*. Species in home gardens are mostly trees (e.g. *Phyllanthus acidus*) and climbers (e.g. *Tiliacora triandra* and *Momordica charantia*), followed by a few terrestrial herbs (e.g. *Centella asiatica*).
- Upland fields, mainly consisting of fields with cash crops of cassava and sugar cane, contain 37% of the wild food plant species. No plants were exclusive to the upland fields. Wild food plant species that occur in upland fields also grow in other locations, mainly woody areas (84%), rice fields (69%) and home gardens (69%). Most species are trees such as *Syzygium gratum* and *Careya arborea*.
- Swamps contained 17% of the plants. Three out of 15 plants were exclusive to swamps, but these are rarely found. The rest of the plant species also occur in rice fields, with the exception of *Neptunia javanica* which is a terrestrial herb found in home gardens and roadsides. Regarding their growth form, 75% are aquatic herbs such as *Hydrolea zeylanica*, while 25% are terrestrial herbs such as *Oenanthe javanica*.
- Thirteen percent of the plants grow on roadsides. No plants were exclusive to roadsides. All plants found at roadsides also grow in home gardens. Nine roadside plant species also occur in the rice fields, seven in the upland plantations and six in the woody areas. Most of the wild food roadside plant species were trees such as *Pithecellobium dulce* and *Cassia siamea.* There are a few climbers such as *Passiflora foetida*.

Wild food plants are widely distributed in the anthropogenic landscape. The results show that 80% of the wild food plants can be found in multiple growth locations, particularly rice fields, woods and home gardens. Forty percent of the wild food plants we documented grow in two different locations, 24% grow in three locations and 16% grow in four or more different locations. This can be explained, in part, by species being moved from one place to another facilitated by different degrees of management. This is consistent with the findings of Price (1997) and Chanaboon *et al.* (2005), who reported the presence of wild food plant management practices in Northeast Thailand.

Out of the 38 tree species, 31 (82%) are to be found in the secondary woody areas, 26 (68%) in the rice fields, 22 (58%) in home gardens and 22 (58%) in upland fields. As discussed in the introductory section, the presence of trees is a common characteristic of rice ecosystems in Northeast Thailand. Trees grow in hillocks, shelters, tree rows and pond margins diversifying the habitats and facilitating the presence of climbers and other plants in the fields (Figure 2). Most trees are maintained in paddies due to their use value (Grandstaff *et al.* 1986). For instance, two thirds of the trees are medicinal (66%) and, in addition, some provided timber and fuel.

Multiplicity of uses, including parts used

The edible parts of wild food plants vary from reproductive structures (flowers, fruits, seeds) to vegetative organs (leaves, shoots, stalks of flower, stems and sometimes the whole aerial part is consumed). For somewhat less than half of the plants only one part is edible (47%), e.g. only the shoots of *Neptunia oleracea* are consumed. More specifically, for 25% of the plants two parts are eaten, which is the case of *Adenia viridiflora* (shoot and fruit). For 12%, three parts are eaten, such as *Senna sophera* (shoot, flower and fruit). And for 16% of the plants, more than three parts are eaten as for *Limnocharis flava* (shoot, flower, stalk of flower and fruit).

In order to facilitate the analysis, eight categories of different parts consumed were established (see Figure 3):

- Young shoots sprouting from roots, stems or tips of plants are consumed in 53% of the wild food plants, such as *Bambusa bambos, Senna sophera* and *Telosma minor*. Shoots are widely consumed regardless of the growth form and life cycle of the plant.
- Fruits, which can be eaten unripe and/or ripe depending on the plant, are consumed in 39% of plants, mainly trees and climbers. The fruit of *Tamarindus indica* is very popular both unripe (it is sour, seasoned with fish sauce and chili) and ripe (it is very sweet, eaten raw or its juice added to a dish of food).
- Flowers or inflorescences are consumed for 24% of plants. Typical species are *Dolichandrone serrulata* and *Curcuma singularis.*

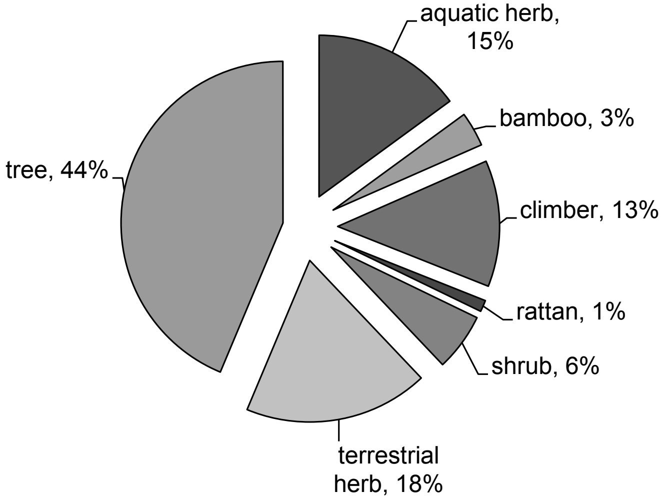

Figure 1. Growth forms of wild food plants.

Figure 2. The presence of trees characterizes the rice fields in Northeast Thailand.

- Whole aerial parts, including shoots, young leaves and tender stems, are consumed for 14% of plants. This is the case of many terrestrial and aquatic herbs including *Limnophila aromatica* and *Glinus oppositifolius*, with the exception of *Cuscuta chinensis* that is a climber.
- Leaves, mainly eaten when young and tender as a raw vegetable or cooked in traditional dishes, are consumed for 9% of plant species like the climber *Cassytha filiformis* and the tree *Leucaena leucocephala.*
- Seeds are consumed for 7% of plants. For example, the seeds of *Irvingia malayana* are eaten roasted as a snack.
- Stalks of flower or inflorescence are eaten in the case of 6% of the plants, including *Nymphaea pubescens* whose stalk is eaten raw as a side dish.
- Stems are consumed for 5% of the plants, including the edible stems of the aquatic herb *Ludwigia adscendens,* the inner core of the trunk of the tree *Borassus flabellifer* (used to make sweets), and the rhizomes of the terrestrial herb *Alpinia malaccensis*.

More than two thirds of the wild food plants presented other uses besides food (71%). Some 35% of plants had one additional use, while 26% of the plants had two additional uses, 7% had three additional uses, and three plants had four or more additional uses (see Figure 4).

- Medicine was the most widely mentioned additional use (60% of the plants). Moreover, it is remarkable that out of the 30 plants with an additional use, 28 have medicinal uses. Some examples of medicinal plants are the herbs *Centella asiatica* and *Ludwigia adscendens*.
- Fodder use was reported for 16% of the plants. More than half of these fodder plants (9 plants) are also regarded as medicine, such as *Leucaena leucocephala* and *Coccinia grandis*. Fodder plants are mostly herbs, trees and bamboos.
- Twelve percent of the plants are used as fuel, like *Nephelium hypoleucum* and *Cratoxylum formosum*. Plants used as fuel were mainly trees growing in the rice fields and home gardens, many of them are also found in the woody areas.
- Timber was reported for 8% of plants. It included trees such as *Xylia xylocarpa* and *Spondias pinnata.*
- Eight percent of the plants are used for making local handicrafts. The three bamboo plant species are typically used in handicraft production such as in weaving hang mats. The wood of *Artocarpus lacucha* is used to make a traditional musical instrument similar to a xylophone called ‘pong lang’, which is regarded as the symbol of Kalasin Province.
- Domestic use was reported for 6% of plants. For example the rattan *Calamus* sp. is used for making home utensils.

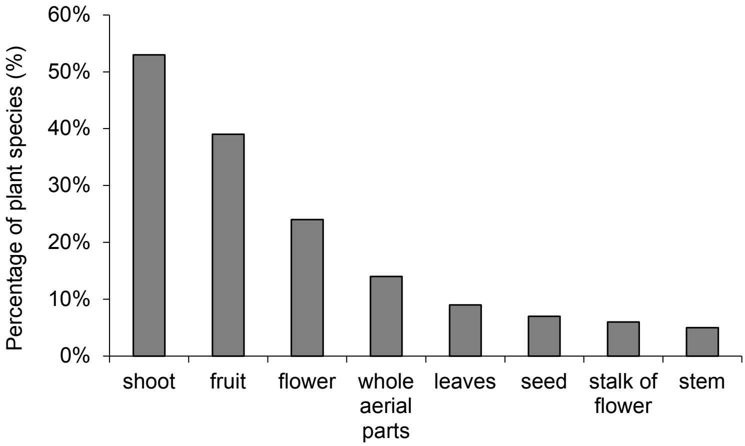

Figure 3. Edible parts of wild food plants.

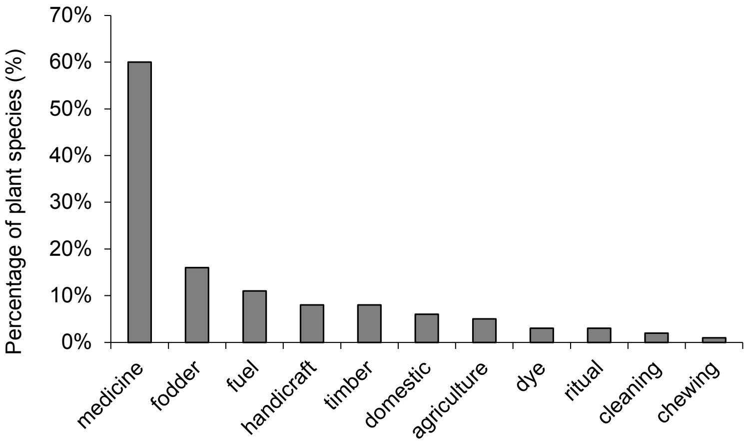

Figure 4. Additional uses of wild food plants.

- Five percent of the plants have auxiliary uses. The leaves of *Azadirachta indica* are utilized to make natural insecticide. *Leucaena leucocephala* (Leguminoseae) is used as fertilizer. All four plant species are also used as medicine.
- Ritual use was reported for 3% of the plants. The Buddhist monks spread holy water using the leaves of *Phyllanthus acidus*. Villagers make curry with the young leaves of *Aegle marmelos* and give it to the monks in blessing ceremonies.

- Dye was mentioned for 3% of plants used as natural colorants. The fruit of *Tamarindus indica* is used as dye for fish nets. The bark of *Cratoxylum formosum* is utilized to dye clothing.
- Two plants are used for cleaning, for example *Cassia siamea* is used for making shampoo.
- Only one plant is used for chewing. The bark of *Artocarpus lacucha* is chewed, sometimes with betle nut.

Consistent with the findings of Price (2005) for Northeast Thailand, the importance of wild food plants as food-medicines is present in the current findings. The results indicate that these wild food-medicine plants are important not only for their curative properties, but also for their nutritional and preventive properties. Indeed, this overlapping role as a source of both food and medicine has been documented for farmers' use of wild plants in numerous parts of the world. For example in Vietnam (Ogle *et. al.* 2006), among the Hausa of Northern Nigeria (Etkin and Ross 1982), among Albanians and Southern Italians in Lucania (Pieroni and Quave 2005), in the North West Bank, Palestine (Ali-Shtayeh *et al.* 2008), and in the Inner Mongolian Autonomous Region, China (Wujisguleng and Khasbagen 2010). Furthermore, undoubtedly, there is an overlap of food, medicine and animal feed, given that almost two thirds of fodder plants are also medicinal (9 out of 14 fodder plants). These results seem to follow the pattern of Ogle *et al.* (2006) who discussed the multiple functions of wild food plants in Vietnam.

Villagers also mentioned additional uses of wild food plants related to the ecological services they provide. For instance, they commented that the aquatic herb *Monochoria hastata,* which is regarded as a weed of rice fields, provides shade for fish. Additionally, many trees were acknowledged as habitats of red ants and other edible insects. Fish and insects, among other animals, are also gathered from the rice fields constituting an important part of the local diet.

Growth form, growth location, edible parts and additional uses of wild food plants are presented in Table 2.

CONCLUSIONS

This study shows the remarkable importance of anthropogenic ecosystems in providing wild food plants. This is reflected in the great diversity of plants found, contributing to the food and nutritional security of rice farmers in Kalasin, Northeast Thailand. The data compiled in this study shows that the majority of wild food plants grow in the different aquatic, semi-aquatic and terrestrial sub-systems offered by rice agro-ecosystems. Trees presented more plants than other growth forms, constituting an important feature of different terrestrial sub-systems of the paddies, such as hillocks, tree rows and shelters. Many important plants are aquatic and terrestrial herbs, as well as climbers. Both annual and perennial species are present in significant numbers.

One of the main findings is that most wild food plants are found in multiple locations, and more than half of them grow either in rice fields and home gardens, rice fields and woods, home gardens and woods, or rice fields, home gardens and woods. No plants were exclusive to home gardens and very few plants were exclusive to woods and rice fields. From these results we assert that farmers play an active role in managing many of these plants, for example, transplanting them from the woods to the fields or to home gardens, making them available in those anthropogenic places located closer to their house and village. This assertion follows the patterns proposed by the 'botanical dietary paradox', which clarifies the use of so many wild food plants by farmers in that when deforestation occurs, farmers change to gathering new wild food plants closer to home, including the weeds of agriculture (Ogle and Grivetti 1985; Price and Ogle 2008).

Another major point to note from the results of this research is that more than half of the wild food plants have many edible parts, and more than two thirds of them have additional uses. Shoots, sprouting from the tips of plants, stems or roots, were the most widely cited as consumed regardless of the growth form or life cycle of the plant. Fruits were also common, particularly collected from trees and climbers. Wild food plants presented more than eleven additional uses, accentuating their overall relevance for rice farmers. The most common additional use was for medicine.

The data compiled in this study highlights the necessity to better understand the role of anthropogenic ecosystems in providing wild food plant resources. Further research needs to be carried out on the seasonal quantification of their environmental availability, as well as the location of actual gathering events. Finally, research on transplanting and other management practices would allow us to better comprehend the distribution of these plants in the different ecosystems.

Table 2. Growth form, life cycle, growth location, edible parts and additional uses of wild food plants.

Scientific name	Growth form / Life cycle[a]	Growth location(s)	Edible part(s)	Additional use(s)
Aizoaceae				
Glinus oppositifolius (L.) Aug.DC.	terrestrial herb / A	rice field	whole aerial parts	
Amaranthaceae				
Amaranthus viridis L.	terrestrial herb /A	rice field, home garden	shoot, whole aerial parts	medicine, fodder
Anacardiaceae				
Mangifera caloneura Kurz	tree / P	woods, upland fields	fruit	timber, domestic
Spondias pinnata Kurz	tree / P	rice field, home garden, woods, upland fields, roadside	leaves, fruit	medicine, timber
Annonaceae				
Polyalthia debilis Finet & Gagnep.	shrub / P	home garden, woods, upland fields	fruit	medicine
Polyalthia evecta Finet & Gagnep.	tree / P	home garden, woods, upland fields	fruit	medicine
Uvaria pierrei Finet & Gagnep.	climber / P	home garden, woods	fruit	
Araceae				
Amorphophallus sp.	terrestrial herb / A	rice field, woods	shoot	
Araliaceae				
Irvingia malayana Oliver	tree / P	rice field, woods	seed	medicine, timber, fuel, fodder
Arecaceae				
Borassus flabellifer L.	tree / P	rice field, home garden, upland fields	flower, fruit, stem	medicine, handicraft
Calamus sp.	rattan / P	rice field, home garden, upland fields	shoot, fruit	domestic

Table 2. (continued)

Asclepiadaceae				
Telosma minor Craib	climber / P	rice field, home garden, woods	shoot, flower, fruit	medicine
Basellaceae				
Basella rubra L.	climber / P	rice field, home garden, woods, upland fields	shoot	medicine
Bignoniaceae				
Dolichandrone serrulata Seem.	tree / P	woods	flower	medicine
Oroxylum indicum Vent.	tree / P	rice field, home garden, woods, upland fields	shoot, flower, fruit	medicine
Burseraceae				
Canarium subulatum Guillaumin	tree / P	woods	seed	medicine, fuel, fodder
Campanulaceae				
Lobelia begonifolia Wall.	terrestrial herb / A	rice field	whole aerial parts	
Lobelia sp.	terrestrial herb / A	rice field	whole aerial parts	
Clusiaceae				
Cratoxylum formosum (Jack) Benth. & Hook.f. ex Dyer	tree / P	rice field, home garden, woods	shoot, leaves, flower	fuel, domestic, dye
Garcinia cowa Roxb.	tree / P	rice field, woods	shoot, fruit	
Compositae				
Blumea balsamifera DC.	terrestrial herb / P	rice field	shoot	medicine, ritual
Emilia sonchifolia (L.) DC.	terrestrial herb / A	rice field	whole aerial parts	
Convolvulaceae				
Cuscuta chinensis Lam.	climber / A	rice field, home garden, roadside	whole aerial parts	
Ipomoea aquatica Forssk.	terrestrial herb / P	roadside	shoot	medicine, fodder

Table 2. (continued)

Cucurbitaceae				
Coccinia grandis (L.) Voigt	climber / P	home garden, roadside	shoot, flower, fruit	medicine, fodder
Momordica charantia L.	climber / A	rice field, home garden	shoot, fruit	medicine
Ebenaceae				
Diospyros rhodocalyx Kurz	tree / P	rice field, home garden	fruit	medicine
Euphorbiaceae				
Phyllanthus acidus (L.) Skeels	tree / P	rice field, home garden	shoot, fruit	medicine, ritual
Fagaceae				
Castanopsis sp.	tree / P	woods	seed	medicine, fuel
Gnetaceae				
Gnetum sp.	tree / P	rice field, woods	seed	
Hydrocharitaceae				
Ottelia alismoides (L.) Pers.	aquatic herb / P	rice field, swamps	whole aerial parts	
Hydrophyllaceae				
Hydrolea zeylanica (L.) J.Vahl	aquatic herb / A	rice field, swamps	shoot, flower	medicine
Lauraceae				
Cassytha filiformis L.	climber / P	rice field, home garden	leaves, flower, stalk of flower, stem	
Lecythidaceae				
Barringtonia acutangula (L.) Gaertn.	tree / P	rice field, home garden	shoot, flower	
Careya arborea Roxb.	tree / P	woods, upland fields	shoot, flower	
Leguminosae				
Adenanthera pavonina L.	tree / P	home garden, woods	shoot, flower	
Cajanus cajan (L.) Millsp.	shrub / P	rice field, home garden, upland fields	seed	medicine

Table 2. (continued)

Cassia siamea Lam.	tree / P	rice field, home garden, woods, upland fields, roadside	shoot	medicine, cleaning
Dialium cochinchinense Pierre	tree / P	woods, upland fields	fruit	medicine, domestic
Leucaena leucocephala (Lam.) de Wit	tree / P	rice field, home garden, woods, upland fields, roadside	shoot, leaves, fruit	medicine, fuel, fodder, auxiliary
Neptunia javanica Miq.	terrestrial herb / P	home garden, roadside, swamps	shoot	
Neptunia oleracea Lour.	aquatic herb / p	rice field, swamps	shoot	
Pithecellobium dulce (Roxb.) Benth.	tree /P	rice field, home garden, roadside	fruit	fuel
Senna sophera (L.) Roxb.	shrub / P	rice field, home garden	shoot, flower, fruit	medicine
Sindora siamensis Teijsm. ex Miq.	tree / P	rice field, woods, upland fields	fruit	medicine
Tamarindus indica L.	tree / P	rice field, home garden, woods, upland fields, roadside	shoot, fruit	medicine, timber, fuel, fodder, dye, cleaning
Xylia xylocarpa Taub. var *kerrii* (Craib & Hutch) I.C. Nielsen	tree / P	rice field, woods, upland fields	seed	medicine, timber
Liliaceae				
Asparagus racemosus Willd.	terrestrial herb / P	rice field, home garden, woods, upland fields	shoot	
Limnocharitaceae				
Limnocharis flava Buchenau	aquatic herb / A	rice field, swamps	shoot, flower, stalk of flower, fruit	

Table 2. (continued)

Marsileaceae				
Marsilea crenata C.Presl	aquatic herb / P	rice field	whole aerial parts	medicine
Meliaceae				
Azadirachta indica A.Juss. var. *indica*	tree / P	rice field, home garden, woods, upland fields	shoot, flower	medicine, auxiliary
Azadirachta indica A.Juss. var. *siamensis* Valeton	tree / P	rice field, home garden	shoot, flower	medicine, timber, auxiliary
Menispermaceae				
Cissampelos pareira L.	climber / P	home garden, woods, upland fields	shoot, leaves	medicine
Tiliacora triandra Diels	climber / P	home garden, woods, upland fields	shoot, leaves	medicine, domestic
Menyanthaceae				
Nymphoides indica (L.) Kuntze	aquatic herb / P	swamps	shoot	
Moraceae				
Artocarpus lacucha Roxb.	tree / P	rice field, woods, upland fields	fruit	medicine, handicraft, chewing
Myrtaceae				
Psidium guajava L.	tree / P	rice field, home garden, woods, upland fields, roadside	fruit	medicine
Syzygium cumini (L.) Skeels	tree / P	rice field, home garden, woods, upland fields	fruit	medicine
Syzygium gratum (Wight) S.N.Mitra	tree / P	rice field, home garden, woods, upland fields	shoot, fruit	
Nymphaeaceae				
Nymphaea pubescens Willd.	aquatic herb / P	rice field, swamps	stalk of flower	medicine

Table 2. (continued)

Onagraceae				
Ludwigia adscendens (L.) H.Hara	aquatic herb / A	rice field, swamps	shoot, leaves, stem	medicine, fodder
Opiliaceae				
Melientha suavis Pierre	tree / P	woods	shoot, flower	
Passifloraceae				
Adenia viridiflora Craib	climber / A	woods, upland fields	shoot, fruit	medicine
Passiflora foetida L.	climber / A	rice field, home garden, upland fields, roadside	shoot, fruit	
Poaceae				
Bambusa sp.	bamboo / P	rice field, home garden, woods	shoot	fuel, handicraft, fodder
Bambusa bambos (L.) Voss	bamboo / P	rice field, woods, upland fields	shoot	handicraft, fodder
Vietnamosasa ciliata (A.Camus) T.Q.Nguyen	bamboo / P	woods	shoot	handicraft, fodder
Pontederiaceae				
Eichhornia crassipes (Mart.) Solms	aquatic herb / P	rice field, swamps	shoot, flower	handicraft, fodder
Monochoria hastata (L.) Solms	aquatic herb / A-P	rice field, swamps	shoot, flower, stalk of flower	handicraft, fodder
Monochoria vaginalis C.Presl	aquatic herb / A-P	rice field, swamps	whole aerial parts	medicine
Rhamnaceae				
Ziziphus mauritiana Lam.	tree / P	rice field, home garden, woods, upland fields, roadside	fruit	timber, fuel, dye
Ziziphus oenoplia (L.) Mill.	shrub / P	rice field, home garden, woods	fruit	medicine
Rubiaceae				
Oxyceros horridus Lour.	shrub / P	home garden, woods	shoot, leaves	medicine

Table 2. (continued)

Rothmannia wittii (Craib) Bremek.	tree / P	woods	fruit	
Rutaceae				
Aegle marmelos Corrêa	tree / P	rice field, home garden, woods, upland fields	shoot, fruit	medicine, ritual
Sapindaceae				
Lepisanthes rubiginosa (Roxb.) Leenh.	tree / P	rice field, home garden, woods	fruit	medicine
Nephelium hypoleucum Kurz	tree / P	home garden, woods, upland fields	fruit	medicine, fuel
Schleichera oleosa (Lour.) Oken	tree / P	rice field, upland fields	fruit	
Scrophulariaceae				
Limnophila aromatica Merr.	terrestrial herb / A	rice field, home garden	whole aerial parts	medicine
Umbelliferae				
Centella asiatica (L.) Urb.	terrestrial herb / P	rice field, home garden	whole aerial parts	medicine
Oenanthe javanica DC.	terrestrial herb / P	swamps	shoot	
Zingiberaceae				
Alpinia malaccensis C.Presl	terrestrial herb / P	rice field, woods	shoot, flower, stem	medicine, auxiliary
Curcuma singularis Gagnep.	terrestrial herb / P	woods	flower	medicine
Curcuma sp.	terrestrial herb / P	woods	flower, stalk of flower	medicine
Zygnemataceae				
Spirogyra sp.	aquatic herb / A	rice field, swamps	whole aerial parts	medicine
Unidentified				
sp. 1	tree / P	woods, upland fields	shoot	medicine
sp. 2	aquatic herb / A	swamps	shoot	medicine, fodder

[a] P is perennial and A is annual.

CHAPTER 5

Distribution and diversity of wild food plants in rice ecosystems of Northeast Thailand*

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Abstract
Rice fields are not only central for staple food production but also are bio-diverse and multi-functional ecosystems. Wild food plants are an important element of this biodiversity providing critical components to the subsistence system of poor farmers. In Northeast Thailand, the seasonal diversity of wild food plants across sub-systems of lowland rice fields was compared. Data was collected in 102 randomly selected sampling sites corresponding to seven different rice sub-systems. Seasonal abundance and frequency of occurrence of individual gathered plants were quantified. Shannon and Simpson diversity indexes, as well as rank abundance curves were calculated per sub-system and per season. A total of 42 species belonging to 28 families are reported. Wild food plant communities differ per sub-system and more species and higher diversity indexes were observed in the rainy season in most sub-systems. The most diverse sub-systems were shelters, hillocks, pond margins and tree rows. Ponds, dikes and field margins presented lower diversity, but are habitat of specific aquatic species important for the local diet. The multiple uses of wild food plants have implications for *in situ* conservation of rice ecosystem biodiversity.

Keywords: Abundance, diversity, rice ecosystem, seasonality, Southeast Asia, ecology, weed.

* Submitted.

INTRODUCTION

Rice ecosystems cover more than 135 million ha in Asia and represent the largest single use of agricultural land use on the continent (IRRI 2004). In the less favourable environments in Asia, approximately 80 million families rely on rice production often with small land holdings and low yields, and these are among the poorest in the world (IRRI 2005). These rice fields are often bio-diverse (Bambaradeniya and Amerasinghe 2003; Halwart 2006) and multi-functional (Huang *et al.* 2006; Matsuno *et al.* 2006) agro-ecosystems, providing ecosystem services and commodities indispensable for the poor (Grandstaff *et al.* 1986; IRRI 2007). The importance of these rice ecosystems for food security and maintenance of biodiversity, and the need for sustainable management has been emphasized by the International Rice Commission (Halwart 2006).

Lowland rice ecosystems may comprise multiple sub-systems including ponds, hillocks and tree rows in which wild food plants occur. These places have shown to be essential for wild food plant gathering. Wild food plants, or non-domesticated plants that exist on a continuum from 'truly' wild to wild cultivated and semi-domesticated plants (Harris 1989), provide critical components for the subsistence system of farmers in Northeast Thailand, which is the poorest and largest region of the country (Moreno-Black and Somnasang 2000; Price 1997). Wild food plants gathered in the rice fields of Northeast Thailand have different food uses, such as *Cassia siamea* for making a type of curry sauce (Grandstaff *et al.* 1986), *Azadirachta indica* for consuming as vegetable (Prachaiyo 2000) and *Irvingia malayana* for the use of oil seeds (Vityakon 1993). Price (1997) and Somnasang *et al.* (1988) reported that farmers in Northeast Thailand gather more wild food plants from rice fields than from any other ecosystem, whereas Maneechote (2007) and Vongsaroj (2005; 1999) emphasized the importance of edible weeds in rice fields in Thailand. The consumption of wild food plants from rice ecosystems elsewhere in South East Asia has also been reported, for example Philippines (Foronda 2007), Cambodia (Balzer *et al.* 2003) and Laos (Kosaka *et al.* 2006b).

Foods gathered in the wild have gained the attention of researchers, yet understanding the complexity of these systems is in its infancy (Heywood 1999; Scoones *et al.* 1992). Wild food plants are not commonly included in agricultural research (Chweya and Eyzaguirre 1999) and are often ignored in land-use planning, rural extension and agricultural policies (Cunningham 2000). While there has been much research on agronomy and varietal improvement, rice ecosystems are often poorly understood. This is particularly so regarding the provision of foods and medicines which may be underestimated and undervalued (Bambaradeniya and Amerasinghe 2003; Halwart and Bartley 2007; Schoenly *et al.* 1998; Vergara 2001).

Moreover, agricultural scientists may consider such food plants as weeds that compete with the crop and need to be eradicated (Bambaradeniya and Amerasinghe 2003; Chandrasena 1988), consequently most research on wild plant diversity in paddies is merely focused on weed management.

Ecological studies on the useful biodiversity of rice ecosystems are scarce (Bambaradeniya and Amerasinghe 2003; Kosaka 2006) and their ecological characterization remains a significant challenge (Schoenly *et al.* 1998), even though it is known that the distribution and diversity of these plants will affect their availability for domestic consumption, and agricultural intensification is becoming a threat to the maintenance of most rice sub-systems (Cruz-Garcia and Peters 2010). In Laos, tree species composition and distribution in relation to rice fields, levees and termite mounds were described and compared to different environments (Kosaka *et al.* 2006a; b). These studies, however, did not quantify wild food plant diversity across different rice sub-systems. To date there have been no systematic and empirically based reports that quantify wild food plant abundance in rice ecosystems of Southeast Asia. Such study could provide insights to enable the development of more productive lowland rice systems without jeopardizing the provisioning of ecosystem services which are so important for the poor (Millennium Ecosystem Assessment 2005).

A quantitative study on the seasonal diversity of wild food plants in different sub-systems of rice ecosystems in Northeast Thailand was undertaken. The objectives of the study were: (a) to quantify the seasonal abundance and occurrence of gathered plants in different sub-systems of rice ecosystems, and (b) to compare the botanical diversity of different sub-systems using diversity indices and rank abundance curves. The research followed an 'agro-ecosystem' approach which allows a more multidisciplinary and holistic perspective (Conway 1985). Accordingly, the rice agro-ecosystem not only comprises organisms, populations, communities and ecosystems as a nested hierarchy, but is also constituted by several sub-systems such as ponds and shelters. In this paper, the word 'field', when talking about 'rice fields' and 'paddy fields' with a general and plural connotation, refers to the rice ecosystem. The word 'field' when used in 'field margins' as a sub-system of the rice ecosystem, specifically refers to the borders of the rice plots.

METHODS

Study site

Northeast Thailand is geographically defined by the Korat Plateau that is generally a flat shallow depression with dispersed ponds and swamps (Parnwell 1988). Natural vegetation largely consists of dry dipterocarp forest (Prachaiyo 2000). Soils are commonly heavily leached fine sandy loams, highly saline and poorly drained, with low quantities of organic matter, phosphates and nitrogen (Parnwell 1988). Soils are either alfisols or inceptisols (see Thailand Land Development Department 2008).

