Ecology and Development Series No. 35, 2006

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Opportunities and constraints of integrated farming system in Northeast Thailand. A case study of the Huai Nong Ian catchment, Khon Kaen province

Cuvillier Verlag Göttingen

ABSTRACT

Continuous land degradation is endangering household food security in Northeast Thailand. To stop land degradation and regain productivity, farmers have organized themselves in groups to come up with integrated farming system (IFS). This type of farming modifies the commercial farming system (CFS), which relies on rice-based monocropping, by adopting production of vegetables, trees, livestock and fish. The objectives of the IFS are multiple: to enhance food production for the household, to maintain the natural resource base that contributes to food security and the well-being of the rural people, to contribute to income generation, and to be accepted by local communities.

The objectives of the study were to assess the performance of the IFS and whether the above objectives are met. A survey was conducted in the Huai Nong Ian catchment in the Khon Kaen province of Northeast Thailand, where IFS has been promoted among the farmers in since 1997. Conceptually, the study is based on the framework of a multifunctional agriculture. This framework attributes four main functions to agriculture: food security, environmental, economic, and social functions.

The catchment was stratified into three areas: upper, middle, and lower areas to take account of the large variation in biophysical factors. For each farming system and for each area respectively, three, two, and three farm households were selected in pairs of one integrated farm and one commercial farm, i.e. a total of 16 farm households. Data were collected using Rapid Rural Appraisal (RRA) techniques. The farms were then compared based on farm type and on the level of integration between enterprises on the farm.

The IFS has a higher diversity of enterprises, biodiversity, and activities than the CFS. A higher land productivity of the IFS was revealed. Labor productivity was 1.3 times higher. The IFS has 123% more food species and a 124% higher share of consumed own-produced food than the CFS, which suggests a secure supply of food from the own farm in the IFS. A higher diversity of genetic resources, which can be used for social purposes, suggesting that indigenous knowledge is maintained in the IFS through a higher species diversity.

Tree communities in the IFS showed a higher stem density, which was 13 times higher than in the CFS, a larger basal area, an additional vertical layer of saplings, and a medium-sized crown social position, indicate a better growth performance of the tree communities. Levels of soil organic matter content were significantly higher in the IFS. In addition, the number of irrigation months as a supplement to rainfall was three months longer for the IFS, as most of these farms had established farm ponds, allowing a longer period of crop production and a better protection from yield risks due to droughts.

The findings support the notion that diversification and integration of enterprises on the farm is feasible in economic and ecological terms in the study area. The switch to the IFS, however, constrained by low availability of family labor, high initial start up costs together with high fixed costs, and a small farm size, while benefits are only received after 3 to 5 years. Improved information provision, possible through a better sharing of experiences among farmers, is required for its successful adoption. In addition, a well functioning financial market and policies supporting integrated resource management are crucial for the IFS to become widely adopted.

Potentiale und Grenzen integrierter Landbausysteme in Nordost-Thailand: eine Fallstudie aus dem Huai Nong Ian Einzugsgebiet, Provinz Khon Kaen

KURZFASSUNG

Anhaltende Landdegradation bedroht die Nahrungssicherheit der Haushalte im Nordosten von Thailand. Es wird angenommen, dass im Vergleich zur konventionellen Landwirtschaft mit Reisanbau, die integrierte Landwirtschaft Landdegradation verhindern und die Bodenfruchtbarkeit durch die Integration von komplementären Produktionseinheiten wie Anbau von Ackerpflanzen, Baumkulturen, Tierhaltung und Aquakultur wiederherstellen kann. Die Studie testet diese Behauptung mit Daten aus dem Gebiet von Huai Nong Ian in der Khon Kaen Provinz im Nordosten Thailands, wo integrierte Landwirtschaft seit 1967 praktiziert wird.

Bei den Farmen im Untersuchungsgebiet wurden drei Farmtypen unterschieden und das Untersuchungsgebiet dementsprechend in drei Bereiche eingeteilt. Für jeden Bereich wurden drei, zwei bzw. drei Farmhaushalte, d.h. insgesamt 16 Haushalte, ausgewählt. Daten wurden mit Hilfe von Fragebögen und Felduntersuchungen erhoben. In der Analyse wurden die Daten der verschiedenen Farmtypen verglichen und ein Vergleich zwischen den Farmen auf der Grundlage des Integrationsgrads zwischen den Produktionseinheiten durchgeführt.

Die Ergebnisse zeigen, dass die integrierten Farmen signifikant höhere Nahrungsmittelvielfalt und Bruttoeinkommen von der Farm sowie einen niedrigeren Anteil an Kosten für den Kauf von Nahrungsmitteln und eine höhere Boden- und Arbeitsproduktivität aufweisen. Außerdem besteht bei integrierten Farmen die Tendenz zu einem höheren Gehalt an bodenorganischem Material, da die Baumdichte auf diesen Farmen höher ist. Die Anzahl der Bewässerungsmonate zusätzlich zum Niederschlag ist höher auf den Farmen mit Teichen, da diese eine längere Anbauperiode erlauben.

Obwohl verglichen mit den konventionell geführten Farmen alle integrierten Farmen signifikante Verbesserungen erreichten, zeigten die Farmen mit einer größeren Verfügbarkeit von Arbeitskräften aus der Familie und einem größeren Anbaubereich wesentlich bessere Ergebnisse als die Farmen ohne diese Ressourcen, da zusätzliche Produktionseinheiten einen höheren Einsatz von Arbeitskräften und eine größere landwirtschaftliche Fläche benötigen. Die vorliegende Untersuchung zeigt drei entscheidende Einschränkungen in bezug auf Integration und Diversifizierung: niedrige Verfügbarkeit von Arbeitskräften aus der Familie, hohe Anfangsinvestitionen zusammen mit hohen festen Kosten sowie eine kleine landwirtschaftliche Fläche.

Die Ergebnisse unterstützen die Annahme, dass Diversifizierung und Integration von Farmressourcen vom wirtschaftlichen Gesichtspunkt aus machbar sind und dass die oekonomische Leistung der Farmen davon profitieren kann. Sie zeigen außerdem, dass die integrierte Landwirtschaft eine geeignete Technologie zur Wiederherstellung von degradiertem Land darstellt. Der Wechsel zur integrierten Landwirtschaft erfordert jedoch erhebliche Anfangsinvestitionen, während ein finanzieller Nutzen erst nach mehreren Jahren erzielt wird. Hinzu kommt, dass entsprechende Information bzw. Erfahrungen über integrierte Landwirtschaft für einen erfolgreichen Wechsel erforderlich sind. Ein gut funktionierender Finanzmarkt, eine Politik, die Ressourcenmanagement unterstützt und ein verbesserter Informationsfluss zu den ressourcenarmen Bauern sind entscheidende Faktoren fuer eine weitere Verbreitung der integrierten Landwirtschaft.

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LIST OF ABBREVIATIONS

AIT	Asian Institute of Technology, Thailand
CFS	Commercial farming system
CIRDAP	Centre on Integrated Rural Development for Asia and the Pacific
DBH	Diameter at breath height (1.30 m)
DMR	Department of Mineral Resources, Thailand
DOA	Department of Agriculture, Thailand
DOL	Department of the Livestock, Thailand
EGAT	Electricity Generation Authority of Thailand, Thailand
FAE	Faculty of Agricultural Economics, Kasetsart University, Thailand
FAO	Food and Agriculture Organization
GBH	Girth at Breath Height (1.30 m)
GO	Government Organization
GPS	Global Positioning System
ICLARM	The International Center for Living Aquatic Resources Management
IFS	Integrated farming system
IIRR	International Institute for Rural Reconstruction
ILEIA	Low External Input Sustainable Agriculture
IVI	Important Value Index
LP	Linear programming
KKU	Khon Kaen University, Thailand
KU	Kasetsart University, Thailand
MOI	Ministry of Interior, Thailand
NESDP	National Economics and Social Development Plan
NGO	Non Government Organization
NSO	National Statistic Office Thailand
OAE	Office of Agricultural Economics, Thailand
OECD	Organization for Economic Co-operation and Development
RFD	Royal Forest Department, Thailand
RRA	Rapid Rural Appraisal
TMD	The Meteorological Department, Thailand

1 INTRODUCTION

1.1 Background problem

Degradation of production resources, as reflected in a declining soil fertility and water availability, is often emphasized as a constraint to crop productivity (Edwards et al. 1990; Theng 1991; Hoffman and Carroll 1995; Halvorson et al. 1996; Kobayashi 1996; Noble et al. 2000; Eswaran et al. 2001). Numerous studies show that the farming in the northeast Thailand has extended into the marginal lands where biophysical resources are becoming degraded (Panitchapong 1988; Ratanawaraha et al. 1989; OAE 1998; Imaizumi et al. 1999; NSO 2000; RFD 2002; Little 2004). This raises concerns, both about the maintenance of production levels with regard to the food security and welfare of the population, and about environmental sustainability of the farming system in a broad sense (O'Donnel et al. 1994; Hussain and Doane 1995; Craswell 1998; Adireksarn 2001; Limpinuntana et al. 2001; Moncharoen et al. 2001; Wijnhound et al. 2001; Craswell 2002; Senanarong 2002).

Increased use of improved seeds and fertilizers has been the predominant production choice emphasized to increase crop productivity of the commercial farming system in these degraded environments. This choice is characterized by the cultivation of a few cash crops and maximization of the yield by following the recommended amounts of improved seeds, mineral fertilizers, and other agrochemicals. However, the expected high crop yields were never obtained in many cases in this region, as the resource-poor farmers could not afford the input levels necessary for obtaining these yields (Ratanawaraha et al. 1989; OAE 2000; Wijnhound et al. 2001; Limpinuntana et al. 2001).[1] This is due, for example, to limited transportation and delivery services, and because fertilizers and other inputs are costly and difficult to use due to risk of crop failure caused by floods and droughts, and to unfavorable inherent soil properties in the region (Ratanawaraha et al. 1989; OAE 2000; Konboon et al. 2001). Furthermore, inefficient utilization of pesticides may adversely affect the environment, and the farmers' and consumers' health (Paopongsakorn et al. 1998). In addition, the

[1] The term "resource-poor farmers" as used here is defined in the glossary. The definition may vary not only from country to country, but also within a country and even within a region of a country.

commercial farming system resulted in a decrease in the diversity of the system as only few crops were cultivated.

The farmers' livelihood is endangered by the degradation of natural resources associated with the above production choice. Since 1997, an effort to sustain the farming system has been made by promoting an integrated farming system. There are multiple objectives for promoting the integrated farming system, and these extend beyond food production. The objectives are: enhancing food production, maintaining goods that contribute to food security and rural livelihoods, and economic vitality (Thamrongwarangkul 2000, 2001; Jitsanguan 2001). For example, integrating fruit trees and farm ponds are thought to contribute to the sustainability of land-use intensification, provide a more secure food supply from the farm, enhance incomes, and improve other functions of the farm (Blair et al. 1990; Lightfoot and Minnick 1991; Handayanto et al. 1994; AIT 1994a; Kleinman et al. 1995; Palm 1995; Willett 1995; Wonprasaid et al. 1995; Syers and Craswell 1995; KKU 2001; van Brakel et al. 2003). Diversification of farming activities should also improve the utilization of labor, reduce unemployment in the area, and provide a source of living for those households that operate their farm as a full time occupation (Thamrongwarangkul 2001; van Brakel et al. 2003). Based on the literature, the important characteristics of the integrated farming system are differentiated from the commercial farming system in Table 1.1.

The table shows that the integrated farming system is characterized by a high diversity of genetic species, enterprises and practices, which are employed to attain the household objectives. The synergy between enterprises increases with the diversity on the farm and is fundamental to the integrated farming system concept. The commercial system cannot be moved to the direction of the integrated system if there are no synergies between enterprises through the integration of activities. Therefore, the distinction between the integrated farming system and the commercial farming system is not absolute, but is rather a matter of degree of integration of resources in the farm system.

Table 1.1: Relative characteristic comparison of the integrated farming system with the commercial farming system in Northeast Thailand

Aspects and properties	Farm type	
	Integrated	Commercial
Biophysical characteristics		
1. Farm age	Young	Old
2. Irrigation infrastructures	Many	Few
3. Diversity (of crops, animals & enterprises)	High	Low
Socio-economic characteristics		
4. Farming area owned by the household	Large	Small
5. Family labor	Much	Little
6. Labor saving technologies (tractors, water pumps)	Few	Many
7. Hired labor	Much	Little
8. Off-farm income	Much	Little
Outputs		
9. Productivity	High	Low
10. Soil fertility	High	Low
11. Financial profitability (gross farm income)	High	Low
12. Flexibility of product use[a]	Much	Little
13. Diversity (of activities, products & income sources)	High	Low
14. Stability[b]	High	Low

[a] the flexibility of product use refers to the availability of alternative ways of product disposal such as home consumption instead of sales (Dillon and McConnell 1997). [b] system stability refers to the absence or minimization of year to year fluctuations in either production or value of output. It also implies either stability in input costs, yields and prices or counterbalancing movements in these influences on values of output (Dillon and McConnell 1997).

Whether practicing integrated farming gives the best prospect for securing food, whether it is economically viable, whether it maintains or improves the quality of the natural resource base and whether it is locally accepted are issues inadequately addressed in the literature. In particular, there are only few studies on the functions of biodiversity in the integrated farming system in rainfed areas. This study proposes to identify how secure access to food and other objectives as mentioned above can be achieved in the integrated farming system.

1.2 Literature review

The review of literature has the following four objectives: 1) to discuss the concept of integrated farming systems; 2) to review the potential of the integrated farming system in different aspects; 3) to identify the limitations to the integrated farming system; and 4) to identify knowledge gaps about the integrated farming system. Based on this literature review, the conceptual framework will be defined in Chapter 3.

1.2.1 Concept of integrated farming systems

The integrated farming system is practiced in many different countries in many different ways. Yet, a common characteristic of the integrated farming system is a combination of crop and livestock enterprises. Other forms of integrated farming include combinations with aquaculture or trees.

Many studies have defined the concept of integrated farming systems differently. For example, Agbonlahor et al. (2003), in their study in Nigeria, define the concept as a type of mixed farming that combines crop and livestock enterprises in a supplementary and/or complementary way. Okigbo (1995) defines the system as a mixed farming system that consists of at least two separate, but logically interdependent parts, of crop and livestock enterprises. Radhamani et al. (2003) give an alternative definition of integrated farming system as a "component of farming system", which is a whole farm approach aimed at minimizing risk, increasing production and profits while improving the utilization of organic wastes and crop residues. Jayanthi et al. (2000) study the system in Tamil Nadu, India, and conceptualize the system as a mix of animals and crops: animals are raised on agricultural waste while animal power is used to cultivate the land and manure is used as fertilizer and fuel. Edwards (1997) narrowly defined the system as an aquaculture system that is integrated with livestock, and in which fresh animal manure is used for fish feeding.

Because synergies between enterprises are fundamental to the idea of integrated farming, it is important to clearly define the concept in the research. Here the integrated farming system is defined as the combination of two or more complementary enterprises in a farm that include both crops and animals (Lightfoot and Minnick 1991; Jitsanguan 2001; KKU 2001; Radhamani et al. 2003). A farm with complementary enterprises is, for example, one in which animals are fed with crop residues and the manure is applied to the crops. According to this, integration occurs when outputs (usually by-products) of one enterprise are used as inputs by another, within a farming system. The difference between mixed farming and integrated farming is that enterprises in the integrated farming system are mutually supportive and depend on each other (Csavas 1992).

The above-mentioned reports show that the first role of an integrated farming system is to maintain the production of food and other goods that contribute to food security. Other functions include achieving environmental sustainability, and contributing to the economic development in the rural areas and of society in general.

The integrated farming system concept is compatible with the framework of multifunctionality of agriculture. Within this framework, multifunctionality is interpreted in terms of multiple roles assigned to agriculture (Price 2000; OECD 2001; FFTC 2002; Wynen 2002; Barthelemy and Nieddu 2004; Groenfeldt 2005). In this view, agriculture as an activity is entrusted with fulfilling four main functions in society: food security; environmental; economic; and social functions (OECD 2001). In general, increasing the number of functions tends to increase the stability of agriculture and land used (Price 2000). This concept is thus fitted in the broadest framework of Sustainable Agriculture (SA) (Normal et al. 1997; Mundy 1997), and Sustainable Land Management (SLM) as highlighted in the framework for evaluating SLM by Smyth and Dumanski (1993).

1.2.2 The practice of integrated farming systems

Integrated farming is not a new type of farming system. In fact, it is a traditional way of farming in many countries like Indonesia, Vietnam, Rwanda, China, Malaysia, and Thailand (Gliessman et al. 1981; Csavas 1992; Tokrishna 1992; ILEIA 1996; Choosakul 1999; Praphan 2001). Yet, the commercial cropping of a few cash and staple crops, as promoted by the government, have largely replaced the integrated farming system (Ruaysoongnoen and Suphanchaimart 2001).

Continuous production of cash crops without external inputs reduced the ability of these soils to retain essential nutrients, which has resulted in a rapid decline in soil fertility and an eventual loss of productivity (Willett 1995; Panitchapong 1998; Craswell 1998; Wijnhound et al. 2001; Limpinuntana et al. 2001; Noble and Ruaysoongnoen 2002). Moreover, the reliance on a few crops in combination with a high risk of crop failure from insects, diseases, and uncertain rainfall, exposes farmers to high variability in yields and incomes (Reijntjes et al. 1992; Ashby 2001). In addition, some authors point out that the commercial farming system entails a threat to the environment by loss of genetic resources and a possible toxic effect of intensive mineral fertilizer and pesticide use on the natural resources and human health (Paopongsakorn et al. 1998; Ashby 2001).

The integrated farming system is now being re-introduced in some areas, as a sustainable alternative to the commercial farming system in marginal lands, with the objective of reversing resource degradation and stabilizing farm incomes. Many studies have reported improvements in some aspects when integrated farming is practiced. For example, Lightfoot and Minnick (1991) report that integration of trees not only offers income security but also gives ecological protection. At the same time, the use of diverse plants and animals widens the sources of income. Waste and by-products are transferred between enterprises and help to reduce the need for, and costs of external inputs by recycling available nutrients (Csavas 1992; Little and Edwards 2003). Altieri et al. (2004) and Lightfoot and Minnick (1991) mentioned that no serious pest or disease problems have been reported for the system. Likewise, animals on a farm provide inputs to other enterprises and constitute a source of meat and milk, a means of savings, and a source of social status as reported by KKU (2001), Schiere et al. (2002), and Little and Edwards (2003).

1.2.3 The potential of integrated farming systems

The integrated farming system has received much attention and the concept is widely promoted in many areas in both developing countries and some developed countries such as Australia (Craswell, personal communication 2005). Published studies on the potential of the integrated farming system can be divided into two main groups: 1) studies that assess financial viability using financial analysis of farm budgets, and 2) studies that optimize resource allocation using whole farm programming. Each of these is discussed in the following.

Financial analysis

Farmers' income is the main focus of this group of studies (Dillon and Hardaker 1993; Dillon and McConnell 1997; Ashby 2001). Many studies based on site experiments or farm trials revealed that trees and vegetables crops can be highly lucrative. Financial analyses in these studies indicate that the systems provide a net surplus income beyond the consumption needs of the household. These studies also reported that free time is used by farmers for other on-farm activities. However, the validity of these financial analyses based on experiments or farm trails can be biased because the economic factors are typically disturbed in such research set ups, and might therefore not be representative of real conditions. This argument is illustrated in the following examples.

Govindan et al. (1990) studied financial budgets of farms in Tamil Nadu. They set up an experiment with poultry and fish culture and used financial analysis to assess the system. The study concluded that under the conditions of this area, higher income and on farm labor use can be generated by integrating different enterprises on the farm. Similarly, Rangasamy et al. (1996) studied the integration of poultry, fish and mushroom with rice cultivation also in Tamil Nadu, for which they conducted five years of experiments. Financial analysis was used to assess the feasibility of the system. The study concluded that the system increases net farm incomes and on-farm labor use compared with the conventional cropping system. Radhamani et al. (2003) also reviewed several experiences of the integrated farming system that positively evaluated the economic viability.

The results from the above studies derived from farm trials where farmers are regularly provided with inputs such as genetic resources, labor, irrigation and information about the farming system. In real world farm production, availability of and access to these inputs is variable and often relates to factors that go beyond the immediate control at the farm level.

An alternative is to evaluate the system on existing integrated farms. For example, for the Philippines, Dalsgaard and Oficial (1997) outlined an approach to model, describe, analyze and quantify the productive and ecological characteristics of the agroecosystem at the level of the farm. The study employed a range of techniques (bioresource flow diagrams, farm transects, direct observation, field measurements, farm records and informal discussion) to develop a model and compare it with the commercial farming system. The comparative analysis suggested that diversification and integration of resource management can be productive, profitable and manageable, given access to labor and secure tenure.

In Cameroon, Ngambeki et al. (1992) demonstrated the profitability of the system by integrating livestock into the present crop based farms in the north of the country. They used a multi stage random sample survey. The study showed that integrated farming resulted in better financial benefits and a better use of intermediate farm resources such as manure, draft power, and crop residues.

In Thailand, successful experiences with the integrated farming system have been described in reports of pilot projects initiated by her Majesty the King of Thailand, and case studies conducted by GOs, NGOs, Sustainable Agriculture Charity (Thailand), JIRCAS, FAO, and academic institutions like the DOA, the Asian Institute of Technology (AIT), Kasetsart University (KU) and Khon Kaen University (KKU). A few examples are reviewed in the following.

Tokrishna (1992) reported successful farm integration of duck raising and fish enterprises. The study estimated that this farmer was able to earn a net profit of 1,850 US$ ha^{-1} of which 87% came from fish. Fish yield was 3.5 t ha^{-1}.

Three reports from KKU (2001) described the success of the integrated farming system on demonstration farms in the rainfed areas of Saraburi, Kalasin, and Petchaburi. Integrated farm ponds and fruit trees were introduced to the commercial farming system in these areas.

In the Saraburi area, the study evaluated rice yields and farm incomes over three years (1989-1992) and compared it with initial production levels using financial analysis of farm budgets. The study reported that rice yields and farm incomes gradually increased. The rice yield increased from 0.4 - 1.9 t ha^{-1} to 2.6 t ha^{-1} in the third year. The rice yield increased, because farmers were able to transplant the seedlings to the paddy field in the beginning of the wet season and there was thus enough water throughout the growing season in spite of erratic rainfall.

In the Kalasin area, similar indicators were evaluated from a three-year-old demonstration farm (1993-1996) by KKU (2001). They reported that total farm income increased from 9,870 to 12,434 baht $household^{-1}$ between 1994 and 1995 by integrating fish culture, chicken, and ducks. The households obtained additional vegetables and food crops such as sweet corn and peanuts in the dry season through irrigation using farm ponds. The average rice yield increased from 1.5 to 2.5 t ha^{-1}.

In the Petchaburi area, Tabtimoon (1996) reported that diversity of food crops increased due to integration of fruit trees into the farms. Financial analysis of farm budgets revealed that the initial cost decreased from 17,642 baht $farm^{-1}$ in the first year (1994) to 13,984 baht $farm^{-1}$ in the next year. The net farm income increased from banana, papaya, rice, and vegetables though the fruit trees such as jack fruit and mango had not yet borne. The initial cost decreased in the second year, because no more initial investment for the fruit seedlings was necessary, while the perennial fruit crops such as banana and papaya started to bear fruits and generated cash to the farm.

In the Nakhonratchashima and Khon Kaen provinces, Kaewsong et al. (2001) evaluated the socioeconomic status of 30% of the members of a farmer network that promoted the integrated farming system in 2001. Data were collected through semi-structured interviews, observation, and farm surveys and by means of a focus model used to evaluate the functioning of the farmer network. The study revealed that the average total income of the members was higher than in other areas in the northeast region.

The Faculty of Agricultural Economics (FAE-KU) (2000) evaluated the socioeconomic impact on 10 selected farms in the northeast region at various stages of establishment. Data in the 1999 crop season obtained through interviews and financial analysis were used to evaluate net farm income, which were then compared with the first year in which the farm had converted from the commercial farming system to the integrated farming system. This study revealed that the average increment in net farm income was 56,170 baht farm^{-1} per year.

Pant (2002) assessed the potential and economic viability of integrated agriculture-aquaculture (IAA) under three different agro-ecological settings: drought-prone, rainfed lowland, and rolling land in the Khon Kaen and Buriram provinces in 1999. Data were collected through structured questionnaires from a sample of 234 farm households practicing IAA. The study revealed that enterprise compositions within the IAA system varied between three agro-ecological setting, yet rice paddy, fruit, vegetables, chicken, ducks, and aquaculture enterprises were common on all farms. However, in all agro-ecologies, livestock production was extensive due to limited use of supplementary feed. In the drought-prone agro-ecology, rice yields were 2.5 t ha^{-1}, which is nearly double as high as in the rainfed lowlands. The study also reported that farm households in the lowlands responded to demands in the nearby market by producing significantly higher amounts of fruits and vegetables than the other two agro-ecologies. Among the different agro-ecologies, the rainfed lowland had the lowest gross farm income.

Optimal resource allocation

Another aspect dealt with by studies on the integrated farming system is the allocation of resources and the improvement in the quality of resources on the farm. Six such studies are described in the following.

Schiere et al. (2002) studied the role of livestock and provided criteria for the sustainability of integrating livestock in cropping production, which they then used for scenario analyses. The study used linear programming (LP) to optimally allocate resources over time and space. The results of the scenario studies illustrated options and trade-offs between different crop and livestock combinations in terms of their sustainability criteria. The study concluded that livestock are essential for the sustainability of the system.

In southern Nigeria, Agbonlahor et al. (2003) determined the optimal resource allocation for farm planning that can both satisfy productivity requirements for profitability and continued soil fertility to achieve sustainability. The study employed a LP approach to determine the optimal resource use. The study concluded that a sustainable system is possible in this area through the integration of poultry and crop enterprises.

In the lowland area of Tamil Nadu, India, Jayanthi et al. (2000) estimated water use efficiency for the system by integrating cropping, poultry, pigeon, fish, and mushroom cultivation by means of field experiments. The study used a standard method to estimate water use. The results revealed that integrated farming requires less water per unit of production than monocropping.

In Malaysia, Alsagoff et al. (1992) evaluated the contribution of aquaculture to the overall farm income in a central area of the country, by obtaining data from 10 farms and using LP. The study revealed that aquaculture has the potential to increase the present farm income 3.3 times if resources are allocated optimally to fish culture and broiler meat enterprises.

In Thailand, Kobayashi (1996) developed appropriate technologies to reduce water loss from farm ponds in the integrated farming system by conducting experiments comparing floating materials (foam, bamboo, and dry coconut) in the farm ponds. The experiments revealed that the foam and bamboo are suitable for this purpose, whereas dry coconut is not.

The prospect of improved research methods for the integrated farming system is also an issue. For example, Lightfoot and Minnick (1991) advanced the idea of the farmers' diagrams for improving qualitative methods for on-farm research on integrated farming systems. The study demonstrated these diagrams for example farms in Vietnam, Bangladesh, and Malawi. They suggest testing this method in several areas and improving it for wide-scale use.

Constraints

Although example studies have shown that the system is feasible in socioeconomic terms, actual adoption of integrated farming is rather limited and unevenly spread among farmers as reported by some studies. These studies are described as follows.

The study by Ngambeki et al. (1992), using a LP model of an integrated farming system in Cameroon, revealed that the major production constraints are animal feed shortage, labor bottlenecks, and soil degradation. For China, Csavas (1992) reported that most farms depend on imported feed rather than recycled inputs. This is because resource-poor farmers generally do not have a feedlot type of livestock production.

For the Philippines and Ghana, Lightfoot (1997) reported that the four main constraints on adoption of the system are: 1) a long transition period, which can take 3 to10 years, while farmers could not forgo food production and income over this period; 2) labor shortage, especially for small families, which effectively prevented them from adopting integrated farming techniques; 3) lack of secure land rights; and 4) a disincentive to adopting integrated farming resulting from government subsidies, credits for fertilizers, and herbicides.

Banerjee et al. (1990) assessed the impact on the allocation of the farm area to different types of crops and livestock. Data were obtained through a survey using stratified random sampling and a purposively selected sample in Uttra Pradesh. LP was used to estimate the allocation of resources in the farm. The study revealed that there are few opportunities for increasing farm net returns with the limited amount of capital available.

In the case of northeast Thailand, the study by Thamrongwarangkul (2001) reported that resource-poor farmers often can not go beyond the transition period due to their need for food and for immediate economic returns to meet cash needs such as for schooling, medical treatment, and loan-repayment. A similar conclusion was reached in a study by the FAE-KU (2000). On the other hand, Tokrishna (1992) pointed out that a farmer who becomes successful and wants to expand the area of his integrated farm in Thailand would be limited by access to an adequate water supply, to animal feed, and market outlets.

1.2.4 Knowledge gaps on integrated farming systems in northeast Thailand

The integrated farming system aims at efficient use of land resources in a sustainable way and has received much attention from researchers in the past. Price (2000) and Groenfeldt (2005) suggested four aspects in evaluating the role of agriculture relevant to sustainable land use management: productive functions of food and other primary goods contributing to food security; environmental functions; economic functions; and social and/or cultural functions. Yet, all above-reviewed studies evaluated the integrated farming system under specific aspects such as financial analysis and optimal resource allocation. A review of the literature reveals a paucity of information on the environmental aspects of the integrated farming system.

The integrated farming system has a major impact on biodiversity, and constitutes the main productive elements of agriculture that are necessary for a continued improvement and adaptation to the changing needs of the household. However, not environmental functions but economic aspects, such as household income and on-farm labor use, have received most attention in case studies. The identified knowledge gap therefore relates to the contribution of a greater biodiversity to the secure supply of food to the farm household in the integrated farming system, as well as the social functions of this diversity.

1.3 Objectives

The general objective of the study is to examine the performance of the integrated farming system and its effects on agricultural functions, including food security and environmental, economic, and social functions in the lowland rainfed area of the Khon Kaen province. The study focuses on farms that are involved in integrating crop and animal enterprises (trees, fish, vegetables, poultry, cattle, and pigs) for a different number of years and that have less than 7 ha, and compares these with commercial farming systems. The specific objectives are:

1) To quantify the biodiversity that contributes to a secure supply of food, the share of purchased food from outside the farm, farm income, productivity, and cultural acceptability for farms with varying levels of integration.
2) To assess the soil fertility, growth performance of tree communities, and irrigation months of farms with varying levels of integration.
3) To identify the constraints to integrating and diversifying resources on the farm.

2 STUDY AREA

The study area is located in the northeast of Thailand, which is a region characterized by relatively poor soil conditions, a high reliance on rainfed agriculture, and a relatively low level of development compared to other regions in the country. When agricultural development is constrained by many factors, an in-depth knowledge of the area is essential for understanding the constraints and opportunities of the system.

The purpose of this chapter is to give an overview of the biophysical and socioeconomic conditions of the research area. Section 1 explains the methods of the site selection. Topography, soils, and climate are the basic forces shaping the biophysical conditions and are described in Sections 2, 3 and 4, respectively. Water resources are essential in rainfed agriculture, and are the subject of Section 5. The last three sections focus more on the human impact on the landscape. Section 6 describes the original forest type, Section 7 describes the socioeconomic conditions of the area, and finally, Section 8 describes the land-use management.

2.1 Site selection

The framework of the study is based on the research agenda of the International Water Management Institute (IWMI) for Southeast Asia in 2001, which deals with land degradation in northeast Thailand. The focus of the study is on resource-poor farmers confined to marginal agricultural production areas, with limited land and water resources. During the site selection, the techniques of Rapid Rural Appraisal (RRA) (Wattenbach and Friedrich 1996; Crawford 1997; Ondura 1998; Linda et al. 2004) were used to collect information on, among other things, the farmers' perception on the integrated farming system and changes in their farming systems within the last decades in the area where the integrated farming system is promoted.

Farmer networks in four provinces (Yasothorn, Ubon Ratchathani, Sakonnakorn, and Khon Kaen) were consulted during the selection of the study area as integrated farming has been promoted in each of these (Figure 2.1). The sites were then selected from areas with less than 1,300 mm precipitation per year. Based on this criterion, the area in Khon Kaen was selected from these four areas.

Figure 2.1: Four visited areas in northeast Thailand where the integrated farming system is promoted through farmer networks

The study area was further narrowed down by focusing on those areas where both commercial and integrated farming are practiced, to allow the comparison between the farming systems. According to this criterion, the water catchment area Huai Nong Ian was selected. The location of the Huai Nong Ian catchment is shown in Figure 2.2.

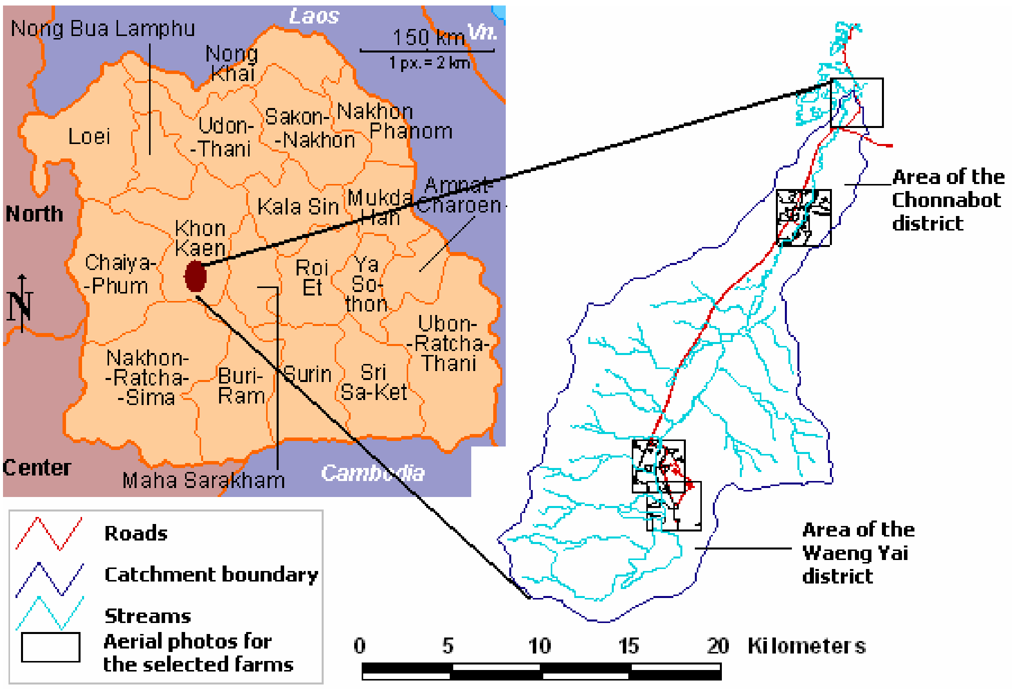

Figure 2.2: Huai Nong Ian catchment area with selected study sites in the Waeng Yai and Chonnabot districts, Khon Kaen province, Thailand

2.2 Topography

The water catchment Huai Nong Ian is located in the Khorat river basin, between 15°45′54″ and 16°00′57″ north latitude and 102°25′00″ and 102°30′49″ east longitude. The catchment covers an area of 285 km^2. The catchment is located in two districts: Waeng Yai district with an area of 129 km^2 and the Chonnabot district with an area of 156 km^2. The area of the catchment covers four adjoining topographic maps: 5541 III (Ban Pai), 5540 IV (Pon), 5441 II (Kaeng Kor), and 5440 I (Khon Sawan).

The average slope of the catchment is 0 to 2%. The highest point is 265 m asl in the Huai Yang, Waeng Yai district, and the lowest point is 156 m asl in the village Gud Lom in the Chonnabot district. The stream flows from the southwest to the northeast of the catchment area over a distance of 30 km.

Based on the geomorphological map of the northeast (DMR 2000), the rock in the catchment area is classified as a ‘sao-kua’ rock unit. This rock consists of shale stone and silt stone components. Fine sandstone and gravel stone are scattered. In some areas, rock salts are deposited in strata below the catchment area. In the dry season, the level of the water table is less than 1 m.