Northeast Thailand has a Tropical Savannah climate (Köppen 'Aw') distinguished by a dry season extending from November to April that comprises a cool and a hot period, and a rainy season extending from May to October that is caused by an annual monsoon coming from the southwest (Tomita *et al.* 2003; Wijnhoud 2007). Meteorological data was obtained from Kamalasai station in Kalasin Province, the nearest to the research area, for the complete time range of data collection: starting at the beginning of the dry season 2007-2008 (November 2007) and finishing at the end of the rainy season of 2009 (October 2009) (Figure 1).

Northeast Thailand constitutes one of the country's main agricultural regions, with 94% of inhabitants living in rural areas. Rice is the main crop in the region grown on 70% of the arable land (Prapertchob 2001). Rain-fed rice is usually transplanted glutinous (sticky) varieties that are both the dietary staple and most significant source of income. Glutinous rice is eaten accompanied by wild food (Halwart 2006). In the dry season, if irrigation water is available, farmers grow direct seeded rice, mushrooms or vegetables; but where there is no access to irrigation no crops are grown.

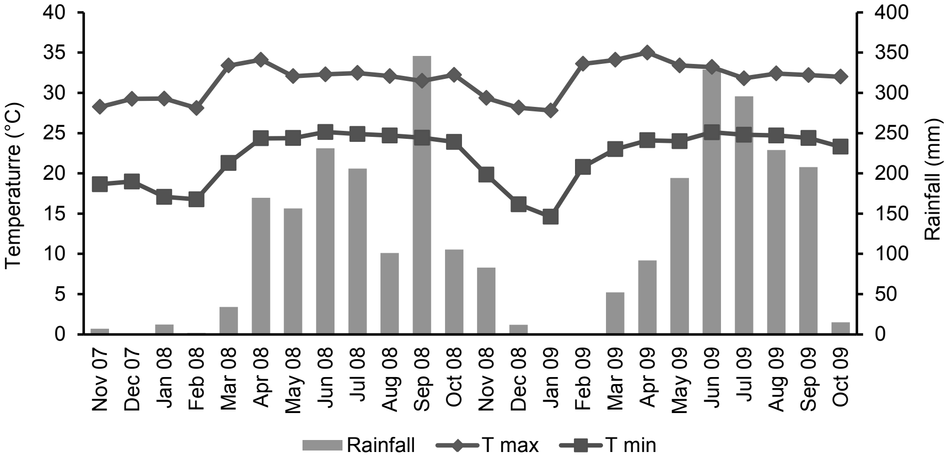

Figure 1. Maximum temperature (T max), minimum temperature (T min) and rainfall during the period of data collection: starting at the beginning of the dry season 2007-2008 (November 2007) and finishing at the end of the rainy season 2009 (October 2009).

Methods of data collection

The study was conducted in two adjacent rice farming villages in Northeast Thailand, Ban Sa-at Tai (16°25'N, 103°34'E) and Ban Sa-at Somsi (16°24'N, 103°34'E), both located in Tambon Nua, Ampher Muang, Kalasin Province. These were formerly a single village and are still connected by sharing a temple. A previous study in these villages had identified 61 wild food plants gathered from the paddy rice fields (Cruz-Garcia and Price 2011). The list of wild food plants was compared with the 'Global compendium of weeds' (HEAR 2007) and 'Weeds reported in rice in South and Southeast Asia' (Moody 1989).

Seven sub-systems of the rice ecosystems were identified from recognizance field visits where researchers and local experts walked across the rice fields around the villages to observe the sub-systems where wild food plants grew. These sub-systems were field margins, shelters, tree rows, hillocks, pond, pond margins and dikes. The fields were all at altitudes between 140 and 145 m above sea level. Sampling sites were randomly selected for each sub-system and, as required, optimal quadrat size and shape were established following Krebs (1999). A total of 102 sampling sites were identified within 19 randomly selected fields, each corresponding to different households within the village area, covering a surface of 11828 m^2. Sampling sites were recorded using GPS and positioned on a satellite map in order to re-locate the sites on subsequent visits (Figure 2). Species abundance for wild food plants was recorded in March (dry season) and September (rainy season) in the years 2008 and 2009, and frequency of occurrence was calculated. The sampling of each sub-system was conducted as follows:

- Field margins (n=22) included sampling units 10 m long and 1 m wide randomly chosen from the 13 rice fields, and together these units covered a total area of 220 m^2. The entire rice field was not sampled as wild food plants occur only on the field margins during the rainy season as the fields are occupied with transplanted rice. In the dry season, most fields are usually flooded where direct seeded rice is grown and, as a result, hardly any wild food plants occur. Even shallow water depth can prevent the growth of common rice weeds (Kent and Johnson 2001) and flooding is likely to affect the presence of certain wild food plants (Figure 3).
- Shelters (n=9) are small huts that provide temporary cover and shade, and these constitute an important place for workers to rest or to take meals when working in the paddies. Fields commonly have one or two shelters, depending their size, and some fields have a 'small garden' of food plants adjacent to the shelters. All wild food plants around sampled shelters were counted, including those in the gardens (Figure 4). All sampled shelters together covered a total area of 1945 m^2, with an average of 216 m^2 per shelter.

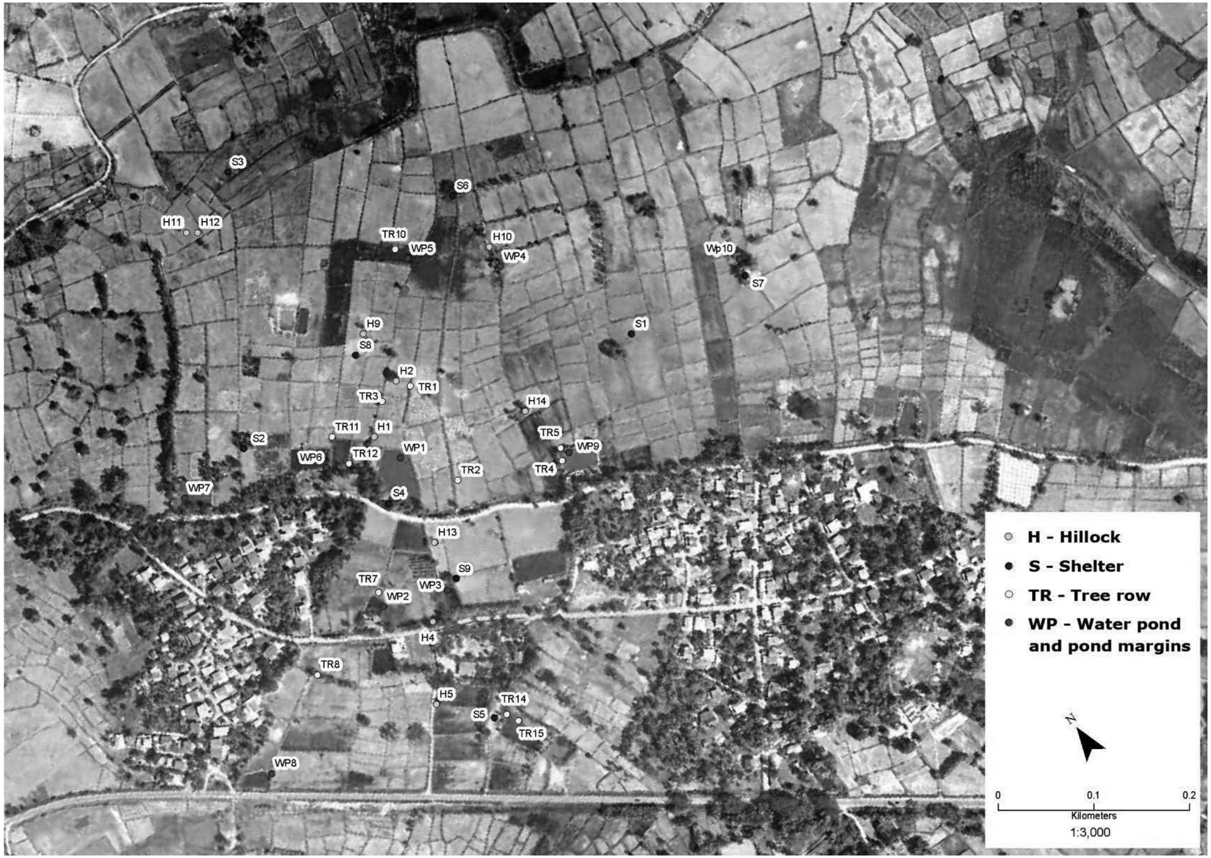

Figure 2. Satellite image of the research area showing non-randomly selected sampling sites. Sampling sites corresponding to hillocks, shelters, tree rows, water ponds and pond margins.

- Tree rows (n=12) are located in between field plots where trees were mostly planted by farmers. Generally, sampled tree rows had a width of 1 m, but differed in length. Sampled tree rows together had a total area of 705 m^2. All wild food plants growing in tree rows were recorded.
- Hillocks (n=10) are small mounds about 1 m high within the rice fields. Food plants were commonly either transplanted or were remnants from a previous forest. All wild food plants on each sampled hillock were recorded (Figure 5). All sampled hillocks together covered a total area of 919 m^2, with an average of 92 m^2 per hillock.
- Ponds (n=10) are located within the rice fields. Some remained flooded during the dry season, while others totally or partially dried out. The whole area inside each pond was sampled. Sampled ponds cover an area of 6015 m^2, with an average of 60 m^2 per pond. As aquatic plants are difficult to count, the cover percentage and density of each plant species were first estimated and then converted to total number of individuals in the pond (Figure 6).
- Pond margins (n=10) included a 2 m wide border surrounding each sampled pond. All wild food plants found in pond margins were counted. Pond margins sampled covered a total area of 1824 m^2.
- Dikes (n=20) were randomly selected every season and year, and these comprised main dikes (1.5 m wide) and primary branches of dikes (1 m wide). Each sampling site had a length of 10 m and included the levees on both sides of the dike, which were approximately 0.5 m wide at the water level in the field. Together the dikes sampled covered a total area of 200 m^2.

Methods of data analysis

Species diversity and abundance data were analysed for each season. For each species, absolute abundance and frequency of occurrence were calculated for the entire study area, by each sub-system, for each year (2008 and 2009) and by each season (dry and rainy). Absolute abundance (Ab), defined as the number of individual plants of a species per unit area (100 m^2, unless indicated otherwise), was estimated as the total number of plants divided by the total area (m^2) within all sampling sites of a particular sub-system. Frequency of occurrence, defined as the percentage of observations where the species was present, was calculated as: (a) the percentage of sampling sites where the species occurred in a sub-system ($Freq_{SS}$), and (b) the percentage of sub-systems where the species occurred ($Freq_{SUB\text{-}S}$). It is important to consider these measurements as complementary.

Figure 3. Field margins with different flooding depths.

Figure 4. Shelter in the rice ecosystem.

Figure 5. Hillock in the rice ecosystem.

Figure 6. Pond and its margins in the rice ecosystem.

Rank abundance curves[†] were plotted for each sub-system, year and season. We used the negative binomial rank abundance curve fit model developed by Neuteboom and Struik and their in-house developed software (2005a; b; c). This curve fit model is versatile and flexible as it fits linear to deeply concave abundance curves very well as long as at least five species are present. The negative binomial rank abundance curve fit model is ruled by parameters with a clear interpretation:

- k_{nb} is the exponent, an inverse index of aggregation used as the dispersion parameter of the distribution related to the amount of clustering. It ranges from zero to one when the curve is concave, is equal to one when the relationship is linear and is higher than one when the curve is convex. This parameter is thus related to the degree of concavity of the rank abundance curve. Curves with only a few dominant species have less evenness and a k_{nb} value differing from 1.
- m_{nb} is the mean of the negative binomial distribution.
- c is a parameter indicating the curvature and correcting for the level of difference between the fitted curve and the observation points: the closer to one the better the fit.

With this model a species-diversity index '$S_{n1\text{-infinite}}$' was calculated, defined as 'the expected number of singleton species (species present with one individual) in an infinitely large sample' (2005c, 167). Finally, the mean least square deviance 'LSD' was calculated, in order to assess the quality of the fit. It is expected that the closest to 0 the LSD value the better the fit. Both LSD and c are complementary measurements for explaining how good the curve fit is.

Finally, species data from sub-systems were compared according to their species richness, as well as Simpson and Shannon diversity indexes (Magurran 2004). Species richness (Sp_d) was estimated as species density or the number of species per unit area (100 m^2, unless indicated otherwise). The Shannon index, referred to as H', was obtained according to the formula:

$$H' = -\sum p_i \, Ln \, p_i$$

where p_i is the relative abundance (proportion) of individuals in the *i*th species. Higher values of this index indicate a high species evenness and richness. The Simpson index, referred to as D, was calculated with the formula:

[†] In the rank abundance curve, also termed dominance-diversity curve, species are plotted along the x axis from most to least abundant and their abundances are presented in the y axis in Log scale. The logarithm is used in order to place in the same graph species with abundances that differ in orders of magnitude (Magurran 2004). Abundance was calculated by summing up the numbers of individuals per species in a series of replicate samples (absolute abundance). The curve obtained (total rank abundance curve) is, with a level difference, the same as the rank abundance curve for the average numbers of individuals per species per sample (average rank abundance curve), and as such independent of clustering of individuals within species (Neuteboom and Struik 2005c). Rank abundance curves represent both species richness and evenness (Southwood and Henderson 2000).

$D = \sum n_i (n_i-1) / N(N-1)$

where n_i is the number of individuals in the *i*th species (absolute abundance) and N is the total number of individuals. Values of the Simpson index range from 0 to 1; values closer to 0 indicate a higher diversity.

RESULTS

Wild food plants: absolute abundance and frequency of occurrence

A total of 42 wild food plant species, within 28 families, were observed, and 126826 individuals were counted in 2008 and 133459 in 2009 within a total sampled area of 11828 m^2, with averages of 1072 and 1128 individuals per 100 m^2 respectively. The most common family was Leguminosae represented by eight species (four Caesalpinioideae, three Mimosoideae and one Papilionoideae), followed by Pontederiaceae with three species. A total of 31 species was observed in the dry season (Appendices 1 and 2) and 40 species were found in the rainy season (Appendices 3 and 4). Twenty nine species were found in both seasons, while 11 were exclusive to the rainy season and 2 to the dry season. According to their growth form, 17 species (40%) were trees, 10 (24%) aquatic herbs, six (14%) terrestrial herbs, five (12%) climbers, three (7%) shrubs and one (2%) rattan. Absolute abundances and frequencies of occurrence ($Freq_{SS}$ and $Freq_{SUB\text{-}S}$) were consistent between the two years of sampling, thus it was possible to work with the averages of the years for species absolute abundance and frequency of occurrence.

Seventy six percent of the species are cited as weeds by the Global Compendium of Weeds (HEAR 2007), 43% of the species were considered weeds in rice fields of South and Southeast Asia (Moody 1989) and 33% of the species were considered weeds in rice fields in Thailand (Moody 1989) (Appendices 1 and 3). All species classified as weeds of rice fields in Thailand were herbs (either aquatic or terrestrial) whereas plants classified as weeds by HEAR (2007) include trees, shrubs and climbers. Some examples of edible herbs classified as weeds are *Ipomoea aquatica, Marsilea crenata, Ottelia alismoides* and *Monochoria vaginalis*.

The most abundant species observed in the dry season were the herbs *Lobelia* sp. and *Glinus oppositifolius*, both classified as rice weeds (Moody 1989) with 87000 and 28250 individuals counted, respectively, averaged across the years 2008 and 2009. These are small herbs observed only in the dry season covering a substantial portion of the surface of dried ponds and their margins (5095 m^2 and 2744 m^2 respectively). They are commonly eaten by the villagers during this period constituting an important component of food security. The weedy herbs *Ipomoea aquatica, Marsilea crenata, Neptunia oleracea* and *Nymphaea pubescens* were also dominant, observed in areas with some access to water. *Leucaena leucocephala*, whose roots, leaves and fruits are commonly consumed as vegetable, was the most abundant tree in most sub-systems. Absolute abundance of food plant species was closely related to growth form with herbs occurring in highest numbers. To provide indication of spatial distribution the frequency of occurrence of the plants in the different sub-systems ($Freq_{SUB-S}$) was calculated. Across the seven sub-systems, the trees *Leucaena leucocephala, Azadirachta indica* A. Juss. var. *siamensis*, *Tamarindus indica* and *Ziziphus mauritiana* had the greatest occurrence (highest $Freq_{SUB-S}$) in the dry season and were found in four out of seven sub-systems. Fourteen species occurred in three out of seven sub-systems while more than half of the species (18 of 31) grew in only one or two sub-systems.

The most abundant species in the rainy season across all sub-systems was *Ipomoea aquatica* (locally called 'phak bung'), with a mean annual total number of 7946 individuals growing in rice field margins, dikes, ponds and margins at an average density equivalent to approximately one individual per 100 m^2. This species, which is common in the local cuisine with its shoots being eaten as vegetable, is used as medicine and animal fodder, but susceptible to locally sold herbicides. Other abundant species in the wet season were the aquatic weedy plants *Marsilea crenata*, *Neptunia oleracea, Eichhornia crassipes* and *Nymphaea pubescen*s. The weedy herbs *Ottelia alismoides* and *Centella asiatica*, which were not found in the dry season, were also observed in large quantities. Only 23% of species (nine out of 40) grew in four or more of the sub-systems. The species occurring in most sub-systems in the rainy season (highest $Freq_{SUB-S}$) were the trees *Cassia siamea*, *Azadirachta indica* var. *siamensis,* as well as the aquatic fern *Marsilea crenata* (71% or five out of seven subsystems), with *Cassia siamea* seedlings being more frequent in the rainy season. The herbs *Ipomoea aquatica* and *Hydrolea zeylanica*, as well as the trees *Tamarindus indica*, *Psidium guajava, Leucaena leucocephala* and *Ziziphus mauritiana* were present in four out of seven sub-systems. Trees were expected to be found in the similar quantities and frequencies in both seasons, yet in some cases they presented higher quantities and frequencies in the rainy season due to the presence of seedlings. Many tree seedlings, however, did not survive through the dry season. Sixty percent of plant species were observed in only one or two sub-systems.

The seasonality of species abundance differed between sub-systems:

- Field margins only contained wild food plants in the rainy season while transplanted rice was present. The aquatic fern *Marsilea crenata* had the greatest absolute abundance, followed by the aquatic weedy herb *Ottelia alismoides*. These occurred in 52% and 16% of the sampling sites respectively ($Freq_{SS}$). *Monochoria vaginalis* and *Ipomoea aquatica* were also present though at lower frequencies of occurrence. Duration and depth of flooding of the field affected the presence of herbs, and hardly any wild food plants were present in fields with the deepest flooding. All herbs found were classified as weeds of rice and worldwide (HEAR 2007; Moody 1989).

- In shelters, *Leucaena leucocephala* (56% of the sites) was the most abundant and frequently occurring species across both seasons. *Spondias pinnata* and *Tamarindus indica* were present in large numbers at more than half of sampled sites during both seasons ($Freq_{SS}$). *Azadirachta indica* var. *siamensis* was also abundant and frequent. *Coccinia grandis*, regarded as weed in Southeast Asia, occurred mainly in the rainy season and was present at 44% of the sites.
- As trees were the main component of the tree row sub-system, there was hardly any difference in species composition between dry and rainy seasons, apart from the presence of the herbs *Centella asiatica* and *Marsilea crenata* in the rainy season at some of the sites. The most abundant trees were *Azadirachta indica* var. *siamensis* and *Spondias pinnata*; the latter was the most frequent (33% of sampling sites).
- On hillocks, the trees *Lepisanthes rubiginosa* and *Leucaena leucocephala* were the most abundant plants in both seasons. Trees occurred at 10 to 20% of the sampling sites ($Freq_{SS}$) and were more frequent than climbers and shrubs, which were also characteristic of hillocks.
- In ponds, the most abundant plant in the rainy season was *Ipomoea aquatica*, also most frequently occurring in the surveyed ponds (80% in the rainy season). The aquatic herbs *Neptunia oleracea*, *Nymphaea pubescens* and *Eichhornia crassipes* were also very abundant during the rainy season and grew together with *Ipomoea aquatica* in those ponds that remained flooded during the dry season. While these aquatic species were the most abundant during the rainy season, the small terrestrial herbs *Lobelia* sp. and *Glinus oppositifolius* were present in very high numbers in dried-out ponds in the dry season and respectively covered up to 65% and 35% of the area.
- In pond margins the most frequently occurring trees were *Leucaena leucocephala, Tamarindus indica* and *Psidium guajava*, present in 35-45 % of sample sites in both seasons. *Leucaena leucocephala* was the most abundant tree, followed by *Cassia siamea* and *Spondias pinnata.* Herbs were also abundant in pond margins, especially *Ipomoea aquatica* that was present in 20% of the sites in both seasons ($Freq_{SS}$). *Glinus oppositifolius* was the most abundant herb in the dry season, whereas *Centella asiatica* was also abundant in the rainy season.
- In dikes, the most abundant plant was *Marsilea crenata* in both seasons, while *Ipomoea aquatica* was abundant during the rainy season. Both plants occurred

with the greatest $Freq_{SS}$ in the rainy season and were present in 28% of the sampling sites. During the dry season, in more than 90% of the sampling sites no plants occurred.

Commonly, the most abundant species also had the greatest frequencies of occurrence, but this was not always the case. Some trees or climbers, with low abundances in comparison to herbs, presented high frequencies of occurrence ($Freq_{ss}$). For example, *Tamarindus indica* appeared in 56% of the sampled shelters in the dry season but with an absolute abundance of 0.5 individuals per 100 m^2 (10 individuals counted). The opposite also occurred, for example, the tree *Azadirachta indica* var. *siamensis* had a high absolute abundance of 1.3 individuals per 100 m^2 (20 individuals counted) but in the dry season occurred at only 22% of sampled shelters.

The species with the lowest abundance in the sampled area were the trees *Dialium cochinchinense*, *Borassus flabellifer*, *Careya arborea*, *Schleichera oleosa,* the shrub *Polyalthia debilis* and the climber *Telosma minor.* They not only presented the lowest absolute abundances but also occurred in only one sub-system. *Dialium cochinchinense* and *Borassus flabellifer* presented only one individual growing in a shelter, and *Careya arborea* presented one individual found in a hillock. These plants were only observed during the first year of research as by the second year they were cut down by the villagers. *Schleichera oleosa* also occurred as two individuals in a shelter, one of these was cut down; and one individual *Polyalthia debilis* on a hillock and two in a shelter were all cut down in the second year of study. *Telosma minor*, which only occurs during the rainy season, was only observed during the first year. None of these plants were classified as weed, except *Careya arborea* that is considered a weed by HEAR (2007).

Some plants were only found in one sub-system and in only one season, likely due to their specific niche requirements especially regarding water, but were present in large absolute abundances. These included the aquatic herbs *Eichhornia crassipes*, *Neptunia oleracea*, *Nymphaea pubescens*, *Monochoria hastata*, growing in ponds, and *Ludwigia adscendens* and *Monochoria vaginalis* both growing in rice field borders during the rainy season. Also the terrestrial herbs *Emilia sonchifolia* (present on the dikes during the rainy season), and *Lobelia* sp. and *Glinus oppositifolius* (growing in the ponds during the dry season when the water has dried up) belong to this category. *Glinus oppositifolius* was also found in the borders of the ponds. All these species were classified as weeds in rice fields in Southeast Asia (Moody 1989).

Diversity indexes at sub-system level

Shannon and Simpson diversity indexes, as well as species richness (species density) were consistent across the two years of sampling (2008 and 2009) in all rice sub-systems, allowing the mean values for the two years to be compared (Tables 1 and 2). In comparing sub-systems, using Shannon and Simpson indices yielded similar results, which were consistent in both seasons, whereas the results obtained from analysing species density showed large seasonal fluctuations. As no species were observed in field margins in the dry season, this sub-system was excluded from the analysis for this season.

Table 1. Species density (Spd), Shannon diversity index (H') and Simpson diversity index (D) of wild food plants per sub-system in the dry season[1].

Sub-system	Sp_d[2]	H'	D
field margin	N.A.[3]	N.A.	N.A.
shelter	0.72	1.75	0.27
tree row	1.70	2.15	0.13
hillock	1.09	1.69	0.26
pond	0.09	0.60	0.63
pond margin	0.79	0.55	0.80
dike	1.25	0.04	0.99

[1] All values are averages of the years 2008 and 2009.
[2] Number of species per 100 m^2.
[3] Not applicable because no species were observed in the sampled area.

Table 2. Species density (Sp_d), Shannon diversity index (H') and Simpson diversity index (D) of wild food plants per sub-system in the rainy season[1].

Sub-system	Sp_d[2]	H'	D
field margin	3.18	0.57	0.72
shelter	0.85	1.71	0.34
tree row	1.84	1.07	0.56
hillock	1.25	1.64	0.26
pond	0.11	0.86	0.59
pond margin	0.96	1.64	0.34
dike	3.00	0.75	0.62

[1] All values are averages of the years 2008 and 2009.
[2] Number of species per 100 m^2.

In general, more wild food species were found in the rainy season in all sub-systems than in the dry season, as these are subject to water availability. Many wild food plants require some care in order to survive in the dry season. Highest species density in the dry season occurred in tree rows (Sp_d=1.70), where different transplanted species (12 species on average) are closely planted. In the rainy season, field margins showed the highest species density (Sp_d=3.18), followed by dikes (Sp_d=3.00). In both cases, the results were affected by the small sampling area rather than the low number of species observed in this season. Farmers tended to collect wild food plants from rice borders rather than dikes, which is perhaps a function of where people usually walked. Ponds showed the lowest species density in both seasons (Sp_d=0.09 in the dry season and Sp_d=0.11 in the rainy season).

Comparing seasons using the Shannon and Simpson diversity indices shows dikes, field margins and pond margins to have increased diversity in the rainy season compared to the dry season, while this was less so in ponds. The former sub-systems offer moist and wet conditions to plants during the rainy season rather than extended intervals of flooding, as in ponds, which limits the range of species tolerant of this. Further, at the ponds and margins the herbs *Glinus oppositifolius* and *Lobelia* sp., which tended to be dominant, were not present during this period. Conversely, in tree rows the wild food plant diversity sharply decreased in the rainy season due to the presence of *Centella asiatica* and *Marsilea crenata,* which were dominant. Wild food plant diversity in hillocks and shelters was similar between seasons.

Tree rows, which is a managed sub-system, showed the highest diversity (H'=2.15, D=0.13) in the dry season based on the Shannon and Simpson diversity indices, followed by shelters (H'=1.75, D=0.27) and hillocks (H'=1.69, D=0.26). Shelters (H'=1.71, D=0.34) and hillocks (H'=1.64, D=0.26) also showed a high diversity in the rainy season together with pond margins (H'=1.64, D=0.34), where this high diversity is explained by the moist/wet conditions.

Dikes had least diversity in the dry season (H'=0.04, D=0.99) together with water ponds (H'=0.60, D=0.63) and their margins (H'=0.55, D=0.80), due not only to lack of water but also low evenness and the presence of dominant herbs in dry conditions (see above). In the rainy season, field margins (H'=0.57, D=0.72) and dikes (H'=0.55, D=0.80) had the least diversity.

Sub-systems and the negative binomial rank abundance curve fit

Rank abundance curve fit values according to the negative binomial model indicate differences between years of sampling, and hence results are presented separately for 2008 and 2009 (Tables 3 and 4). Rank abundance curves were not fitted for dikes and field margins in the dry season as there were less than five species present (no wild plant species were observed in field margins in this season), which is the minimum required for conducting this analysis. Comparisons of negative binomial values excluded these two sub-systems.

Mean least square deviations (LSD) and curvatures (c) from analyses of negative binomial rank abundance for sub-systems were consistent between the dry seasons of 2008 and 2009 (Table 3). Good curve fits are apparent for the dry season data for shelters, hillocks and pond margins, as shown by curvatures (c) that were close to 1 in both years, as well as the good quality of the fits (with LSD values close to 0). Values for ponds (c= 0.636 in 2008, c=0.732 in 2009) and tree rows (c=0.782 in 2008 and

Table 3. Parameters of the negative binomial rank abundance curves fit in the dry season for the years 2008 and 2009.

Sub-system	S_{n1}[1]	m_{nb}[2]	k_{nb}	c	LSD[3]
			year 2008		
field margin	N.A.[4]	N.A.	N.A.	N.A.	N.A.
shelter	10.52	2.503	0.249	0.951	0.067
tree row	16.98	8.064	0.489	0.782	0.040
hillock	18.67	5.414	0.298	0.844	0.041
pond	0.77	0.072	0.189	0.636	0.546
pond margin	8.01	0.337	0.045	0.998	0.050
dike	N.A.	N.A.	N.A.	N.A.	N.A.
			year 2009		
field margin	N.A.	N.A.	N.A.	N.A.	N.A.
shelter	5.32	2.084	0.430	0.978	0.071
tree row	16.98	8.064	0.489	0.782	0.040
hillock	12.40	3.765	0.316	0.867	0.036
pond	0.77	0.071	0.189	0.732	0.346
pond margin	21.00	1.031	0.050	1.010	0.087
dike	N.A.	N.A.	N.A.	N.A.	N.A.

[1] Species diversity index defined as the expected number of singleton species (species present with one individual) in an infinitely large sample.

[2] Parameters of the negative binomial curve fit.

[3] Mean least square deviance.

[4] Not applicable because less than five species were observed, which is the minimum required to conduct analysis.

Table 4. Parameters of the negative binomial rank abundance curve fit in the rainy season for the years 2008 and 2009.

Sub-system	S_{n1}[1]	m_{nb}[2]	k_{nb}	c	LSD[3]
			year 2008		
field margin	1.27	0.217	0.257	1.029	0.077
shelter	13.86	3.860	0.289	0.953	0.024
tree row	11.94	1.827	0.160	0.958	0.057
hillock	11.19	2.882	0.269	1.022	0.189
pond	2.38	0.615	0.320	1.027	0.098
pond margin	8.70	1.951	0.237	1.011	0.037
dike	0.52	0.647	3.398	0.993	0.236
			year 2009		
field margin	1.85	0.204	0.146	1.045	0.397
shelter	8.90	2.018	0.240	0.982	0.049
tree row	46.51	2.913	0.063	0.932	0.034
hillock	7.78	2.427	0.333	0.973	0.112
pond	0.40	0.472	4.278	0.997	0.496
pond margin	7.28	2.221	0.327	1.000	0.053
dike	5.66	0.249	0.048	0.988	0.007

[1] Species diversity index defined as the expected number of singleton species (species present with one individual) in an infinitely large sample.