2.3 Soil resources

According to the soil classification map (LDD 2003), fine sandy to very fine loamy textures with low to moderate fertilities are prevalent in the catchment. Soil pH ranges from 7 to 9. Along the topography of the catchment (Figure 2.3), three soil types are found: Ustifluvents, Paleaquults, and Tropaquepts. The distribution of the soil types is as follows:

1) Flood plains in the lower catchment. The plains are annually inundated by floodwater overflowing the riverbanks. Tropaquepts soils cover this area. In the area between the flood plain and river in the lower catchment, Ustifluvents is the main soil type here.
2) Low and middle terraces in the middle catchment above the flood plain. This area is covered by Paleaquult soils.
3) Middle terraces in the higher area are found in the upper catchment. This area is covered by Paleaquult soils.

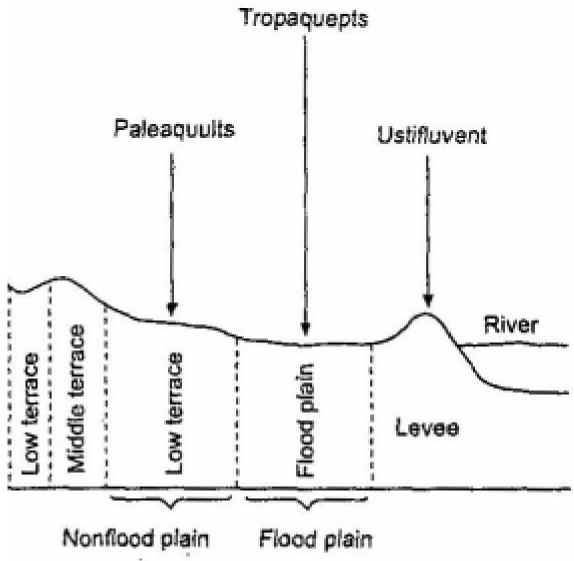

Figure 2.3: Transect of topography and soil in the study area (Source: Modified from Limpinuntana 2001)

The Ustifluvents have a fine to medium texture and are well drained and slightly acid. The Paleaquult soils have poor drainage and are saturated at certain times during the year. The Tropaquepts are fine textured and poorly drained.

Typical soil-related problems for farm production in this area are: shallow soil, skeleton soil, sandy soil, soil salinity, and low available nutrients. This is because most of the parent material in the region is composed of alluvial deposits or of weathered sandstone, forming sandy or sandy loam soil types (Moncharoen et al. 1987; Kohgo et al. 2000; Moncharoen et al. 2001; Limpinuntana 2001).

2.4 Climate and rainfall

Following the climate classification of the tropics and subtropics based on the concept of humid and arid annual seasons (after Troll and Paffen 1964), the climate in the study region is classified as tropic, subdivision ‘warm tropics’, which supports plant growth throughout the year (12 thermic vegetation months) (Lauer 1993). The climate in the region is usually influenced by the southwest monsoon and tropical cyclones from the South China Sea. The region has three seasons: rainy season (May to October), dry season (November to January), and hot-dry season (February to April). The temperature in the dry season is usually lower than during the other seasons, as it is influenced by cold weather coming from the northeast, i.e., from China.

The bimodal distribution of rainfall is influenced by the monsoons. In the rainy season, the first period of rainfall (May to June) is dominated by the southwest monsoon, while the second period (July to October) is dominated by both the southwest monsoon and tropical cyclones from the South China Sea (Vorasoot et al. 1985; KKU 1998). The rainfall in the second period is more frequent and intense than during the first period. A dry period usually occurs between the two rainfall peaks.

The mean annual precipitation is 1,229 mm and the average number of rain days is 108. The highest mean precipitation is 246 mm in September, whereas the lowest mean precipitation is 6 mm in January (Figure 2.4).

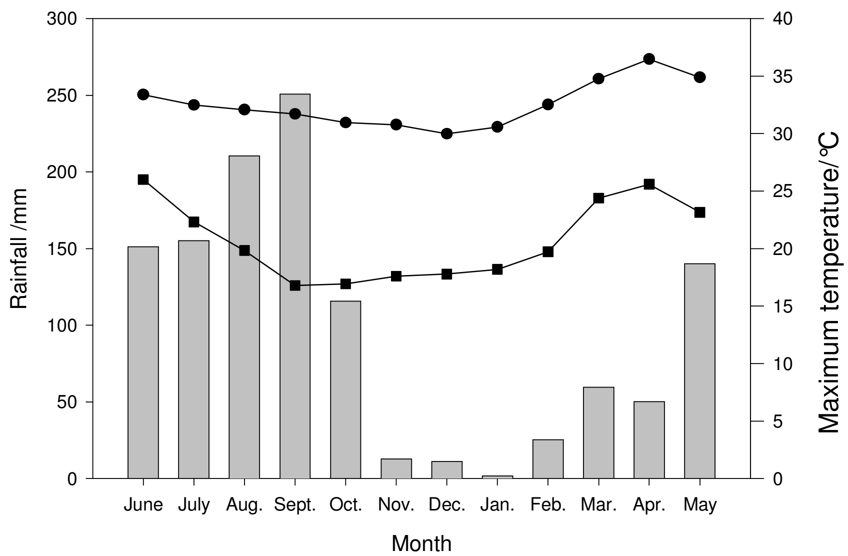

Figure 2.4: Mean monthly rainfall (vertical bars), pan evaporation (▪) and mean temperature (•) in Khon Kaen, Thailand (Source: Imaizumi et al. 1999)

The annual evaporation rate is about 1,676 mm. The mean annual temperature is 26.6 °C; the highest monthly mean temperature is 30 °C in April and the lowest 22 °C in December. In spite of an annual rainfall of over 1,000 mm, the amount of evaporation is greater than rainfall (Figure 2.4) (Imaizumi et al. 1999).

Occasionally, floods occur in certain years in the area near to the Huai Nong Ian stream and the lower catchment in the Chonnabot district near the Chi River. Drought in the catchment results from the uneven distribution of rainfall in the area within the year, and within the rainy season, as well as from year to year (Limpinuntana 2001).

2.5 Water resources

Natural surface water resources in the study area are influenced by the hydrological characteristics of the Chi River basin. The hydrograph of the discharge of the Chi River rises and falls sharply and has more than one peak in each season. This indicates the inefficiency of the watershed (Srisuk 1994). In the hydrological cycle of the study region, 15% of the precipitation is runoff, 10% is ground water re-charged, and the remaining 75% is evapotranspiration. The low gradient of the riverbed underlain by a layer of laterite may cause water logging and inundation when the rainy season starts and water begins to flow in the river. The rivers are deep and have scant flows in the dry season, but bank overflows can be observed in the rainy season (Donner 1978).

Groundwater

Groundwater in the region exists in unconsolidated sediments and in the cracks, joints, faults, and bedding planes of the sedimentary rock such as shale, silt, and sandstones (McGowan Pty. Ltd. 1983; Tuckson 1983; DMR 2000). Since the study area is underlain by a layer of rock with salt formations, many areas have salinity problems and are unsuitable for groundwater development (Patamatamkul 2001). The average yield of most wells is about 2 m^3 h^{-1} (Srisuk 1994; Imaizumi et al. 1999). Because of their low yield, groundwater sources are generally developed for domestic consumption only.

Surface water

The main surface water sources can be divided into two types: natural lakes and rivers and their tributaries. In the catchment area, irrigation water for agriculture is supplied from two water storage reservoirs (natural lakes) and one natural main stream and its seven tributaries. The two reservoirs are Tung Puen Pued and Nong Kongkaew. The main stream is Huai Nong Ian, which is connected to Lake Tung Pueng Pued and passes through the catchment area in Waeng Yai, and has an outlet to the Chi River in the Chonnabot district with a length of about 30 km.

The seven tributaries are: Huai Don Chim, Huai Kud Hu, Hui Khi Nak, Huai Khi Na, Hui Muang, Huai Krapi, and Hui Kae. The Tung Puen Pued and Nong Knog Kaew reservoirs and Huai Nong Ian stream are dredged and maintained by the Royal Irrigation Department (RID) (RID 1995). Tung Pueng Pued impounds 550 million m^3 of water and is classified as a small irrigation project according to the KKU (1998) classification: large, medium, and small with a capacity of ca. 3,430, 1,218, and 647 million m^3, respectively. This reservoir supplies the Huai Nong Ian stream with water for the cultivated area in the Waeng Yai and Chonnabot districts, and drains naturally through the Chi River (RID 1995).

Another type of irrigation system is based on water pumped from the Chi River in the lower catchment, the Chonnabot district, established and maintained by the Electricity Generating Authority of Thailand (EGAT 2001). A pumping station equipped with 24-inch diameter pumps, together with two 15-km distribution canals, supplies irrigation water for 30 farm households in the Wangwoen and Gudlom villages. Pumping irrigation projects for irrigation of the arable land along the Chi River, together with dredging, aim to increase the storage capacity of the reservoirs and stream.

In addition, innumerable small-scale irrigation systems, including small reservoirs, diversion weirs, shallow and deep wells, farm ponds, and rainwater collection facilities, are present along the main stream and in the catchment area.

Utilization of ground and surface water sources such as lakes, streams, and small farm ponds is low. The main limitations for the use of water resources in the catchment are:

1) Groundwater sources are inadequate for extensive irrigation. The average yield of groundwater is relatively low and threatened by salt rock formations.
2) The rainfall pattern in the region is notoriously erratic. The variability of rainfall from year to year is also extremely high. The most reliable rainfall months are August, September and early October (Vorasoot et al. 1985; AIT 1994b).
3) The low capacity and inefficiency of watersheds in absorbing and releasing water is the result of rapid runoff during the wet season and low runoff during the dry season (Srisuk 1994). Furthermore, topographic factors limit the possibilities for water storage. Lack of sufficient storage capacity is caused by bedding plane, sedimentation and erosion (Imaizumi et al. 1999).
4) High salinity of surface water caused by deep saline groundwater discharge as base flow into the river (Arunin 1992; Tanaka 1997).

2.6 Forest resources

According to the forest type classification in Thailand, the forest type in the study area consists of: dry dipterocarp forest; riverine forest; riparian forest; and man-made forest or plantation (Smitinand 1994; Prachaiyo 2000; Dhamanonda 2001).

Dry Dipterocarp forest

Dry dipterocarp forest (DDF) is characterized by broadleaf trees growing on relatively dry sites. Most of the tree species are in the Dipterocarpaceae family. This forest type is widely found in the area where the annual rainfall ranges from 1,000 to 3,000 mm year^{-1} during 5 to 6 months. The soil under this forest type is sandy and shallow with a low nutrient supply capacity; this is why the people do not clear this forest for agricultural use (Smitinand 1994; Prachaiyo et al. 1995; Prachiyo 2000; Jamroenprucksa 2001).

Dominant species in DDF include *Dipterocarpus tuberculatus*, *D. obtusifolius*, *Shorea obutsa*, *S. siamensis*, *Xylia xylocarpa* and *Irvingia malayana* among others. Tree trunks of girth at breath height (GBH) 30 to 100 cm in species such as *Cratoxylon formosum*, *Careya arborea*, *Vitex pinnata*, *V. glabrata*, and *Dillenia obovata* dominate in DDF. Saplings with GBH less than 30 cm consist of woody climbers and the young generation of upper layer species such as *Terminalia bellerica*, *T. mucronata*, *Canarium kerrii*, *S. siamensis*. These saplings grow slowly due to forest fires in the dry season, poor soil, and the long dry period. Another layer found in this forest type includes seedlings and ground cover plants that limit the growth of herbs and the seedlings of big trees. In the open forest, the ground is covered with grass, often replaced by bamboo, and scattered thorny shrubs. Annual fires usually remove the layer of dry leaves and burn sapling and ground covers.

Riverine forest

Riverine forest is a unique type of forest found in the study area. It is closely related to the ‘Bung’ and ‘Tham’ forests. These forests have developed in the flooded areas during the rainy season along the Chi riverbanks and its tributaries. The swamps usually become dry in the dry season. On elevated flat areas, *Dipterocarpus obtusifolius* are often found. Shrubs occur on the banks of the stream, whereas thorny bamboos occupy the tops of the riverbanks (Prachaiyo 2000; Dhamanonda 2001).

Riparian forest

Riparian forest in the study area is found in the natural lake in the upper catchment and lower catchment. There are four different types of vegetation in this type of forest: floating plants, suspended plants, submerged anchored plants, and anchored plants (Cook 1974). Floating plants are found in the open areas of water. Dominant species are *Azolla pinnata* (red azolla), *Pistia stratiotes* (water lettuce), and *Nymphoides indicum* (snow flake). Suspended plants grow in the open areas of a water body where sunlight is strong. Submerged anchored plants grow above the water surface. Dominant species are *Nymphaea pubescens*, *N. nouchali*, *Nelumbo nucifera* (kamal). Anchored plants are also to be found above the water surface, the majority are grasses. Dominant species are *Scleria poaeformis* (prue), *Eleocharis dulcis* (Chinese water chestnut) and *Fimbristylis miliacea* (grass like fimbry). In the area with less water in the dry season along the banks of the lake or river, dominant species are *Marsilea crenata* (water clover), *Ipoemoea aquatica* (water spinach), and *Cyperus difformis* (variable flat sedge).

Man-made forest

Man-made forests or plantations dominated by eucalyptus are also found in the study area. In some areas, small patches of eucalyptus are also planted for commercial purposes. Small patches of this forest are scantly distributed through the catchment area. According to a survey by Sunthornhao (1999), eucalyptus plantations accounts for about 47% (207,785 ha) of the total plantation area in the country.

2.7 Socioeconomic resources

Administratively, the study catchment covers six sub districts, i.e., three sub-districts in the Waeng Yai and three sub-districts in the Chonnabot district.

Infrastructure and communication

Two highways (Nos. 2233 and 2199) are the main roads connecting the study area to Bangkok and Khon Kaen. The distances from Bangkok to Khon Kaen and from Khon Kaen to the Tung Puen Pued lake are approximately 372 km and 85 km, respectively. The distance from the lower catchment (Chonnabot district) to Lake Tung Puen Pued in the upper catchment is about 55 km. Other transportation systems do not exist in the catchment area.

Demography

In year 2001, the Waeng Yai and Chonnabot districts comprised 65 villages with a total of 9,457 households and a population of 33,021 (MOI 2001). The number of males and females was 16,532 and 16,489, respectively. The annual population growth rate is approximately 0.6% (NSO 2000).

Incomes

Household income varied from household to household. The average household income in the Waeng Yai and Chonnabot districts was 96,363 baht household^{-1} per year (NSO 1998). Farm income contributed 45.7% to the total household income whereas the other 54.3% was generated from non-farm employment and from remittances from members that have migrated from the farm, and other sources. The average wage rate in agriculture was 80 baht per person per day (OAE 1998).

Migration

The low incomes associated with the uncertainty of agricultural revenues have increasingly induced males and females to leave agriculture in search of higher income opportunities (Patamatamkul 2001; Ruaysoongnoen and Suphanchaimart 2001; Ruaysoongnoen 2002). Out-migration in this region includes seasonal migration (mainly during the off-farm season) and permanent migration. Farm labor migrates from this region to the larger cities such as Bangkok and other commercial provinces in the country as well as to foreign countries (Hussain and Doane 1995; Patamatamkul 2001).

2.8 Agricultural land management

Traditionally, farmers open up forest areas for agriculture when necessary, using the low input production system carried over from their ancestors, without any attempt to improve the soil as long as there is enough forest land to be cleared (Ruaysoongnoen and Suphanchaimart 2001; Little 2004). On much of the terraced land, the forest has been considerably modified by growing upland crops, such as kenaf, cotton, and maize.

On the lower part of the terrace, most of the original forest has been removed and the land is now used to grow rice. It is also common practice to leave several big trees standing in the paddy fields (Dhamanonda 2001; Jamroenprucksa 2001). However, land-use patterns have dramatically changed from subsistence to semi-subsistence and commercial farming due to biophysical and socioeconomic factors as mentioned in Chapter 1.

Today, agricultural land in this catchment is typically used for rice paddies, sugar cane, cassava, fruit orchards, forest plantations and livestock. The total area of the two districts (404 km^2) is covered with five different types of production systems: 1) paddy fields (67.7%); 2) fruit orchards such as mango, jackfruit, and coconut (1.9%); 3) upland crops (24.6%); 4) livestock (5.5%), and 5) aquaculture (0.3%) (LDD 2003).

Rice is the main crop planted from May to October (wet season) and the second rice from December to February (dry season). Average rice yield for both seasons in the Waeng Yai and Chonnabot districts were respectively 1.1 and 1.4 t ha^{-1} between 1997 and 1998 (OAE 2000). In the Waeng Yai and Chonnabot Districts, the average farm size is 4.5 ha.

3 MATERIALS AND METHODS

The objective of this chapter is to introduce the concepts used and to describe the process of data collection and analysis. The chapter is structured as follows. Section 1 presents the conceptual framework of the study. Section 2 describes the sampling procedure for selecting the farms. Based on the conceptual frame, the relevant variables are identified in Section 3. Section 4 describes how data were collected. The last section outlines the statistical methods used to analyze the data, results of which are presented in the following chapter.

3.1 Conceptual framework

In northeast Thailand, the benefits from the integrated farming system are expected to extend beyond higher crop yields and include the benefits from environmental service delivery and its acceptance by local habitants (Thamrongwarangkul 2000, 2001; Jitsanguan 2001). Efficient use of the agricultural land is therefore important, as the degradation of the natural resources endangers the food security situation (Smyth and Dumanski 1993). Recognizing the multiple objectives of the integrated farming system, the framework of agricultural multifunctionality (OECD 2001) is used as a conceptual framework for this study. The study interprets the multiple roles of the integrated farming system in terms of various functions of agriculture according to the concept of a multifunction agriculture.

The multifunctionality concept provides an approach to evaluate an agricultural system and land use by: 1) widening the focus to include other environmental services; and 2) providing a framework for comparative valuation of trade-offs and synergies between the different functions of agriculture (Price 2000; OECD 2001; Groenfeldt 2005). Likewise, the concept of multifunctionality favors a perspective that recognizes the existence of multiple outputs (OECD 2001).[2] It thus facilitates understanding of the interactions between agriculture related land use, multiple goods and multiple outputs produced by agriculture, and their contributions to achieving wider social objectives (Price 2000).

[2] The term "multiple outputs" is generally preferred as it allows the inclusion of intended outputs and not only unintended side effects.

Within the multifunctionality framework, certain principles are considered fundamental and are intended to govern the functioning of agriculture. These principles are: food security function, environmental function, economic function and, social functions (OECD 2001). The importance of four functions is elaborated in the following.