[2] Parameters of the negative binomial curve fit.

[3] Mean least square deviance.

2009) indicate substantial differences between the fitted curve and the observation points. In the tree rows the curvature data are likely influenced by more intensive management. For ponds, which also showed a poor fit (LSD=0.546 in 2008, LSD=0.346 in 2009), a low curvature could be partly explained by the low number of species.

The curvature values for data from all sub-systems in the rainy season indicate the fitted curves closely matched the data points well for both years. Further, the LSD values were low for shelters, hillocks, pond margins and tree rows in both years (Table

4). Dikes, field margins and ponds, however, showed some differences between 2008 and 2009 regarding LSD[‡].

The diversity in tree rows, hillocks and ponds was consistent in the dry season of both years regarding $S_{n1\text{-infinite}}$ diversity index (Table 3). Tree rows and hillocks presented the highest diversity, whereas ponds the lowest in this season. These results were fully consistent with those obtained with Shannon and Simpson diversity indexes. S_{n1} index indicates variability between both sampling years for shelters and pond margins. These differences were not observed in the results of Shannon and Simpson indexes in either year.

In the rainy season, S_{n1} index in field margins, shelters, hillocks and pond margins was consistent for both sampling years (Table 4). Tree rows, shelters and hillocks, followed by pond margins, showed the highest diversity. On the other hand, despite the variability between both years as illustrated by convex curves in either 2009 or 2008, ponds and dikes presented a low S_{n1} value. Field margins also presented low S_{n1} diversity. Very similar trends were observed in the results obtained with Shannon and Simpson indexes.

The parameters k_{nb} and m_{nb} of the negative binomial rank abundance curve were consistent for both sampling years in the dry season (Table 3). The highest value was for tree rows (k_{nb}=0.489 in 2008 and 2009, m_{nb}=8.064 in 2008 and 2009) followed by hillocks and shelters, explained by having less dominant species and a higher mean for the binomial distribution. These sub-systems presented a higher diversity according to the indexes previously analysed. On the contrary, the values of k_{nb} and m_{nb} were the lowest for ponds and their margins, indicating the presence of few dominant species in the dry season. This can be explained by the extreme abundance values of the herbs *Lobelia* sp. and *Glinus oppositifolius,* distinctive of this season, which covered a large percentage of dried pond surfaces and their margins.

In the rainy season, all values of m_{nb} were consistent between both years, whereas k_{nb} was consistent for all ecosystems except ponds and dikes, which were the only sub-systems presenting a convex curve in one of these years (k_{nb}=0.320 in 2008, k_{nb}=4.278 in 2009; k_{nb}=3.398 in 2008, k_{nb}=0.048 in 2009, respectively). The convexity of the curve is related to a value of k_{nb} higher than 1, indicating the presence of several dominant species and very few with low abundance. Hillocks, shelters and pond margins presented higher means for the binomial distribution (m_{nb}) and higher values of k_{nb}, indicating that these sub-systems have less dominant species than the others. This was reflected in their higher diversity values.

[‡] Having a good curvature but not an adequate LSD can be explained by the presence of extreme values in the data set (which is the case of field margins) or by the convexity of the curve fit (which was characteristic of ponds and dikes) in either years.

DISCUSSION

Rain-fed and irrigated rice fields, with a temporary dry phase in this region, have been defined as 'temporary, seasonal wetland ecosystems agronomically managed with a variable degree of intensity' (Bambaradeniya and Amerasinghe 2003, 3). Wild food plants growing in paddy rice fields are scattered throughout the agro-ecosystem resulting in a 'mosaic of rapidly changing ecotones' (Bambaradeniya and Amerasinghe 2003, 6), presenting a patchwork of diverse aquatic, semi-aquatic and terrestrial habitats that interact ecologically (Fernando 1995; IRRI 2004). Hillocks, shelters, pond margins and tree rows are examples of sub-systems providing terrestrial habitats during the rainy season when many areas are flooded. Dikes can be temporarily dry or flooded and these constitute sub-systems with semi-aquatic habitats. Fields and ponds remain flooded during the rainy season (and in the dry season when irrigation water is available), providing aquatic habitats for wildlife. All seven sub-systems are important in providing wild food plants to farmers in Northeast Thailand thereby helping to ensure their food and nutritional security.

Rice fields in the study possess a great diversity of wild food plants, reflected in the observation and quantification of 42 species belonging to 28 botanical families. Wild plant communities are different for each of the sub-systems (Chandrasena 1988). Hillocks and shelters are characterized by the presence of trees, climbers and shrubs, whereas water pond margins also contain terrestrial and aquatic herbs. Ponds, field margins and dikes mainly comprise aquatic and terrestrial herbs, while in tree rows mainly trees and shrubs are observed. Many wild food plants in the rice-based ecosystem may be regarded as opportunistic biota, which are physiologically adapted to the ecological conditions and temporal variation during the crop cycles (Bambaradeniya 2003) and well adapted to anthropogenic disturbance (Shimoda 2007). This is reflected in the fact that the most abundant and frequently occurring aquatic and terrestrial herbs are classified as rice weeds in South and Southeast Asia (Moody 1989).

Wild food plant diversity and use-values

Almost three quarters of the wild food plant species have additional uses besides food, such as medicinal, animal fodder, fuel, timber, agricultural, domestic, ritual, for making handicraft, cleaning and dying (Cruz-Garcia and Price 2011). About one third (38%) of the wild food plant species have between two to six additional uses besides food, while 36% have one additional use which is mainly medicinal. At least half of the species observed in every sub-system has additional uses besides food (Table 5).

Table 5. Additional uses of wild food plants in rice sub-ecosystems.

	% species with additional uses
tree row	93
pond margin	81
hillock	87
field margin	78
shelter	89
pond	50
dike	80

More than 80% of wild food plants in tree rows, shelters and hillocks had additional uses.

It is not just by chance that many wild food plants have multiple uses, and farmers maintain and encourage selected species in their fields based on their perceptions of rarity and level of use value (Price 2003). These perceptions influence farmer interactions with the species in their fields affecting species abundance and distribution (Grandstaff *et al.* 1986). The results obtained confirm Grandstaff's findings, given that 82% of trees, which tended to have either been transplanted or were remnants from a previous forest, had multiple uses. The same pattern was reported for Champasak, southern Lao (Natuhara *et al.* In press) where most trees around paddy fields are regarded as useful by local farmers.

Comparison of diversity indexes and sub-systems

The diversity index of most sub-systems increased in the rainy season (95% of recorded species). Shelters, hillocks and pond margins were the most diverse, as reflected in the indexes (S_{n1}, H' and D); whereas in the dry season the highest diversity values were for tree rows and hillocks. Farmers protect or encourage certain wild food plants to use or eat while they are resting or having lunch in the shelters usually during the harvesting period. Many shelters have small fenced gardens with protected plants. Likewise, hillocks are important for the value of the trees that grow there. The same is the case of tree rows, which are increasingly managed sub-systems. Pond margins are highly diverse sub-systems due to the wide variety of habitats they offer, which are not only suitable for woody species, but also for aquatic herbs that grow with the presence of moist and wet conditions.

Although ponds, dikes and field margins showed the least species diversity in both seasons, these comprise unique habitats for weedy herbs and other aquatic wild food plants, such as *Nymphaea pubescens*, which are an important component of the local cuisine. This is supported by the analysis of frequency of occurrence ($Freq_{SUB-S}$). Some species are specific to one or two sub-systems due to particular niche requirements, whereas others are present in different sub-systems under a wide range of ecological conditions. More than half of the plants occurred in only one or two sub-systems in both seasons, and most of these species were present with very low abundance. Consequently, it is clear that specific sub-systems are crucial for the maintenance of certain specific plant species. From these results we assert that all sub-systems, regardless their diversity index, are important for the 'in situ' conservation of biodiversity in rice ecosystems of Northeast Thailand.

Contribution to ecosystem services

This study highlights that diversity of species and sub-systems in rice fields are important provisioning components of ecosystem services, specifically as a source of food. But agricultural intensification, which leads to landscape homogenization, constitutes a threat to this biodiversity and the ecosystem services it provides. Ecosystem service degradation has negative consequences for human well-being constituting an impediment to the achievement of the Millennium Development Goals (Haines-Young and Potschin 2010; Millennium Ecosystem Assessment 2005). If rice field's sub-systems, such as shelters, tree rows or hillocks, would disappear, it would certainly affect the availability of several important plant species, threatening the food and nutritional security of poor households. It is imperative to recognize that the value of paddy rice fields is not purely economic and goes far beyond that only rice yield.

Appendix 1. Wild food plants observed in the dry season, classified by growth form and ordered by family and scientific name, indicating weed category and absolute abundance (Ab) [1] as number of individuals of a species per 100 m^2.

Botanical family	Scientific name	Weed category[2]	field margin	shelter	tree row	hillock	pond	pond margin	dike
Aquatic herb									
Hydrophyllaceae	*Hydrolea zeylanica* (L.) J.Vahl	G / SEA / Th					0.8		
Leguminosae	*Neptunia oleracea* Lour.	G / SEA					2.5		
Limnocharitaceae	*Limnocharis flava* Buchenau	G / SEA / Th					0.6		
Marsileaceae	*Marsilea crenata* C. Presl	G / SEA / Th							25.0
Nymphaeaceae	*Nymphaea pubescens* Willd.	G / SEA / Th					1.3		
Pontederiaceae	*Eichhornia crassipes* (Mart.) Solms	G / SEA / Th					0.6		
Climber									
Cucurbitaceae	*Coccinia grandis* (L.) Voigt	G / SEA		0.3		0.2			
	Momordica charantia L.	G						0.3	
Menispermaceae	*Tiliacora triandra* Diels			0.5					
Shrub									
Leguminosae	*Cajanus cajan* (L.) Millsp.	G		0.5	0.4			0.2	
	Senna sophera (L.) Roxb.	G				0.5		0.4	0.3
Terrestrial herb									
Aizoaceae	*Glinus oppositifolius* (L.) Aug. DC.	G / SEA / Th					448.9	68.5	
Campanulaceae	*Lobelia* sp.	G / SEA / Th					1446.4		
Convolvulaceae	*Ipomoea aquatica* Forssk.	G / SEA / Th					14.3	4.1	0.3
Tree									
Anacardiaceae	*Spondias pinnata* Kurz	G		0.5	1.0			0.4	
Araliaceae	*Irvingia malayana* Oliver				0.1	0.2			
Arecaceae	*Borassus flabellifer* L.			0.5					

Appendix 1. (continued)

Euphorbiaceae	*Phyllanthus acidus* (L.) Skeels	G	0.1	0.1				
Lecythidaceae	*Barringtonia acutangula* (L.) Gaertn.		0.3	0.3			0.2	
	Careya arborea Roxb.	G			0.2			
Leguminosae	*Cassia siamea* Lam.	G	0.3		0.2		0.5	
	Dialium cochinchinense Pierre		0.3					
	Leucaena leucocephala (Lam.) de Wit	G	2.8	0.1	0.9		1.4	
	Pithecellobium dulce (Roxb.) Benth.	G	0.2		0.2		0.2	
	Tamarindus indica L.	G	0.5	0.3	0.2		0.3	
Meliaceae	*Azadirachta indica* A. Juss. *var. siamensis* Valeton	G	1.3	1.3	0.3		0.2	
Myrtaceae	*Psidium guajava* L.	G	0.5	0.1			0.2	
	Syzygium cumini (L.) Skeels	G		0.3			0.2	
Rhamnaceae	*Ziziphus mauritiana* Lam.	G		0.3	0.2		0.5	2.3
Sapindaceae	*Lepisanthes rubiginosa* (Roxb.) Leenh.			0.1	2.2		0.4	
	Schleichera oleosa (Lour.) Oken		0.8					

[1] All values are averages of the years 2008 and 2009.

[2] G, globally classified as weed by the Global Compendium of Weeds (HEAR 2007); SEA, weed in rice fields in South and Southeast Asia (Moody 1989); Th, weed present in rice fields of Thailand (Moody 1989); blank spaces mean that the plant is not classified as weed.

Appendix 2. Wild food plants observed in the dry season, classified by growth form and ordered by family and scientific name, indicating frequency of occurrence ($Freq_{SS}$) [1] as percentage of sampling sites where a species occurred in a sub-system.

Botanical family	Scientific name	field margin	shelter	tree row	hillock	pond	pond margin	dike
Aquatic herb								
Hydrophyllaceae	*Hydrolea zeylanica* (L.) J.Vahl					0.05		
Leguminosae	*Neptunia oleracea* Lour.					0.10		
Limnocharitaceae	*Limnocharis flava* Buchenau					0.05		
Marsileaceae	*Marsilea crenata* C. Presl							0.08
Nymphaeaceae	*Nymphaea pubescens* Willd.					0.05		
Pontederiaceae	*Eichhornia crassipes* (Mart.) Solms					0.05		
Climber								
Cucurbitaceae	*Coccinia grandis* (L.) Voigt		0.06		0.05			
	Momordica charantia L.						0.05	
Menispermaceae	*Tiliacora triandra* Diels		0.11					
Shrub								
Leguminosae	*Cajanus cajan* (L.) Millsp.		0.11	0.08			0.10	
	Senna sophera (L.) Roxb.				0.05		0.05	0.03
Terrestrial herb								
Aizoaceae	*Glinus oppositifolius* (L.) Aug. DC.					0.30	0.10	
Campanulaceae	*Lobelia* sp.					0.10		
Convolvulaceae	*Ipomoea aquatica* Forssk.					0.55	0.20	0.03
Tree								
Anacardiaceae	*Spondias pinnata* Kurz		0.50	0.33			0.10	
Araliaceae	*Irvingia malayana* Oliver			0.08	0.20			
Arecaceae	*Borassus flabellifer* L.		0.11					

Appendix 2. (continued)

Euphorbiaceae	*Phyllanthus acidus* (L.) Skeels	0.22	0.08				
Lecythidaceae	*Barringtonia acutangula* (L.) Gaertn.	0.11	0.08			0.20	
	Careya arborea Roxb.			0.10			
Leguminosae	*Cassia siamea* Lam.	0.22		0.20		0.20	
	Dialium cochinchinense Pierre	0.06					
	Leucaena leucocephala (Lam.) de Wit	0.44	0.08	0.25		0.45	
	Pithecellobium dulce (Roxb.) Benth.	0.22		0.20		0.15	
	Tamarindus indica L.	0.56	0.17	0.10		0.45	
Meliaceae	*Azadirachta indica* A. Juss. *var. siamensis* Valeton	0.22	0.17	0.20		0.20	
Myrtaceae	*Psidium guajava* L.	0.11	0.08			0.30	
	Syzygium cumini (L.) Skeels		0.17			0.20	
Rhamnaceae	*Ziziphus mauritiana* Lam.		0.17	0.10		0.10	0.03
Sapindaceae	*Lepisanthes rubiginosa* (Roxb.) Leenh.		0.08	0.20		0.10	
	Schleichera oleosa (Lour.) Oken	0.11					

[1] All values are averages of the years 2008 and 2009.

Appendix 3. Wild food plants observed in the rainy season, classified by growth form and ordered by family and scientific name, indicating weed category and absolute abundance (Ab) [1] as number of individuals of a species per 100 m^2.

Botanical family	Scientific name	Weed category[2]	field margin	shelter	tree row	hillock	pond	pond margin	dike
Aquatic herb									
Hydrocharitaceae	*Ottelia alismoides* (L.) Pers.	G / SEA / Th	81.6				1.0		
Hydrophyllaceae	*Hydrolea zeylanica* (L.) J.Vahl	G / SEA / Th	2.5				0.9	0.8	12.3
Leguminosae	*Neptunia oleracea* Lour.	G / SEA					17.2		
Limnocharitaceae	*Limnocharis flava* Buchenau	G / SEA / Th	0.2				0.2	0.1	
Marsileaceae	*Marsilea crenata* C.Presl	G / SEA / Th	598.9		7.9	1.9		0.5	155.3
Nymphaeaceae	*Nymphaea pubescens* Willd.	G / SEA / Th					8.0		
Onagraceae	*Ludwigia adscendens* (L.) H.Hara	G / SEA / Th	2.5						
Pontederiaceae	*Eichhornia crassipes* (Mart.) Solms	G / SEA / Th					13.0		
	Monochoria hastata (L.) Solms	G / SEA / Th					0.7		
	Monochoria vaginalis C. Presl	G / SEA / Th	12.7						
Climber									
Asclepiadaceae	*Telosma minor* Craib					0.2			
Cucurbitaceae	*Coccinia grandis* (L.) Voigt	G / SEA		0.3		0.2			
	Momordica charantia L.	G		0.3				0.5	
Menispermaceae	*Tiliacora triandra* Diels			0.5					
Passifloraceae	*Passiflora foetida* L.	G / SEA				0.5		0.5	0.5
Rattan									
Arecaceae	*Calamus* sp.	N.A.		0.3					

Appendix 3. (continued)

Shrub									
Annonaceae	*Polyalthia debilis* Finet & Gagnep.			0.5		0.5			
Leguminosae	*Cajanus cajan* (L.) Millsp.	G		0.2	0.5			0.2	
	Senna sophera (L.) Roxb.	G				0.5		0.2	
Terrestrial herb									
Compositae	*Emilia sonchifolia* (L.) DC.	G / SEA / Th							5.0
Convolvulaceae	*Ipomoea aquatica* Forssk.	G / SEA / Th	7.3				128.8	7.4	24.3
Scrophulariaceae	*Limnophila aromatica* Merr.	G / SEA	2.5						4.8
Umbelliferae	*Centella asiatica* (L.) Urb.	G / SEA / Th			12.4			4.8	
Tree									
Anacardiaceae	*Spondias pinnata* Kurz	G		0.5	1.0			0.4	
Araliaceae	*Irvingia malayana* Oliver				0.1	0.2			
Arecaceae	*Borassus flabellifer* L.			0.3					
Euphorbiaceae	*Phyllanthus acidus* (L.) Skeels	G		0.1	0.8				
Lecythidaceae	*Barringtonia acutangula* (L.) Gaertn.			0.4	0.3			0.2	
	Careya arborea Roxb.	G				0.5			
Leguminosae	*Cassia siamea* Lam.	G	0.2	0.3		0.2		0.6	0.8
	Dialium cochinchinense Pierre			0.3					
	Leucaena leucocephala (Lam.) de Wit	G		4.7	0.1	2.8		1.2	
	Pithecellobium dulce (Roxb.) Benth.	G		0.1		0.2		0.2	
	Tamarindus indica L.	G		0.6	0.3	0.5		0.3	
Meliaceae	*Azadirachta indica* A. Juss. var. *siamensis* Valeton	G		0.8	1.3	0.3		0.2	0.3
Myrtaceae	*Psidium guajava* L.	G		0.5	0.1			0.2	0.3
	Syzygium cumini (L.) Skeels	G			0.3			0.2	
	Ziziphus mauritiana Lam.	G		0.8	0.2	0.2		0.5	

Appendix 3. (continued)

Sapindaceae	*Lepisanthes rubiginosa* (Roxb.) Leenh.		0.1	2.2		0.3
	Schleichera oleosa (Lour.) Oken	0.8				

[1] All values are averages of the years 2008 and 2009.

[2] G, globally classified as weed by the Global Compendium of Weeds (HEAR 2007); SEA, weed in rice fields in South and Southeast Asia (Moody 1989); Th, weed present in rice fields of Thailand (Moody 1989); blank spaces mean that the plant is not classified as weed; N.A. not applicable because of the small sampled area.

Appendix 4. Wild food plants observed in the rainy season, classified by growth form and ordered by family and scientific name, indicating frequency of occurrence ($Freq_{SS}$) [1] as percentage of sampling sites where a species occurred in a sub-system.

Botanical family	Scientific name	field margin	shelter	tree row	hillock	pond	pond margin	dike
Aquatic herb								
Hydrocharitaceae	*Ottelia alismoides* (L.) Pers.	0.16				0.05		
Hydrophyllaceae	*Hydrolea zeylanica* (L.) J.Vahl	0.07				0.10	0.05	0.10
Leguminosae	*Neptunia oleracea* Lour.					0.20		
Limnocharitaceae	*Limnocharis flava* Buchenau	0.02				0.05	0.05	
Marsileaceae	*Marsilea crenata* C.Presl	0.52		0.04	0.05		0.05	0.28
Nymphaeaceae	*Nymphaea pubescens* Willd.					0.25		
Onagraceae	*Ludwigia adscendens* (L.) H.Hara	0.05						
Pontederiaceae	*Eichhornia crassipes* (Mart.) Solms					0.15		
	Monochoria hastata (L.) Solms					0.10		
	Monochoria vaginalis C. Presl	0.09						
Climber								
Asclepiadaceae	*Telosma minor* Craib				0.05			
Cucurbitaceae	*Coccinia grandis* (L.) Voigt		0.44		0.10			
	Momordica charantia L.		0.06				0.10	
Menispermaceae	*Tiliacora triandra* Diels		0.11					
Passifloraceae	*Passiflora foetida* L.				0.05		0.10	0.03
Rattan								
Arecaceae	*Calamus* sp.		0.06					
Shrub								
Annonaceae	*Polyalthia debilis* Finet & Gagnep.		0.11		0.05			

Appendix 4. (continued)

Leguminosae	*Cajanus cajan* (L.) Millsp.		0.11	0.08			0.10	
	Senna sophera (L.) Roxb.				0.05		0.05	
Terrestrial herb								
Compositae	*Emilia sonchifolia* (L.) DC.							0.03
Convolvulaceae	*Ipomoea aquatica* Forssk.	0.11				0.80	0.20	0.28
Scrophulariaceae	*Limnophila aromatica* Merr.	0.09						0.15
Umbelliferae	*Centella asiatica* (L.) Urb.			0.08			0.10	
Tree								
Anacardiaceae	*Spondias pinnata* Kurz		0.56	0.33			0.10	
Araliaceae	*Irvingia malayana* Oliver			0.08	0.20			
Arecaceae	*Borassus flabellifer* L.		0.06					
Euphorbiaceae	*Phyllanthus acidus* (L.) Skeels		0.22	0.04				
Lecythidaceae	*Barringtonia acutangula* (L.) Gaertn.		0.11	0.08			0.20	
	Careya arborea Roxb.				0.05			
Leguminosae	*Cassia siamea* Lam.	0.02	0.22		0.15		0.20	0.05
	Dialium cochinchinense Pierre		0.06					
	Leucaena leucocephala (Lam.) de Wit		0.56	0.08	0.25		0.40	
	Pithecellobium dulce (Roxb.) Benth.		0.22		0.20		0.20	
	Tamarindus indica L.		0.56	0.17	0.05		0.40	
Meliaceae	*Azadirachta indica* A. Juss. var. *siamensis* Valeton		0.33	0.17	0.20		0.20	0.03
Myrtaceae	*Psidium guajava* L.		0.11	0.08			0.30	0.03
	Syzygium cumini (L.) Skeels			0.17			0.20	
Rhamnaceae	*Ziziphus mauritiana* Lam.		0.17	0.13	0.10		0.10	
Sapindaceae	*Lepisanthes rubiginosa* (Roxb.) Leenh.			0.08	0.20		0.05	
	Schleichera oleosa (Lour.) Oken		0.11					

[1] All values are averages of the years 2008 and 2009.

CHAPTER 6

Spatial and seasonal diversity of wild food plants in home gardens of Northeast Thailand*

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Abstract

Wild food plants are a major component of home gardens, which are diverse and multi-layered agro-ecosystems, constituting an important resource for poor farmers. The spatial and seasonal diversity of wild food plants was analysed across home garden sub-systems in Northeast Thailand, presenting an innovative analysis of home garden structure. Data was collected in 77 sampling sites corresponding to five different home garden sub-systems. Absolute abundance and frequency of occurrence were quantified per individual wild food plant species in both dry and rainy seasons. A total of 20 species corresponding to 13 botanical families were reported. Results show that species abundance and frequency of occurrence, as well as vertical stratification, vary seasonally and spatially within home gardens. Diversity, as observed in the analysis of Shannon and Simpson diversity indexes, also differed seasonally and across sub-systems. Home gardens showed higher diversity in the dry season, implying the presence of active human management. Although the most common sub-system was yard, which presented the highest species diversity in both seasons, all sub-systems should be regarded equally important for the maintenance of wild food plant diversity given that altogether they provided different habitats for plant growth. This study shows that it is not possible to attribute a specific function to each sub-system due to the presence of species with multiple uses across sub-systems. Finally, it is concluded that Northeast Thai home gardens constitute a valuable component for in situ conservation of plant genetic resources.

Keywords: Home garden, wild food plant, agro-forestry system, diversity index, abundance, frequency of occurrence, seasonality, Southeast Asia, Thailand.

* Submitted.

INTRODUCTION

Home gardens are diverse and multi-layered agro-ecosystems or agroforestry systems with a very complex structure (Fernandes and Nair 1986), comprising small-scale production units surrounding the homestead of families, which are maintained with family labour and complement the functions of other farming systems such as agricultural fields. Home gardens provide households with food, medicine, fodder and other products, which not only are for self-consumption, but also, in some cases, for sale (Kumar and Nair 2004). Home gardens have existed in the tropics for millennia since prehistoric times (Niñez 1985) and have probably been the oldest expression of agriculture in Southeast Asia (Wiersum 2006), playing an essential part in the process of domestication of fruit trees and the development of agriculture (Miller and Nair 2006). However, wild food plants, which are those species existing on a management continuum from 'truly' wild to wild cultivated and semi-domesticated excluding locally domesticated plants (Harris 1989), constitute a major component of home gardens that has received little attention by scientists (Chweya and Eyzaguirre 1999). Nowadays, many rural societies from around the world rely on wild food plants as essential component of their diet, especially during lean seasons and scarcity periods (Etkin 1994; Heywood 1999; Turner and Davis 1993).

Seasonal and spatial diversity of wild food plants in home gardens needs to be quantified, because this variation will affect their availability for domestic consumption. Wild food plant research, however, hardly ever has had such focus. Moreover, the seasonal and spatial diversity of species within home gardens has received little attention in comparison to the analysis of between home garden diversity (Abebe *et al.* 2010). In order to conduct a realistic study on species diversity within home gardens, it is essential to have a clear understanding of home garden structure. Although there are different classification schemes for analysing the structure of tropical home gardens, none of these has been collectively accepted (Kehlenbeck and Maass 2004). This paper presents the results of a study conducted in Northeast Thailand that proposes an innovative analysis of home garden structure in relation to the seasonal and spatial diversity of wild food plants, incorporating the examination of vertical strata and species functionality across different sub-systems or micro-zones within home gardens. The introductory section of this paper starts discussing the importance of plant diversity in home gardens, followed by a brief review on previous studies about home garden structure and the major challenges in their study, finishing with the presentation of our research in Northeast Thailand.

Importance of plant diversity in home gardens

The diversity of plant species present in home gardens has been acknowledged as an important factor for their sustainability and productivity (Kehlenbeck *et al.* 2007), and regarded as one of home garden's most striking features (Hoogerbrugge and Fresco 1993). In this way, home gardens play a crucial role in the conservation of plant genetic resources (Eyzaguirre and Linares 2010; Galluzzi *et al.* 2010; Torquebiau 1992). The main function of the majority of home gardens is providing fruits and vegetables for home consumption, comprising several wild food plants, as complement to the staple (Fernandes and Nair 1986; Hoogerbrugge and Fresco 1993). These plants are crucial for assuring food security and dietary diversity of farming households (Akrofi *et al.* 2010; Niñez 1985). Farmers ensure the availability of food plants in their home gardens throughout the year (Lok 2001), especially in times of stress (Nazarea and George 1997).

Home garden structure

In home gardens annual and perennial species of trees, shrubs and herbs, often in combination with livestock, are maintained in integration (Fernandes and Nair 1986; Torquebiau 1992) re-creating diverse habitats important for plants and animals (Kehlenbeck *et al.* 2007). Each structural ensemble of home gardens conforms an specific niche, which is intrinsically related to the others, and their species composition, size and location is defined by local management strategies (Kumar and Nair 2004). Each arrangement commonly depends on plant symbiotic relationships aimed to reduce labour and improve soil fertility (Niñez 1985).

Most research on the structure of home gardens has been either focused on species diversity (e.g. Peyre *et al.* 2006) or verticality regarding the different layers of canopy strata constituting them (e.g. Gajaseni and Gajaseni 1999). Not only diversity and verticality of home gardens, however, are important, but also their horizontality in relation to the presence of different zones within home gardens. In this regard, Lok, Méndez and Somarriba (2001) referred to home garden micro-zonation where every zone is allocated to specific functions and management. For example, Alvarez-Buylla *et al.* (1989) observed in Southwest Mexico the presence of different areas constituting home gardens, such as the yard surrounding the house with sparsely distributed woody species, the ornamental garden densely planted mainly with herbs and occasionally with a living fence, and the orchard containing useful trees and shrubs. Similarly, Greenberg (2003) observed that Mayan home gardens have different zones, for example, some plants grow along the street, others behind the house near the kitchen, and others in different kinds of containers (cans, bowls and buckets).

Challenges in the study of home garden structure

It is possible to assert that, following Kumar and Nair's assertions (Kumar and Nair 2004), who compared different studies conducted on tropical home gardens, it is necessary to combine different methodological and theoretical approaches, integrating home garden diversity, verticality, horizontality and functionality in relation to wild food plant growth. In this regard, the use of micro-zonation would facilitate the comparison of different structural areas within home gardens that vary in terms of diversity (Lok 2001). Such research would certainly contribute to having a better understanding of home garden structure given that each one of its components has an established role in space and time (de Clerck and Negreros-Castillo 2000). This is undoubtedly necessary because: (a) studying home gardens has frequently been problematic due to their complexity (Lok 2001), (b) micro-zones have hardly ever been the object of analysis (Lok 2001), (c) more rigorous research on the ecological basis of home gardens is needed (Nair 2001), and, finally, (d) a new methodological approach in relation to multi-strata systems is required (Nair 2001).

Our study in Northeast Thailand

Home gardening is widely practiced in Thailand, where it has been reported that some home gardens have been present in the same site for more than 200 years (original in Thai by Makaraphirom cited in Gajaseni and Gajaseni 1999). Wild food plants are an important component of Thai home gardens, especially in the Northeast, where farmers actively cultivate, manage and gather these plants (Moreno-Black *et al.* 1996; Price 2005; Wester and Yongvanit 1995), which play a very important role in their food security (Price 1997; Somnasang and Moreno-Black 2000). In this way, Moreno-Black *et al.* (1994, 1996) reported that 29% of the useful plant species growing in home gardens in North-eastern Thailand are locally classified as wild and 95% of households presented wild food plants in their home gardens. However, quantitative studies of home gardens in Thailand are rare (Gajaseni and Gajaseni 1999) and there is no research conducted on seasonal and spatial diversity of wild food plants across home garden micro-zones in the Thai Northeast, which is the poorest area of the country (National Statistical Office of Thailand 2001).

This paper presents the results of a quantitative study on the seasonal and spatial diversity of wild food plants in home garden ecosystems in Kalasin, Northeast Thailand. The structure of home gardens was analysed horizontally comparing different sub-systems, and vertically comparing the growth form of the different species observed. The vertical layers merely characterized by the presence of either locally domesticated food plants or useful non-edible species were not focus of this research. The specific objectives of the study were: (a) to quantify the seasonal abundance and frequency of occurrence of individual gathered plants (climbers, herbs, shrubs and trees) in different sub-systems of home gardens, and (b) to compare different home garden sub-systems in terms of their diversity indexes.

In this paper, a sub-system resembles what has been named as a micro-zone by other authors (Greenberg 2003; Kumar and Nair 2004; Lok 2001; Méndez *et al.* 2001). The research followed an agro-ecosystem approach to home gardens, because this perspective is rigorous, well focused but flexible in design, which permits having an holistic perspective in their study (Conway 1985). Accordingly, home gardens not only comprise organisms, populations, communities and ecosystems as a nested hierarchy, but are also formed by several sub-systems such as fenced gardens, yards, hedgerows and pots.

METHODS

Study site

Northeast Thailand is characterized by having heavily leached fine sandy loam, highly saline and poorly drained soils, with low quantities of organic matter, phosphates and nitrogen (Parnwell 1988). Northeast Thailand has a Tropical Savannah climate (Köppen 'Aw') (Tomita *et al.* 2003; Wijnhoud 2007), with an annual monsoon defining the rainy season, from May through October, and the dry season, from November through April including a cool period and a hot period. Meteorological data was provided by Kamalasai station in Kalasin Province, the nearest to the research area, for the complete time range of data collection that started at the beginning of the rainy season 2006 (May) and finished at the end of the dry season 2006-2007 (April 2007) (Figure 1). The monthly average rainfall was 210 mm in the rainy season, comprising 88% of the annual rainfall, and 25 mm in the dry season.

North-easterners of Thailand have adjusted to this environmental variability developing a combined subsistence system that depends on glutinous rice as main source of income and dietary staple accompanied with the consumption of wild foods (Halwart 2006; Moreno-Black *et al.* 1996; Somnasang *et al.* 1998). Cultivation of transplanted glutinous rice occurs in the rainy season, whereas in the dry season farmers cultivate either direct seeded rice, mushrooms, vegetables or cannot practice agriculture depending on their access to irrigation. Wild food plants are collected from forests, fields and home gardens, among other places (Moreno-Black *et al.* 1996; Price 1997). Wild food species are an essential source of minerals and vitamins for the families (Somnasang *et al.* 1998). Women, who inherit the land, are the main gatherers of wild fruits and vegetables. They also play an essential role in the maintenance of wild food plants in home gardens in Northeast Thailand, prepare them for consumption in the daily meals and make the decisions regarding species, planting and protection (Moreno-Black *et al.* 1996; Moreno-Black *et al.* 1994; Price and Ogle 2008) (Figure 2).

Methods of data collection

Research was conducted in two adjacent villages in Northeast Thailand that are connected by sharing a temple. These villages, called Ban Sa-at Tai (16°25'N, 103°34'E) and Ban Sa-at Somsi (16°24'N, 103°34'E) situated in Tambon Nua, Ampher Muang, Kalasin Province (145 m above sea level), were originally one village that divided into two due to population growth. The botanical names of the species were based on research conducted by one of the authors in the same villages, who published a list of 87 wild food plants (Cruz-Garcia and Price 2011). In this study plant names were obtained by elicitation with local people, thus it could happen that some species that are regarded as 'wild' by farmers, might be considered as domesticated in other regions.

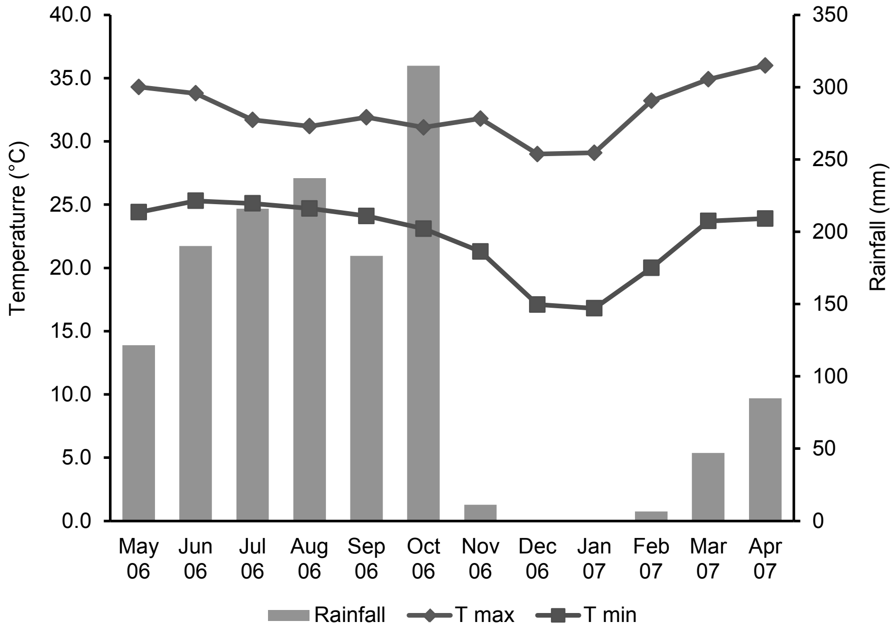

Figure 1. Maximum temperature (T max), minimum temperature (T min) and rainfall during the period of data collection: starting at the beginning of the rainy season 2006 (May 2006) and finishing at the end of the dry season 2006-2007 (April 2007).

Figure 2. Women play an essential role in maintaining wild food plants in home gardens in Kalasin, Northeast Thailand.

Five different sub-systems corresponding to home gardens, namely fenced garden, fenced garden margin, yard, household boundary and pot, were identified by researchers and local experts in a recognizance field visit. Sampling sites were randomly selected for each sub-system, defining optimal quadrat shape and size if needed (Krebs 1999). The total 77 sampling sites belong to 20 randomly selected home gardens, which corresponded to 20 different households. These sampling sites covered a total area of 2749 m^2. Absolute abundance and frequency of occurrence were calculated per wild food plant species, analysing the same sampling sites in August 2006 (rainy season) and February 2007 (dry season). Data for the dry season was collected in February before the temperatures rise and it becomes difficult to maintain wild food plants in the home garden. The sampling of each sub-system was conducted as follows:

- Fenced gardens (n=12) are small fenced areas within the home garden where farmers mainly grow domesticated plants and a few wild food plants to use for food (vegetable) and medicine. The plants in this sub-system are generally watered and protected. The fence also prevents the entrance of animals to the garden. All wild food plants belonging to each sampled fenced garden were counted. All sampled fenced gardens covered a total area of 182 m^2, with an average of 15 m^2 per garden.

- Fenced garden margins (n=12) include a 0.5 m wide border surrounding each sampled fenced garden. Plants are not protected against animals. Farmers usually do not take care of the plants growing in this area directly but they do it rather indirectly, for instance, these plants incidentally receive water and nutrients applied to the species growing inside the fence. All wild food plants found in fenced garden margins were counted. Sampled margins covered a total area of 126 m^2.
- Yards (n=20) comprise the home garden area surrounding the house but excluding fenced gardens and their margins, hedgerows, fences and pots. They are characterized by presenting widely spaced vegetable plants and trees. Some plants are protected, for example by placing sticks around small trees. Some species that are important for the local cuisine are planted near the kitchen, water jar or toilet so they can indirectly receive water while cooking, washing the dishes or body. All wild food plants belonging to each sampled yard were counted. All sampled yards together covered a total area of 2266 m^2, with an average of 113 m^2 per yard.
- Household boundaries (n=12) include hedgerows and fences that delimit the household compound. They are mainly composed of woody species. They differ in width and length, covering a total area of 172 m^2. All plants growing in hedgerows and fences were counted.
- Pots (n= 21) are either small containers made of ceramic with an average diameter of 0.25 m, or big containers made of old tires with a diameter of 0.50 m. Depending on their size, pots could have only one species or mixtures of plants. Pots are placed on the top of columns or walls higher than one meter, so chicken and other animals cannot destroy them. All wild food plants found in sampled pots were counted. All pots covered a total area of 3 m^2.

Methods of data analysis

Data were analysed per species, sub-system and season. Absolute abundance and frequency of occurrence were calculated per plant species for each sub-system and the whole home garden ecosystem in both seasons (dry and rainy). Absolute abundance, referred to as Ab, is the number of individual plants of a species per unit area (100 m^2, otherwise indicated), estimated by the sum of the number of individual plants divided by the total area (m^2) of all sampling sites belonging to a sub-system. Frequency of occurrence (presence frequency) is the percentage of observations where the species was present: (a) the percentage of sampling sites where the species occurred in a sub-system, referred to as $Freq_{SS}$, and (b) the percentage of sub-systems where the species occurred, referred to as $Freq_{SUB-S}$. These measurements (Ab, $Freq_{SS}$ and $Freq_{SUB-S}$) complement each other.

Species richness, Simpson and Shannon diversity indexes were calculated per sub-systems (Magurran 2004). Species richness (Sp_d) was obtained as species density, quantifying the number of species per unit area (100 m^2, otherwise indicated). The Shannon index (H'), was obtained according to the following formula:

$$H' = -\sum p_i \operatorname{Ln} p_i$$

where p_i is the relative abundance (proportion) of individuals in the *i*th species. The higher the value of H' the higher the species evenness and richness. The Simpson index (D), was estimated with the following formula:

$$D = \sum n_i (n_i-1) / N(N-1)$$

where n_i is the number of individuals in the *i*th species (absolute abundance) and N is the total number of individuals. D values closer to 0 indicate a higher diversity, whereas those closer to 1 indicate a lower diversity.

RESULTS

Wild food plant abundance and frequency of occurrence

Seasonal abundance across sub-systems

A total of 20 wild food plant species corresponding to 13 botanical families were observed, and 1390 individuals were counted in a total sampled area of 2749 m^2, with an average of 0.5 individuals per m^2. The family with the highest number of species was Leguminosae (six species), followed by Cucurbitaceae and Menispermaceae (two species each). A total of 19 species were observed in the dry season (Appendix 1 and 2) and all 20 species were found in the rainy season (Appendix 3 and 4). *Limnophila aromatica* was the only species that was not observed in the dry season. According to their growth form, nine species (45%) were trees, four (20%) climbers, four (20%)

terrestrial herbs, two (10%) shrubs and one (5%) rattan. No aquatic herbs were observed in home gardens.

The tree *Tamarindus indica* and the terrestrial herb *Centella asiatica* clearly showed the highest absolute abundance observed in the total sampled area in the dry season, with 286 and 284 individuals counted respectively. *Centella asiatica* is a medicinal herb very common inside fenced gardens where it shows its highest density (137 individuals per 100 m^2). It is also present in yards and pots. *Tamarindus indica* is very common constituting fences (155 individuals per 100 m^2) where it grows as shrubby tree due to pruning. Tamarind also grows in yards and fenced gardens. This plant, which is an important tree in the region, has multiple uses as food. For instance, its fruit, locally called 'bak kaam', is widely consumed ripe and unripe as snack or its juice is added to some dishes, and its shoots are eaten as vegetable. The tree *Leucaena leucocephala* was also abundant in this season, followed by the terrestrial herb *Amaranthus viridis*, the tree *Phyllanthus acidus*, the rattan *Calamus* sp. and the climber *Tiliacora triandra*.

The most abundant plant in the rainy season in the total sampled area was *Tamarindus indica*, followed by the terrestrial herb *Limnophila aromatica* and the tree *Leucaena leucocephala*, with 386, 79 and 54 individuals counted respectively. Hundred more individuals of *Tamarindus indica* were counted in comparison to the dry season, corresponding to new seedlings that started growing given to the presence of rain. However, most of these seedlings will not survive the following dry season. *Limnophila aromatica* or 'phak kayeng' is only found in pots (2633 individuals per 100 m^2). This plant is commonly transplanted from rice fields, where it naturally grows, to home garden pots in this season. *Limnophila aromatica*, which is also medicinal, constitutes an important ingredient of the local cousin, especially liked for its aromatic smell. *Leucaena leucocephala*, only found constituting fences, is another important tree with multiple edible parts (shoot, leaves and fruit) and many additional uses besides food such as medicine, fuel and fodder. The terrestrial herbs *Amaranthus viridis* and *Centella asiatica*, the tree *Phyllanthus acidus* and the terrestrial herb *Ipomoea aquatica* were also abundant during this season.

Seasonal occurrence across sub-systems ($Freq_{SUB-S}$)

Regarding the frequency of occurrence of species in all five different home garden sub-systems ($Freq_{SUB-S}$) in the dry season, almost half of the plants were found growing in 50% or more places. *Tiliacora triandra* was the species found in most sub-systems (80%, highest $Freq_{SUB-S}$). *Tiliacora triandra*, locally called 'yaa nang', plays an essential role in local cousin, reason why most households grow it and take care of it in their home gardens. *Tamarindus indica, Centella asiatica*, *Amaranthus viridis* and

Phyllanthus acidus, as well as the climbers *Cissampelos pareira, Coccinia grandis*, *Momordica charantia* and the tree *Spondias pinnata* were found in 50% of the sub-systems. Four species (of total 19) grew in two sub-systems and six species (of total 19) were observed in only one sub-system.

The tree *Spondias pinnata* was the species found in most sub-systems (80%, highest $Freq_{SUB\text{-}S}$), although it was not largely abundant. The fruit of *Spondias pinnata* called 'bak kawek' characterizes the 'som tam' (papaya salad) prepared in this region, in contrast with the rest of the country. 'Som tam' is an important local dish that is very frequently consumed, especially at lunch time. The climbers *Amaranthus viridis* and *Momordica charantia* were found in 50% of the places. The majority of the plants (85%) were only found in one or two sub-systems in this season.

The rarest species were the trees *Barringtonia acutangula* and *Pithecellobium dulce*, as well as the shrubs *Cajanus cajan* and *Senna sophera*, which not only showed the lowest absolute abundances but also occurred in only one sub-system. *Barringtonia acutangula* and *Senna sophera* grew in yards, *Pithecellobium dulce* in household boundaries, whereas *Cajanus cajan* grew in yards during the hot season and fenced garden margins in the rainy season. Some plants, such as *Calamus* sp. and *Limnophila aromatica*, were specific to only one sub-system but were present with a large absolute abundance. *Calamus* sp. grows only in yards; whereas *Limnophila aromatica* grows only during the rainy season in pots where it has been transplanted from the rice fields.

Spatial abundance and occurrence within sub-systems ($Freq_{SS}$)

The abundance and occurrence of wild food plant species not only presented seasonal differences, but also spatial differences with respect to their distribution in different sub-systems as follows:

- Wild plants were growing in small quantities in fenced gardens, presenting low frequencies of occurrence in the sampling sites ($Freq_{SS}$). This is because fenced gardens are mainly meant for domesticated plants, however, most wild food plants growing in fenced gardens have been transplanted and are managed. Only three species were observed in more than one home garden, namely *Tamarindus indica* and *Coccinia grandis* in the dry season, and the climber *Cissampelos pareira* in the rainy season. *Centella asiatica* was observed in big quantities in one garden, whereas for all other species only four to one individuals were found.
- Wild food plants presented not only low abundances (Ab), but also the lowest frequencies of occurrence in sampling sites ($Freq_{SS}$) because none of the species was found in more than one home garden. Besides, none of these species, except for *Amaranthus viridis*, was observed consecutively in both seasons.

- Yards showed considerably more wild food plant species than other sub-systems. The most abundant plant was *Tamarindus indica*, which also occurred in 50% of the sampling sites ($Freq_{SS}$). *Amaranthus viridis* was also abundant but not frequent and the rattan *Calamus* sp. was only abundant in the dry season. *Phyllanthus acidus*, followed by the climber *Tiliacora triandra*, occurred frequently in yards.
- In household boundaries, which include hedgerows and fences, the most abundant plants were *Tamarindus indica* and *Leucaena leucocephala*, occurring in 50% or more of the sites ($Freq_{SS}$). The trees *Phyllanthus acidus* and *Pithecellobium dulce* were also present but in smaller quantities and less frequently. The climbers *Tiliacora triandra* and *Momordica charantia* were present in small quantities in the dry season.
- In pots, the most abundant plants were the medicinal herb *Centella asiatica* in the dry season and the herb *Limnophila aromatica* in the rainy season, followed by *Tiliacora triandra* that was observed in both seasons.

Vertical stratification of wild food plants

A total of three vertical layers were observed: herb, shrub and tree layers. The tree layer included both understory and canopy. Climbers grow either on sticks (facilitated by farmers) or on woody species. Individuals of climber species, depending on their age, were classified as part of the herb layer or shrub layer. In the same way, individuals of tree species, depending on their age, were part of the herb, shrub or tree layer; and young individuals of shrub species belonged to the herb layer. Rattans were part of the shrub layer. The wild food plant strata present in each sub-system were similar in both dry and rainy seasons, with slight differences in the growth form of the species that composed them.

Pots only presented a herb layer where two species of herbs and one climber grow in the rainy season, whereas two climber and one herb species grow in the dry season. Climbers growing in pots are young plants climbing a stick. Household boundaries showed only a tree layer with five different species of trees in the rainy season, whereas, in the dry season, two species of climbers started to grow. Fenced garden margins showed a herb and a shrub layer in both seasons. The shrub layer was always conformed by climbers, but the proportion of the various growth forms corresponding to the species observed in the herb layer differed according to the season. In the dry season the herb layer of fence garden margins included only herbs, but in the dry season also young shrubs and trees. These young shrubs and trees did not survive the coming dry season and no tree layer grew in the years following the study. Fenced gardens and yards showed three layers in both seasons. Fenced gardens showed herbs, climbers and trees in the herb, shrub and tree layers respectively. In the dry season the herb layer also showed some young individuals of a few species of trees and climbers. Most of these young trees were eliminated from the fenced garden when the domesticated vegetables and other herbs were planted in the next rainy season. The shrub layer in the yard was constituted by shrubs, climbers and a species of rattan in both seasons.

Seasonal diversity of wild food plants

Seasonal diversity across sub-systems

Ninety percent of the home gardens (n=20) showed wild food plants in both seasons. However, wild food plant diversity was notoriously greater in the dry season. Not only the number of individuals observed in the total sampled area was higher in the dry season (771 and 619 individuals in dry and rainy season, respectively), but also the average number of individuals (39 and 31 individuals in dry and rainy season, respectively) and average number of species (4.1 and 3.6 species in dry and rainy season, respectively) across all sampled home gardens (Table 1). Moreover, home garden means of species density, Shannon and Simpson indexes indicated that wild food plant diversity was higher in the dry season. In this way, species density (Sp_d) in the dry season was 12.0 species per 100 m^2, against 7.3 species per 100 m^2 in the rainy season; Shannon diversity index (H') was 1.06 in the dry season and 0.81 in the rainy season; and Simpson diversity indexes were 0.29 and 0.36 respectively.

Number of individuals, number of species and all diversity indexes presented great variability across home gardens in both seasons, which was reflected in their high standard deviations. The highest variability in both seasons was observed in the number of individuals (SD=113 in dry season and SD=83 in rainy season), followed by species density (Sp_d) in the dry season (SD=21.7). This indicates that wild food plant diversity in home gardens greatly differs across households.

Home gardens showed on average three different sub-systems (SD=1.7) in a mean area of 137 m^2 (SD=184m^2). However, they differed in the number of sub-systems they contained. Thirty percent showed all five sub-systems and 10% four sub-systems, whereas 15% showed three sub-systems, 12% two sub-systems and 30% only one sub-system. The home gardens that did not show wild food plants were amongst those that only comprised one sub-system. Usually home gardens with a bigger area possess more sub-systems. For instance, home gardens with four or five sub-systems had an average area of 231 m^2 (SD=150m^2) and the average area of home gardens with one or two sub-systems was 84m^2 (SD=220m^2). Regarding the number of home gardens in

Table 1. Mean and standard deviation of number of individuals, number of species, species density (Sp_d), Shannon diversity index (H') and Simpson diversity index (D) of wild food plants across all sampled home gardens in both dry and rainy season.

	dry season		rainy season	
	mean	SD	mean	SD
Number of individuals	39	113	31	83
Number of species	4.1	2.8	3.6	3.0
Sp_d[1]	12.0	21.7	7.3	6.6
H'	1.06	0.51	0.81	0.66
D	0.29	0.31	0.36	0.36

[1] Number of species per 100 m^2.

which each sub-system was present, all sub-systems were observed in at least 50% of home gardens. Fenced gardens and their margins, household boundaries and pots were present in 50% of home gardens. Yards were present in 95% of home gardens, this is for 19 out of 20 households (one household had an area that only allowed having a single pot).

Seasonal diversity within sub-systems

When comparing both seasons, results showed that 60% of sub-systems presented higher species density (Sp_d) and greater diversity according to Shannon (H') and Simpson indexes (D) in the dry season, which was the case for yards, household boundaries and pots (Table 2). On the other hand, in the rainy season fenced garden margins presented a higher diversity according to all indexes and fenced gardens according to Shannon and Simpson indexes (Table 3).

Regarding the differences among subsystems on the basis of Shannon and Simpson diversity indexes, yards presented the highest diversity in both seasons (H'=2.58, D=0.09 in the dry season, H'=2.36, D=0.11 in the rainy season). However the species density of yards was the lowest in both seasons (Sp_d=0.8 in the dry season, Sp_d=0.7 in the rainy season) because they showed much bigger areas within home gardens where wild food plants are heterogeneously spread. In yards both transplanted and non-transplanted terrestrial herbs, climbers, trees and sometimes also shrubs and rattans were grown, but there were no visibly dominant species. Fenced gardens, followed by household boundaries, showed the highest species density in the dry season (Sp_d=5.5 and Sp_d=4.7 respectively), because they possessed the highest number of species, mainly transplanted, in a smaller area. However, fenced gardens showed the lowest diversity according to Shannon and Simpson indexes in this season (H'=0.28, D=0.91), which can be partly explained by the dominance of the herb *Centella asiatica*.

Fenced garden margins presented the highest species density in the rainy season (Sp_d=4), which was related to an increase in the number of species over time. Fenced gardens and their margins also showed higher diversity indexes, given that farmers cultivated different species of domesticated, wild vegetables and other herbs taking advantage of the presence of water. In the rainy season pots and household boundaries showed the lowest diversity (H'=0.46, D=0.74 and H'=0.45, D=0.76 respectively), which was clearly expected not only due to the low number of species but also to the dominance of few plants as *Limnophila aromatica* that is commonly cultivated in pots, and the trees *Tamarindus indica* and *Leucaena leucocephala* commonly constituting household boundaries.

DISCUSSION

This study shows the remarkable importance of wild food plants as components of home gardens, reflected in the fact that 85% of home gardens presented wild food plants in both seasons and 10% in one season (only one household did not have these plants because they only had enough area adjacent to the house for a single plant pot). Moreover, the data compiled in this study highlights the great diversity of wild food plants home gardens possess, echoed in the observation and quantification of 20 species belonging to 13 botanical families. Research findings allow to assert that home gardens are essential in providing wild food plants to families in Northeast Thailand, where this resource is an importance component of their dietary diversity and food security (Cruz-Garcia and Price 2011).

Table 2. Species density (Sp_d), Shannon diversity index (H') and Simpson diversity index (D) of wild food plants per sub-system in the dry season.

Sub-system	Sp_d[1]	H'	D
fenced garden	5.49	0.28	0.91
fenced garden margin	2.38	0.74	0.54
yard	0.79	2.58	0.09
household boundary	4.65	0.74	0.59
pot	N.A.[2]	0.54	0.72

[1] Number of species per 100 m^2.

[2] Not applicable because of the small sampled area.

Table 3. Species density (Sp_d), Shannon diversity index (H’) and Simpson diversity index (D) of wild food plants per sub-system in the rainy season.

Sub-system	Sp_d[1]	H'	D
fenced garden	2.75	1.43	0.19
fenced garden margin	3.97	1.50	0.16
yard	0.66	2.36	0.11
household boundary	2.91	0.45	0.76
pot	N.A.[2]	0.46	0.74

[1] Number of species per 100 m^2.

[2] Not applicable because of the small sampled area.

Seasonality, diversity and structure

The results obtained in this study show that species abundance and frequency of occurrence, as well as vertical stratification vary seasonally and spatially within home gardens. Diversity, as observed in the analysis of Shannon and Simpson diversity indexes, also differ seasonally and across sub-systems. These findings confirm Kumar and Nair’s affirmation that, in order to disentangle the complexity of home garden structure it is necessary to conduct an integrated temporal and spatial analysis of its diversity (Kumar and Nair 2004). Moreover, these results quantitatively showed that micro-zones (sub-systems) can be permanent, temporary or cyclical (Lok 2001).

The research findings revealed that the spatial structure within home gardens is diverse. All sub-systems were present in 50% or more home gardens, which showed to have three sub-systems in average. The most common sub-system was yard, present in 95% of home gardens. Yards also presented the highest diversity in both seasons. Household boundaries, pots, fenced gardens and their margins were present in half of the home gardens. Although yards were more common and diverse, all sub-systems should be regarded equally important for the maintenance of wild food plant diversity, given that they provide different habitats for plant species. Many plant species have specific niche requirements, which is reflected in the fact that 85% of the species in the rainy season and 10 out of 19 species in the dry season were found in only one or two sub-systems.

Regarding seasonality, the differences observed between both dry and rainy seasons were substantial. In the dry season home gardens showed: (a) higher average number of individuals and number of species across households, (b) higher wild food plant diversity according to average species density, Shannon and Simpson indexes, (c) higher diversity of wild food plants in more than half of sub-systems. These findings are contrary to the initial expectation that the rainy season would present a higher diversity given that the presence of water facilitates the growth of most species. Therefore these results cannot be explained by physical environmental factors alone. The findings suggest that human management is a major factor for assuring the maintenance of wild food plant diversity under the presence of higher environmental stress. These results seem to follow the pattern of Moreno-Black *et al.* (1996) who emphasized that wild food plants are not only tolerated when grew spontaneously, but also actively transplanted and protected in Northeast Thai home gardens. Further research is required on the seasonality of management practices and understanding farmer's impetus for having an increased availability of this resource during the dry season, which could certainly be related to assuring food security and nutritional diversity.

The vertical stratification of home gardens is dynamic and changes with time. Strata evolve with the years and might be affected by seasonality. For instance, the presence of tree species would not necessarily involve having canopy strata, which is the case when the tree individuals are still young. It could also be the case that these young individuals would not survive the next dry season and no canopy strata would develop in the near future, as shown in the results of this study. In order to have a better understanding of vertical stratification of home gardens, it is necessary to conduct long term studies including the effects of seasonality.

Comparison with other studies in Thailand and the Thai Northeast

Comparing with a previous study about home gardens conducted by Moreno-Black *et al.* (1996) in the same village 20 years ago, it is possible to assert that the average diversity of wild food plants per home garden has increased or remains the same. The results of this study show that on average a home garden has 4.1 wild food plant species in the dry season, whereas in the previous study 4.0 non-domesticated useful species were observed in the same season (they did not assess during the rainy season). Moreover, in both studies home gardens presented a maximum of 10 wild species, and a minimum of none. However, it is important to remark that whereas the previous study counted both edible and non-edible useful species, this research only focused on edible species. Probably if other useful plants are added to the current analysis the diversity would increase and surpass the results obtained in the past. Is the availability of wild food plants increasing in home gardens? This is an interesting question that requires further research and could deliver interesting results that would contribute to understanding home garden dynamics through time.

Some species, such as *Tiliacora triandra* and *Calamus* sp. were also listed by the previous study in the Thai Northeast, but it was not possible to conduct a thorough comparison with all plants of their list because most of them were not identified up to species level (Moreno-Black *et al.* 1996). Further comparison with Gajaseni and Gajaseni's research (1999) on home gardens in other regions of Thailand, showed that a species common to their four research sites (located in Sukhothai, Srisatchanalai, Nondhaburi and Ayudhaya) also listed by the present study was the tree *Phyllanthus acidus*. Other wild food plant species in common were the climber *Coccinia grandis* observed in Sukhothai and Srisatchanalai, the herb *Centella asiatica* reported for Nondhaburi, and the trees *Tamarindus indica* and *Psidium guajava* listed for Sukhothai and Ayudhaya.

Functional characteristics of wild food plants

Home gardens are characterized by the presence of multiple purpose species (Galluzzi *et al.* 2010) (Fernandes and Nair 1986), given that an important factor to select the species for growing and maintaining in these ecosystems is their variety of uses and derived products (Gajaseni and Gajaseni 1999). This diversity of products is obtained with low labour and inputs (Kehlenbeck and Maass 2004). The functionality of home gardens and multiple uses of their species have been reported around the world. For example, for southern Ethiopia (Abebe *et al.* 2010), in southeast Mexico (Alvarez-Buylla Roces *et al.* 1989), central Sulawesi in Indonesia (Kehlenbeck and Maass 2004), and central Vietnam (Vlkova *et al.* 2011). This is certainly also the case for Northeast Thailand. Comparing with previous findings of the senior author (Cruz-Garcia and Price 2011) 95% of wild food plant species growing in home gardens have additional uses besides food (19 out of 20 species). For example, tamarind, besides food, has six additional uses (medicine, timber, fuel, fodder, dye and cleaning) and provides a place of shadow outside the house within the household compound. The functional groups observed were the following: medicinal (95% of species), animal fodder (25%), fuel (20%), domestic (15%), timber (10%), dye (10%), cleaning (10%), auxiliary (5%) and ritual (5%). It is remarkable how many species are also utilized as medicine. The remarkable food-medicine overlap of wild food plants has also been documented in other places and is a major characteristic of this resource (Etkin and Ross 1982; Ogle *et al.* 2003; Pieroni and Quave 2005; Vandebroek and Sanca 2007).