1) Evidence from most of farming research illustrates the central role of food security in achieving sustainable social and economic development in rural areas and for society in general (FFTC 2002; Othman 2004; Groenfeldt 2005). Food security is the first priority of agriculture. Furthermore, food security is recognized as one of the main principles in the framework of SLM (Smyth and Dumanski 1993; Craswell 2002) and Sustainable Agriculture (Norman et al. 1997; Mundy 1997).
2) The environmental function is regarded as one of the fundamental function of agriculture (Price 2000; Groenfeldt 2005). In this regard, agricultural land forms the basis of terrestrial biodiversity by providing the biological habitats and genetic reserves for plants, animals and micro-organisms. Agricultural land also regulates the storage and flow of surface and underground water, and influences its quality (Sombroek and Sims 1995; Hediger and Lehmann 2003).
3) The economic function of agriculture refers to its role in producing economic value (Smyth and Dumanski 1993). This economic value is not limited to farm production but includes the input requirements, i.e. fertilizers, services, capital, and agricultural products that are processed, transported, marketed, and distributed, which all generate income for many companies not immediately involved in farming (Price 2000; OECD 2001; Hediger and Lehmann 2003).
4) The social function refers to the idea that agricultural land provides, stores, and protects the evidence of the agricultural history of mankind (Sombroek and Sims 1995). The maintenance and dynamism of rural communities is fundamental to sustaining agriculture and improving the livelihood of the rural population and its future generations (Price 2000). Agricultural practices can fail, in time, if their social impact is unacceptable (Smyth and Dumanski 1993).

In view of sustainability within the context of agricultural multifunctionality, these fundamental requirements must be viewed in a positive light. However, some trade-offs between objectives may be unavoidable; for example, lower land productivity may be accepted if this is necessary to improve or protect the resource base.

3.2 Sampling procedure

The performance of the integrated farming system is evaluated through farm pairing, which involves the comparison of selected farms in the integrated farming system with adjacent farms in the commercial farming system with a similar soil type and water resources. This was because time-series data were unavailable. To control for the spatial variation in biophysical factors in the catchment, sample farms were selected in the upper catchment, middle catchment and lower catchment.

Aerial photographs covering the three catchment areas in 1992 were acquired. These photographs with a scale of 1:15,000 were used to identify three different areas for the selection of farms. This included the natural adjacent vegetation area where original vegetation still exists, which was used as a reference. For each of the three areas in the catchment, the area that had been used for rice paddy cultivation for more than 30 years and which had been integrated with other production systems was marked for sampling. Similarly, the adjacent natural vegetation area that had been abandoned for at least 30 years was selected and marked as a reference for further investigation.

During the selection process, ranges of RRA techniques, as described by Chambers (2002), were used to select sample farms. The RRA techniques include direct observations, expert interviews, and semi-structured interviews with farm households. The farms were identified through visits, and past, present, and future management plans were discussed with each farm household.

The 16 farm households were selected in the catchment area. All selected farm households agreed to participate in the study. The participating farmers were informed about the objective of the study and assured that information would be kept confidential. The participating farmers responded positively and were willing to share the relevant information.

A 16 farm households was arranged in eight pairs of one integrated farm and one commercial farm. Three pairs of farms were located in the upper catchment, two pairs in the middle catchment, and three pairs in the lower catchment. In the upper and middle catchment, all integrated farms had practiced integrated farming for more than five years, while in the middle catchment only one farm had practiced it for longer than five years and the other farm had only practiced it for two years (until 2002).

The selected farm households had different levels of integration of farm enterprises. Figure 3.1 graphically shows the selected farm households on a scale from low levels of integration on the left, to high levels of integration on the right. Farm households with a low level of integration combine rice cultivation with poultry and vegetables. Farm households at the other end of the scale have aquaculture, cattle, trees, and mushrooms in addition.

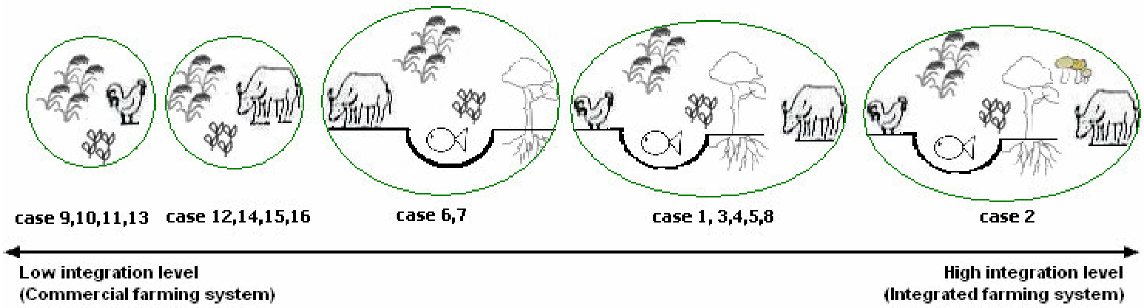

Figure 3.1: Farming systems and selected farm households ranked by level of integration

3.3 Selection of variables

Variables are selected that quantify four principles (food security, environmental, economic, and social functions) and values are compared between the two systems.

Integration level of the farm system

The aim of this study is to compare the integrated farming system with the commercial farming system. Yet, as shown in Chapter 1, the distinction between the two farming systems is not an absolute one but rather a matter of degree of integration. Two complementary approaches of analyzing the integrated farming system are therefore used and different statistical techniques are applied to analyze each and to check for robustness. The two approaches are: first, a comparison of farms based on farm types. For this, the farms were divided into two groups: the integrated farming system and the commercial farming system. Second, a comparison between farms based on the level of integration. Integration level is in line with the concept of IFS as it measures the synergies between different enterprises in the farm. This is a continuous discrete rather than a binary variable; how this is constructed is explained in the data collection and analysis section.

Measuring biodiversity in the farming system

Two different variables were used to assess the biodiversity in the farming system: richness of species and diversity according to difference in growth habits of plants.

Measuring food security functions

According to the definition of food security by FAO (2002), household food security is reached when all household members have physical and economic access to sufficient food and can meet their food preferences. Based on this definition, the situation of food security is difficult to measure. To simplify the measurement of food security, it can be assumed that household food security is reached when the various types of food are available in the household's own production system all year round. This measurement comes closer to the situation of food security as judged by the farm households, because farm households are likely to judge the level of food security in terms of the diversity and amounts of food and the extent to which preferences for a particular type of food are satisfied (Reijntjes et al 1992; Dillon and Hardaker 1993).

Based on the above justification, the availability of food can be characterized by type, proportion, distribution, and amount of food in the farming system. First, the type of food available on the farm closely corresponds to the richness of food species. Second, the proportion of available food is measured as the share of the value of the food that is produced and consumed within the household. Third, the distribution of food is equated with the year-round harvesting time of food. Fourth, the available amount of food is equated with the yield of food crops.

The species richness used as food was used to evaluate the degree of food availability. The variable share of home produced food was included in the analysis to give a balanced picture of the food that was actually produced and consumed by the households and of the dependency on food from the local markets. It was assumed that surplus food production, i.e., what is left after the subsistence requirements of the household are met, is sold or exchanged for other goods (Edwards et al. 1993; KKU 2001). The distribution of food was measured by establishing the seasonal calendar of important on-farm activities. Measuring the available amount of food was measured by current crop yield.

Measuring economic functions

Productivity is an indicator of relative efficiency of resource use and management practices (Dillon and McConnell 1997). Variables of gross farm income, current crop yield, and labor productivity were used to estimate resource values pertaining to the productivity of the land and labor resources on the farm.

Measuring environmental functions

Maintaining or improving soil and water quality is crucial for sustainable land use (Noble and Randall 1998; Viyakorn 2001; Craswell 2002; Whitbread et al. 2002). In low-input agricultural systems, where inorganic fertilizers are less affordable and water is limited, the integration of selected tree species and water reservoirs are only two examples of practices in which the recycling of nutrients and fertility status of the soil is increased (Kapetsky and Barg 1997; Noble and Randall 1998; Viyakorn 2001; Little and Edwards 2003). According to this, the variables of available tree communities in the farm system, species richness of soil covers, and irrigation months in addition to rainfall were used to assess the performance of the farm system from an environmental viewpoint.

Measuring social functions

The farming system is perceived as the basis of the rural livelihoods. Thus, one important role of farming systems is the maintenance of the rural community, including the agricultural culture (Reijntjes et al. 1992; Price 2000; Jitsanguan 2001; Kaewsong 2001; KKU 2001). In this regard, the diversity of on-farm activities was used to measure for the acceptability of the system. Further three biodiversity indicators were used to measure the social acceptability of the farming system: richness of species use for local rituals, medicinal purposes, and housing purposes.

3.4 Data collection and analysis

Integration level

The type of farming system (i.e., integrated farming system, denoted as IFS, and commercial farming system, denoted as CFS) is a discrete and dichotomous variable. In addition, a variable capturing the level of integration, denoted as IL, was developed.

A matrix approach was used to derive IL at each farm. Table 3.1 shows this matrix including all different crop and animal enterprises. To quantify IL, the number of interactions between enterprises was counted. When there was no synergy between two enterprises, these did not increase the integration variable. For each synergy between enterprises, IL was incremented with one. For example, if cattle manure is applied on vegetable plots, then the score 1 is recorded at the intersection of the cattle row with the vegetable column. If cattle are also fed with vegetable residues, then another score of 1 is recorded at the intersection of the vegetable row and the cattle column in the matrix. Aggregating all scores gives the total integration level.

Table 3.1: Example of matrix defined to derive integration level (IL) at each farm

From/To	Rice	Vegetables	Trees	Cattle	Fish	Poultry	Pig	Sum
Rice	0	0	1	1	0	1	1	4
Vegetables	0	0	0	1	1	1	1	4
Trees	0	1	0	1	0	0	0	2
Cattle	0	1	1	0	0	0	0	2
Fish	0	0	0	0	0	0	0	0
Poultry	0	1	1	0	1	0	0	3
Pig	0	1	1	0	0	1	0	3
Total scores								**18**

In this way, a mixed farming system was separated from IFS (Chapter 1), as a mixed farming system can have many enterprises but still a low level of integration. This variable has a continuous scale and is hence more suitable for regression analysis.

Species richness by growth habit

Species richness by growth habit was used to describe the species composition in the tree community. Growth habit of each species was classified using the Preisinger (2001) classification as shown in Table 3.2. Species of all plants were initially identified by their local Thai name and samples were collected if the researcher could not immediately identify the species. Species identification was carried out by a taxonomist from the faculty of Pharmacy, KKU, and using taxonomic keys and manuals from the Forest Herbarium of the Royal Forest Department (RFD) in Bangkok.

Table 3.2: Classification of growth habit by Preisinger (2001) used in this study

Woody growth habit	Abbreviation
Rosette trees, forming a single terminal crown of broad, compound leaves (Arecaceae)	RT
Shrubs	SH
Sparsely ramified, short-lived, treelets, which regenerate mainly from seeds, forming lobed or compound leaves (Melastomataceae, Moraceae)	ST
Winding or twining plants (lianas)	WT
Herbaceous growth habit	
Broad-leaved forbs (Musaceae inter alia)	BF
Graminoid herbs, spreading by rhizomes (Poaceae)	GR
Graminoid herbs, spreading by stolons (Poaceae)	GS
Graminoid herbs, forming, tussocks (Poaceae, Cyperaceae)	GT
Herbs, spreading by rhizomes (Polypodiaceae)	HR
Spread climbers (sometimes with wooden parts at the base)	SC
Upright or prostrate growing, herbs with medium or small leaves	UH
Winding herbs or vines	WH

Species richness for food

Species richness is defined as the number of different species present in a particular area (Lamprecht and Pancel 1993; Palmer 2003). For each farm, the species richness was calculated by counting the number of different species and summing this number for each purpose. In this study, five main groups of species use were distinguished: as food; used for medicine; used for local rituals; used for housing (ornamental, constructions, and shadings); and as soil covers.

The data on different species were collected through the farm survey. Each species was initially identified by its Thai local name and by the purpose the farm household used it for.

Share of home produced food

Household cash food expenditures were analyzed to determine the share of purchased food and home consumption.

Cash food expenditures were defined as the total value of cash of daily food purchased from outside the farm, such as at local markets or from neighbors, over a one year period (baht $year^{-1}$). A farm household can generate high cash food expenditures when it has a large number of household members. To control for this, cash food expenditure were expressed in baht $capita^{-1}$ rather than in baht $household^{-1}$. Cash food expenditures were measured from the purchase of grains, roots, tubers, sugars, oils, fruits, vegetables, meat, fish, and eggs.

Home consumption was defined as the total value of own produced food consumed by the farm household itself over a one-year period (baht $year^{-1}$). Home consumption of food was expressed in baht $capita^{-1}$. The food that was consumed by the farm household included staple crops, vegetables, fruits, and animal products.

The total food expenditure was calculated as the sum of purchased food outside the farm and home consumption, both valued at market prices. The share of home produced food was calculated as a percentage of home produced food in the total value of food expenditure.

The data on daily cash food expenditures were collected through semi-structured and informal interviews that were tape-recorded (Chambers 2002). Data were validated using a triangulation strategy, as data were collected from more than one source of information in the same household to improve accuracy of information and give a better understanding of the context and divergent perspectives (Johnson 1997; Linda et al. 2004).

Important Value Index

Important Value Index, denoted as IVI (%), was used to describe species composition and ranks the most dominant species of a tree for each sample plot on the study farm (Curtis and Macintosh 1951). Each sample plot was divided into 16 subplots, measuring 5 m x 10 m, i.e., 800 m^2 in total. Important Value Index was calculated from the relative frequency, relative dominance, and relative abundance separately for each system and study farm.

1) Frequency is the number of times a given species is found on a plot. Relative frequency, denoted as RF, is the percentage contribution in a given species to the total species found in the sample plot (Lamprecht and Pancel 1993; Laar and Akca 1997; Palmer 2003).

2) Relative dominance, denoted as RDo, is the total cross section area of a given species at each sample plot divided by the total basal area of all species combined in a given sample plot (Laar and Akca 1997; Palmer 2003).
3) Abundance is a measure of the number of stems of a species *s* in a sample plot. Absolute abundance is the number of individual stems per a given species (Lamprecht and Pancel 1993; Palmer 2003). Relative abundance, denoted as RA, is the abundance of a given species (by stem measure), divided by the total abundance of all species combined in a given sample plot.

In each tree stand, IVI of a given species was calculated as (Curtis & Mackintosh 1951):

$$IVI = RF + RDo + RA \tag{3.1}$$

Stand height

Stand height is expressed as the mean height of all trees. The height of individual trees was measured in meters. Stand height together with crown social position was used to provide information on maximum reachable tree heights and to indicate vertical growth of trees as affected by farm management.

In each sample plot, trees were furthermore classified into three classes according to their height and diameter measured at 1.30 m (DBH) (Sukwong 1974). Each individual tree was classified by using the criteria of height ≥ 1.30 m and diameter at 1.30 m ≥ 5 cm; sapling by height ≥ 1.30 m and diameter ≤ 5 cm; seedling by height less than 1.30 m. The height of individual trees was subsequently used to determine the stand height.

The height of individual trees was measured using a haga meter. The diameter was measured in meters, using diameter tape (50 cm) by measuring the perimeter of the stem at 1.30 m from the ground. For each individual plant, data on height and diameter were obtained simultaneously.

Tree crown social position

The crown social position was classified based on Dawkins (1987). Five classes were classified for this study:

- Class 1 Crown in the shade on all sides and no direct light. Extremely suppressed trees over long periods of time, common in social position 1, eventually die off; and
- Class 2 Crown with no overhead light and partially shaded; and
- Class 3 Crown partially exposed to overhead light and lateral shade; and
- Class 4 Crown in full overhead light and lateral shed; and
- Class 5 Crown in full overhead and lateral light.

Stem density

Stem density is the number of individual trees per unit area. The density is measured in stems ha^{-1} (Lamprecht and Pancel 1993; Palmer 2003). For example, if 11 tree stems are found on 0.5 ha, then the stem density is 22.

Stand basal area

Stand basal area is here used for woody trees. Stand basal area is an area occupied by the cross section of the stem of a tree at 1.30 m above the ground. For each species, basal area refers to the cross sectional area of all trees of a given species combined in a given sample plot (Laar and Akca 1997; Weyerhaeuser and Tennigkeit 2000; Palmer 2003).

The vegetation resources in the farm area were examined from January to February 2003. Data on species composition and stand characteristics were collected simultaneously. The transect method was applied in order to cover the diversity of the vegetation in the farm area (Sukwong 1974; Bunyawechewin 1983, 1985, 1986; Prachaiyo 2000). A transect line was laid down across areas with different uses on the farm. Sample plots with a size of 10 x 80 m (800 m^2) were established using measuring tape (25 m) and a prism compass. Boundaries of temporary plots were marked with plastic ropes.

To compare the growth of tree stand status on the farm, a similar method was applied in two selected areas with reference points in adjacent natural vegetation. Since the area of natural vegetation did not allow the same size of sample plots, the plot size was adjusted to 20 x 40 m (800 m^2). Data on the vegetation of each farm were also recorded.

Species richness of soil covers

A measure of species richness of soil cover was used to estimate the effect of IFS on environmental functions. Species richness for soil cover is the number of different kinds of plant species potentially used as soil covers and/or forages. Species richness for soil cover was estimated from the number of species for which stems and leaves were mostly not removed from the soil and were left in the field during the year. Data collection and the analysis of the variable of species richness function as soil covers are described under the species richness for food section.

Irrigation months

The number of irrigation months in addition to rainfall was used to assess how long the irrigation infrastructures in the farm can supply water for agricultural activities. The number of irrigation months was estimated from the permanent water reservoirs, such as farm ponds and wells. Based on the average rainfall and climate in the study area, the number of irrigation months in addition to rainfall was counted from the beginning of November to end of April (beginning of dry season to the end of hot and dry season).

Data on water resources on the farm were collected in the farm survey between September 2002 and January 2003. A range of RRA techniques, i.e. transect walks, semi-structured interviewing, direct observation (Chambers 2002), and farm mapping (Wattenbach and Friedrich 1996; Kapetsky and Barg 1997; Onduru et al. 1998) were used to collect the data.

For the classification of on-farm water sources, attributes of irrigation facilities in the farm were collected, such as location, use of the surrounding area, construction, and shape. The locations of on-farm water reservoirs were marked on the map. The number of reservoirs per type was counted and recorded. The size of the reservoirs was measured in meters using a measuring tape (50 m). Data related to construction and water manipulation were obtained through semi-structured interviews with key informants.