Yards and household boundaries comprised wild food plant species belonging altogether up to nine different functional groups besides food, whereas those species growing in pots belong altogether only to two functional groups besides food. The percentage of species belonging to each functional group, except for medicine, varied per sub-system (Figure 3). These results show that it is not possible to attribute a specific function to each sub-system. The presence of species with multiple uses across sub-systems indicates that each of them has diverse functions for farming

Figure 3. Percentage of wild plant species presenting multiple uses besides food per sub-system in home gardens.

families. Moreover these functions will also vary across seasons with the change in species composition.

In situ conservation of home garden diversity

This study shows the remarkable importance of home gardens in Northeast Thailand for providing wild food plants, reflected on the diversity found in ecosystems and their sub-systems. Home gardens play an important role not only in the food security but also in the local livelihoods of the region given the great assortment of products they offer besides food. They are also important in the process of domestication of useful plant species. Home gardens, presenting great diversity at multiple levels and in small spaces (Galluzzi *et al.* 2010), should be a valuable component of 'in situ' conservation efforts of plant genetic resources in the Thai Northeast.

Appendix 1. Wild food plants observed in the dry season, classified by growth form and ordered by family and scientific name, indicating absolute abundance (Ab) as number of individuals of a species per 100 m^2.

Botanical family	Scientific name	fenced garden	fenced garden margin	yard	household boundary	pot
Climber						
Cucurbitaceae	*Coccinia grandis* (L.) Voigt	2.0	0.8	0.2		
	Momordica charantia L.			0.2	0.6	66.7
Menispermaceae	*Cissampelos pareira* L.	0.5	0.8	0.1		
	Tiliacora triandra Diels	0.5		0.3	2.3	1.0
Rattan						
Arecaceae	*Calamus* sp.			0.6		
Shrub						
Leguminosae	*Cajanus cajan* (L.) Millsp.			0.4		
	Senna sophera (L.) Roxb.			0.2		
Terrestrial herb						
Amaranthaceae	*Amaranthus viridis* L.	2.0	4.8	0.6		
Convolvulaceae	*Ipomoea aquatica* Forssk.			0.3		
Umbelliferae	*Centella asiatica* (L.) Urb.	137.4		0.4		9.0
Tree						
Anacardiaceae	*Spondias pinnata* Kurz	0.5		0.4	0.6	
Clusiaceae	*Cratoxylum formosum* (Jack) Benth. & Hook.f. ex Dyer	0.5		0.9		
Euphorbiaceae	*Phyllanthus acidus* (L.) Skeels	0.5		0.6	1.7	
Lecythidaceae	*Barringtonia acutangula* (L.) Gaertn.			0.1		
Leguminosae	*Cassia siamea* Lam.			0.9	0.6	
	Leucaena leucocephala (Lam.) de Wit			0.2	47.7	
	Pithecellobium dulce (Roxb.) Benth.				1.7	
	Tamarindus indica L.	2.0		0.8	154.7	
Myrtaceae	*Psidium guajava* L.	0.5		0.9		

Appendix 2. Wild food plants observed in the dry season, classified by growth form and ordered by family and scientific name, indicating frequency of occurrence ($Freq_{SS}$) as percentage of sampling sites where a species occurred in a sub-system.

Botanical family	Scientific name	fenced garden	fenced garden margin	yard	household boundary	pot
Climber						
Cucurbitaceae	*Coccinia grandis* (L.) Voigt	0.17	0.08	0.15		
	Momordica charantia L.			0.15	0.08	0.05
Menispermaceae	*Cissampelos pareira* L.	0.08	0.08	0.15		
	Tiliacora triandra Diels	0.08		0.20	0.17	0.05
Rattan						
Arecaceae	*Calamus* sp.			0.20		
Shrub						
Leguminosae	*Cajanus cajan* (L.) Millsp.			0.05		
	Senna sophera (L.) Roxb.			0.05		
Terrestrial herb						
Amaranthaceae	*Amaranthus viridis* L.	0.08	0.08	0.05		
Convolvulaceae	*Ipomoea aquatica* Forssk.			0.10		
Umbelliferae	*Centella asiatica* (L.) Urb.	0.08		0.05		0.10
Tree						
Anacardiaceae	*Spondias pinnata* Kurz	0.08		0.05	0.08	
Clusiaceae	*Cratoxylum formosum* (Jack) Benth. & Hook.f. ex Dyer	0.08		0.10		
Euphorbiaceae	*Phyllanthus acidus* (L.) Skeels	0.08		0.40	0.17	
Lecythidaceae	*Barringtonia acutangula* (L.) Gaertn.			0.15		
Leguminosae	*Cassia siamea* Lam.			0.10	0.08	
	Leucaena leucocephala (Lam.) de Wit			0.15	0.58	
	Pithecellobium dulce (Roxb.) Benth.				0.17	
	Tamarindus indica L.	0.17		0.50	0.50	
Myrtaceae	*Psidium guajava* L.	0.08		0.10		

Appendix 3. Wild food plants observed in the rainy season, classified by growth form and ordered by family and scientific name, indicating absolute abundance (Ab) as number of individuals of a species per 100 m^2.

Botanical family	Scientific name	fenced garden	fenced garden margin	yard	household boundary	pot
Climber						
Cucurbitaceae	*Coccinia grandis* (L.) Voigt			0.9		
	Momordica charantia L.	0.5	0.8	0.4		
Menispermaceae	*Cissampelos pareira* L.	2.0		0.4		
	Tiliacora triandra Diels			0.3		33.3
Rattan						
Arecaceae	*Calamus* sp.			0.3		
Shrub						
Leguminosae	*Cajanus cajan* (L.) Millsp.		2.4			
	Senna sophera (L.) Roxb.			0.4		
Terrestrial herb						
Amaranthaceae	*Amaranthus viridis* L.	2.2	2.4	0.6		
Convolvulaceae	*Ipomoea aquatica* Forssk.		1.6	0.4		
Scrophulariaceae	*Limnophila aromatica* Merr.					2633.3
Umbelliferae	*Centella asiatica* (L.) Urb.					433.3
Tree						
Anacardiaceae	*Spondias pinnata* Kurz	0.5	0.8	0.9	0.6	
Clusiaceae	*Cratoxylum formosum* (Jack) Benth. & Hook.f. ex Dyer	0.5		0.9		
Euphorbiaceae	*Phyllanthus acidus* (L.) Skeels			0.4	1.7	
Lecythidaceae	*Barringtonia acutangula* (L.) Gaertn.			0.1		
Leguminosae	*Cassia siamea* Lam.			0.2		
	Leucaena leucocephala (Lam.) de Wit				31.4	
	Pithecellobium dulce (Roxb.) Benth.				0.6	
	Tamarindus indica L.			0.8	215.1	
Myrtaceae	*Psidium guajava* L.			0.9		

Appendix 4. Wild food plants observed in the rainy season, classified by growth form and ordered by family and scientific name, indicating frequency of occurrence ($Freq_{SS}$) as percentage of sampling sites where a species occurred in a sub-system.

Botanical family	Scientific name	fenced garden	fenced garden margin	yard	household boundary	pot
Climber						
Cucurbitaceae	*Coccinia grandis* (L.) Voigt			0.10		
	Momordica charantia L.	0.08	0.08	0.05		
Menispermaceae	*Cissampelos pareira* L.	0.17		0.05		
	Tiliacora triandra Diels			0.30		0.05
Rattan						
Arecaceae	*Calamus* sp.			0.15		
Shrub						
Leguminosae	*Cajanus cajan* (L.) Millsp.		0.08			
	Senna sophera (L.) Roxb.			0.05		
Terrestrial herb						
Amaranthaceae	*Amaranthus viridis* L.	0.08	0.08	0.10		
Convolvulaceae	*Ipomoea aquatica* Forssk.		0.08	0.10		
Scrophulariaceae	*Limnophila aromatica* Merr.					0.19
Umbelliferae	*Centella asiatica* (L.) Urb.					0.05
Tree						
Anacardiaceae	*Spondias pinnata* Kurz	0.08	0.08	0.10	0.08	
Clusiaceae	*Cratoxylum formosum* (Jack) Benth. & Hook.f. ex Dyer	0.08		0.10		
Euphorbiaceae	*Phyllanthus acidus* (L.) Skeels			0.25	0.08	
Lecythidaceae	*Barringtonia acutangula* (L.) Gaertn.			0.15		
Leguminosae	*Cassia siamea* Lam.			0.20		
	Leucaena leucocephala (Lam.) de Wit				0.50	
	Pithecellobium dulce (Roxb.) Benth.				0.08	
	Tamarindus indica L.			0.50	0.50	
Myrtaceae	*Psidium guajava* L.			0.10		

CHAPTER 7

Household seasonal gathering of wild food plants in anthropogenic ecosystems. Implications for the poor and vulnerable*

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Abstract

Wild food plants are essential for the food security and nutritional diversity of most vulnerable families such as those with chronically ill members and the poor. Gathering and consumption of wild food plants from anthropogenic ecosystems have been documented in multiple cultural contexts and have a major importance during lean seasons complementing seasonal crop availability. Nevertheless, studies on the seasonal implications of wild food plant gathering in anthropogenic ecosystems for vulnerable families are very rare. This paper presents the findings of a 12 month study conducted in a village in Northeast Thailand on the seasonal complementarity of anthropogenic ecosystems with respect to wild food plant gathering and the implications for vulnerable households. Field work was conducted from March 2008 to February 2009 in two adjacent villages with a total of 136 households. Data collection consisted of a household census on demographic and socio-economic information. Household vulnerability was analysed in relation to presence of chronic illness, total dependency ratio, ownership of rice field and economics. A sub-sample of 40 households was visited every month to conduct 7-day recalls over a 12-month period on wild food plant acquisition events.

This paper establishes that wild food plants are vital for local food security based on the great number of species gathered (n=50), high monthly percentages of households gathering wild food plants ranging from 100% to 93%, and high number of wild food plant collection events (n=2196). All households gathered these plants from paddy fields and home gardens, and most of them from roadsides, throughout most of the year. The results of this study show that wild food plants constitute a 'rural safety net' acting as a buffer against food shortage during the lean months. Findings reveal that anthropogenic ecosystems are complementary throughout the year with respect to wild food plant gathering. This has tremendous implications for the household diet in Northeast Thailand, particularly for vulnerable households.

Keywords: Wild food plant, gathering, household, anthropogenic ecosystems, vulnerability, poverty, seasonality, rice farmers, Southeast Asia, Thailand.

* Submitted.

INTRODUCTION

The 'Cross-cutting Initiative on Biodiversity for Food and Nutrition' led by FAO and Bioversity International, under the umbrella of the Convention of Biological Diversity, recognizes the essential role of agricultural biodiversity for improving the nutritional and health situation of the poor (Heywood 2011). In this regard, wild food plants, which exist on a continuum of human management from 'truly' wild to semi-domesticated and cultivated species (Harris 1989; Wiersum 1997a; b), are crucial for most vulnerable families such as those with chronically ill members (Barany *et al.* 2001; Johns and Eyzaguirre 2006) and for people who have few assets in terms of land, livestock or cash (Daniggelis 2003). Moreover, diversification in agricultural systems, including those promoting wild food plant availability, is particularly important for most vulnerable social groups: the higher the diversity, the greater their self-sustainability and self-reliance (Heywood 2011). Nevertheless, studies on the seasonal implications of wild food plant gathering from diversified agricultural systems for vulnerable families are very rare. Likewise, little importance has been given to the contribution of this resource in the food security debate (Price and Ogle 2008). This paper presents the findings of a 12-month study conducted in a village in Northeast Thailand on the seasonal complementarity of anthropogenic ecosystems with respect to wild food plant gathering and the implications for households.

Gathering and consumption of wild food plants from anthropogenic ecosystems, defined as environments disturbed by human activity, particularly agricultural fields and home gardens, have been documented in multiple cultural contexts with millions of people in rural areas dependent upon the role they play in food security and dietary diversity (Bharucha and Pretty 2010; Cotton 1996; Etkin 1994; Heywood 1999; Pieroni 2003; Scoones *et al.* 1992). For example, it has been documented that farming families in Vietnam gather wild food plants from various agricultural environments (Ogle and Grivetti 1985) and these species constitute essential sources of macro and micro nutrients (Ogle *et al.* 2001). The nutritional importance of these foods has also been recognized in Thailand (Ngarmsak 1987). For instance, not only in Northern Thailand do *Sígaw Karen* people collect wild food plants from rice fields, fallow agricultural areas and forests (Johnson and Grivetti 2002), but also in the Northeast of the country we find that *Isaan* farmers gather these foods from home gardens and different habitats such as water ponds and shelters in diversified rice systems (Cruz-Garcia and Price 2011).

Gathering of wild resources constitutes a crucial household coping strategy in times of famine or scarcity for farming societies from around the world. These plants have a major importance during lean seasons complementing seasonal crop availability when farming households do not have enough staple foods because the stored harvest is finished (Adaya *et al.* 1997; Grivetti and Ogle 2000; Heywood 1999; Scoones *et al.* 1992). Wild food plants constitute an essential buffer against hunger for those rice farming communities attaining low yields in Southeast Asia (Bharucha and Pretty 2010), especially during lean months preceding harvesting, which is certainly the case in Northeast Thailand (Prapertchob 2001).

Huss-Ashmore in her introduction to the book 'Coping with seasonal constraints' (1988) emphasised that the study of seasonality, specifically intra-annual fluctuations and their impact on rural societies, has largely been neglected. She also remarked that a clear understanding of the relationship between environmental seasonality and the seasonality of human response is needed. Although it is widely recognized that wild food plants are important for the food security and dietary diversity of vulnerable families, their seasonal consumption has only been documented by very few authors. For example, in Côte d'Ivoire, Herzog *et al.* (1996) conducted monthly 24-hour recalls on food intake, including uncultivated plants, over a one year period. Nordeide *et al.* (1996) conducted interviews on food consumption frequency of green leaves and other wild foods in the rainy season and post-harvest season in a number of villages in Southern Mali. Mertz *et al.* (2001) kept food diaries of wild and cultivated vegetables with 14 households in south-eastern Burkina Faso. Nevertheless, none of these studies analysed the seasonal contributions of different anthropogenic ecosystems in providing these plants and such studies have never been conducted among rice farming communities in Northeast Thailand. This is certainly necessary for achieving a thorough understanding of the actual implications of this resource during the course of the year especially for the poor and more vulnerable households in this region.

This study

This study provides a complete and accurate overview of gathering in a farming village. The objective of this study was to analyse the seasonal complementarity of different anthropogenic ecosystems for wild food plant collection throughout the year, analysing gathering events for household food consumption. The gathering data was interfaced with a selection of household economic and demographic variables of the same families. Finally, wild food plant gathering in relation to vulnerable households is analysed and discussed.

This study uses Niehof's definition (2004, 323) of household as a 'family-based co-residential unit' that shares most household resources, daily activities and takes care of the primary needs of its members. Vulnerable households are those that are unable to create, maintain or possess sufficient assets for addressing their basic needs, which makes them unable to cope with stress, change and risks without being harmed (Niehof and Price 2001). Although migrants do not participate in daily household activities, they are considered household members in this study because they may contribute through remittances.

Research context

The research was conducted in Kalasin Province, Northeast Thailand. This region is also locally referred to as *Isaan*. Kalasin is located at 152 m above sea level in the Korat Plateau, which geographically defines this region. Soils are highly saline, poorly drained and with low fertility (Parnwell 1988). The region is characterized by a Tropical Savannah climate (Köppen 'Aw') (Wijnhoud 2007) with an annual monsoon defining a rainy season that provides 90% of the annual rainfall. This season has a monthly average rainfall of 214 mm, maximum temperature of 32°C and minimum temperature of 24°C. The dry season, which is divided in a hot and a cool period, has a monthly average rainfall of 23 mm, maximum temperature of 32°C and minimum temperature of 19°C (Hijmans *et al.* 2005).

The Northeast is the poorest region in Thailand, where 20% of households have an annual income at or below that listed as average household monthly income (National Statistical Office of Thailand 2001). The staple in Northeast Thailand is glutinous rice consumed with a diversity of wild foods gathered largely from rice fields, home gardens, roadsides and woods (Cruz-Garcia and Price 2011). Wild food plants are eaten raw as a snack or side-dish, or cooked in soups and sauces. Women are the main wild food plant gatherers and are the main custodians of the knowledge on species specific management, use and preparation, guarding the food security and nutritional diversity of their families (Moreno-Black *et al.* 1994; Price and Ogle 2008).

The production of transplanted glutinous rice, which has low yields in comparison to the rest of the country (Prapertchob 2001), occurs in the rainy season. Some farmers have upland fields where they produce cash crops such as sugar cane or cassava. Paddy rice fields present a diversity of habitats such as shelters, water ponds and hillocks, where wild food plants grow. In the dry season farmers with access to irrigation will produce direct seeded rice, vegetables, and mushrooms. The presence of apple snails (locally called 'cherry snails' due to the pink colour of their eggs) is a serious problem for rice production. Farmers apply molluscicides after rice transplanting and some poisonings have been reported among rice farmers using molluscicides or herbicides. Another important concern of the farmers is Leptospirosis, which is a bacterial infection mainly transmitted by field rats. People can be infected through Leptospirosis urine contaminated soil, water and food.

North-easterners speak a dialect of the Lao language called *Isaan* that is written using the Thai scripts. Villagers learn Thai language at school. People conceptually distinguish wild from domesticated species, using the term *geht eng* that means 'birth itself' when referring to wild plants (Cruz-Garcia and Price 2011; Price 1997). Prefixes are important for plant naming mainly referring to the edible part of the plant. For instance, *bak* and *maak* mean fruit (บัก, หมาก), *yod* means shoots (ยอด), *bai* refers to leaf (ใบ), and *dok* means flower (ดอก). Another frequent prefix is *phak* that means vegetable (ผัก) (Price 1997), including shoots, leaves, stems and even whole aerial parts consumed as vegetable.

Households in the rural areas of Kalasin have on average four family members and 23.6% of households are female headed (National Statistical Office of Thailand 2001). Customary inheritance of land is through women and residence is matrilocal, facilitating women's detailed knowledge of their physical and social environment (Price and Ogle 2008). A stem family cycle starts when daughters once married bring their spouses to live within the parental home. When the first child is born, they build a separate house within the parental household compound. During this period, called multi-household compound, daughter's and parents' households share land, labour and the rice granary. The youngest daughter and her husband will never move out of her parents' house, which she will inherit. Inheritance of land mainly occurs when the parents are old and land is distributed among daughters (Foster 1978; Mizuno 1978; Price 2003). The stem family cycles, however, are being affected by out-migration.

Rural Thai households depending on small scale and subsistence production, especially from the Northeast, are characterized by the presence of seasonal or permanent out-migration for labour in the urban industrial economy. Economic returns, however, may not be frequent or adequate enough and vary among households (Mills 1997). Remittances are economically important because they diversify income, but the loss of farm labour due to migration constitutes a problem for the local agricultural economy. Remittances are mainly utilized for meeting basic needs and occasionally conspicuous consumption (Jones and Kittisuksathit 2003).

METHODS

Field work was conducted from March 2008 to February 2009 in two adjacent villages with a total of 136 households, where the authors identified a total of 87 wild food plants growing in anthropogenic ecosystems including plants consumed as fruits and vegetables (Cruz-Garcia and Price 2011). Firstly, the village cropping calendar was verified with key informants. Secondly, a 100% sample of the village was selected for an in-depth demographic and socio-economic household census (n=136 households). Data was provided by the family heads (either the father or the mother). The list of variables was defined with local specialists that had ample research experience on the socio-economic situation of Northeast Thailand (Chamruspanth 2001; Chamruspanth and Kunurat 2000). The following information was recorded for each household:

- Household composition, specifying number of children, elderly and adults. Children were considered those 14 years old or younger, whereas elderly were 65 years or older. Working age adults were older than 14 and younger than 65 years (United Nations 2001). The number of adult migrants (permanent or seasonal) was also recorded.
- Presence of chronically ill household members.
- Household assets in terms of ownership of rice field, area of field and possession of goods (TV, fan, radio, refrigerator, rice cooker, stove, car, motorcycle, bicycle, plough, mobile phone, home phone, computer and stereo).
- Household economics, in terms of total income, remittances, expenditures and debts in the year. Income was quantified including the sale of rice, cows, buffalos, ducks, chicken, vegetables, fish, pigs, as well as wage labour. Expenditures included the costs of rice production (ploughing, sowing, transplanting, harvesting, milling, seeds and agro-chemicals), petrol, food, clothes, medicines, electricity, irrigation water, telephone, donations to the Buddhist temple and children's education. Debts include money borrowed from the village fund, the Agricultural Cooperative Bank, Government Savings Bank, relatives, private money lenders and other sources.

Household vulnerability was analysed in relation to presence of chronic illness, total dependency ratio, ownership of rice field and economics. These variables were calculated as follows:

- Presence of chronic illness was recorded as either present or absent in any household member.
- Total dependency ratio was calculated as the relation of number of children and elderly to the working age adults including and excluding migrants, according to these formulas adjusted from the 'World Population Ageing 1950-2050' report of the United Nations (2001):

  $$\text{Total dependency ratio including migrants} = \frac{(\text{number of children + elderly}) \times 100}{\text{number of adults including migrants}}$$

  $$\text{Total dependency ratio excluding migrants} = \frac{(\text{number of children + elderly}) \times 100}{\text{number of adults excluding migrants}}$$

  The higher the ratio, the higher the burden on the working age adults to maintain the children and elderly, who are assumed to be economically dependent on them. It is important to remark that chronically ill persons were not subtracted to calculate dependency ratio.
- Ownership of rice fields was documented as either presence of land or absence (landless). It was considered that a household owns a field when: (a) they work in their own field, (b) they work in a field of their parents, which could also be the

case depending on the stage of family phase, (c) they work in a field given by relatives with use rights, so the household does not have to give anything in exchange to their relatives.

- The following economic variables were obtained: total income (including remittances), total expenditures, total gross income (income minus expenditures) and total debts per year. In some analysis total remittances was also used as a variable, especially when examining migration. Remittances were included in the final calculation of total income after analysing and observing that both migration and remittances did not have any significant effect on wild food plant gathering (discussed later in this article).

Migration and material style of life (MSL) were also calculated per household in order to see if they have any influence on the results. These were calculated as follows:

- Migration was calculated as presence or absence of any adult migrant in the household, as well as number of migrants per household.
- Material style of life, which is an indicator of relative wealth in a community, summarizes the data on household material goods assets in one single index. Goods were ordered in a Guttman scale from most to least common among households that were assigned scale types according to their possession of goods (De Walt 1979; Van Willigen and De Walt 1985). The higher the scale the more goods the household possesses, including least common goods, which are usually the most expensive such as a car or computer.

A total of 40 households were selected from the census, which is equivalent to almost 30% of the selected villages. Twenty of these households were randomly selected, whereas the other half was purposely selected in terms of having any chronically ill family member, having many children or elderly, or being landless. Households were visited every month to conduct 7-day recalls over a 12-month period on wild food plant acquisition events. Seven-day recalls were chosen because the reference period of one week was recommended over one-day or two-week recalls, given the impossibility of doing personal consumption diaries (Beegle *et al.* 2010). Semi-structured interviews were conducted with female heads of households given that it has been reported by previous research that women in Northeast Thailand are the main knowledge holders and gatherers of wild food plants as they procure for their household's daily food consumption (Moreno-Black *et al.* 1994; Price 2003; Price and Ogle 2008). Women were asked about wild food plants acquired, mode of acquisition, purpose of acquisition and place where the plant was obtained.

Data was entered in a relational data base (Microsoft Access ©) in terms of acquisition events with one event being one household's acquisition in an explicit acquisition mode (gathering, purchase, received as a gift) with an particular purpose (to eat, to offer to the temple, to give as present, for exchange) of one specific species, in a specific place and in a given month. Given that the focus of this article is on gathering of wild food plants for family consumption, only gathering events for the purpose *to eat* were further analysed. In this way, one gathering event refers to one household's gathering of one specific species in a specific ecosystem and in a given month, with the purpose of consumption. Using these data the following variables were calculated for analysing the seasonality of wild food gathering across anthropogenic ecosystems:

- Number of gathering events per month in each ecosystem.
- Number of species gathered per month in each ecosystem.
- Number of households gathering wild food plants per month in each ecosystem.

A case study conducted in Central Thailand reported that farmers gather wild food before spraying pesticides in rice fields and over application of pesticides in this region caused a serious decline in the availability of these species (Price 2000). Therefore, interviews were conducted with the selected female heads of households on whether they had some general concerns regarding wild food plant gathering in rice fields, in order to analyse the effect of pesticide application on gathering patterns or other possible concerns. The interview consisted of a single open ended question.

Non-parametric statistical analyses were applied to explore the effect of household profiles on wild food plant gathering and the relations between household vulnerability and gathering using the PASW Statistics 18 (SPSS) software. Data on household number of gathering events and amount of species gathered per month in each ecosystem were compared to household demographic and socio-economic variables. Wilcoxon-Mann-Whitney tests were conducted in analyses concerning household nominal binary variables, namely presence of chronic illness and migration. Spearman rank-order correlation coefficients were obtained in order to assess the possible association between gathering variables and ordinal or interval household variables, i.e. total dependency ratio, income, expenditures, gross income, remittances, debts and material style of life (Siegel 1988). Only probability values below or equal to 0.05 are considered statistically significant. Results that reach the 0.10 level of probability are reported as approaching statistical significance in order to indicate a trend.

RESULTS

Demographic and socio-economic characteristics of households

Regarding the demographic characteristics of the village, results showed that households had on average 4.7 members of whom 3.5 were working age adults and the rest children and elderly (Table 1). Excluding migrants, however, households had on

Table 1. Demographic and socio-economic profile of the households comparing means (or percentages if explicitly indicated) of village population and sample, indicating the significance of the independent one-sample t-test.

	Population[1] (n=136)	Sample[2] (n=40)	t-test significance[3]
Demographic information			
Household size (nr)	4.7	5.2	
Children (nr)	0.9	1.1	
Elderly (nr)	0.3	0.3	
Adult migrants (nr)	1.1	1.5	0.084
Total dependency ratio including migrants[4]	48.9	41.1	
Total dependency ratio excluding migrants	91.6	84.8	
Households with adult migrants[5] (%)	58.2	72.5	0.036
Households with chronically ill members (%)	25.0	35.0	
Socio-economic information: household assets			
Ownership of rice field[6] (%)	96.9	90.0	
Rice field area (ha)	1.5	1.4	
Material style of life[7]	11.0	11.4	
Socio-economic information: annual household economics[8]			
Income (US$)	3055	3096	
Expenditures (US$)	2390	2499	
Gross income (US$)	665	598	
Debts (US$)	1431	1536	
Remittances (US$)	879	793	

[1] Missing values ranging from 0 to 2 for demographic variables and from 0 to 19 for socio-economic variables.

[2] No missing values for demographic variables and missing values ranging from 0 to 7 for socio-economic variables.

[3] Only significant values below or equal to 0.05 and trends at 0.10 are presented.

[4] Total dependency ratio is the relation of number of children (younger or equal to 14 years) and elderly (older or equal to 65 years) to the number of working age adults (older than 14 and younger than 65 years).

[5] Working age adults that migrated permanently or seasonally.

[6] Statistical analysis not conducted given the low number of landless households (n=4).

[7] Material style of life is as an indicator of relative wealth that summarizes information on household goods assets; mean of total income, expenditures, gross income, debts and remittances for the year.

[8] 1 US$ = 29.925 Thai Bahts, exchange rate 20 July 2011.

average only 2.4 adults of working age, which was reflected in a very high total dependency ratio, almost twice higher than the dependency ratio including migrants. Migration was a major feature of the village, where almost three fourth of the households had one or more adults who had migrated to cities either seasonally or permanently. In this way, remittances were an important component of income constituting up to 29% of it. One fourth of the families had one or more chronically ill family members, who stayed at home and could not fully participate in the agricultural activities. Consequently, lack of labour was a common problem for agricultural production. Nevertheless, during rice transplanting and harvesting that were the most labour intensive moments in rice cultivation, most adult migrants returned home to help their families.

Most families owned a rice field. Landlessness was purposely over-represented in the sample because all four landless households of the village were selected for the study in order to better capture vulnerability. No statistical analysis was conducted with this variable because of the low number of landless families. The area of rice fields ranged from 0.2 ha to 4 ha. Material style of life varied among families, the lowest score was for a family that only had one of the goods on the list of items (rice cooker), whereas the highest scores were for two families having a car and a computer.

Gross income was extremely low, at a mean of US$ 1.8 per day, without taking into account household debts. Eighty eight percent of households, however, had debts. If household debts were deducted from the gross income, the household budget was negative. In these terms, an average household in this village was economically vulnerable.

The independent one-sample t-test was conducted in order to analyse the representativeness of the sample with respect to the village population. Results showed that only two out of 15 analysed variables were not representative of the population, namely presence of adult migrants and number of adult migrants in the household (at 0.05 and 0.10 level, respectively). Households were not purposely selected with respect to migration, but migrants happened to be over-represented in the household sample. These differences, however, did not have a major influence on the results of this study, because, as will be explained later, migration showed to have no influence on wild food plant gathering. Contrastingly, despite that 20 households were purposely selected for the presence of any chronically ill member, the sample was representative of the population regarding this variable.

Acquisition of wild food plants

A total of 2460 wild food plant acquisition events were reported after conducting monthly 7-day recalls with the 40 households sampled throughout the year. From this total, 89% of the events corresponded to gathering, 10% to market purchase and 1% of plants were obtained as a present. Most gathering events were done with the purpose to eat (2196 events). Forty-six gathering events were meant for preparing food and giving it as an offering to feed the Buddhist monk. Three events were meant to give as present and two for exchange. A few gathering events had a double purpose (2%), for example to eat and also to give as a food offering to the monks. The focus of this article is only on wild food plant gathering with the purpose to eat, so the results of this article are based on these 2196 gathering events.

Overall households gathered a total of 50 different wild food plant species to eat corresponding to 32 botanical families (Table 2). It is important to emphasize that in the rainy season the monthly average of gathered wild food plant species was 32, almost 50% higher than in the rainy season (22 species). All sampled households gathered wild food plants throughout most of the year: 80% of households gathering every single month and 13% gathering 11 months out of the year. Only two families gathered 10 months and one gathered 7 months out of the year.

All households gathered wild food plants from paddy fields and home gardens, and most of them (68%) also from roadsides (Figure 1). The highest percentages of species gathered and gathering events corresponded to home gardens (78% of species, 53% of events), followed by paddy fields (70% of species, 39% of events). Five percent of all gathering events occurred in roadsides, corresponding to 24% of species. One third of households gathered from secondary woody areas (33%) and only few households from swamps (8%), corresponding to 16% and 4% of the species, respectively.

Seasonal complementarity of different anthropogenic ecosystems

More than half of the gathering events occurred in the six months that make up the rainy season (62%). The rainy season starts in May and afterwards rice transplanting occurs in June and July. The percentage of households gathering wild food plants in home gardens and rice fields was very constant during this season (Figure 2). The number of gathering events in these ecosystems remained almost constant during the rainy season, reaching its maximum in September, which coincides with the maximum rainfall, reported in this year and maximum plant height before grain development of transplanted rice. The number of species gathered in rice fields, however, decreased by almost 50% in July when farmers applied pesticides. In August this percentage increased only slightly. This phenomenon was not reflected in the observed number of gathering events or in the percentage of households gathering. This is because farmers stopped gathering wild food plant species that grew in the aquatic and semi-aquatic habitats of paddy fields. They continued collecting from terrestrial sub-systems in the rice fields, such as shelters and hillocks, and increased their gathering from roadsides.

Table 2. List of wild food plant species gathered to eat indicating botanical family, scientific name, local name in Thai script and English transliteration of local name[1].

Scientific name	English transliteration of local (*Isaan*) name	Local (*Isaan*) name
Aizoaceae		
Glinus oppositifolius (L.) Aug.DC.	Phak kaen khom	ผักแก่นขม
Amaranthaceae		
Amaranthus viridis L.	Phak hom	ผักหม
Anacardiaceae		
Spondias pinnata Kurz	Bak kawek	บักกอก
Annonaceae		
Polyalthia debilis Finet & Gagnep.	Bak lok kok	บักลกคก
Polyalthia evecta Finet & Gagnep.	Bak tong leeng	บักต้องแล่ง
Arecaceae		
Calamus sp.	Bak waai Waai	บักหวาย หวาย
Asclepiadaceae		
Telosma minor Craib	Phak kik Dok kik Bak kik	ผักขิก ดอกขิก บักขิก
Basellaceae		
Basella rubra L.	Phak pang	ผักปั๋ง
Bignoniaceae		
Dolichandrone serrulata Seem.	Kee paa	แคป่า
Oroxylum indicum Vent.	Phak lin faa Bak lin faa Yod lin faa Bai lin faa	ผักลิ้นฟ้า บักลิ้นฟ้า ยอดลิ้นฟ้า ใบลิ้นฟ้า
Campanulaceae		
Lobelia begonifolia Wall.	Phak luem phua	ผักลืมผัว
Clusiaceae		
Cratoxylum formosum (Jack) Benth. & Hook.f. ex Dyer	Phak tew	ผักติ้ว
Garcinia cowa Roxb.	Phak moong Bak moong	ผักโมง บักโมง
Compositae		
Emilia sonchifolia (L.) DC.	Phak lin pii	ผักลิ้นปี่
Convolvulaceae		
Ipomoea aquatica Forssk.	Phak bung	ผักบุ้ง
Cucurbitaceae		
Coccinia grandis (L.) Voigt	Phak tam nin Bak tam nin Tam nin	ผักตำนิน บักตำนิน ตำนิน

Table 2. (continued)

Momordica charantia L.	Phak sai Bak phak sai	ผักไส่ บักผักไส่
Euphorbiaceae		
Phyllanthus acidus (L.) Skeels	Bak yom Yod bak yom	บักยม ยอดบักยม
Hydrocharitaceae		
Ottelia alismoides (L.) Pers.	Phak hob hep	ผักโหบเหบ
Lecythidaceae		
Barringtonia acutangula (L.) Gaertn.	Phak kadon naam Kadon naam	ผักกะโดนน้ำ กะโดนน้ำ
Careya arborea Roxb.	Phak kadon kok Kadon kok	ผักกะโดนโคก กะโดนโคก
Leguminosae		
Adenanthera pavonina L.	Phak lam	ผักล่ำ
Leucaena leucocephala (Lam.) de Wit	Phak kased Bak kased Yod phak kased Kased	ผักกะเสด บักกะเสด ยอดผักกะเสด กะเสด
Neptunia oleracea Lour.	Phak kased naam	ผักกะเสดน้ำ
Pithecellobium dulce (Roxb.) Benth.	Bak kaam lian Kaam lian	บักขามเลียน ขามเลียน
Cajanus cajan (L.) Millsp.	Bak tua heea Tua heea	บักถั่วแฮ ถั่วแฮ
Cassia siamea Lam.	Phak khee lek Khee lek	ผักขี้เหล็ก ขี้เหล็ก
Senna sophera (L.) Roxb.	Phak let ket	ผักเล็ดเค็ด
Tamarindus indica L.	Bak kaam Bak kaam som Maak kaam Yod kaam	บักขาม บักขามส้ม หมากขาม ยอดขาม
Limnocharitaceae		
Limnocharis flava Buchenau	Phak kanjong Bak kanjong Phak pai	ผักคันจอง บักคันจอง ผักพาย
Marsileaceae		
Marsilea crenata C.Presl	Phak waen	ผักแว่น
Meliaceae		
Azadirachta indica A.Juss. var. *indica*	Phak ki nin	ผักคินิน
Azadirachta indica A.Juss. var. *siamensis* Valeton	Phak kadaw Yod kadaw Yod phak kadaw	ผักกะเดา ยอดกะเดา ยอดผักกะเดา

Table 2. (continued)

Menispermaceae		
Cissampelos pareira L.	Bai maa noi Maa noi	ใบหมาน้อย หมาน้อย
Tiliacora triandra Diels	Yaa nang Bai yaa nang	ย่านาง ใบย่านาง
Myrtaceae		
Psidium guajava L.	Bak sidaa noi	บักสีดาน้อย
Syzygium gratum (Wight) S.N.Mitra	Phak mek Maak mek	ผักเม็ก หมากเม็ก
Nymphaeaceae		
Nymphaea pubescens Willd.	Phak sai bua Sai bua	ผักสายบัว สายบัว
Opiliaceae		
Melientha suavis Pierre	Phak waan paa	ผักหวานป่า
Pontederiaceae		
Monochoria hastata (L.) Solms	Phak top Phak top thai	ผักตบ ผักตบไทย
Monochoria vaginalis C.Presl	Phak e-hin	ผักอีฮีน
Rhamnaceae		
Ziziphus mauritiana Lam.	Bak tan noi	บักทันน้อย
Rubiaceae		
Oxyceros horridus Lour.	Bai kat kaaw	ใบคัดเค้า
Rutaceae		
Aegle marmelos Corrêa	Bak tuum Maak tuum Yod maak tuum	บักตูม หมากตูม ยอดหมากตูม
Sapindaceae		
Lepisanthes rubiginosa (Roxb.) Leenh.	Bak huat kaa	บักหวดข่า
Schleichera oleosa (Lour.) Oken	Bak kawe Luk kawe Maak kawe	บักค้อ ลูกค้อ หมากค้อ
Scrophulariaceae		
Limnophila aromatica Merr.	Phak kayang	ผักกะแยง
Umbelliferae		
Centella asiatica (L.) Urb.	Phak nok	ผักหนอก
Zingiberaceae		
Alpinia malaccensis C.Presl	Kaa paa	คาป่า
Curcuma singularis Gagnep.	Dok ka-jeeuw	ดอกกะเจียว

[1] A more extensive list is published in Cruz-Garcia and Price (2011).

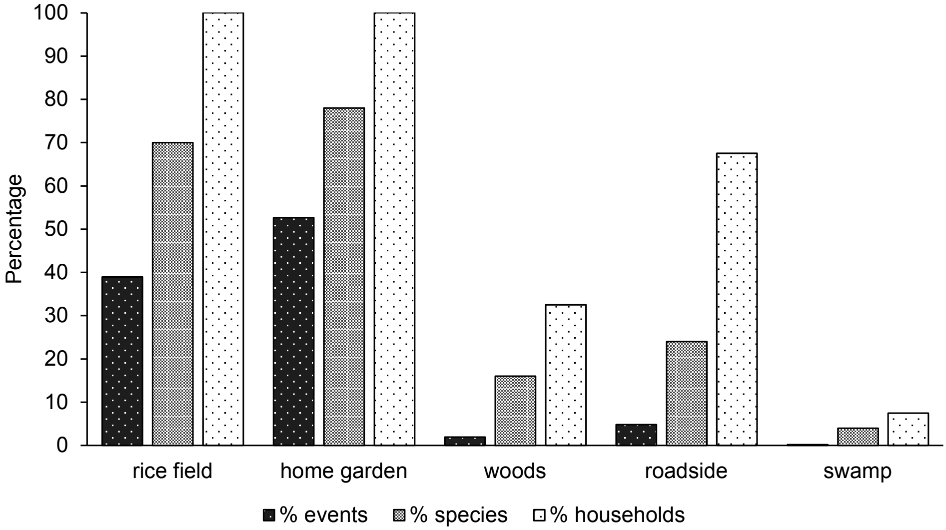

Figure 1. Percentage of gathering events for eating in one year (n=2196 events), percentage of species gathered (n=50 species) and households gathering in each ecosystem (n=40 households).

During these two months, the number of collection events, species gathered and percentage of households gathering wild food plants from roadsides reached its highest point in the season. People generally wait three weeks after pesticide applications before they start gathering again from the field areas they think are impacted.

Seventy-six percent of the farmers stated that they felt anxious about eating wild food plants from the rice fields. The most common concern was ingesting toxic agro-chemicals (96% of responses), followed by the presence of disease (48%) and dirty water (16%). In this context 'disease' refers to either illness caused by pesticide poisoning or Leptospirosis, both of which have already been reported as occurring in the village. Farmers that do not apply pesticides on their own fields are concerned that irrigation water would bring along residues of pesticides applied in neighbouring fields. These farmers reported a higher number of gathering events and species gathered from home gardens (significant at the 0.05 level, Wilcoxon-Mann-Whitney test for independent samples). Moreover, they reported fewer gathering events and gathered fewer species from the paddies (0.01, Wilcoxon-Mann-Whitney test).

The rainy season ends in the month of October when usually both the rice stocks in the household granary and the money obtained from the prior harvest are finished.

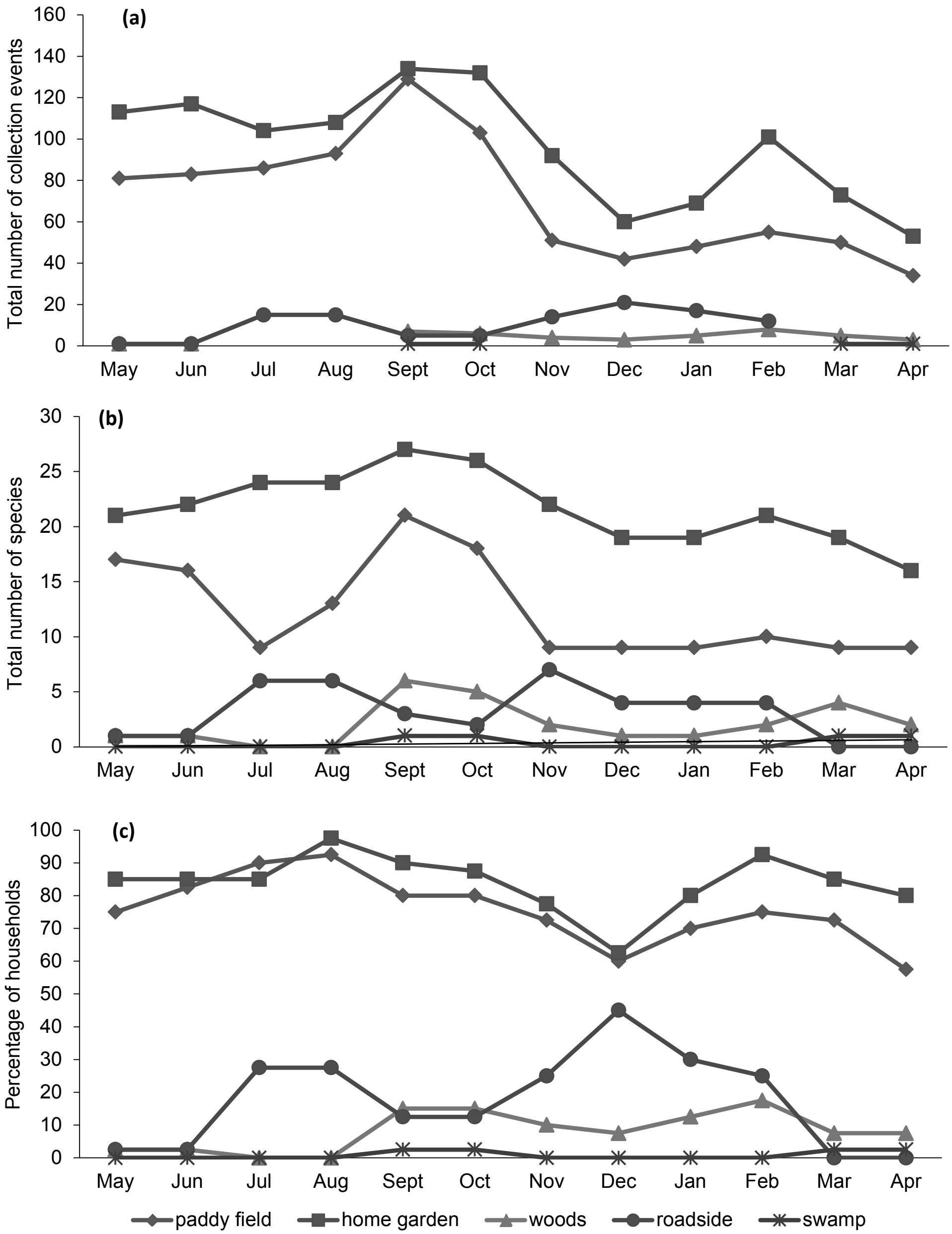

Figure 2. Wild food plant gathering throughout the year per ecosystem, presenting results of 7-day recalls conducted monthly (n=40 households). (a) Number of collection events (n=2196). (b) Number of species gathered (n=50). (c) Percentage of households gathering wild food plants (n=40). Rainy season occurs from May to October; dry season includes a cool period from November to February and a hot period from March to April.

Although there was a great decrease in rainfall, the number of collection events, species gathered and percentage of households gathering wild food plants remained very high this month.

Gathering of wild food plants decreased with the beginning of the dry season (cool period) and harvesting of transplanted rice in November. After harvesting most farmers burn the straw that is left in their fields, usually in November and December. This was clearly reflected in the remarkable decrease in the number of gathering events, species gathered and households gathering in the paddies, which reached their lowest values in these months. November and December were also characterized by a substantial increase in wild food plant gathering at roadsides, most noteworthy in the fact that the percentage of households gathering in this ecosystem reached its yearly maximum of 45%. Wild food plant gathering in home gardens also decreased after rice harvesting.

After rice harvesting and straw burning, those farmers with access to irrigation water will cultivate direct-seeded rice, mushrooms, or vegetables. Pesticide application, which takes place in January, has no impact on wild food gathering in paddies because usually no edible weeds grow in field borders of direct-seeded rice. During the dry season, gathering in paddies, which only occurs in shelters, hillocks and (half)-dried ponds, was considerably less than in the rainy season because only a few edible weed species grow and few trees provide fruit under the dry conditions of this season. Surprisingly, the percentage of households that kept on gathering wild plants was very high despite the low number of food species available in the paddies. Gathering of these few species, more importantly the herbs *Ipomoea aquatica*, *Centella asiatica* and *Glinus oppositifolius*, remained constant throughout these months given that they play an important role in the dry season's local diet. Regarding home gardens, the number of gathering events also decreased in the dry season, but there was neither a notable decrease on the diversity of species gathered nor on the percentage of households that gather these species.

A second food shortage occurred during the lean months of March and April before direct seeded rice harvesting, corresponding to the hot period of the dry season. In this period, the availability of wild food plants across all ecosystems dramatically decreased due to high temperatures and extremely dry conditions, which was clearly reflected in the decline of gathering events. The percentage of households gathering plants, however, remained high: these families depended on these few key species available.

Finally, the number of gathering events and species gathered in woods and swamps was very low throughout the year. Gathering from these ecosystems was mainly related to the environmental availability of specific wild food plant species. Woods mainly provide seasonal gourmet or delicacy fruits, as well as edible flowers.

Vulnerability, migration and wild food plant gathering

Household vulnerability was assessed by the presence of chronic illness, total dependency ratio, ownership of rice field and household economics. In addition, the influence of migration and material style of life (MSL) on gathering was controlled for in the data analysis. Households with a chronically ill family member reported gathering fewer species from rice fields (Wilcoxon-Mann-Whitney test at 0.10 level) but reported more gathering events from roadsides (Wilcoxon-Mann-Whitney test at 0.10 level). Landless households reported on average 3.7 times more gathering events from roadsides and gathered 1.4 more species from roadsides than those households owning a paddy field. Otherwise, there was no significant difference in gathering with respect to area of land owned. Although MSL was not initially considered a variable related to vulnerability, households with a lower MSL also reported more gathering events (Spearman's ρ at 0.05) and species gathered (Spearman's ρ at 0.10) at roadsides.

No relations were found between wild food plant gathering with income and expenditures separately, but the influence of gross income, which is equivalent to income minus expenditures, on gathering was significant. Households with lower gross income reported more gathering events across all ecosystems (Spearman's ρ at 0.10), gathered more species in total (Spearman's ρ at 0.05), and gathered more species in rice fields and home gardens (Spearman's ρ at 0.10). Households with higher debts reported fewer gathering events (Spearman's ρ at 0.10). Households with lower remittances reported more gathering events and species gathered in roadsides (Spearman's ρ at 0.10).

No relationship between migration, number of gathering events and number of wild food plant species gathered in any of the agro-ecosystems appeared in the results. In the same way, there were no differences observed between total dependency ratio including and excluding migrants with respect to gathering. In both cases households with a higher dependency ratio gathered a greater number of wild food plant species across all ecosystems (Spearman's ρ at 0.05). No significant differences were observed with respect to specific ecosystems.

DISCUSSION

The results of this study revealed some important aspects for understanding the seasonal complementarity of anthropogenic ecosystems with respect to wild food plant gathering and the tremendous implications for the household diet in Northeast Thailand, particularly for vulnerable households.

Implications for nutritional diversity and food security in Northeast Thailand

The research findings showed that wild food plant gathering from anthropogenic ecosystems was done mainly for the purpose of domestic consumption and that they constituted a major part of the diet. The great diversity of wild food plants gathered in this area, corresponding to 50 species belonging to 32 botanical families, and the high monthly number of gathered species, ranging from 36 to 18, reaffirmed for Northeast Thailand the general statement that wild foods provide a great dietary diversity, as concluded in a published comparative analysis of wild food gathering in agricultural areas around the world (Bharucha and Pretty 2010).

This paper establishes that wild food plants are vital for local food security based on the high monthly percentages of households gathering wild food plants, ranging from 100% to 93%, and high number of wild food plant collection events (2196) recorded using 7-day recalls over a 12-month period. Despite the seasonal variations in the number of gathering events and number of species gathered, the percentage of households gathering plants was almost constant throughout the year, which implies that this resource is in general essential for local families regardless of seasonality.

This is comparable to the findings of Shackleton *et al.* (1998) who reported that all of the surveyed households in the central Lowveld savannah region in South Africa consumed wild vegetables. Similarly, Pérez-Negrón and Casas (2007) reported that 96% of surveyed households in Santiago Quiotepec, Mexico, gathered cultivated and wild edible plants, and nearly 88% of households gathered wild fruit. This was, however, not the case among Chepang people of Nepal, where only 58% of households consumed uncultivated foods for more than 3.5 months a year (Prasad Aryal *et al.* 2009).

Importance of anthropogenic ecosystems

It has been asserted that dietary diversity is founded on farming systems diversity (Frison *et al.* 2011). This study provides evidence to assure that this is also the case for Northeast Thailand, where people gather numerous wild food plant species from a wide array of anthropogenic farming systems including home gardens, paddy fields, roadsides, secondary woods and swamps. Likewise each ecosystem provides aquatic, semi-aquatic and/or terrestrial habitats fulfilling niche requirements of different species of edible trees, shrubs, herbs, vines and rattans.

Farmers gather wild food plants across farming ecosystems depending on their access possibilities as well as species availability. In addition, when gathering occurs in the private property of a neighbour, gathering depends on species specific gathering rights that may vary per location (Price 1997). In this way, the landless may be able to collect limited amounts of wild food plants from other's rice fields subject to the species in question.

The results of this study illustrate that home gardens and rice fields constitute the most important sources of wild food plants, reflected in the high number of species gathered (ranging from 16 to 27 per month for home gardens and from 9 to 21 for rice fields) and the high percentage of households gathering wild food plants in these ecosystems (ranging from 63% to 98% per month for home gardens and from 58% to 93% for rice fields). Home gardens constitute an integral component of the farming system (Kumar and Nair 2004) and play an essential role in counteracting malnutrition and food insecurity (Kehlenbeck *et al.* 2007). Similarly, it has been documented that agricultural fields are essential for providing not only staple crops but also wild food plants crucial for the food security of farming communities (Price and Ogle 2008; Scoones *et al.* 1992).

The maintenance of almost a constant number of species gathered in home gardens all year round, even surprisingly keeping high values during the dry season implies the presence of human management. Indeed, it has been reported that farmers cultivate and manage wild food plants in Northeast Thai home gardens (Moreno-Black *et al.* 1996; Price 2005; Wester and Yongvanit 1995). However, wild food plant gathering in paddies presented much higher monthly variations, due primarily to species environmental availability and cultivation practices in transplanted rice.

Seasonal implications of wild food plant gathering

Results show that wild food plant gathering is important throughout the year, even after rice harvesting when families have increased their resources. This is reflected in the high number of gathering events reported with the 7-day monthly recalls (ranging from 279 to 93 per month), the fact that most households (80%) gathered wild food plants every single month of the year, and the high percentages of household gathering these plants every month. The year-round consumption of wild food plants has also been reported across the world, for example in Arribes del Duero, Spain (González *et al.* 2011), the Tehuacán-Cuicatlán valley in Mexico (Pérez-Negrón and Casas 2007) and in Southern Zambia (Mnzava 1997).

It is possible to conclude from the results of this study that wild food plants constitute a 'rural safety net' acting as a buffer against food shortage during the following lean months:

- October, when 100% of households depended on 32 wild food plant species before harvesting of transplanted rice.

- March and April, corresponding to the hot season when, despite the dramatic decrease on the environmental availability of several species, from 98% to 100% of households relied on the remaining 18 to 23 species.

Likewise, the important role of wild food plants for household food security during food shortages has also been reported for other rice farming communities and agricultural societies in the world. For instance, during the *monga* season in Bangladesh, when stored food is finished before rice harvesting (Mendoza and Johnson 2008), households depend on non-conventional food plants with a high content of amino-acids, minerals and essential fatty acids for meeting their basic nutritional needs (Kumar Paul *et al.* 2011). During periods of seasonal stress corresponding to the end of the rainy season, the diet of *Tuareg* pastoralists depends on nutritious wild grasses, among other resources (Smith 1992). Wild food plants provide farmers in West Africa with essential nutrients and additional calories during periods of famine (Lockett *et al.* 2000) and have been important for survival during times of food shortages in different Mediterranean countries (González *et al.* 2011).

The influence of pesticide application and wild food plant gathering in paddies

This case study provides evidence that most farmers are afraid to get sick when collecting or consuming wild food plants from rice fields because of pesticide intoxication or Leptospirosis. These farmers gather significantly more wild food plants from home gardens and wait three weeks after pesticide application for re-starting their gathering activities in rice fields. This was reflected in a dramatic decrease of almost 50% less species gathered from rice fields in the month of July.

The negative effects of pesticide application on wild food plant gathering has also been documented in Northern Thailand, where some respondents asserted that pesticide use, which caused illness among families and livestock in the area, was the major threat to the availability of wild edible plants growing along paddy waterways (Johnson and Grivetti 2002). In a study conducted in Central Thailand, which is characterized by high input rice production, it was documented that pesticide application and land use changes contributed to the decrease of wild food plant gathering in the paddies (Price 2000). Contrarily, in a study conducted in Laguna and Nueva Ecija, the Philippines, where farmers were not aware of the potential negative effects that the excessive use of pesticides would have for human health, it was documented that the amount of wild food gathered from their paddy fields was not affected by the level of pesticide application (Warburton *et al.* 1995).

Implications for vulnerable households

The fact that vulnerable households in terms of lower gross income and higher dependency ratio gather a significantly higher number of wild food plant species across anthropogenic ecosystems shows that they rely significantly more on biodiversity. From these findings it is possible to assert that wild food plant gathering constitutes an important household coping strategy especially for the most vulnerable families who are those less able to deal with situations of stress.

These findings are consistent with the results of a comparative analysis of wild food gathering across continents concluding that this resource is important to the poorest households worldwide (Bharucha and Pretty 2010). For example, it was reported that the poorest families in Kurigram District, Bangladesh, depend heavily on non-conventional plants during the famine periods (Islam *et al.* 2011), in South Africa poor families without a constant income depend more on wild and cultivated local vegetables (Hart 2011) and wild food plants are critical to the survival of the most vulnerable people in West Africa (Lockett *et al.* 2000).

The importance of wild food plants for families with a high dependency ratio has also been reported in other regions such as Limpopo Province, South Africa, where indigenous vegetables, including wild plants, are essential for children and the elderly (Hart 2011). In another district of the same country, it was found that households with an increased dependency ratio due to adult mortality rely more on wild vegetables (Twine and Hunter 2010).

Households with any chronically ill family member or elderly have labour constraints. This was observed in the lower number of species gathered from rice fields in comparison to the other households. These families prefer to gather closer to their house, either in home gardens or roadsides. The proximity of home gardens to the house is convenient for assuring food security especially for these families whose members cannot usually manage to gather wild food plants in agricultural areas. This was also observed in a study conducted in rural Ghana, where Akrofi *et al.* (2010) found that households with an HIV chronically ill family member had a more diverse diet, specially due to the consumption of more food plant species gathered from gardens that are closer to home.

Public roadsides are an important ecosystem in terms of wild food plant gathering not only for families with a chronically ill member, but also for vulnerable households in general and during those months when it is not possible to gather from the paddies. This was reflected in the following three findings:

- Families with a chronically ill member, the landless, households with lower remittances and those with a lower material style of life (MSL) reported considerably more gathering events in roadsides.

- Landless households, households with lower remittances and those with a lower material style of life (MSL) gathered a higher number of species from roadsides.
- The number of gathering events and percentage of households gathering from roadsides were higher during the months of pesticide application and straw burning in the paddies.

Roadsides can be regarded either as a secondary option when families cannot gather in paddies or as an important buffer complementing rice fields.

Migration and gathering

Remittances, as additional cash income, had a negative relationship with wild food gathering, whereas migration *per se* was not a variable influencing gathering. Not all migrants send remittances to their families in the village and the amount of money they send is variable. The presence of migrants in a family did not show any statistical relation with the number of wild food plant gathering events and species gathered and, moreover, there were no differences observed between both dependency ratios, including and excluding migrants, with respect to gathering.

To the contrary, Wester and Yongvanit (1995) suggest that out-migration in Northeast Thailand may contribute to the decrease in wild food plant knowledge and use. This assertion, however, could be more relevant for the younger generations, when migration would affect wild food plant gathering due to the current absence of knowledge transmission from parents to their children. Migration was not an issue when current gatherers learned about wild food plants from their parents. Nowadays, however, almost a whole adult/parental generation is missing in the village due to migration, thus traditional patterns of knowledge transfer are certainly being affected. Setalaphruk and Price (2007), who recently conducted research in the same village, stated that although children are able to identify wild food plants by their names, they lack specific tactic knowledge with respect to gathering practices. In this way, there is an on-going process of knowledge erosion that certainly will have consequences on wild food plant gathering in the future.

CHAPTER 8

General discussion

INTRODUCTION

The general objective of this study, conducted in Kalasin, Northeast Thailand, was to contribute to the understanding of wild food plant gathering by rice farmers, by developing a theoretical and analytical framework supported by multi-facetted empirical evidence on the spatial and seasonal complementarity of anthropogenic ecosystems and sub-systems, as well as their implications for the food security and dietary diversity of households. The research objective was operationalized in four research questions serving as a guide to conduct empirical research:

1. To what extent do anthropogenic ecosystems complement each other with respect to wild food plant provisioning and gathering, as well as in relation to rice farming activities?
2. To what extent do different sub-systems, comprising rice ecosystems and home gardens, seasonally complement each other in terms of diversity and functionality (regarding multiplicity of uses of wild food plant species)?
3. How does wild food plant diversity in rice ecosystems and home gardens differ seasonally, regarding the abundance and frequency of occurrence of individual gathered plant species?
4. Does wild food plant gathering have implications for the food security and dietary diversity of households, especially the most vulnerable and during lean months?

The study was conducted from an ethnobotanical perspective, which provides an interdisciplinary approach to the study of the relations between humans and plants, using local cognitive and value systems as a starting point. This implied the integration of both quantitative and qualitative methods of data collection and analysis, drawn from the disciplines of botany, ecology and anthropology. In order to answer the research questions, the theoretical and analytical frameworks are presented and discussed in Chapter 1, the overview of ethnobotany is detailed in Chapter 2, and the current perspectives on the study of wild food plants are explained in Chapter 3. Then Chapters 4, 5, 6 and 7 comprise the results of the fieldwork conducted in Kalasin, Northeast Thailand. Chapter 4 presents a complete botanical inventory of wild food plants in the research site and provides information on research question 1 (growth location of wild food plants) and research question 2 (multiple uses of wild food plants). Chapter 5 discusses research questions 2 and 3 with respect to rice fields, whereas Chapter 6 evaluates the same questions regarding home gardens. Finally, Chapter 7 provides information for research question 1 (wild food plant gathering and rice farming activities) and deals with research question 4. The focus of this chapter is to further discuss the research questions in relation to the general objective of the study.

This Chapter is divided into six sections. The first section presents a reflection on the theoretical model on spatial and seasonal complementarity of ecosystems and sub-systems for farming societies. The second section comprises the evaluation of the main empirical findings with respect to the research questions, which were formulated at ecosystem, sub-system, species and household level. The third section presents a reflection on critical scientific issues in ethnobotany, whereas the fourth section discusses the practical implications of the study. The Chapter ends with the fifth section that reflects on the analytical approach and provides some recommendations for future research, and the sixth section containing the final conclusions.