Soil organic matter

Soil samples were collected to quantify the quality of soil resources. Physical properties of soils were also measured and used to establish a relation between soil chemical properties and land management.

Soil sampling took place from December 2002 to January 2003. The aerial photographs were used to identify the areas where rice paddy fields were originally located, where the area has been modified for other production systems, and where water reservoirs have been constructed, and to locate areas surrounded by natural vegetation. The results of different types of land uses from the images were marked and cross-checked by interviewing key informants from the households. Based on this information, sampling sites were located in the areas specifically used for crop production and woodland.

For the purpose of chemical analysis, 15 composite soil samples were collected from each farm under rice paddy and perennial areas at three depths: 0-10 cm, 10-20 cm, and 20-30 cm. Each composite sample is a mix of 15 sub-samples taken at each depth. Fine roots and inorganic materials were removed from the soil samples. Methods for Soil and Plant analysis (Daly 1992) were used for the soil sample preparation. Samples were air-dried for a minimum of 24 hours, then ground and sieved with a 2 mm mesh. For each sample, 350 g were stored in a plastic bag and labeled with the farm name, soil depth, and date of sampling.

The soil chemical properties determined were: pH, electrical conductivity (EC), cation exchange capacity (CEC), and organic matter content (SOM), using method as described in Methods for Soil and Plant analysis (Daly 1992). Samples were analyzed in the laboratory of the Soil Chemical Division, DOA. Soil pH was determined in a mixture of soil and water, with a ratio of 1:2.5. The EC was measured in milli-siemen per centimeter (mS cm^{-1}), determined in soil solution using a conductivity meter and reported at 25 °C. The CEC (exchangeable Ca^{2+}, Mg^{2+}, K^+, and Na^+) was measured in milli-equivalent per 100 grams of soil (meq $100g^{-1}$), and was extracted by 1*N* ammonium acetate at pH 7. SOM was measured as a percentage (%), using the modified Walkley-Black method (Nelson and Sommers 1996).

During the laboratory analysis, quality control check samples (QC) were used in order to cross-check the results produced by the laboratories. Two replicates were measured in the same batch. The QC samples also employed 'in-house standards' taken from materials with parameters of known value, which are subjected to the same preparation and analytical procedures as the routine samples. Certain parameters were measured repeatedly to evaluate the control status of both the analytical preparation and the instruments.

For the purpose of physical analysis, undisturbed samples were taken by cylindrical tube (soil core) with a diameter of 7.62 cm. Five soil cores were taken from each farm at a depth of 0-30 cm. Soil cores were then carefully removed from the cylindrical tubes and placed in clean containers. The containers were labeled with the farm name, soil depth and date of the sample.

Soil physical properties of bulk density (BD), aggregate stability and texture were subsequently analyzed in the laboratory of the Soil Physical Division, DOA. Soil bulk density was measured in grams per cubic centimeter (g cm^{-3}), and determined using a cylindrical core of known volume and the mass of the dried soil. Soil texture was measured as a percentage of total weight (%) of sand (particle between 0.05 to 2.0 mm), silt (0.002 to 0.05 mm), and clay (< 0.002 mm), which was determined using the hydrometer method. Aggregate stability was determined as a percentage of total weight (%) of soil (particle between 0.1 to 2.0 mm), by wet sieving through mesh sizes 2.0, 1.0, 0.5, 0.25, and 0.1 mm and based on the mass of oven dried soil in each particle size (Le Bissonnais 1996). The total aggregate stability was calculated by summing the mass of all particle sizes.

Soil profiles

The upper-, middle- and lower areas of the catchment have different soil properties. Three profiles were established to study the variation in soils over these three areas, one in the upper catchment area, one in the middle catchment area and one in the lower catchment area. The study of the soil profiles was done simultaneously with the soil sampling. Profiles were established in the undisturbed area of the farm. To analyze the chemical and physical properties of each profile, two replicated undisturbed soil samples were taken following the same procedures as for the physical and chemical samples.

The observation and description of the soil profiles were done in accordance with the USDA soil classification (1993) by a soil taxonomist from the Land Development Department (LDD) in Bangkok. From each layer in the profile, a sample of 1 kg of soil was collected for the preparation of a soil micro-monolith. Representative soil micro monoliths of each profile were made at the regional office of the LDD in the Khon Kaen province. Soil samples from the profiles were sent to the laboratory of the LDD in Bangkok. The soil chemical and physical attributes (pH, EC, CEC, SOM, BD, available water content, texture) were determined using standard laboratory methods.

Crop yield

Crop yield, i.e., the crop-specific land productivity is expressed in kg ha^{-1} per year. Crop yields were calculated for rice, vegetables, and perennials. If farm households grew rice two times in one year (major rice and second rice), then the rice yield was aggregated from two cropping seasons and the cropping area was counted twice.

Data on harvested output for rice, vegetables, fruits, non-timber products, values from sold crops and animal products, and total cultivated area were obtained from semi-structured interviews.

Total output

Total land productivity was calculated as the output from crops and animals divided by the production area. Total output is the sum of crop and animal output. Total output is expressed in baht ha^{-1} instead of kg ha^{-1} because kilograms of rice and kilograms of vegetables cannot directly be compared.

Crop output was aggregated from the total revenues from rice, vegetables, and perennials in baht. Animal output was aggregated from the total revenue from cattle, pigs, poultry, and fish in baht.

The relation between IL and total output is approximated using correlation analysis. Since output is not only a function of IL, but also of total production area as, total labor, SOM and total fertilizer use, these variables were also included in the model.

Labor productivity

Labor productivity is expressed as the value of output per unit of labor to allow comparison between farms. The total amount of labor input is the sum of working days from family labor and hired labor. Because no activity-specific labor allocation data were collected, it was assumed that the distribution of labor over crop and animal production was proportional to the share of crop and animal in the total gross returns (baht $year^{-1}$). It was furthermore assumed that the area for crop production and animal production can be separated from each other.

Data about the number of family labor, hired labor, working hours, and working days were collected during the socioeconomic household survey, using the range of RRA techniques, i.e., direct observation and semi-structured interviews (Swanson et al. 1997; Chambers 2002). The triangulation approach was used to improve accuracy of information (Johnson 1997; Linda et al. 2004).

Gross farm income

The measurement and evaluation of annual returns and cost on a whole farm basis were determined using the method of economic evaluation of the farm system as developed by FAO (Dillon and McConnell 1997).

Gross farm income is defined as the value of the total output of the farm over a one-year accounting period. It includes the value of outputs produced during the accounting period and which is: sold; used for household consumption; used on the farm for seed or livestock feed; used for payments in kind; given to others; or in store at the end of the accounting period. Any output produced in earlier year that sold or used in the current period was excluded from the current gross farm income to avoid double counting (Dillon and Hardaker 1993). In the calculation of gross farm income, fixed cost is excluded since these have to be met whatever is produced and even if nothing is produced (Dillon and McConnell 1997). Gross farm income is obtained as total gross return less variable cost.

Variable cost is defined as total expenses that are specific to a particular crop and/or livestock enterprise. To avoid a confounded comparison between IFS and CFS, interest payments were excluded from variable cost. Fixed cost is those farm expenses that do not vary in this fashion. Data on annual returns and costs of farm production were expressed in baht farm^{-1} per year.

Because livestock is not sold annually, an adjustment is made for including returns from livestock in the average farm returns. The value of inputs for cattle raising, denoted as I_{Cattle}, and output of cattle, denoted as O_{Cattle} were calculated as follows:

$$I_{Cattle} = [5{,}000/4] \times ST \tag{3.2}$$

$$O_{Cattle} = [(350-60)/4] \times 120 \times ST \tag{3.3}$$

where 5,000 is the average purchase price (in baht) of calves; 4 is the average number of years required for raising the cattle; ST is the number of cattle in the farm stock; 350 is the average slaughter weight of the cattle in kg; 60 is the average weight of the calves at time of purchase; 120 is the average value of sold meat in baht kg^{-1}.

Net farm income was used as an indicator of farm profitability and to compare different farms in terms of economic performance (Dillon and Hardaker 1993). The net average return is expressed in baht year^{-1}. However, farm income depends also on the quantity of labor at the farm, the farm gross returns were converted into per capita units (baht capita^{-1}). Net farm income is obtained from the gross farm income less fixed cost.

Data on annual costs and returns for the whole farm were collected using semi-structured and informal interviews and recorded into a field notebook. Data were validated using the triangulation approach (Johnson 1997; Linda et al. 2004). For the purpose of analysis, regular household expenditures were categorized into four types: 1) food expenditures; 2) agricultural expenditures plus fixed costs (i.e., equipment repairs; and operating cost and fixed costs); 3) loan repayments; and 4) other consumptions (clothing, school, donations, housing, utilities, vehicle, entertainment, medical, etc.).

Species richness used for social purposes and diversity of on-farm activities

Three biodiversity variables were used to estimate the effect of IFS on social functions: the richness of species use for local rituals, medicinal purposes, and housing purposes. First, species richness for local rituals is the number of plant species with a potential use in local rituals, i.e. making merits and religious ceremonies. Second, species richness for medicinal purposes is the number of species with a potential use for medical purposes. Third, species richness for housing is the number of species used for multiple purposes by the household, i.e. species that used for ornamentation, construction, or shadings purposes.

Data collection and the analysis of species richness for local rituals, medicinal and housing purposes are described in the section on species richness for food.

Seasonal calendar of on-farm activities

The seasonal calendar of important on-farm activities was used to describe two important variables, i.e., the diversity of on-farm activities and the distribution of food within the farming system.

Data about seasonal activities were collected during the socioeconomic household survey using a range of RRA techniques, i.e., direct observation and semi-structured interviews (Swanson et al. 1997; Chambers 2002).

Other socioeconomic household conditions

The purpose of the household survey was to collect more in depth information on socioeconomic conditions of each farm household. The techniques of RRA as described by Chambers (2002) and Swanson (1997) were used for this purpose. The information was mostly collected through semi-structured and informal interviews on socioeconomic status, land use, farm management, and family history. Data were validated using the triangulation approach, as data were collected from more than one information source to improve accuracy of information (Johnson 1997; Linda et al. 2004). The general questionnaire was designed to elucidate household structural characteristics, farm practices associated with allocation of specific land uses on the farm, and farm production. These data were collected between December 2002 and April 2003.

The key informants for the interviews were selected based on the following two criteria: member of the household being able to recall the historical land use, and second, the regular sharing of food and employment on the farm. The guideline questions were pre-tested with five farms. Field traveling plans and logistics such as making an appointment regarding the place and time for the interviews were arranged either through the village headman or head of household. The second round of informal interviews was conducted using adjusted guideline questions.

Data on the household size by gender, age group, and employment were used to describe household characteristics. Family labor was divided into three age classes: persons younger than 15 years old, between 15 and 65 years old (labor force), and those older than 65 years. Persons between 15 and 65 years old are considered the most effective family labor.

Data on employment status were classified into four types, based on working location and the time spent on the farm. The descriptions of each type of employment are shown in Table 3.3.

Table 3.3: Classification of employment status in farm household

Work status	Area of job or profession
On-farm	Farming, silk weaving, fish cultivation, plantation
Non-farm	Employed by government or company, wage service, retailer
Unemployed	Unemployed, study, illness or disabled, i.e., not able to work
Migrated from farm	Members are no longer living in the same house > 1 year (have left for job away from farm)

Other biophysical resources

Data on allocation of certain areas for specific uses were used to describe biophysical characteristics on the farm. For classification purposes, the primary zones as reported by the farmers were used to draw the preliminary farm map. A physical farm map was drawn using GRAMIN GPS III plus.

Further data on management unit were collected through a range of RRA techniques, i.e., farm mapping, direct observation, and transect walks (Wattenbach and Friedrich 1996; Kapetsky and Barg 1997; Onduru et al. 1998; Chambers 2002). The details of current land use were recorded using a digital camera (Nikon Coolpix 2100, 2 million pixels). Frequency of each management unit in the farmland was counted and recorded in a field notebook. For farm mapping purposes, total farm area and area of each zone were measured in square meters (m^2) using measuring tape (50 m), and expressed as a percentage of total area. Different management unit zones were identified on each farm as shown in Table 3.4.

Table 3.4: Classification of certain areas to specific management in farmland

	Management unit	Specific use
1	Paddy field	Area of permanent rice paddy field and buns used for walking
2	Cropland	Area of vegetable plots and herbaceous crops
3	Water area	Area of permanent irrigation infrastructures, fish cultivation
4	Woodland	Area of fruit and multi-purpose trees used for fuel wood, timber, forage, ornamental
5	Buildings area	Area of residential, barn, shed
6	Open land	Area used for grazing during dry season, covered with grass and weeds. The area includes bare land used for multipurpose and temporary activities by the family

Resource flow diagramming was used to characterize resources in a farm and to provide a basis for production activities in a farm (Lightfoot and Noble 1993; Dalsgaard and Oficial 1997). The diagramming begins with an interview. The key informant identifies the production activities and recycling activities during the discussion and walks with the farmer through the farm.

3.5 Statistical analysis

Descriptive statistics and relationship analyses were the main methodological tools used. The study compared the differences in means and medians of each variable between IFS and CFS. The mean of each variable was calculated by averaging values for each variable from all eight sample farms, separately for each farming system.

The differences in means and medians between the two farming systems were compared using an un-paired t-test for comparing means and the Mann-Whitney test as a non-parametric counterpart for comparing medians. The non-parametric Mann-Whitney test was the preferred test for significance because the survey had a small sample size and the data were not normally distributed (Motulsky 1995; Mullee 2002). An unpaired parametric t-test with a 95% and 99% confidence interval was used for comparison; however, parametric tests assume a Gaussian distribution, which is difficult to verify for small samples (Motulsky 1995).

Relationship analysis is based on the idea of causality, and separates dependent variables from independent, or explanatory. The relationship and effects between variables were tested and approximated by a linear regression model and other suitable statistical models depending on the type of dependent and independent variables. The statistical program STATA 8 was used to test relationships and approximate the effects.

4 RESULTS

This chapter is divided into two sections. The first section describes the socioeconomic and biophysical characteristics of the sample farm household and their natural resources. The second section tests the hypotheses, stated in the previous chapter. The results are discussed in Chapter 5.

4.1 Farm characteristics

Socio-economic characteristics

Table 4.1 shows absolute frequencies and mean values of socio-economic characteristics for IFS and CFS.

Table 4.1: Absolute frequency and mean of socio-economic characteristics of the farm households in the study area

Characteristics	Absolute frequency		Mean per farm	
	IFS	CFS	IFS	CFS
Family members (person)	41	30	5	4
Age 0-14 years	7 (17)	11 (37)	1	1
Age 15-65 years	34 (83)	16 (53)	4	2
Age >65 years	0 (0)	3 (10)	0	0
Employment status (person)				
On-farm employed	27 (66)	19 (63)	3	2
Off-farm employed	3 (7)	0 (0)	0	0
Non-employed	11 (27)	11 (37)	1	1
Income (baht year^{-1})				
Farm income	8	8	59,146 (27.4)	36,608 (24.9)
Non-farm income	7	7	155,718 (72.1)	110,400 (75.0)
Other incomes	7	7	1,171 (0.5)	156 (0.1)
Total income	*8*	*8*	*301,427*	*210,519*
Expenditures (baht year^{-1})				
Food	8	8	3,294 (8.3)	5,749 (12.9)
Agricultural inputs	8	8	10,821 (27.3)	7,486 (16.8)
Loan repayment/debts	8	8	16,650 (42)	26,932 (60.3)
Others	8	8	8,847 (22.3)	4,462 (10.0)
Total	*8*	*8*	*39,612*	*44,629*
Transportation				
Distance from the market (km)	8	8	5.5	5.9
Car ownership (unit)	4	0	-	-
Motorbike ownership (unit)	8	8	-	-
Bicycle ownership (unit)	8	8	-	-
Public transportation (unit)	8	8	-	-

Percentages in parenthesis.

The employment status of the household members reflects the age class distribution. The majority of household members in both farming systems were in the

15–65 age class, though the percentage of household members in this class was higher in the integrated farms. A high proportion of the household members were employed on the farm, i.e., 66% for the integrated farms and 63% on the commercial farms. The household income in baht household^{-1} varied widely between households. The household income from farming was 59,146 baht for integrated farms and only 36,608 baht for commercial farms. Integrated farm households also outperformed commercial farm households in non-farm income, as this valued 155,718 baht for the first and 110,400 baht for the second.

The main expenditures on all farms are for loan repayments. The commercial farms had higher levels of debt servicing (26,932 baht farm^{-1}) than the integrated farms (16,650 baht farm^{-1}). Integrated farms spent 8.3% of total expenditures on food, while commercial farms spent 12.9% on this category. Yet, the number of family members who regularly share food was larger on integrated farms than on commercial farms. To gain more insight into food production activities on the farm, in Table 4.2 the annual average values of the purchased inputs is summarized.

Table 4.2: Descriptive statistic for annual purchased inputs for agriculture; crop year 2002-2003-mean

Mean purchased values (baht year^{-1})	IFS	CFS
Inorganic fertilizers	1,263 (11.7)	1,180 (15.8)
Organic fertilizers	1,285 (11.9)	1,051 (14.0)
Seeds	678 (6.3)	784 (10.5)
Animals	5,313 (49.1)	2,500 (33.4)
Transportation	258 (2.4)	226 (3)
Veterinary cost	171 (1.6)	136 (1.8)
Irrigation fuel	414 (3.8)	179 (2.4)
Hired labor	1,439 (13.3)	1,430 (19.1)
Pesticides and herbicides	0	0
Total	*10,821*	*7,486*

Percentages in parenthesis. Purchased inputs excluded farm fixed cost.

The table shows that the value of total purchased inputs is 45% higher at integrated farms than at commercial farms. This difference is mainly explained by a 112% higher investment in animals on the integrated farms. Another difference is the purchase of irrigation fuel on integrated farms, which is more than double the amount purchased on commercial farms and is mainly because integrated farms make more intensively use of irrigation pumps.

The average distance of farm households to their respective markets was about the same for both types of farms: 5.5 km for the integrated farms and 5.9 km for the commercial farms, which is not surprising given the paired sample design. Cars, motorbikes, bicycle and public busses are the main means of transport between farm and local markets. Half of the integrated farms had their own car to transport their products to the local market, while none of the commercial farms owned a car.

Biophysical characteristics

Farm maps are used to describe the characteristics of biophysical resources on integrated farms and commercial farms. One integrated farm (case 1) and one commercial farm (case 9) are selected here to illustrate this mapping approach and are shown in Figure 4.1. Corresponding farm age, area, irrigation facilities, and other production enterprises on a farm are included in Table 4.3.

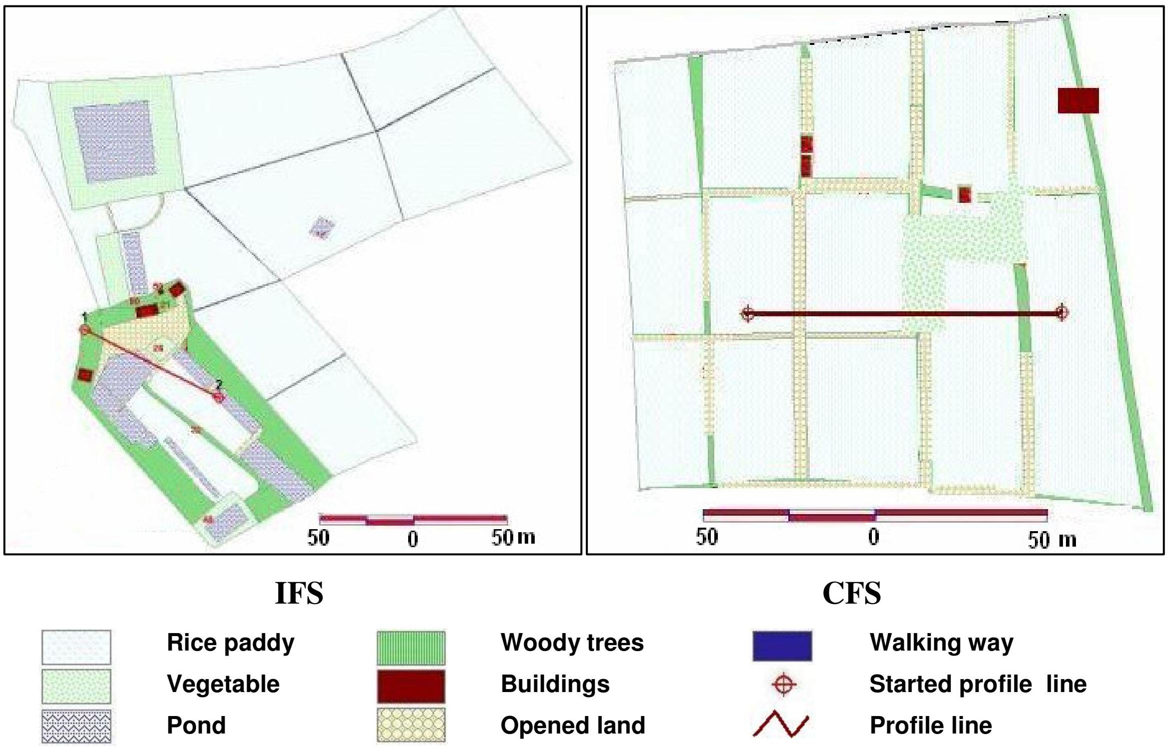

Figure 4.1: Farm map representing biophysical characteristics on an IFS and a CFS

The average age of the current farming system was 10 years for integrated farms, which is the time since conversion from commercial farms to integrated farms;

the system in the commercial farms was older and average age was 29 years old. The farm size varied considerably between the two farming systems. The average integrated farms (3.9 ha) were larger than the average commercial farms (2.7 ha).

At all farms, six management units were identified using farm mapping techniques as shown in Figure 4.1: paddy fields, vegetable plots, water reservoirs, woodlands, building areas, and open land (see classification of management units in Chapter 3). Woodland and water reservoirs are the main physical differences between the two farming systems.

In the right pane in Figure 4.1, the management of farm area by the commercial farm households is shown. Most of the areas on the farm were allocated to rice. In the rainy season when the paddy is flooded, the area was used for temporary aquaculture to raise fish, which were either of natural origin or bought. When the rice had been harvested from the paddy and it was dry, the area was used for numerous purposes. For example, during the day, the households used it as a playground for their children and for other activities. Besides direct use of the paddy fields by the households, it was observed that the rice paddies provide habitats for animals and plants, e.g., fishes, crickets, beetle bugs, birds, grasses and other upright herbaceous plants.

In the left pane in Figure 4.1 the management of farm area by the integrated farm households is shown. The households in the IFS used the area of rice paddy similar to those in the CFS. The integrated farm households increased the use of woody land: as a nursery for seedlings; to collect timber and non-timber products; to protect water resources in the ponds from evaporation and erosion from the banks; and for family activities. It was observed that the tree communities provide habitats for animals and insects such as butterflies, crickets, birds, rats, grasshoppers, beetle bugs, flies, ants, and earthworms.

The uses of water reservoirs observed in the IFS were: to store water and to irrigate vegetables and crops; to drain water from the paddy when the area was flooded; to raise fishes; and for recreation purposes. In addition, the farm ponds lie in the wet areas providing habitat for other plants and animals such as fishes, frogs, crabs, larvae, waterbugs, snails, shrimps, and snakes, which some can be used for human consumption.

Two types of labor saving technologies were used at all farms: two-wheel tractors and small horse-powered water pumps. The CFS is characterized by a higher frequency of two-wheel tractors but a lower frequency of small horse power water pumps (Table 4.3).

Table 4.3: Biophysical resources of farms in the study area, in frequencies

Characteristics	IFS	CFS
Average farm age (year)	10	29
Average farming area (ha)	4	3
Zones of management (no.of farm)		
Rice paddy field	8	8
Vegetables plots	8	8
Water reservoir area	8	0
Wood land	8	0
Building area	8	8
Open land	8	8
Labor saving technologies (no.of unit)		
Two-wheels tractors	3	7
Small horse-powered water pump	7	2
Irrigation infrastructure (no.of unit)		
Farm pond closed out-let	16	0
Farm pond open out-let	1	0
Well	1	0
Irrigation canal	3	3
Crop enterprises (no.of farm)		
Rice	8	8
Vegetables	8	8
Fruit trees	8	0
Animal enterprises (no.of head)		
Cattle	37	7
Fish	5,950	0
Pigs	22	2
Poultry	446	93

Data collected in year 2002-2003 from 8 integrated farms and 8 commercial farms.

Figure 4.2 shows cross-sections for four types of irrigation facilities found in both farming systems: farm pond with closed outlet, farm pond with open outlet, wells, and off-farm water sources associated with irrigation projects.

Farm pond with closed outlet is located on the boundary between the paddy fields and upland fields. Farm pond with open outlet is located in the bottom of a valley. A well located near to buildings and the homesteads. An irrigation canal laid along the side of boundary between paddy and upland fields. A water gate forms an outlet connecting the canal and the farmland.

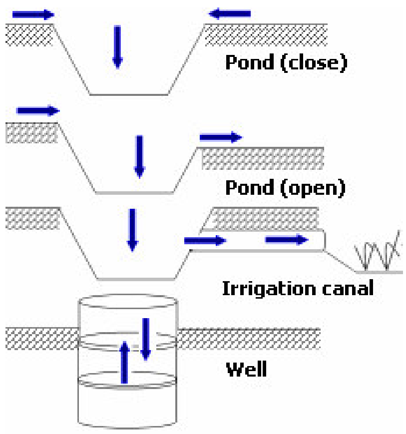

Figure 4.2: Cross-section of irrigation facilities found on the farms

All eight integrated farms together had 16 ponds with closed outlet, but none of the commercial farms had a this type of pond. One farm pond with open outlet and another one of well were found on integrated farm, yet these were absent on commercial farms. Irrigation canals were found only in the lower catchment, on both integrated farms and commercial farms.

4.2 The integrated farming system compared to the commercial farming system

4.2.1 Land-use activities

Table 4.4 shows that the different zones of farm area management and water use in the integrated farms resulted in the higher diversity of products related to enterprises.

Table 4.5 summarizes the seasonal calendar of important activities observed on all farms during the year. Sections a) and b) show main activities on integrated and commercial farms, respectively. Section c) shows the activities related to food collection in the vicinity of the farm.

Due to high fluctuation in rainfall, the timing of the land and water use is not fixed but is adapted to the prevailing conditions by the farmers. For example, aquaculture in the farm ponds starts when the water level is high enough, and the start of activities in the rice enterprise depend on the start of the rains.

Table 4.4: Diversity of management units, activities and important products observed in the IFS and CFS

Management unit	Important products	Recycle products	Activities
Rice paddy	rice grain	straws	land preparation, planting, fertilize, harvesting, processing grain, herding & recycle products
Vegetables plots	lettuces, onion, bean, limes, parsley, basils, chili	residues, fresh leave	land preparation, planting, weeding, fertilize, harvesting, processing vegetables & recycle products
Water area	fishes, frogs, shrimps, insects		planting, feeding, fishing, processing fishes & recycle products
Wood land	papayas, mangoes, bananas, jack fruits, guavas, tamarind	dry & fresh leaves, branches	digging, planting, thinning, weeding, collecting fruits, processing fruits, timbers & non-timbers, recycle products
Building area	eggs, chicken, ducks, pork, beef, mushrooms	animal manures	feeding, veterinary services, herding, collecting eggs, processing eggs and meat & recycle farm products
Open land	small tools, products to store, sell, eat		processing products, making tools, family activities, construction, ceremony, making merits & walking paths

Table 4.5: Seasonal activity calendar for the two different farming systems in study area

a) Observed diversity of on-farm activities and species in the IFS

	Jan ☼	Feb ☼☼	Mar ☼☼	Apr ☼☼	May ☂	Jun ☂	Jul ☂	Aug ☂	Sep ☂	Oct ☂	Nov ☼	Dec ☼
Major Rice (2)	second rice	**->**		-	*major rice*						**->**	**<-**
Vegetable (47)	all kinds of vegetables, i.e. basil, chili, galangal, shallot, tomato											**->**
Farm pond (5)	-	-	-	-	-	tilapia, catfish, local crap, frog, shrimp						**->**
Livestock (5)	bull, cow, water buffalo, chicken, duck, pig											**->**
Trees (25)	banana, mango, sa-dao, guava, jackfruit, coconut											**->**
Mushroom[c]	mushroom			**->**	-	-	-	-	-	-	-	-

b) Observed diversity of on-farm activities and species in the CFS

	Jan ☼	Feb ☼☼	Mar ☼☼	Apr ☼☼	May ☂	Jun ☂	Jul ☂	Aug ☂	Sep ☂	Oct ☂	Nov ☼	Dec ☼
Rice (1)	second rice			-	*major rice*						**->**	**<-**
Vegetable (21)	all kinds of vegetables, i.e. basil, chili, galangal, shallot, tomato											**->**
Livestock (3)	bull, cow, water buffalo, chicken, duck, pig											**->**
Trees (7)	takob-bha, kee-kek, lime, coreland, kae											**->**

c) Observed diversity of activities and species of in the two farming systems

	Jan ☼	Feb ☼☼	Mar ☼☼	Apr ☼☼	May ☂	Jun ☂	Jul ☂	Aug ☂	Sep ☂	Oct ☂	Nov ☼	Dec ☼
Wild vegetables	bamboo shoot		**->**	-	-	-	-	-	-	-	-	-
	mushroom							flood				**->**
Wild insects	ant egg		*crickets*	**->**	-	-	-	-	-	-	-	-
	all kinds of insects			**->**	*water insects*		**->**	-	-	-	-	-
	all kinds of fish, frog, and shrimp						**->**	-	-	-	-	-

Total number of species on the farms in parenthesis. c the activity only practices in farm case 2. ☼☼ hot-dry season. ☼ dry season. ☂ rainny season.

Crop-related activities are: land preparation; planting; growth improvement and protection; harvesting; post-harvesting; and integration of resources (using the by-products to complement other enterprises). Activities in animal enterprises are: growth improvement and protection (feeding, veterinary services); herding; collecting eggs; and integration of resources. As shown in Table 4.4 and Table 4.5, the objectives, practices and management units are more diverse for the integrated farms.

4.2.2 Resource flows in the farm systems

Figure 4.3 compares the flow of resources in the farm system between the IFS and CFS. In the IFS, the figure presenting the case that has the highest integration of enterprises in this study (case 2). On the CFS, the figure presenting the paired farm of the integrated farm (case 10).

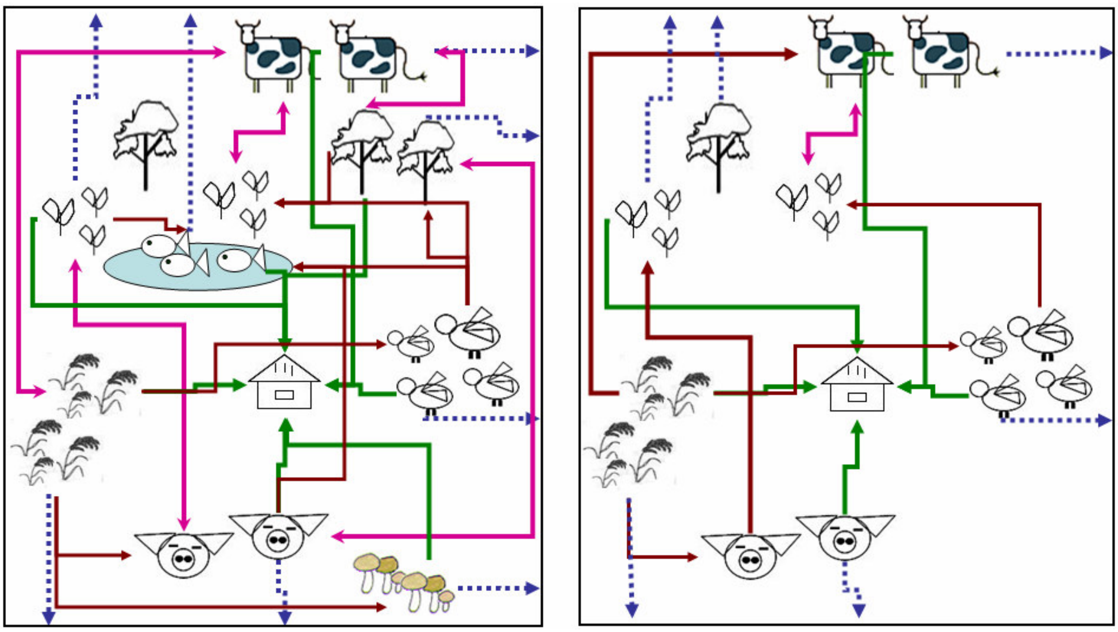

Figure 4.3 Resource flow diagram on the IFS in upper catchment (case 2) and paired farm on the CFS (case 10)

The left and right pane of the figure show bio-resource components in the IFS and CFS. The green line represents the flow of resources that are used as food for household consumption. The pink line represents the linkage of resources that flow in two directions between two enterprises in the farm system. The brown line represents the linkage of resources that flow from one enterprise to other enterprises in the system.

The dotted lines represent the flow of other wastes generated in the farming system to outside the system.

Figure 4.3 shows that the IFS has a higher diversity of bio-resources components in the farming system than the CFS. On all farms, direct use of animal waste is the most widely observed. Examples of the observed linkages between enterprises in the integrated farms are: the feeding of crop residues to pigs, poultry and fish; the feeding of solid waste from poultry to carnivorous fish (catfish); and the adding of solid waste from cattle, pigs and poultry to vegetable plots and trees. However, the number of uses or reuses of by-products in the commercial farms is lower than in integrated farms. The commercial farms generated fewer by-products due to the smaller number of different enterprises and a lower number of individual units in each enterprise (Table 4.4).

4.2.3 Diversity by growth habits

All existing plant species were categorized according to growth habits as shown in Table 4.6. Table 8.2 gives the total number of stems by growth habit. It can be seen that the composition of growth habit types on integrated farms is more diverse than on commercial farms and in the natural vegetation area.

Within nine growth habits found in the farm systems, the highest species richness fell in the upright herbaceous (UH) followed by spread climbers (SC) and rosette trees (RT), respectively. Whether the species richness under each growth habit for integrated farms tended to be larger than those for commercial farms was tested. The rank sum and t-test show consistent results for growth habit on sparsely ramified (ST): the mean and median level were significantly different at 5%, and on upright herbaceous species (UH) at 1%. For the graminoid, rhizomes (GR) and spread climbers (SC): the mean level were significantly different from those on commercial farms at 5%, and the median level were significantly different at 1%.

Between integrated farms and commercial farms, the upright herbaceous (UH) showed the highest richness, followed by rosette trees (RT). This suggests the importance of these two growth habits on the farms in the study area. Examples of upright herbaceous species used on all farms were: *Allium cepa* (shallot), *A. sativum* (garlic), *Arachis hypogaea* (peanut), *Boea glabriflora* (lettuce), *Brassica alboglabra*

(Chinese broccoli), *B. pekinensis* (heading Chinese cabbage), *Mentha arvensis* (common mint), *Ocimum spp* (sweet basil).

Table 4.6: Descriptive statistics and statistical results for species richness by growth habits found on the integrated farms, commercial farms and natural vegetation area

Growth-form habit	IFS	CFS	Sig.	Natural area
Mean ± SD				
RT-rosette trees	10 ±7	5 ±2	.070	26 ±4
SH-shrub	1 ±1	2 ±1	.732	5 ±1
ST-sparsely ramified	6 ±3	2 ±1	.022	9 ±1
BF-broad leaved forbs	1 ±0	0	-	0
GR-graminoid, rhizomes	5 ±2	3 ±1	.023	3
GS-graminoid, stolons	1 ±0	0	-	0
HR-herb, rhizomes	1 ±0	1 ±0	.149	-
SC-spread climbers	14 ±13	2 ±1	.040	5 ±5
UH-upright herb	23 ±12	9 ±2	.007	3 ±1
Median (min,max)				
RT-rosette tree	11 (1;19)	5 (2;8)	.201	26 (23;29)
SH-shrub	1 (1;3)	1 (1;3)	.697	5 (4;6)
ST-sparsely ramified	7 (1;10)	3 (1;4)	.030	9 (8;9)
BF-broad leaved forbs	1 (1;2)	-	-	-
GR-graminoid, rhizomes	4 (3;9)	3 (2;4)	.009	3 (3;3)
GS-graminoid, stolons	1 (1;1)	-	-	-
HR-herb, rhizomes	1 (1;2)	1 (1;1)	.143	-
SC-spread climbers	10 (4;45)	1 (1;3)	.002	5 (1;8)
UH-upright herb	18 (12;45)	9 (7;13)	.001	3 (2;3)

Species was classified using the growth habit classified by Preisinger (2001).