REFLECTION ON THE THEORETICAL FRAMEWORK

The empirical results of the study provide substantial evidence to confirm the postulations of the theoretical model proposed in Chapter 1 on the spatial and seasonal complementarity of ecosystems and sub-systems for farming societies, with respect to wild food plant gathering. Chapters 4, 5, 6 and 7, which comprise the results obtained from fieldwork conducted in Kalasin, Northeast Thailand, have demonstrated that rice farmers gather a great diversity of wild food plants across anthropogenic ecosystems throughout the year. Anthropogenic ecosystems, comprising several complementary sub-systems, are remarkably important in providing these plants for human consumption, contributing to the food security and dietary diversity of farming households, with major seasonal implications for the most vulnerable households. The detailed explanation of how the results of the study support the theoretical model is presented in the following section (evaluation of major empirical research findings).

The research findings show that smallholder farmers embrace a complexity of practices, resources and agro-ecosystems that, as Michon and De Foresta (1997) pointed out, cannot be captured with current linear models of domestication. The results of this study demonstrate that this complexity is a major feature of farmers' coping strategies, especially regarding their food security and dietary diversity. Therefore, neglecting these complexities obscures the scientific understanding of the interactions between farming societies and anthropogenic ecosystems, as well as the implications that these complexities have for rural livelihoods. This has not only theoretical implications, but also practical repercussions for future agricultural programmes, food policies, biodiversity conservation initiatives and poverty alleviation strategies at regional and global level (discussed later on in this Chapter). In this regard, the theoretical model here proposed facilitates ‘zooming’ into the current continuum of domestication (Harris 1989; Wiersum 1997a; b) to elucidate the complexities related to spatial and seasonal complementarity at ecosystem and sub-system level.

It is demonstrated by this study that the ‘socio-economic drive’ increasing along the rain forest – mono-cropping continuum presented by Anderson and Sinclair (1993, 78) and Abebe (2005, 2) is not fully valid at ecosystem scale. Research findings showed that small-scale farmers, regardless their socio-economic conditions, gather wild food plants across different anthropogenic ecosystems and sub-systems that spatially and seasonally complement their availability. For instance, Chapter 7 showed that 93% of sampled households gathered these species every single month or 11 months out of the year, all households gather these foods from rice ecosystems and home gardens, and 68% of families from roadsides.

The rain forest – mono-cropping continuum presented by Anderson and Sinclair (1993, 78) and Abebe (2005, 2) also neglects the importance of small-scale farmer’s strategies of diversification, related to the management and utilization of various ecosystems, sub-systems and species. These strategies constitute an essential rural safety net, not only during lean months and scarcity periods, but throughout the year and with major implications for the most vulnerable households. As discussed in Chapter 7, although all households are actively gathering wild food plants, the most vulnerable ones depend to a greater extent on these species for their subsistence. For instance, households with lower gross income reported a significantly higher number of annual gathering events and species gathered. Likewise, families with a higher dependency ratio reported a statistically higher annual number of species gathered across ecosystems.

From the empirical findings it is also evident that use of ecosystems and sub-systems can change positions along the continuum on spatial and seasonal complementarity here proposed. In this regard, Chapters 5 and 6 clearly showed that abundance and frequency of occurrence of individual species varied seasonally in paddy rice field’s and home garden’s sub-systems; thus affecting their diversity, plant community composition and functionality (due to variable proportions of species with additional uses besides food). Although this study mainly focused on seasonal variations, the ecological variables changed with respect to households. For instance, number of plant individuals, number of species and diversity indexes presented a great variability across family’s home gardens in both seasons, as observed in their high standard deviations. Moreover, home gardens highly differed in the number and types of sub-systems they contained (Chapter 6).

Finally, it is important to emphasize that ecosystem and sub-system complementarity is dynamic, not only regarding seasonal variability, but also long term adaptations to on-going processes of social and environmental change.

EVALUATION OF MAJOR EMPIRICAL RESEARCH FINDINGS

General highlights

The results of this study revealed the great diversity of wild food plants in Kalasin, Northeast Thailand. We found in this area up to 87 annual and perennial wild food plant species, belonging to 47 botanical families, including trees, terrestrial and aquatic herbs, climbers, shrubs, bamboos and a rattan. The edible parts of these food species are diverse, varying from vegetative organs, such as leaves, shoots, stalks of flower and stems, to reproductive structures such as flowers, fruits and seeds. Moreover, more than half of the plants identified as wild food plants have more than one edible part. The overall importance of wild food plants for rice farmers is enhanced by the fact that it has been reported that more than two thirds of these species have additional uses besides food, such as medicine, fodder, fuel, timber and making local handicrafts.

A major finding of this study is that wild food plant gathering is crucial for household food security as demonstrated in the high number of gathering events (n=2196) recorded using 7-day recalls over a 12-month period with a sub-sample of 40 households (Chapter 7). It was also revealed that gathering is crucial for local households throughout the year regardless of the seasonality of occurrence of specific plants. The important role of wild food plants is also reflected in the fact that more than half of the species reported in this area were actually gathered by the sampled households (50 species). The findings show a high monthly number of gathered food species, ranging from 36 to 18, which adds substantial evidence to the role wild food plants play in providing nutritional and dietary diversity (Chapter 7).

The increasing importance of anthropogenic ecosystems for wild food plant gathering (Ogle and Grivetti 1985; Price 1997; Scoones *et al.* 1992) was also reiterated by the findings of this study. Fu *et al.* (2003) stated that the access to forest resources is decreasing for smallholder farmers across Southeast Asia, where farmers increasingly depend on wild species from their home gardens. Likewise Ogle and Grivetti (1985) explained that farmers increasingly rely on agricultural weeds where forests decrease, naming this phenomenon the 'botanical-dietary paradox' (Chapter 4). This is certainly the case in Northeast Thailand, with a large rate of deforestation reported (Vityakon *et al.* 2004; Wijnhoud 2007), where rice farmers gather wild food plants from home gardens, rice fields, roadsides, secondary woods and swamps (Chapter 7). Anthropogenic ecosystems in this region comprise different sub-systems, diversifying the habitats offered for wild food plant species (Chapter 5 and 6). The preceding chapters demonstrated that ecosystem diversity promotes wild food plant species diversity. As clearly Frison *et al.* (2011) stated, dietary diversity is founded on farming systems diversity, and this was evidenced by this study in the Thai Northeast.

'Zooming 1': Complementarity of anthropogenic ecosystems in the landscape of rice farmers

The empirical findings of this study provided evidence to affirm that anthropogenic ecosystems are seasonally and spatially complementary as stipulated in the first level 'zooming 1' of the theoretical model here proposed. The results of this study also further demonstrated that this complementarity is not only regarding wild food plant gathering but also provisioning, as clearly illustrated in Chapters 7 and 4, respectively. Certainly, home gardens and paddy fields, which presented the highest numbers of gathered wild food plant species and highest percentages of households gathering these plants (Chapter 7), cannot be considered in isolation but are complementary components of the farming production system. The linkages between home gardens and paddies have previously been emphasized by Soemarwoto (1987) and Wiersum (2006) for Southeast Asia. Importantly, Abdoellah and Marten (1986) demonstrated that the complementarity of home gardens, upland fields and rice fields in West Java, Indonesia, is essential for meeting the nutritional needs of farming households thanks to crop diversification. Moreover, Gajaseni and Gajaseni (1999, 21), who conducted research in Thailand, stated that 'the dual systems of paddy rice and home gardens have been the foundation of the Thai society of the permanent settlers'. However, the findings of this PhD study go far beyond this assumption, not only by integrating rice paddies and home gardens to the rest of the landscape, but also by offering quantitative evidence to that.

Provisioning versus gathering of wild food plants

Comparing the results obtained in Chapters 4 and 7, it is possible to assert that wild food plants growing in multiple locations, which are the majority of species (80%), are not necessarily gathered in all the ecosystems where they grow. In this regard, comparing the number of provisioned and gathered species per ecosystem it was significant to observe that those ecosystems that are closer to home presented higher proportions of utilized species (Figure 1). In this way, on one hand, all species growing in roadsides (100%), most species growing in home gardens (87%) and more than half of species growing in rice fields (57%) were gathered by the sampled households. But, on the other hand, none of the species (0%) growing in upland fields (mainly adjacent to forest areas), only 13% of the species growing in swamps and 17%

of these present in woody areas were actually gathered by sampled households. Woods, upland fields and swamps are too far from the village, so there are less gathering events taking place in these places regardless of the number of wild food species they provide.

Certainly, public roadsides, despite providing a low quantity of wild food plant species (Chapter 4), are an important ecosystem in terms of wild food gathering, especially for the most vulnerable households (Chapter 7). Roadsides constitute a buffer to rural households during those months when families cannot gather wild food from the paddies. For instance, when straw is being burnt after rice harvesting, gathering in roadsides dramatically increases. Home gardens also showed to be a crucial gathering location when farmers cannot gather in rice fields, such as during the three weeks following pesticide application (Chapter 7).

Human management and species distribution

Across the chapters, it was highlighted that human management plays an important role regarding wild food plant distribution across anthropogenic ecosystems, as evidenced by the following findings:

- Most wild food plants (80%) grow in multiple ecosystems, no species was exclusive to home gardens and very few to rice fields and woods, corresponding

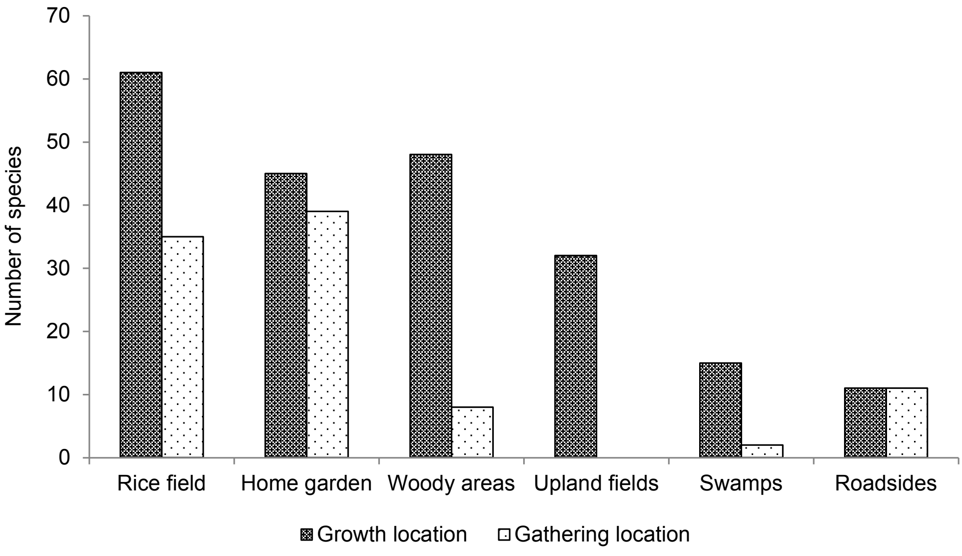

Figure 1. Comparison of anthropogenic ecosystems in terms of number of provided and gathered species

to the presence of transplanting activities (Chapter 4).

- Home gardens presented high wild food plant diversity in the dry season, which is only possible with human management given the harsh environmental conditions (Chapter 6).
- The number of species gathered in home gardens was almost constant throughout the year, which implies that farmers ensure the availability of certain wild food plant species (Chapter 7).
- Trees, which are abundant in rice fields, are not only remnants from a previous forest, but also have been transplanted mainly for the multiple uses they have (Chapter 5).

It is evident from these results that farmers ensure the seasonal and spatial availability of wild food plant species, re-creating the complementarity of anthropogenic ecosystems through management practices. For instance, on one hand, farmers warrant the seasonal provision of certain species by watering them during the dry season. On the other hand, they ensure the spatial availability of wild foods closer to their houses and village by transplanting and maintaining specific species in home gardens and rice fields that constitute, as previously discussed, the most important gathering locations (Chapter 7). Likewise, Chanaboon *et al.* (2005) observed that some ethnic groups in Northeast Thailand transplant wild species from the forests to the fields, Moreno-Black and Somnasang (2000) indicated that farmers transplant wild food plants from the forest to their home gardens, and Price (1997; 2008) reported that women in this region actively manage these species consciously ensuring their availability not only in the future, but also for periods of scarcity. As explained by Michon and De Foresta (1997, 459):

> 'The transfer of wild resources to cultivated lands, from the sphere of 'nature' to that of 'agriculture', is an essential process, for example to capture natural genetic variations or select useful characteristics, to increase population density, stimulate cross breeding, or escape from natural competitors and pests'.

However, the results show that the transfer of planting material also occurs across different ecosystems within the farming landscape, which is equally relevant in domestication processes.

Complementarity at species level

Another research finding is that rice fields and home gardens are complementary with respect to the communities of wild food plant species they possess, in both dry and rainy seasons (Chapters 5 and 6). This was clearly reflected in the fact that 83% of the most abundant and frequently occurring species (n=24) were exclusive to either home gardens or rice fields; whereas only four species, namely the weedy herbs *Centella*

Table 1. Most abundant and frequently occurring wild food plant species in rice fields and home gardens in dry and rainy seasons.

Most abundant and/or frequently occurring species	Dry season		Rainy season	
	Rice field	Home garden	Rice field	Home garden
Amaranthus viridis L.		✓✓		✓✓
Azadirachta indica A. Juss. var. *siamensis* Valeton	✓✓		✓✓	
Calamus sp.		✓✓		✓
Centella asiatica (L.) Urb.		✓✓	✓✓	✓✓
Cissampelos pareira L.		✓✓		✓
Coccinia grandis (L.) Voigt		✓✓		✓
Eichhornia crassipes (Mart.) Solms	✓		✓✓	
Glinus oppositifolius (L.) Aug.DC.	✓✓			
Hydrolea zeylanica (L.) J.Vahl	✓		✓✓	
Ipomoea aquatica Forssk.	✓✓	✓	✓✓	✓✓
Leucaena leucocephala (Lam.) de Wit	✓✓	✓✓	✓✓	✓✓
Limnophila aromatic Merr.				✓✓
Lobelia sp.	✓✓			
Marsilea crenata C.Presl	✓✓		✓✓	
Momordica charantia L.		✓✓		✓✓
Neptunia oleracea Lour.	✓✓		✓✓	
Nymphaea pubescens Willd.	✓✓		✓✓	
Ottelia alismoides (L.) Pers.			✓✓	
Phyllanthus acidus (L.) Skeels		✓✓		✓✓
Psiidium guajava L.	✓		✓✓	
Spondias pinnata Kurz		✓✓		✓✓
Tamarindus indica L.	✓✓	✓✓	✓✓	✓✓
Tiliacora triandra Diels		✓✓		✓
Ziziphus mauritiana Lam.	✓✓		✓✓	

✓✓ Most abundant and/or frequently occurring species.

✓ Species present in this season, but with low abundance and not frequently occurring. The absence of a tick means that the species was not observed in this season.

asiatica and *Ipomoea aquatica*, and the weedy trees *Leucaena leucocephala* and *Tamarindus indica*, were observed in both ecosystems (Table 1).

'Zooming 2': Seasonal complementarity of sub-systems comprised by rice ecosystems and home gardens in terms of diversity and functionality

The results of this study demonstrate that sub-systems are seasonally and spatially complementary, as explained in the second level 'zooming 2' of the theoretical model. In this way, Chapters 5 and 6 demonstrated that the spatial structure of home gardens and rice fields is diverse, and wild food plant diversity changes with the seasons. Home gardens presented not only yards and pots, but also fenced gardens and their margins, as well as fences and hedgerows constituting household boundaries (Chapter 6). Farmers also gather wild food plants from a host of sub-systems associated with rice cultivation activities, such as tree rows, ponds and their margins, hillocks, field margins, shelters and dikes (Chapter 5). Each sub-system provides habitats ranging from aquatic to terrestrial, fulfilling niche requirements of different species. In this way, it is evidenced in this study that the species abundance (Ab) and frequency of occurrence ($Freq_{SS}$ and $Freq_{SUB\text{-}S}$) of 20 and 42 wild food plant species observed and quantified in home gardens and rice fields, respectively, varied seasonally and spatially across the sub-systems (Chapters 5 and 6).

In general terms, the sub-systems presenting the highest diversity in home gardens were yards and fenced garden margins (Chapter 6), and in rice fields were shelters, hillocks, tree rows and pond margins (Chapter 5). However, as expected, species density (Sp_d) and diversity, as shown by the different indexes (S_{n1}, H' and D), differed in both dry and rainy seasons as well as across sub-systems in home gardens and rice fields (Chapters 5 and 6). The research findings evidenced that it is not possible to assure at sub-system level which ecosystem is more diverse when all their sub-systems are placed along a continuum from more to less diverse. This is clearly illustrated in Table 2 that compares the values of Shannon diversity index (H') of all sub-systems belonging to rice fields and home gardens. From Table 2 it is possible to state that: (a) the position of a sub-system in the continuum does not depend on the ecosystem it belongs, and (b) the order of the sub-systems along the continuum differs per season. For instance, while in the dry season household boundaries (belonging to home gardens) are more diverse than pond margins (belonging to rice ecosystems), the opposite occurs in the rainy season. Furthermore, adding to this complexity, it was also observed in this study that species diversity values, number and type of sub-systems per home garden, presented high variability across households (Chapter 6). Then, the location of the use of sub-systems along the continuum might ultimately also change with respect to household.

This study establishes that all sub-systems are important for the maintenance of wild food plant species, regardless the number of species or diversity indexes they presented (Chapters 5 and 6). This is based on the fact that some sub-systems, despite

Table 2. Spatial and seasonal variability of species diversity (H')

A. Dry season

	H'	Sub-system	Ecosystem
high diversity ↑	2.58	yard	home garden
	2.15	tree row	rice field
	1.75	shelter	rice field
	1.69	hillock	rice field
	0.74	household boundary	home garden
	0.74	fenced garden margin	home garden
	0.60	pond	rice field
	0.55	pond margin	rice field
	0.54	pot	home garden
	0.28	fenced garden	home garden
low diversity ↓	0.04	dike	rice field
	N.A.[1]	field margin	rice field

[1] Not applicable because no species were observed in the sampled area.

B. Rainy season

	H'	Sub-system	Ecosystem
high diversity ↑	2.36	yard	home garden
	1.71	shelter	rice field
	1.64	pond margin	rice field
	1.64	hillock	rice field
	1.50	fenced garden margin	home garden
	1.43	fenced garden	home garden
	1.07	tree row	rice field
	0.86	pond	rice field
	0.75	dike	rice field
	0.57	field margin	rice field
	0.46	pot	home garden
low diversity ↓	0.45	household boundary	home garden

having a lower diversity, are essential for the maintenance of specific species. For instance, this is the case of ponds and rice field margins that provide unique habitats for edible aquatic herbs (Chapter 5). As Frison *et al.* (2011) have observed, agricultural diversity is essential for improving productivity, enhancing ecosystem functions and providing adaptability. The more diverse the farming systems in terms of species and sub-systems, the more resilient they are during perturbations. Ecosystem resilience is important for enhancing food security, thus diversity is an essential component in the sustainable provision of a secure food supply.

Regarding sub-system functionality, this study has revealed that all home garden and rice field sub-systems possess multiple functions, given that wild food plant species with multiple uses are scattered across sub-systems (Chapters 5 and 6). This is supported by the following results:

- Almost all species observed in home gardens (95%) and nearly three quarters of these counted in rice fields have extra uses besides food, presenting up to nine and six additional functional groups respectively.
- More than 80% of all food plants observed in every home garden sub-system and at least half of these counted within each rice sub-system, have additional uses besides food.

Additionally, these functions differ seasonally due to the natural seasonal variations in species composition occurring in all sub-systems.

Certainly, as Price (2003) has observed, level of use value and perception of rarity are criteria that encourage farmers to maintain and manage selected wild food plant species in their farming system. These criteria will undoubtedly influence the distribution and abundance of wild plant species in the landscape.

Implications of wild food plant gathering for households

The findings of this study demonstrated that, regardless of seasonality, wild food plant gathering is essential for rural households in Kalasin, Northeast Thailand, with major implications for local food security and dietary diversity. This statement is undoubtedly validated with the results of the 7-day recalls conducted over a 12-month period with a sub-sample of 40 households (Chapter 7), as follows:

- All sampled households gather wild food plants, presenting, as previously mentioned, a high number of gathering events.
- Most households (80%) collected these food species every month of the year.
- The number of households gathering these plants remained almost constant throughout the year.

Moreover, the results evidence that wild food plants constitute a 'rural safety net' for farming families during lean months, when all sampled households gathered these food species (Chapter 7).

The findings of this study ultimately illustrate that wild food plant gathering is an important household coping strategy for vulnerable households. It was revealed that households with lower gross income and higher dependency ratio gathered a statistically significant higher number of wild food plant species. Furthermore households with any elderly or chronically ill family member prefer to collect plants closer to their house, for instance in home gardens or roadsides. The remarkable importance of wild food plants for vulnerable households has also been reported by Daniggelis (2003) and Bharucha and Pretty (2010) for the poor; as well as by Barany *et al*. (2001), and Johns and Eyzaguirre (2006) for families with chronically ill members.

REFLECTION ON CRITICAL SCIENTIFIC ISSUES IN ETHNOBOTANY

This section presents a discussion on the contribution of this study for addressing major critical scientific issues of ethnobotany, especially with respect to the development of current perspectives on wild food plants (Chapter 3), the on-going discussions on the concept of 'wild' food plants (Chapter 3), the understanding of domestication processes (Chapter 2) and the emergent field of bio-cultural diversity (Chapter 2).

Contribution towards current perspectives on wild food plants

The theoretical framework and analytical approach of this research constitute an important contribution to the study of wild food plants from anthropogenic ecosystems, which are becoming increasingly important for food gathering given the alarming decrease in forest areas around the world (named the 'botanical-dietary paradox' explained in Chapter 4; also see Ogle and Grivetti 1985). Furthermore, the theoretical framework, analytical approach and interdisciplinary methodology can certainly be applied in further research on wild food plants in other regions and countries, given that it has been reported that these species constitute a critical component of the subsistence system of farmers throughout the globe (Chapter 3; also see Bharucha and Pretty 2010; Scoones *et al.* 1992). Moreover, this study also contributes to the on-going discussion on the conceptualization of 'wild', which has major repercussions to the way scientists approach these species and communicate with local people about research; and reflects on the issues of bio-cultural diversity in relation to wild food plant use and value (both issues are discussed in the following sections).

Contribution towards on-going discussions on the concept of 'wild' food plants and the study of domestication processes

Ultimately, this study on wild food plants gathered by rice farmers in Northeast Thailand is a challenge to the divisions that have been made for decades between gatherers and agriculturalists, separating both strategies along a continuum of social and livelihood evolution. To preserve humanity's biodiversity of edible species it is necessary to go beyond essentialist dichotomies in the classifications we use to describe and study human food production systems. The classical division of edible plant species into wild or domesticated tends to obscure the intricate interactions humans have with nature that crosses these boundaries (Chapters 1 and 3). These divisions are challenged by extensive documentation, though scattered throughout the literature across the disciplines, that farmers from around the world gather, manage and eat wild food plants (Bharucha and Pretty 2010; Ogle and Grivetti 1985; Scoones *et al.* 1992), and that these food plants, some of which also cross over into medicinal use, are a critical component to farmer's subsistence (Heywood 1999; Prance and Nesbitt 2005).

However, as it was discussed in Chapter 3, there is an on-going debate on the definition of 'wild food plants'. In this regard, Casas *et al.* (1997, 456) argued:

> 'When the process of plant domestication is analysed, a problem that commonly arises is how to determine if the plant populations under study are wild or domesticated. Also, when a domesticated plant is studied it is difficult to determine the degree of domestication (incipient or advanced) the plant has. This issue becomes more problematic when populations of a given species are distributed in a continuum from natural wild sites to man-made habitats'.

This study provides extra insights to the debate about conceptualizing 'wild' plants in anthropogenic ecosystems from an ethnobotanical approach.

Understanding how contemporary cultures navigate the boundary between wild and domesticated plants can lend insights into the human management element in processes of domestication. The utilization of the *emic*, concerning local cognitive systems, is an important starting point of research on domestication, given that 'different groups of people, or 'cultures', perceive and conceive of the world somewhat differently as a result of varying social, historical, cultural, and environmental conditions and experiences' (Brosius *et al.* 1996, 188). Certainly, the ways local people perceive and conceive the environment surrounding them affects the way they interact with it. This is reflected, for instance, in their local conceptualization of 'wild' as a cultural domain, in their local classification of 'wild' food plant species belonging to this domain, as well as in their management and utilization of species, sub-systems and ecosystems.

From this study it is proposed that domestication is a spatially differentiated process, implying that a species may be managed differently in different places (and by different households). Not only species specific management practices may differ, but also a species that is 'wild' in one place may be considered as 'domesticated' in another place. This is reflected in the fact that *Isaan* people categorize as 'wild' species, species such as *Tamarindus indica* and *Psidium guajava*, which are considered 'domesticated' in other regions and/or in the scientific literature. This goes along the lines with Michon and De Foresta (1997) who claimed that local people and scientists may use different classifications for 'wild' and domesticated, with major repercussions in the results of scientific research. In this regard, local people might treat as 'wild' domesticated species that possess a modified genetic make-up product of a previous domestication process. In the same way wild species may become domesticated species, domesticated species may 'escape' to the wild.

As Prance (1995) stated, in order to understand the patterns of biodiversity it is essential to explore the complex dynamics of humans with the environment. Therefore, the investigation of the role of human management in traditional agro-ecosystem diversification is another crucial intellectual issue in ethnobotany (Chapter 2) that was addressed by this study. Research findings showed that small-scale farmers manage their landscape pursuing for diversification and complementarity, by promoting different habitats (and sub-systems) to satisfy niche requirements of a broad range of useful species. Moreover, empirical data provided enough evidence to support the new proposed theoretical model that explains the spatial and seasonal complementarity of anthropogenic ecosystems for farming households with respect to wild food plant gathering.

Wild food plants and bio-cultural diversity

As discussed in Chapter 2, bio-cultural diversity is an important intellectual and research concern in the field of ethnobotany, with the major repercussions being made in the area of conservation and management of biodiversity. Bio-cultural diversity is directly linked to cultural heritage in both material/tangible and intangible cultural elements such as knowledge and beliefs about nature, as recognized by UNESCO (2010). Although bio-cultural diversity was not specifically an issue to be addressed by this study, it is clear that the empirical results provide substantial information to address some important aspects of bio-cultural diversity, especially in relation to conservation and cultural values of wild food plants.

Bio-cultural diversity and *in situ* conservation of biodiversity in anthropogenic ecosystems stand in contrast to most conservation initiatives that occur in more 'pristine' natural protected areas. In this regard, the findings of this study once more re-affirmed that human management of ecosystems and species may also have a positive effect on the conservation of plant genetic resources through ecosystem diversification.

Bio-cultural diversity exists in direct relation to the cultural and spiritual values of plants and ecosystems, including ritual use of plants as well as being part of the local cuisine. In this regard, wild food plants are not only important for food security and nutritional diversity, but also as cultural artefacts. For instance, some bamboo species are utilized for making local handicrafts (e.g. traditional hang mats), the wood of *Artocarpus lacucha* is used for making a traditional instrument called *pong lang* that is a symbol of cultural identity in Kalasin, the leaves of *Phyllanthus acidus* are used by Buddhist monks to spread holy water, and women prepare a curry with the leaves of *Aegle marmelos* that is offered to the monks during blessing ceremonies (Chapter 4).

As demonstrated by Cocks, who conducted research on wild plant resources in South Africa, 'the use of biodiversity is not solely restricted to representing a poor man's activity but it also fulfils a very important cultural role in peoples' livelihoods and provides an important sense of well-being for communities' (Cocks 2006, 172). The fact that all households, regardless their socio-economic conditions, actively gather wild food plants throughout most of the year (Chapter 7), indicates that these species are part of the culinary tradition of *Isaan*. It is possible to state that wild food plant species, which are considered as important ingredients for the preparation of traditional dishes, contribute to the creation of cultural identity through a local *Isaan* culinary identity. Traditional cuisines are regarded as intangible cultural heritage by UNESCO (2010).

PRACTICAL IMPLICATIONS OF RESEARCH FINDINGS

Agricultural programmes, food policies, biodiversity conservation initiatives and poverty alleviation strategies, at the regional and national level, neglect the role that wild food plants play, not only for the nutritional diversity and food security in rural areas, but also for the environmental sustainability of farming systems (Bharucha and Pretty 2010; Chweya and Eyzaguirre 1999; Ogle *et al.* 2003; Prasad Aryal *et al.* 2009). Therefore it has been recognized that a holistic understanding of farming and food systems integrating wild food plants is vital. Certainly, the present study, conducted with rice farming communities in Kalasin, Northeast Thailand, provides such required scientific evidence. On the one hand, the importance of wild food plants for farming households, especially the most vulnerable ones, and the essential role of anthropogenic ecosystem and sub-system diversity in providing these species have been demonstrated in the preceding chapters. On the other hand, the theoretical model, analytical framework and interdisciplinary methodology here developed may be easily applied in other regions and countries of the world.

As Halwart (2003) emphasized, policy makers should be learned on the important role wild food resources play in poverty alleviation and rural food security, in order to make sound decisions regarding resource allocation and pro-poor policies. In this regard, the results of this study could be successfully used as an argument to raise awareness of the importance of wild food plants not only among policy makers, but also local organizations, universities, GOs and NGOs; as well as in the formulation of programmes, projects and policies related to the Millennium Development Goals (MDGs) for the Northeast region of Thailand, which is the poorest region in the country. Certainly, the utilization of wild food plants contributes to achieving five out of eight MDGs (MDG Summit 2010) in Northeast Thailand:

- MDG goal 1 on eradicating extreme poverty and hunger: This food resource is a critical component of the subsistence system of farmers, as evidenced in the following findings (Chapter 7):
  - Fifty wild food plant species are gathered across anthropogenic ecosystems throughout the year.
  - Wild foods were monthly reported in the gathering events of 80% of sampled households.
  - The poorest households are the most dependent on the diversity of wild food plant species (Spearman's ρ at 0.05).
- MDG goals 4, 5 and 6 on improving child and maternal health, as well as combating diseases: The use of wild food plants as medicines and in disease prevention generally overlaps with their use in food and nutrition, as reflected in the fact that 60% of the wild food plant species reported in this area are regarded as medicinal (Chapter 4).
- MDG goal 7 on ensuring environmental sustainability: The diversity of species (42 species observed in rice fields and 20 in home gardens), sub-systems (seven sub-systems identified in rice fields and five in home gardens) and ecosystems (6 different wild food plant growth locations reported) is important to reduce the loss of biodiversity and environmental resources, to increase environmental resilience and to provide valuable ecosystem services (Chapters 4, 5 and 6).

The implications of wild food plants for food security and the poor have already been explained in previous sections, but it is still necessary to discuss the implications that these food species have for agricultural programmes and biodiversity conservation strategies.

Although it has been recognized that wild food plants are vital for the future of agriculture (Scoones *et al.* 1992), in the FAO Aquaculture Newsletter of July 2003

Matthias Halwart clearly stipulated that the contribution of wild food from farming systems to the food security of rural families has been poorly documented due to seasonal and spatial complexity involving resources, environments and people. This is not the case anymore, since this study has challenged these complexities, providing insights that enable the establishment of extra productive lowland farming systems by incorporating the seasonal availability of wild food plants.

Nevertheless, this might be too late if no action is timely taken. Agricultural intensification, which is highly promoted in Thailand, discourages and excludes many wild food plants from agricultural systems in the name of attaining higher productivity. Moreover, the homogenization of agricultural landscapes constitutes a threat to the maintenance of these habitats where wild food plants grow. Certainly, throughout the world, ecosystem fragmentation and degradation are leading to the loss of these habitats (Heywood 1999). Consequences of natural resource degradation have major impacts on the health status of the most vulnerable (Daniggelis 2003) and the poor (Prescott-Allen and Prescott-Allen 1990). This study demonstrates the urgent need that policy makers take cognisance of the ecological and nutritional importance of wild food plant species and farming systems diversity.

Regarding biodiversity conservation, most strategies have been implemented in pristine and natural protected areas but not enough attention has been given to anthropogenic ecosystems (Brookfield and Padoch 1994). From the results of this study, it is proposed to incorporate human managed areas, such as home gardens and rice fields, to major conservation efforts in the Thai Northeast.

Biodiversity, agriculture, food and nutrition are inextricably interconnected, but these linkages are overlooked by most conventional agricultural research, biodiversity conservation initiatives and food policy (Chappell and LaValle 2011; Heywood 2011). This study, through the lens of wild food plants, shows that it is necessary to create synergies among these initiatives towards maximizing the overall productivity of farming systems. This would certainly contribute to develop and maintain a ‘safety net’ for enhancing the farmer’s nutrition, health and livelihoods.

REFLECTION ON THE ANALYTICAL APPROACH AND RECOMMENDATIONS FOR FUTURE RESEARCH

The utilization of three principal analytically and methodologically coherent research components, namely (a) botanical identification and ethnobotanical characterization of wild food plants, (b) quantification of wild food plant diversity in rice fields and home gardens, and (c) analysis of household seasonal gathering of wild food plants, provided an overview of the spatial and seasonal complementarity of anthropogenic ecosystems and sub-systems, as well as their implications for the food security and dietary diversity of households.

In the analytical framework of this study, wild food plant gathering, management and use were utilized to understand the complex relations between farming households and agro-ecosystem diversity. However, this is only one out of many ways to approach this complexity, which was chosen because of the general objective of this study. In the same way, this study mainly focused on the importance of multi-functionality as a major factor affecting farmer's decisions on gathering, management and use of wild food plant species. Future research may also incorporate other variables that may have an influence on farmer's decisions such as species' market value, perceived abundance, ease of collection and social access to gathering. Moreover, extra emphasis may be given to the cultural roles of wild food plants, especially as part of the culinary identity of the *Isaan* region.

The outcomes presented in this study highlight the necessity to analyse the patterns of wild food plant transplanting across the farming landscape and other management practices such as protection and promotion in order to better understand the distribution of wild food plant species across the different anthropogenic ecosystems. It is also recommended to further analyse the seasonality of wild food plant gathering at species level, and to measure gathering pressure in terms of biological and socio-cultural factors. Furthermore, a more exhaustive analysis of the relations among gathering, use (including multi-functionality), management and diversity at species, ecosystem and household level, would certainly provide extra insights to the theoretical model here proposed.

It is also necessary to quantify the economic returns that wild food plant species have for rural households, as well as their nutritional value and medicinal properties. Additionally, a general valuation, not only economical but also cultural, of provisioning, supporting and regulating ecosystem services, is needed in order to have major repercussions in local political conservation efforts.

FINAL CONCLUSIONS

This study provides a multi-facetted characterization of wild food plant gathering by rice farmers. It proposes a theoretical and analytical framework on the spatial and seasonal complementarity of anthropogenic ecosystems and sub-systems with respect to gathering and provisioning of wild food plant species, supported by empirical evidence from fieldwork conducted in Kalasin, Northeast Thailand. The ethnobotanical approach of the study facilitated the combination of quantitative and qualitative research methods of data collection and analysis, drawn from the disciplines of botany, ecology and anthropology. We analysed the seasonal and spatial complementarity of anthropogenic ecosystems and sub-systems comprised by rice fields and home gardens, quantified the seasonal abundance and frequency of occurrence of wild food plants in rice ecosystems and home gardens, and evaluated the implications of wild food plant gathering for local households, especially the most vulnerable. The study demonstrated the remarkable importance of species, sub-system and ecosystem diversity and complementarity for household food security and dietary diversity. The findings of this study can be used as an argument to incorporate wild food plants in future agricultural programs, food policies, biodiversity conservation initiatives and poverty alleviation strategies, at both national and international level. Moreover, this study would certainly enable the development of more productive lowland farming systems in Northeast Thailand incorporating the seasonal provisioning of wild food plants.

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Summary

Wild food plants, ranging from truly wild to wild cultivated, protected and semi-domesticated species, have been recognized as a vital component of the world's food basket, as has been their role for the food security and nutritional diversity of hundreds of millions of rural people around the globe. Most scientific attention in the study of wild food plants has been given to: (a) the study of domestication processes as an ecological and evolutionary continuum, (b) the management of wild plants at species level, and (c) the general societal relevance of wild food plants. However, there is a need to systematically 'zoom in' into the current theoretical model of domestication in order to better understand the complexities related to the complementarity of anthropogenic ecosystems and sub-systems belonging to different plant-food production categories, which are not covered by current research. Explaining these complementarities is imperative because farmer's gathering locations are increasingly from anthropogenic ecosystems, given the decline of pristine environments. Nevertheless, there are neither systematic studies on the ecological characterization of wild food plants across anthropogenic ecosystems, nor studies on the seasonal gathering of these food species across the farming landscape prior to this study. Furthermore, it is necessary to understand the implications that this complementarity has for the food security and dietary diversity of farming households, but it is rare to find any systematic analysis of the seasonal implications of these plants for households, especially the most vulnerable ones.

The general objective of this study was to contribute to the understanding of wild food plant gathering by rice farmers, by developing a theoretical and analytical framework supported by multi-facetted empirical evidence on the spatial and seasonal complementarity of anthropogenic ecosystems and sub-systems, as well as its implications for the food security and dietary diversity of households from an ethnobotanical perspective. A theoretical model based on the spatial and seasonal complementarity of anthropogenic ecosystems and sub-systems for farming households with respect to wild food plant gathering was developed. Field work was conducted in Kalasin, Northeast Thailand, which is the poorest and largest region in the country. The empirical analysis of the theoretical model comprised three principle analytically and methodologically coherent research components: (a) botanical (species level), (b) ecological (ecosystem and sub-system level) and (c) anthropological (household level), which was reflected in the use of quantitative and qualitative research methodologies drawn from (ethno)botany, ecology and anthropology. In line with the research questions, this study provides essential information on the spatial and seasonal complementarity of anthropogenic ecosystems, the frequency of occurrence of wild food plant species and complementarity of sub-systems in home gardens and rice fields, and the implications of wild food plant gathering for families, particularly the most vulnerable ones.

Chapter 1 sketches the general background of the study, including the problem statement, objective, theoretical framework, research questions, analytical approach and outline of the thesis. Chapter 2 provides a description of ethnobotany, the interdisciplinary discipline that studies the dynamic relationships between people and plants starting from the *emic* or local cognitive and value systems, including the history of ethnobotany, main areas of investigation, research methods and main ethnobotanical issues and imperatives. Chapter 3, which presents a general review on wild food plants, starts with the discussion on the conceptualization of 'wilderness' in relation to the continuum of human management from wild to domesticated species, followed by the overlapping roles of wild food plants as food and medicine, their use as famine foods, and the role of women as main wild food plant knowledge holders. The Chapter finalizes by arguing the opposing but not excluding concepts of stigma versus 'revival' attached to some species. The following four chapters (Chapters 4, 5, 6 and 7) present the results of the fieldwork conducted in Kalasin. Chapter 8 provides a general discussion and general conclusions of this study.

Chapter 4 provides a comprehensive botanical inventory of wild food plant species utilized in Kalasin, Northeast Thailand. Results showed a total of 87 different plant species comprising trees, terrestrial and aquatic herbs, climbers, shrubs, bamboos and a rattan, contributing to the nutritional diversity in the region. Rice fields, secondary woody areas and home gardens are the most common growth locations, but most species (80%) can be found in different places. Edible parts vary from vegetative to reproductive organs and more than half of the plants (53%) have more than one edible part. A total of 11 different additional uses, besides food, were identified and more than two thirds of the species were reported to have one or more extra uses. The overlap of food and medicine was also clear, given that more than half of these species are also regarded as medicinal.

Chapter 5 evidenced that rice fields are bio-diverse and multi-functional ecosystems, provisioning not only staple food, but also a total of 42 reported wild food plant species. This chapter compared the seasonal diversity of these food species in seven sub-systems associated to lowland rice production, including shelters, hillocks, ponds and their margins, tree rows, dikes and field margins. Data was collected on abundance and frequency of occurrence of individual species in 102 randomly selected sampling sites for the dry and rainy seasons of 2008 and 2009. Species density, Shannon and Simpson diversity indexes were calculated per sub-system and per

season, as well as the negative binomial rank abundance curve that provides the '$S_{n1\text{-}infinite}$' diversity index and other relevant parameters. As expected, rice fields had more species during the rainy season. The findings showed that communities of wild food plant species are different for each sub-system and season. It was concluded that all sub-systems are important for ensuring wild food plant diversity, because sub-system variability facilitates the presence of different habitats, ranging from terrestrial to aquatic, satisfying niche requirements of different plant species.

Chapter 6 demonstrated that wild food plants are a main component of home gardens through the analysis of the spatial and seasonal diversity of wild food plants in 77 sampling sites corresponding to five sub-systems. The sub-systems included yards, fenced gardens and their margins, hedgerows and fences constituting household boundaries, and pots, across a total of 20 home gardens. Absolute abundance and frequency of occurrence of individual species were recorded for the rainy and dry season (2006 and 2007, respectively). A total of 20 wild food plant species were recorded. It was demonstrated that there is high spatial and seasonal variability not only across home gardens, but also sub-systems, in terms of species abundance, frequency of occurrence, vertical stratification, Shannon and Simpson diversity indexes. In contrast to the expectations, home gardens presented a higher diversity in the dry season because farmers encourage the availability of certain species through management practices. The results of this chapter also evidenced that all sub-systems are important for maintaining wild food plant diversity, because they offer distinct habitats to wild food plant species. The findings of this chapter ultimately illustrate that all sub-systems have multiple functions because most species with multiple uses, besides providing food, are scattered across sub-systems.

Chapter 7 examines the results of a 12-month study conducted with a sub-sample of 40 households, aiming to understand the seasonal complementarity of anthropogenic ecosystems regarding wild food plant gathering and the implications for local households. The families were visited every month from March 2008 to February 2009 to conduct 7-day recalls on wild food plant acquisition events. The findings revealed that gathering of food species is crucial for ensuring food security and nutritional diversity, clearly reflected in the substantial number of gathered species (n=50), high monthly percentages of families gathering these plants (100% to 93%) and the great number of collection events (n=2196). Moreover, it was evidenced that all households gathered wild food plants from both paddy fields and home gardens, whereas most families gathered from roadsides. Although wild food plant gathering was remarkable throughout all year, these food plants were particularly essential for local households during lean months, constituting a 'rural safety net' or buffer against food scarcity. Finally, the results showed that the most vulnerable families, especially those with lower gross income and higher dependency ratio, gathered significantly more species; and families with any elderly or chronically ill member preferred to gather in home gardens and roadsides, which are closer to their home.

Chapter 8 broadens the discussion of previous chapters by reflecting on the theoretical and analytical framework; answering each of the research questions, formulated at ecosystem, sub-system, species and household level; as well as explaining the general implications of the study for agricultural programs, food policies, biodiversity conservation initiatives and poverty alleviation strategies. We highlighted the importance of diversity not only at species level, but also at sub-system and ecosystem level, and confirmed the theoretical model on seasonal and spatial complementarity of anthropogenic ecosystems and sub-systems for provisioning and gathering wild food plants. It was concluded that this complementarity is crucial for household food security and dietary diversity throughout the year.

Samenvatting

In vele culturen worden wilde voedselplanten verzameld als aanvulling op het dieet. In dit verband kunnen wilde planten echt wild zijn, dan wel tot op zekere hoogte geteeld, beschermd of semi- gedomesticeerd. Ze vormen wereldwijd een vitaal element in de voedselvoorziening voor honderden miljoenen mensen in landelijke gebieden en dragen bij aan de diversiteit van het dieet. De meeste wetenschappelijke aandacht in de studie naar wilde voedselplanten gaat uit naar: (a) het bestuderen van domesticatieprocessen als een ecologisch en evolutionair continuüm; (b) het beheer van wilde planten op het niveau van de soort; en (c) het algemene, maatschappelijke belang van wilde voedselplanten. Er is echter behoefte aan het systematisch inzoomen op het bestaande theoretische model van domesticatie ten einde het complexe geheel beter te begrijpen dat te maken heeft met de complementariteit van antropogene ecosystemen en subsystemen behorend bij verschillende plant-voedsel productiecategorieën, die in het huidige onderzoek niet aan bod komen. Het is absoluut noodzakelijk deze complementariteit te verklaren omdat boeren in toenemende mate de wilde voedselplanten in antropogene ecosystemen verzamelen. Immers de ongerepte, natuurlijke ecosystemen nemen overal in areaal af. Voordat dit proefschrift verscheen, werd er echter weinig systematisch studie verricht naar de ecologische karakterisering van dergelijke wilde voedselplanten in antropogene ecosystemen of naar de seizoensafhankelijkheid van het verzamelen van deze soorten in het agrarisch landschap. Bovendien is het noodzakelijk in ogenschouw te nemen dat deze complementariteit gevolgen heeft voor de voedselzekerheid en voor de variatie in het dieet van de boerenhuishoudens. Systematische analyses van de gevolgen van de seizoensafhankelijkheid van het verzamelen van dergelijke planten voor huishoudens zijn echter zeldzaam, vooral waar het de meest kwetsbare huishoudens betreft.

Het algemene doel van deze studie was een bijdrage te leveren aan het begrijpen van het verzamelen van wilde voedselplanten door rijstboeren, door een theoretisch en analytisch raamwerk te ontwikkelen dat wordt ondersteund door veelzijdig empirisch bewijs betreffende de spatiale en seizoensgebonden complementariteit van antropogene ecosystemen en subsystemen, alsmede de gevolgen daarvan voor de voedselzekerheid en variatie in het dieet van huishoudens, en wel vanuit een etnobotanisch perspectief. Er werd een theoretisch model ontwikkeld gebaseerd op de spatiale en seizoensgebonden complementariteit van antropogene ecosystemen en subsystemen voor boerenhuishoudens betreffende het verzamelen van wilde voedselplanten Het veldwerk werd verricht in Kalasin dat ligt in het noordoosten van Thailand en één van de armste en grootste regio's is van dit land. De empirische analyse van het theoretische model omvatte drie belangrijke, analytisch en methodologisch samenhangende, onderzoekscomponenten: (a) een botanische (op het niveau van de soort), (b) een ecologische (op het niveau van het ecosysteem en het subsysteem), en (c) een antropologische (op het niveau van het huishouden) component. Derhalve werden methodologieën gebruikt uit de (ethno)botanie, de ecologie en de antropologie. Overeenkomstig de onderzoeksvragen verschaft deze studie wezenlijke informatie over de spatiale en temporele complementariteit van antropogene ecosystemen, de complementariteit van de subsystemen in moestuinen en rijstvelden, de frequentie van het vóórkomen van wilde planten die als voedsel worden benut, alsmede de gevolgen van het verzamelen van wilde planten voor de families, met name de meest kwetsbare onder hen.

Hoofdstuk 1 schetst de algemene achtergrond van de studie, de probleemstelling, de doelstelling, het theoretisch raamwerk, de onderzoeksvragen en de analytische benadering. Hoofdstuk 1 verschaft daarnaast een overzicht van het proefschrift. Hoofdstuk 2 geeft een beschrijving van het wetenschapsterrein van de etnobotanie, de interdisciplinaire wetenschap die de dynamische relaties tussen mens en plant beschrijft, vanuit de emische systemen, ofwel de lokale cognitie en waarden, met daarin begrepen de geschiedenis, de belangrijkste terreinen van onderzoek, de onderzoeksmethoden en de belangrijkste etnobotanische kwesties, vragen en thema's. Hoofdstuk 3 geeft een algemeen overzicht over wilde voedselplanten en begint met een discussie over de conceptualisering van het begrip wildernis in relatie tot het continuüm van het menselijk beheer van wilde soort tot gedomesticeerde soort, gevolgd door de overlappende functies van wilde voedselplanten als voedsel en als medicijn, hun gebruik als voedsel in tijden van honger, en de rol van vrouwen als belangrijkste kenners van wilde voedselplanten en hun benutting. Dit hoofdstuk wordt afgesloten met een discussie over de tegengestelde maar niet uitsluitende concepten van stigma versus opleving die bij sommige soorten horen. De volgende vier hoofdstukken (Hoofdstukken 4, 5, 6 en 7) beschrijven de resultaten van het veldonderzoek dat in Kalasin werd uitgevoerd. Hoofdstuk 8 geeft een algemene discussie en beschrijft de algemene conclusies van dit onderzoek.

Hoofdstuk 4 verschaft een uitgebreide botanische beschrijving van de wilde plantensoorten die als voedsel worden verzameld in Kalasin, in het noordoosten van Thailand. De resultaten laten zien dat er in totaal 87 verschillende soorten voedselplanten zijn gevonden. Daartoe behoorden bomen, terrestrische kruiden, waterplanten, klimplanten, struiken, bamboes en een rotan. Deze planten dragen bij aan de diversiteit in het dieet van de regio. De belangrijkste vindplaatsen waren rijstvelden, secundaire bosachtige vegetaties en moestuinen. De meeste soorten (80%) konden echter op verschillende plaatsen worden aangetroffen. De eetbare delen omvatten zowel vegetatieve als generatieve organen. Meer dan de helft van de soorten (53%) heeft meer dan één eetbaar deel. Naast het gebruik als voedsel werden in totaal 11 verschillende additionele wijzen van benutting gevonden. Meer dan tweederde van de soorten had één of meerdere extra wijzen van gebruik. De overlap tussen voedsel en medicijn was ook duidelijk: meer dan de helft van deze plantensoorten konden ook als medicijn worden beschouwd.

Hoofdstuk 5 toonde aan dat rijstvelden biodiverse en multifunctionele ecosystemen zijn. Rijstvelden boden niet alleen hoofdvoedsel maar ook in totaal 42 wilde soorten voedselplanten. Dit hoofdstuk vergeleek de seizoensgebonden diversiteit van deze voedselplanten in zeven subsystemen die aan de rijstteelt in het laagland waren verbonden, te weten schuilplaatsen, heuveltjes, vijvers en hun oevers, boomrijen, dijken en akkerranden. In de droge seizoenen van de jaren 2008 en 2009 werden gegevens verzameld omtrent de abundantie en frequentie van vóórkomen van individuele soorten op 102 bemonsteringsplekken die volgens toeval waren geselecteerd. De soortendichtheid en de diversiteitsindices volgens Shannon en Simpson werden berekend per subsysteem en per seizoen. Bovendien werd de negatieve binomiale curve die per soort de relatie tussen abundantie en rang weergeeft, berekend. Met deze relatie kunnen belangrijke parameters, zoals het aantal soorten in een oneindig groot monster met slechts één individu worden bepaald. Zoals verwacht kwamen in de rijstvelden meer soorten voor in het regenseizoen dan in het droge seizoen. De soortengemeenschappen van wilde voedselplanten waren verschillend voor de verschillende subsystemen en seizoenen. Maar alle subsystemen waren belangrijk om de diversiteit aan wilde voedselplanten zeker te stellen, omdat de variabiliteit in subsystemen de aanwezigheid van verschillende habitats mogelijk maakte, variërend van terrestrisch tot aquatisch. Slechts door deze nichediversiteit kon tegemoet worden gekomen aan de verschillende behoeften van de verschillende plantensoorten.

Hoofdstuk 6 liet op basis van de analyse van de spatiale en temporele diversiteit van wilde voedselplanten op 77 bemonsterde plekken (overeenkomend met vijf verschillende subsystemen en 20 moestuinen) zien dat wilde voedselplanten een belangrijk element vormden in moestuinen. Tot deze subsystemen behoorden erven, omheinde tuinen en tuinranden, hagen, omheiningen van de huishoudens en potten. Absolute abundantie en frequentie van vóórkomen van de individuele soorten werden geregistreerd voor het regenseizoen (2006) en het droge seizoen (2007). In totaal werden 20 wilde voedselplanten gevonden. Er bleek een grote spatiale en seizoensgebonden variabiliteit te bestaan, niet alleen tussen de moestuinen, maar ook tussen hun subsystemen, in termen van soortabundantie, frequentie, verticale stratificatie, en Shannon en Simpson diversiteitsindices. In tegenstelling tot wat werd verwacht hadden de moestuinen een grotere diversiteit in het droge seizoen, omdat de boeren door hun beheer de beschikbaarheid van bepaalde soorten bevorderden. De resultaten van dit hoofdstuk laten uiteindelijk zien dat alle subsystemen meervoudige functies hadden, omdat de meeste soorten met hun meervoudig gebruik naast het produceren van voedsel over de subsystemen verdeeld waren.

Hoofdstuk 7 geeft de resultaten weer van een studie die 12 maanden duurde en een deelmonster van 40 huishoudens omvatte. Het doel van deze studie was om de seizoensgebonden complementariteit van de antropogene ecosystemen te doorgronden voor wat betreft het verzamelen van wilde voedselplanten en de implicaties voor de lokale huishoudens. De families werden elke maand bezocht in de periode maart 2008 tot en met februari 2009 om het aantal malen dat gedurende de voorafgaande week wilde voedselplanten werden verzameld, in herinnering te roepen. De resultaten lieten zien dat het verzamelen van voedselplanten cruciaal is voor het zeker stellen van de voedselzekerheid en de diversiteit van dieet. Dat werd duidelijk uit het grote aantal soorten dat werd verzameld (n=50), het hoge percentage families dat deze planten verzamelde (100-93%) en het grote aantal gevallen van verzamelactiviteit (n=2196). Bovendien werd duidelijk dat alle huishoudens actief waren op het gebied van het verzamelen van wilde voedselplanten in zowel de rijstvelden als de moestuinen, terwijl de meeste families ook in de wegbermen verzamelden. Hoewel het verzamelen van wilde voedselplanten gedurende het hele jaar opmerkelijk was, waren deze voedselplanten vooral zeer belangrijk voor de lokale huishoudens tijdens de perioden van schaarste. Op deze wijze werd een ruraal vangnet of buffer tegen voedselschaarste gevormd. Ten slotte toonden de resultaten aan dat de meest kwetsbare families, vooral die met een lager bruto inkomen en een hogere waarde voor de afhankelijkheidsratio, significant meer soorten verzamelden. Families met bejaarde of chronisch zieke leden gaven er de voorkeur aan om te verzamelen in de moestuinen en de wegbermen, omdat die dichter bij huis waren.

Hoofdstuk 8 verbreedt de discussie in de voorafgaande hoofdstukken om vanuit het theoretische en analytische raamwerk een antwoord te geven op elk van de onderzoeksvragen, zoals die voor het ecosysteem, het subsysteem, de soort en het huishouden zijn geformuleerd. Bovendien duidt dit hoofdstuk de algemene implicaties van de studie aan voor landbouwprogramma's, voedselbeleid, initiatieven om de biodiversiteit te behouden en strategieën om de armoede te bestrijden. Het belang van biodiversiteit voor het behoud van wilde voedselplanten wordt benadrukt, niet alleen op het niveau van de soort, maar ook op het niveau van het subsysteem en het ecosysteem. Tevens wordt het theoretisch model omtrent de temporele en spatiale complementariteit van de antropogene ecosystemen en subsystemen bevestigd, zowel ten aanzien van de beschikbaarheid als het verzamelen van wilde voedselplanten. Ten slotte wordt geconcludeerd dat deze complementariteit cruciaal is voor de voedselzekerheid van huishoudens en voor de nutritionele diversiteit gedurende het gehele jaar.

PE&RC PhD Education Certificate

With the educational activities listed below the PhD candidate has complied with the educational requirements set by the C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC) which comprises of a minimum total of 32 ECTS (= 22 weeks of activities).

Review of literature (6 ECTS)

- Literature review of information to all chapters of the thesis (2007-2011); the proposal and review of literature have been presented at KNAW, Amsterdam; UNESCO, Paris; PE&RC discussion group "Sustainable land use and resource management" (2007)

Writing of project proposal (4.5 ECTS)

- Quantitative analysis of seasonal abundance of wild food plants in paddy rice agro-ecosystems in Northern Thailand (2007)

Post-graduate courses (7.5 ECTS)

- Complexity in and between social and ecosystems; CERES and PE&RC (2007)
- Multivariate analysis; PE&RC (2010)
- Generalized linear models; PE&RC (2009)
- Modelling biodiversity; CCSA (2007)
- Biodiversity and ecosystem services; ALTER-Net: "A Long-Term Biodiversity, Ecosystem and Awareness Research Network", Peyresq, France (2010)
- Researching non-industrial agriculture; European Science Foundation (ESF) EARTH Programme: "Early Agricultural Remnants and Technical Heritage, the Dynamics of Non-Industrial Agricultural, 800 Years of Resilience and Innovation", Asturias, Spain (2008)
- Summer field training in methods of data collection; Brandeis University (USA) and Ethno-ecology Laboratory of the Universidad Autonoma de Barcelona (Spain), Beni, Bolivia (2007)

Laboratory training and working visits (4.5 ECTS)

- Wild food plants in Northeast Thailand; Khon Kaen University, Chiang Mai University, Kasetsart University, Walai Rukhavej Botanical Research Institute of Mahasarakham University, Agricultural and Extension Office of Ampher Muang (Kalasin Province), Thailand (2007-2010)
- Plant specimen and literature review; Bangkok Herbarium (BK) of the department of Agriculture at Kasetsart University, Bangkok, Thailand (2010)

Invited review of (unpublished) journal (2 ECTS)

- Editing of peer-reviewed book chapters consisting of five different articles, published by the European Science Foundation; Wild food plants in the present and the past (2009-2011)
- Journal of Ethnobiology and Ethnomedicine; Wild food plant knowledge (2011-2012)

Deficiency, refresh, brush-up courses (3 ECTS)

- Thai language course at American University Alumni language centre, Chiang Mai, Thailand (2008)

Competence strengthening / skills courses (3.8 ECTS)

- PhD Competence assessment; WGS (2007)
- EndNote X2 advanced; Wageningen UR Library (2010)
- For women in science week; UNESCO-L'ORÉAL For Young Women in Life Sciences Program, Paris, France (2007, 2009)
- How to write a world class paper; Wageningen UR Library and Elsevier (2010)

PE&RC Annual meetings, seminars and the PE&RC weekend (1.8 ECTS)

- PE&RC Weekend (2007)
- PE&RC Day: Collapse: is our civilization able to stand the test of time? (2007)
- PE&RC Day: Accelerate scientific progress: expect the unexpected (2008)
- PE&RC Day: Innovation for sustainability: what are the neighbours doing? (2011)

Discussion groups / local seminars / other scientific meetings (6.1 ECTS)

- International Society of Ethnobiology, Student Representative on the Board (2008-2010)
- International Society of Ethnobiology, Elected European representative on the Board (2010-2012)
- Co-organizer of the International Workshop for Emerging Ethnobiologists "Cultivating Mindfulness in Research"; Tofino, Canada (2010)
- Mentor and member of the governing board of the International Network of Emerging Ethnobiologists (2010-2012)

International symposia, workshops and conferences (8.9 ECTS)

- The 4th International Conference of the Ecosystem Services Partnership "Ecosystem Services: Integrating Science and Practice"; Wageningen, the Netherlands (2011)
- International Conference "Biodiversity and the UN Millennium Development Goals: Challenges for Research and Action"; Frankfurt, Germany (2010)
- The 12th International Congress of Ethnobiology; Tofino, Canada (2010)
- The First Asian Conference of Ethnobiology "The Position of Indigenous Peoples, Sacred Places and Participatory Methodology in Cultural and Biological Diversity Conservation; Providence University, Taiwan (2009)
- The 11th International Congress of Ethnobiology; Cusco, Peru (2008)

Curriculum vitae

Gisella Cruz García was born the 19th May 1977 in Lima, Peru. In 2000 she obtained her BSc diploma in Biology from the Universidad Nacional Agraria La Molina, Peru, ranking the first of her graduating class. During her BSc studies she worked as an environmental educator. After completing her BSc, she conducted research on *in situ* conservation of native potatoes in the Peruvian highlands and worked as a lecturer in the Biology Department of the Universidad Nacional Agraria La Molina. She moved to The Netherlands in 2003, and in 2005 she acquired her MSc degree in Management of Agro-ecological Knowledge and Social Change from Wageningen University. For her MSc thesis, she conducted research on knowledge and valuation of wild food plants, comparing tribal and non-tribal children participating in an educational programme in Wayanad, India, in association with the M.S. Swaminathan Research Foundation. In 2007, she received her second bachelor (BC) in Food and Business from Zuyd University, The Netherlands. In the same year she obtained the first ever UNESCO – L'ORÉAL For Young Women in Sciences fellowship for the Europe - North America Region awarded to a scientist in The Netherlands, which allowed her to start her PhD studies. She conducted her PhD fieldwork in Northeast Thailand as Affiliate Research Scholar of the International Rice Research Institute (IRRI, Philippines). During her PhD studies she acquired more than ten different grants/fellowships. She has been interviewed by several national and international media, and she was profiled as an up and coming young scientist in *Science Magazine* in 2009. From 2008 to 2010 she was appointed as Student Representative at the Board of the International Society of Ethnobiology (ISE); and since 2010 she sits as Elected European Representative on the ISE Board. She has five scientific publications, three forthcoming and four under review. In addition she has eight publications for a general public and/or extension. She has co-organized seven and presented in eight scientific conferences and congresses. Since 2010 she has been working as a lecturer in the Sociology of Consumers and Households Group, Social Sciences Department, Wageningen University.

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