Example of rosette tree species are: *Albizia odoratissima* (bansa), *A. lebbeck* (woman's tongue), *Leucaena leucocephala* (Leucaena), *Cassia fistula* (golden shower), *Pterocarpus macrocarpus* (Burma padauk), *Streblus asper* (lamese rough bush), *Diospyros mollis* (maklua), and *Litsea glutinosa* (Indian laurel). Farmers used these species for different purposes. For example, *Albizia* spp are used on the farm as a fuel wood and for making temporary constructions as found in the integrated farms case 1, 2, 3, 6, 7 and natural area. The leaves of *Albizia* spp are used for fodder as found in integrated farms case 1, 2, 6, and 7.

4.2.4 Species richness for different purposes

The diversity of species used at the farms can be classified into five functions: species as food; species used for cultural rites; species used for housing; species used for medicinal purposes; and species as soil covers. The mean number of species used for these functions was respectively 24, 30, 13, 15 and 9 species per farm. Higher numbers of plant and animal species were observed in each of the aforementioned categories for the integrated farms compared to the commercial farms (Table 4.7).

The low number of species used for food on all farms and some unusually low numbers of species used for local rituals and housing led to a slightly skewed distribution curve. The hypothesis was that the number of species as food, used for local rituals, housing, medical purposes, and as soil covers on the eight integrated farms was higher than on the eight commercial farms. For this, it was tested whether the differences in means and medians were statistically significant (Table 4.7).

Table 4.7: Descriptive statistic and statistic results for species richness by production system

Function	IFS	CFS	Sig.
Mean ± SD			
Food	38 ±10	17 ±2	.000
Local rites	38 ±15	21 ±2	.006
Housing	20 ±11	10 ±1	.034
Medical	16 ±4	0 ±2	.001
Soil cover	40 ±27	8 ±2	.004
Median (min,max)			
Food	41 (26;52)	18 (13;19)	.001
Local rites	39 (21;59)	21 (18;25)	.008
Housing	20 (6;33)	11 (8;12)	.090
Medical	17 (11;24)	10 (7;14)	.002
Soil covers	38 (10;74)	8 (5;11)	.002

The rank sum shows that the median number of species used for food, local rites, medical, and soil cover purposes on the integrated farms is significantly different from the median for the commercial farms. However, the number of species used for housing purposes was not significantly different between both farming systems.

The t-test shows that the mean number of species used for food, local rites, housing, medical, and soil covers purposes on integrated farms all significantly differed from the mean of commercial farms. A comparison of the statistical goodness of fit using parametric and non-parametric tests appears to be at odds with respect to housing.

The above results show that the higher species richness for all functions is more likely to appear at a higher integration level. This led to the question: what effect does a higher integration level have on the species richness used for various purposes? The hypothesis was the higher integration level, the higher the probability of species used for the different purposes. Pairwise correlation coefficients are estimated between integration level and five different purposes of species. Table 4.8 present the results.

Table 4.8: Correlation coefficients between species richness and integration level, for five functions

Purpose of species	Correlation coefficient
As food	2.56**
For cultural rites	2.16**
For housing	1.27**
For medicinal	.92**
As soil cover	.69**

*Pairwise correlation coefficients (Pearson). ** significant at 1%.*

Table 4.8 shows that the correlation coefficients for all categories have positive signs, which confirms our hypothesis that farms at higher integration levels use more species for various purposes. The table furthermore shows that an increase in the integration level has the strongest effect on species as food, followed by species used for cultural rites, housing, medicinal use, and as soil cover. These results suggest that increasing the integration level of a farm increases the species richness.

4.2.5 Shared of home produced food

Table 4.9 shows the average and median values of home consumption, purchased food, and total food expenditures per capita. In total, per capita food expenditures are almost equal for both farming systems. These data clearly show that the mean and median level of home consumption are higher on integrated farms than on commercial farms, meaning that the CFS acquire more food from outside the farm.

Table 4.9: Home consumption, purchased food, and total food expenditures per capita by production system, in means, medians, and statistical significances

Percapita food consumption (baht)	IFS	CFS	Sig.
Mean ± SD			
Home consumption	1,647 ±629	801 ±382	.005
Purchased food	783 ±601	1,616 ±388	.005
Total food expenditures	2,429 ±1,030	2,417 ±517	.977
Share of home produced food	68 ±14	33 ±9	.000
Median (min,max)			
Home consumption	1,673 (787;2,559)	760 (425;1,528)	.006
Purchased food	628 (214;2,200)	1,671 (927;2,300)	.009
Total food expenditures	2,258 (1,410;4,758)	2,467 (1,666;3,197)	.401
Share of home produced food	72 (48;91)	32 (22; 48)	.001

The hypothesis tested whether the values of shared of home produced food for integrated farms are higher than those for commercial farms (Table 4.9). The rank sum and t-test show that the median and mean numbers for the integrated farms were significantly different from the median and mean for the commercial farms at 1%.

To extend the analysis, the relation between the share of home produced food was correlated with the integration level. The hypothesis is that at higher levels of integration, the share of purchased food is lower. The relationship is estimated by a linear regression. Table 4.10 presents the results.

Table 4.10: Estimated shared of home produced food as affected by integration level

Explanatory variables	Coefficient	Standard Error
Integration level	4.63	.32**
Constant	19.66	2.56**

*Regression with robust standard errors. R^2= .93; Prob >F= .00. ** significant at 1%.*

The overall goodness of fit of the model is high at 93 %. Coefficient in the linear equation showed a positive sign and was significant. The share of purchased food is clearly reduced with an increasing integration level.

4.2.6 Growth performance of tree communities

The tree profile diagrams of all farms illustrate the structure of tree communities and are shown in Figure 4.4. The analysis of the tree stand structure included woody trees, shrubs, and perennials with a diameter ≥ 5 cm measured at 1.30 m height and with a minimum height of 1.30 m. The value of each variable for each farming system represents the mean of eight sampling stands of eight farms.

The mean basal area, stem density, and stand height for each sampled system are summarized in Table 4.11. The number of tree stems of each individual species found is listed in Table 8.3. The distribution of tree size and tree crown social position in each production system is summarized in Table 4.12 and Table 4.13, respectively.

The importance values index (IVI) was used to rank the most dominant species in each farming system. The relative abundance (RA), relative frequency (RF), relative dominant (RDo) and IVI for tree species on the farms and in the natural vegetation area are given in Table 8.4, 8.5 and 8.6 for integrated farms, commercial farms and natural area, respectively.

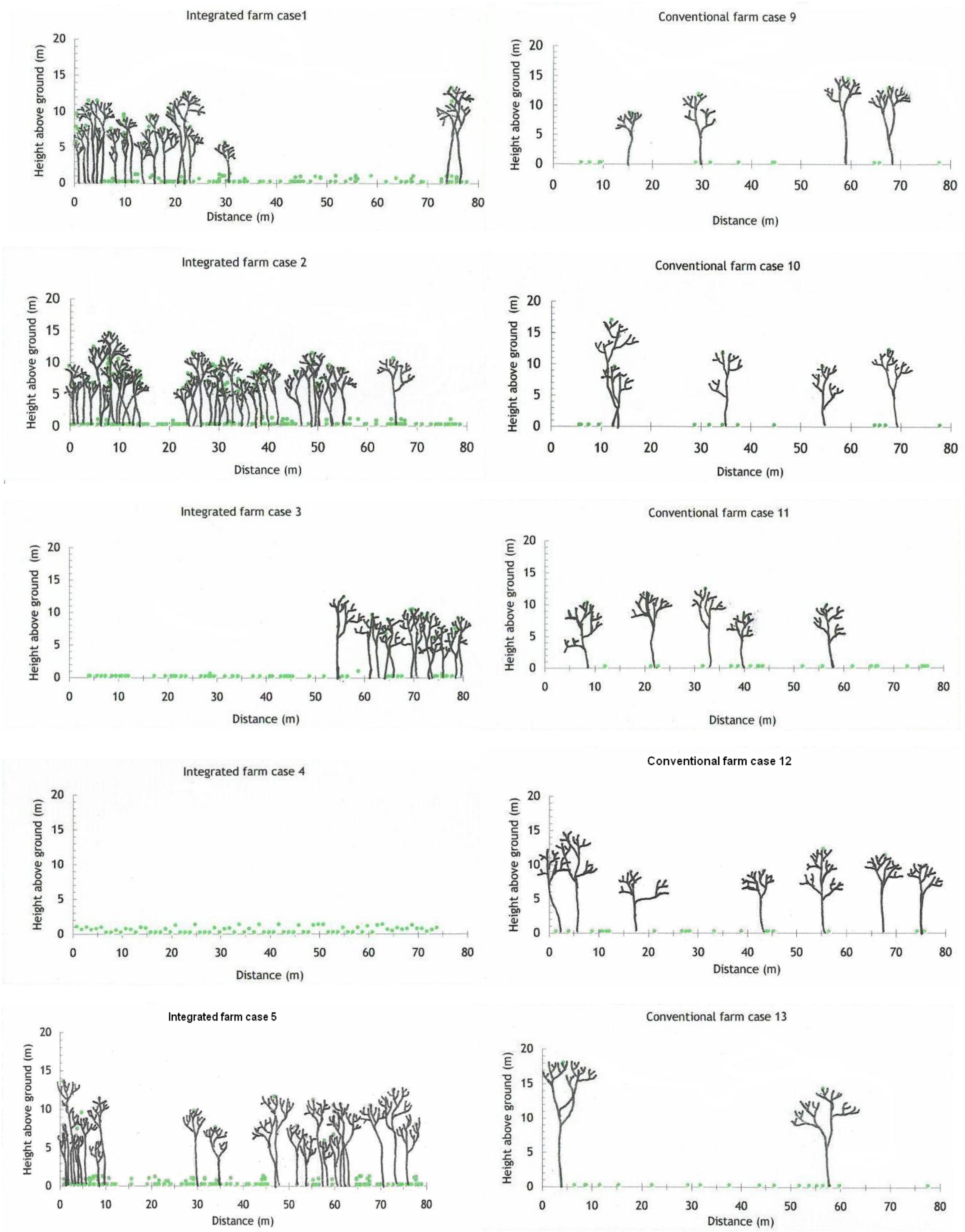

Figure 4.4: Transect profile diagrams representing vertical structure of tree communities on the IFS compared with CFS, and stand in natural area

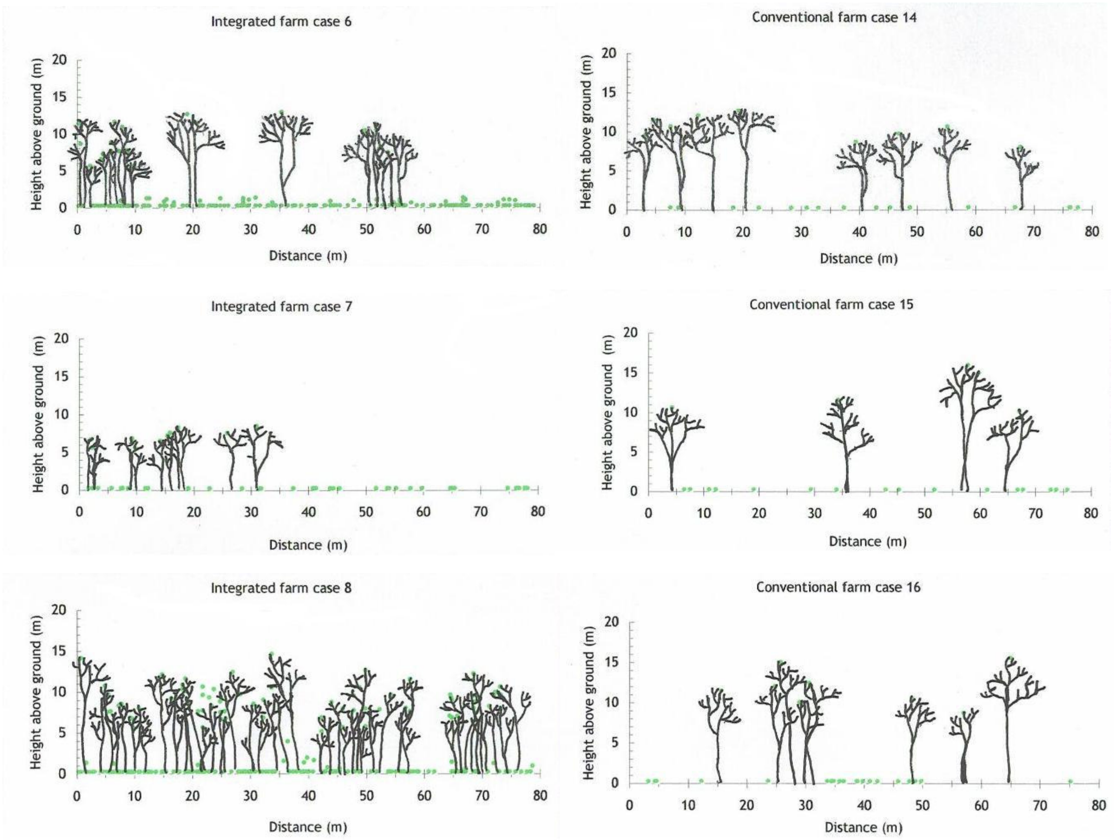

Figure 4.4: continued

Table 4.11: Descriptive statistics and statistic results for average basal area cover of trees, stem density, and height of trees by production system

Stand characteristics	IFS	CFS	Sig.	Natural area
Mean ± SD				
Basal area (m^2 ha^{-1})	.62 ±.57	.06 ±.06	.015	1.14 ±.12
Density (stem ha^{-1})	463 ±320	35 ±17	.002	975 ±460
Median (min,max)				
Basal area (m^2 ha^{-1})	.5 (0;1.39)	.03 (.01;.19)	.001	1.14 (1.05;1.23)
Density (stem ha^{-1})	497 (75;894)	34 (13;63)	.001	975 (650;1300)

The trees communities on integrated farms are composed of three vertical layers: tree layer, shrub layer, and ground cover (Figure 4.4). The height of the tree layer ranged from 4 to 7 m, with an average density of 463 stems ha^{-1} and a basal area of .62 m^2 ha^{-1} (Table 4.11). Others common species of the tree layer were *Bambusa arundinacea* (spiny bamboo), *Leucaena leucocephala* (Leucaena), *Jatropha curcas* (Purging nut), *Annona squamosa* (sugar apple), and *Musa sapientum* (banana). The shrub layer was 1.3 to 4 m high and was dominated by *Eucalyptus* spp, *Terminalia calamansanai* (Philippine almond), *Streblus asper*, *M. longipetiolata* (banana), and *Pithecellobium dulce* (monkey pod). The ground cover was mainly composed of *Albizia* *odoratissima* (bansa), *Schleichera oleosa* (Ceylon oak), *Dipterocarpus alatus* (gurjum tree), *Millingtonia hortensis* (Indian cork tree), and *S. asper* (lamese rough bush).

Trees were generally more evenly distributed on the commercial farms. This resulted in more open tree stands dominated by mature trees. The dominant tree species are shown in Table 8.5. The tree height ranged from 10 to 13 m with stands having an average basal area of .06 m^2 ha^{-1} and an average tree density of 35 stems ha^{-1} (Table 4.11). There was no evidence of seedling recruitment within these scattered stands due to annual cropping activities around the base of the trees. The ground cover at the time of sampling was dominated by a dense population of both edible and non-edible species comprising *Languas galangal* (galangal), *Gomphia serrata* (kayu sepat), *Diospyros rhodocalyx*, *Lycopersicon esculentum*, *D. rhodocalyx*, and *S. asper*.

The rank sum and t-tests indicate that the medians and means of tree basal area and stem density were significant higher for the integrated farms as compared to the commercial farms (Table 4.11).

In the adjacent remnant areas, the most common tree species were *F. indica*, *L. glutinosa*, *Passiflora feolida*, *P. macrocarpus*, and *Mitragyna brunonis* (Table 8.6). The stands were relatively open with an average density of 975 stems ha^{-1}. The average basal area was 1.14 m^2 ha^{-1} with an average stand height ranging from 6 to 7 m (Table 4.11). These stands were stratified into three strata namely, tree layer, shrub layer, and ground cover. The common species in the tree layer included *P. feolida*, *Gardenia erythroclada*, *F. indica* and *L. glutinosa*. The shrub layer was dominated by *M. brunonis*, *Aganosma marginata*, *P. feolida*, *Memecylon geddesianum,* and *Albizia myriophylla*. Finally, the ground cover was densely populated with *S. asper*, *Memecylon geddesianum*, *F. indica*, *A. odoratissima,* and *L. glutinosa*.

The IVI values shown in Table 8.4, 8.5 and 8.6 reflect the dominance of *Azadirachta indica* (neem) on integrated farms and *Flacourtia indica* (governor's plum) on commercial farms. These species are particularly useful for the farm household, for example, for lopping for fodder and firewood, or cutting for timber. Whereas for example, *Azadirachta indica*, which dominated on integrated farms, is a multipurpose species.

Table 4.12 shows the analysis of the size classes with respect to the diameter at 1.3 m height. These analyses show that the trees on integrated farms had a higher number of stems but were mainly small (73.3% were in the class of 0-10 cm diameter), while on the commercial farms there were fewer stems and the trees were mainly larger. Similar to the integrated farms, the trees in the adjacent natural areas were mainly small in size (79.7% were in the class of 0-10 cm diameter).

Table 4.12: Distribution of number of tree stems in each diameter class by production system

Diameter class (cm)	IFS	CFS	Natural area
0-10 cm	311 (73.3)	36 (80)	235 (79.7)
10-20 cm	87 (20.5)	1 (2.2)	48 (16.3)
20-30 cm	15 (3.5)	8 (17.8)	9 (3.1)
30-40 cm	9 (2.1)	0 (0)	0 (0)
40-50 cm	0 (0)	0 (0)	1 (0.3)
50-60 cm	0 (0)	0 (0)	1 (0.3)
60-70 cm	0 (0)	0 (0)	0 (0)
>70 cm	2 (0.5)	0 (0)	1 (0.3)
Total stems	*424*	*45*	*295*

Percentages in parenthesis.

Table 4.13: Distribution of number of trees in each crown social position class

Crown social position	IFS	CFS	Natural area
Class 1	3 (0.7)	0 (0)	1 (0.3)
Class 2	48 (11.3)	0 (0)	26 (8.8)
Class 3	80 (18.9)	6 (13.3)	86 (29.2)
Class 4	264 (62.3)	12 (26.7)	163 (55.3)
Class 5	29 (6.8)	27 (60)	19 (6.4)
Total stems	*424*	*45*	*295*

Percentages in parenthesis.

Table 4.13 shows the results of the analysis of the distribution of tree stems in each class of crown social position. Most trees (60%) on commercial farms were in a higher social position class and had a higher average height but lower stem density (Table 4.11). These characteristics suggest a better crown light availability and overall height growth performance of the individual tree. However, the stand structure is composed of one of a single layer and a few evidences of ground cover. This suggests a lower regeneration and growth performance of the tree communities on commercial farms than on integrated farms.

The middle stories (class 3 and 4) of crown social position of trees on integrated farms appear to be denser because of the increased light levels associated with canopy disturbance from management on a farm. Gaps in canopy cover also tend to facilitate the growth of early succession, upright herbaceous, and spread-climbers species in the under story. It suggests a high level of succession and regeneration of the small trees on integrated farms. Similar to the case of the natural area, crown stories appear to be denser in the middle class (class 3 and 4), suggesting the possible previous succession of the natural vegetation due to the area being disturbed in the recent past (Smitinand 1994; Weyerhaeuser and Tennigkeit 2000).

The analysis of size class and crown social positions of trees at integrated farms shows a similar trend; here the trees were mainly small. The stem density of trees on integrated farms showed a similar trend with trees in the natural area (Table 8.3), indicating a high degree of species homogeneity. In contrast, the RA % and RF % varied among the trees on commercial farms, and the species do not follow a specific trend.

4.2.7 Irrigation months

Irrigation facilities were classified into four types: farm pond with closed outlet; farm pond with open outlet; wells; and off-farm water sources associated with irrigation projects. The characteristics and capacity (m^3) for each type of irrigation facility are shown in Table 4.14.

Table 4.14: Type and characteristics of irrigation facilities found in the farms

Characteristics	Close farm pond	Open farm pond	Well	Irrigation canal
Location	Side of valley	Bottom of valley	Middle of the farm	Connecting to irrigation canal on side of valley
Shape	Rectangular	Trapezoid	Cylinder	Curve parallel side
In-let	Open	Open	Under ground water	Water from the Chi river via irrigation canal
Out-let	Close	Open	Close	Cultivated area
Land use surrounding area	Upper-side for vegetable plots, trees, lower side for paddy field	Paddy field, vegetable plots	Small buildings & trees all around	Upper-side for vegetables and trees, lower side for paddy field
Total storage capacity of all facilities (m^3)	69,332	2,700	34	NC

NC The storage capacity of the cement pipe was not calculated because the pipe was only used to transport water from irrigation canal to the field.

Between the four types of irrigation facilities established on a farm, farm ponds with closed outlets show the highest total storage capacity, followed by farm ponds with opened outlets, and wells. In contrast, irrigation canals can only be used when water is pumped from the Chi-river into the irrigation canal during from December and February every year.

The use of irrigation facilities for food production and irrigation in addition to rainfall are shown in Table 4.15. The water from the farm ponds on the integrated farms was used for fish culture and irrigation of vegetables in addition to rainfall (from October to January). None of those farms used water from farm ponds for rice cultivation as the water from the farm ponds was insufficient.

Table 4.15 Functions of irrigation facilities for food production; irrigation months in addition to rainfall

Functions	IFS				CFS			
	PC	PO	Cn	Wl	PC	PO	Cn	Wl
No of farm use of irrigation facility								
Household use for fish culture	7	1	0	0	0	0	0	0
Household use for vegetable plots	7	1	3	1	0	0	3	0
Household use for second rice	0	0	3	0	0	0	3	0
Average irrigation months	8	8	3	9	0	0	3	0

PC farm pond with closed outlet. PO farm pond with open outlet. Cn canal. Wl well

The farm ponds with closed and opened outlets usually store water for eight months, while the well provided water for nine months. Although the wells can provide water one month longer than the farm ponds, the storage capacity of the well is lower due to the limitation of salt layers in the subsoil, which affect the quality and accessibility of ground water in this area. The wells were therefore used predominantly for domestic purposes, such as for washing clothing and dishes, and only occasionally for the irrigation of the surrounding vegetable gardens.

Table 4.16 shows the mean number of irrigation months in addition to rainfall on integrated farms and on commercial farms, where water is reserved for the irrigation facilities. The irrigation facilities provide an average of three months in addition to the rainfall on integrated farms, whereas commercial farms attained no additional month for production activities. Whether the values on the integrated farms tend to be higher than those on the commercial farms was tested. The rank sum and t-tests indicate that the median and mean number of irrigation months on integrated farms was significantly higher than on commercial farms.

Table 4.16: Descriptive statistics and statistical results for number of irrigation months in addition to rainfall

Irrigation months	IFS	CFS	Sig.
Mean ± SD	3 ±1	0 ±2	.003
Median (min,max)	3 (3;4)	0 (0;3)	.001

As the farm pond is integrated within the farming system, farm ponds increase the diversity of duck and fish species, and provide a habitat for other animals such as frogs, shrimps, and water bugs. The water storage function stabilizes farm production of crops and livestock, and diversifies sources of income. Nutrients are recycled through the use of crop residues and livestock waste in fishponds. Farm ponds furthermore increase the water and nutrient holding capacity of the soil prevents the loss of ground water and thus improves the productive capacity around the pond. The farm ponds thus provide a range of services that improve the sustainability of the farm (Little and Edwards 2003).

However, the results from interviewed (in the IFS) farmers indicate that water provides from farm ponds and wells is still not sufficient for all 12 months in a year. The availability of water from farm ponds is limited by: 1) a high rate of evaporation; 2) soil erosion from the pond bank or upper farmland areas, which causes these irrigation facilities to lose their water storage capacity; and 3) the depth of farm ponds is limited by salt layers. On the integrated farm case 2, the availability of water from the wells is limited by salt layers in the subsoil that affect the quality and accessibility of ground water. Similarly, in the middle catchment of the study area on farm case 4 and 5, the depth of farm ponds is limited by salt layers.

4.2.8 Soil organic matter

The average values of selected soil properties from the samples from integrated farms and commercial farms are compared in Table 4.17.

The distribution of particle size of sand, silt, and clay are shown in Figure 4.5. Each separate farm is shown in these figures, with three different symbols indicating different locations in the catchment (upper, middle, and lower). The horizontal lines give furthermore the overall sample mean, so that it can be easily seen how many farms of each group lay above and below the sample mean.

Table 4.17: Descriptive statistic for bulk density, aggregate stability, sand, silt clay particles, ph, EC, CEC, and organic matter by production system

Soil properties	IFS Mean ± SD	CFS Mean ± SD
Bulk density (g cm^{-3})	1.03 ±.04	1.03 ±.03
Aggregation (%)	4.03 ±1.52	3.42 ±1.17
Sand (%)	44.14 ±22.84	43.34 ±22.03
Silt (%)	31.45 ±13.80	31.90 ±13.30
Clay (%)	24.42 ±11.41	24.54 ±10.88
Soil pH	6.02 ±.80	6.34 ±.74
Soil EC(mS cm^{-1})	.08 ±.08	.15 ±.14
soil CEC(meq 100g^{-1})	10.21 ±3.46	8.83 ±3.39
Soil organic matter (%)	.98 ±.73	.64 ±.43

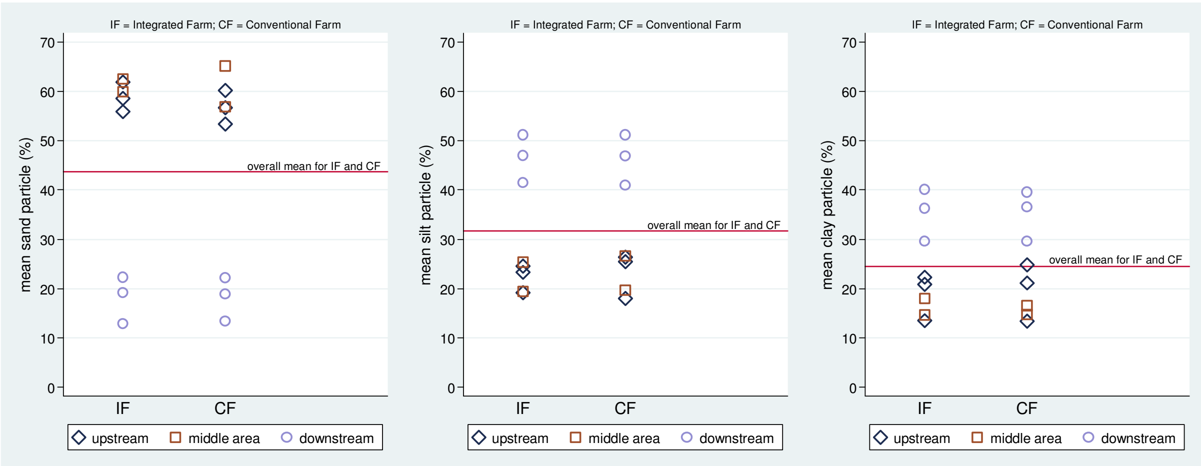

Figure 4.5: Distribution of sand (left), silt (middle) and clay (right) on each farm

The particle size distribution relative to the overall mean for each farming system shows a wide range in particle sizes in both farming systems with no clear distinction between the two systems. It should be noted that all farms within the lower catchment sample group (six farms) had clay contents above the overall mean, while a similar distribution with respect to sand content was observed in those farms located in the upper catchment. This suggests that the upper catchment is dominated by light textured sandy soils while the lower catchment is dominated by heavy textured soils. This may be associated with the redistribution of sediment (clay) material between upper and lower catchment.

Figure 4.6 shows the distribution of SOM on each individual farm and Table 4.18 shows the overall mean values for SOM in each system. In general, the integrated farms tended to have a higher SOM than the majority of the commercial farms.

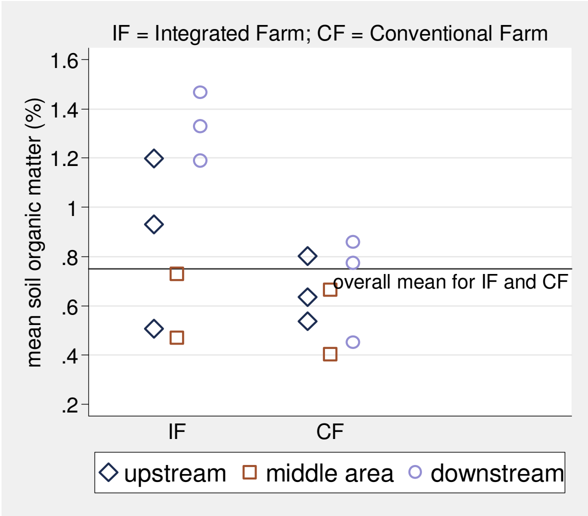

Figure 4.6: Distribution of SOM on all farms

Table 4.18: Descriptive statistics and statistic results for SOM, depth 0-30 cm, by production system

SOM (%)	IFS	CFS	Sig.
Mean ± SD	.98 ±.73	.64 ±.43	.037
Median (min,max)	.69 (.09;3.83)	.51 (.09;2.16)	.074

Data collected from depth 0-30 cm, 2002-2003.

The hypothesis was that the level of soil organic matter contents on integrated farms is higher than on commercial farms. The rank sum indicate that the median values for SOM, measured over each of the three depths (i.e., 0-10, 10-20 and 20-30 cm), were not significantly different between the two farming systems (Table 4.18). Yet, the t-tests indicate the opposite direction, the mean values for SOM was significantly different between the two farming systems with SOM on integrated farms being significantly higher.

Relationship of trees and soil organic matter

In view of maintaining resources in an agricultural system, integration of trees on a farm is expected to improve the supply source of SOM through the integration of activities (Noble and Randall 1998; Vityakon 2001; Whitbread et al. 2002). The question then arose: what are the relationships between availability of trees in the farm system, integration level, and SOM?

A multiple regression analysis was not attempted because of the high mutual correlation between the two explanatory variables of integration level (IL) and tree stem density. The relationship was therefore addressed by estimating the correlation coefficient between: tree stem density as affected by IL; SOM as affected by tree stem density; and SOM as affected by IL. The result is shown in Figure 4.7.

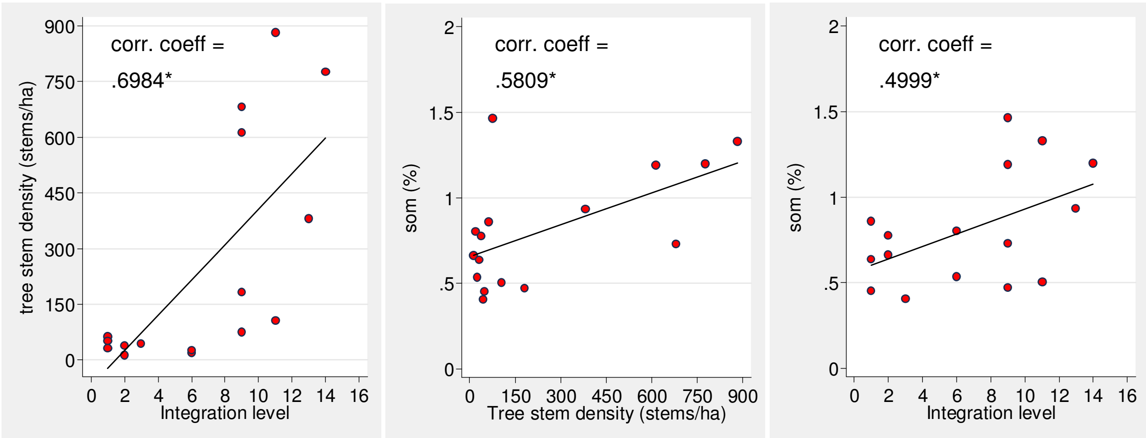

Figure 4.7: Estimated correlation coefficient for tree-stem density as affected by integration level (left); SOM as affected by tree stem density (middle); and SOM as affected by integration level (right). Pairwise correlation coefficients (Pearson). * significant at 5%.

Figure 4.7 shows mutual correlations between SOM (%), IL, and tree stem density (stems ha^{-1}). In the left pane, the integration level on a farm shows a clear positive correlation with stem density. This suggests an increase in the number of trees available on the farm when the integration level in the farm system increases. In the middle pane and right pane respectively, the figures show a positive correlation between SOM and stem density, and SOM and the IL. These results suggest that increasing SOM content on the farm is associated with an increasing number of trees integrated into the farm system and increasing integration level.

4.2.9 Productivity

Crop yield

The average yields over both farm types were 2,641 kg ha^{-1} for rice, 4,420 kg ha^{-1} for vegetables, and 947 kg ha^{-1} for perennials. In the integrated farms, the lowest yields for rice, vegetables, and perennials were 866, 769, and 538 kg ha^{-1}, respectively, while on the commercial farms the lowest yields were 351 kg ha^{-1} for rice, 226 kg ha^{-1} for vegetables, and 0 kg ha^{-1} for perennials. There were also a large number of high yields (above the mean) on both integrated farms and commercial farms. Due to these high values, the distribution curves for rice, vegetable, and perennial production systems are slightly skewed to the right.

Table 4.19: Descriptive statistics and statistic results for rice, vegetable and perennial yields on the farm by production system

Yield (kg ha^{-1})	IFS	CFS	Sig.
Mean ± SD			
Rice	2,783 ±113	2,500 ±115	.000
Vegetables	6,617 ±3,939	2,223 ±1,118	.009
Perennial trees	1,893 ±1,494	0	.000
Median (min, max)			
Rice	2,756 (2,646;2,983)	2,500 (2,321;2,688)	.001
Vegetables	6,188 (2,656;14,750)	2,177 (729;4,333)	.003
Perennial trees	1,405 (313; 4,915)	0	.000

It was tested whether the values in the integrated farms were above those in the commercial farms. The rank sum shows that the median rice, vegetable, and perennial yields in the integrated farms were significantly different from those in the commercial farms. The t-test confirms this result.

Labor productivity

Average family labor, hired labor and labor productivity per farm are given in Table 4.20. Integrated farms had an average of four people working on the farm, commercial farms had considerably less labor available with only two persons on average per farm. The amount of hired labor is about the same for integrated farms and commercial farms, with an average expenditure on hired labor of 1,439 and 1,430 baht $year^{-1}$ for integrated farms and commercial farms respectively. The average labor productivity over all farms was 205 baht day^{-1}. Labor productivity on integrated farms was 241 baht day^{-1} and exceeded that of commercial farms, which was 168 baht day^{-1}.

Table 4.20: Descriptive statistics and statistic results on labor productivity in the different farming systems

Measurement	IFS	CFS	Sig.
Mean ± SD			
Labor productivity (baht day^{-1})	241 ±53	168 ±49	.013
Family labor force (individual)	4 ±1	2 ±1	.001
Hired labor (baht $farm^{-1}$)	1,439 ±157	1,430 ± 223	.929
Median (min, max)			
Labor productivity (baht day^{-1})	228 (173;321)	164 (113;258)	.012
Family labor force (individual)	5 (2;6)	2 (1;3)	.003
Hired labor (baht $farm^{-1}$)	1,400 (1,200;1,700)	1,360 (1,200;1,920)	.527

It was tested whether the values for integrated farms are significantly higher than those for commercial farms. Both the rank sum and the t-tests confirm this hypothesis as shown in Table 4.20. The rank sum and t-tests show a similar result for labor productivity: the median and mean values for integrated farms are significantly different from those for commercial farms. Yet, the values for mean and median on hired labors for the integrated farms were in the opposite direction. These results suggest that integrated farms employed more household members than commercial farms.

Relationship between productivity and integration level

Labor and Land productivity are used as partial indicators of farm productivity. The hypothesis is that the higher the level of integration, the higher the levels of labor and land productivity. Linear regression model are used to approximate the relationship. Table 4.21 shows the results.

Table 4.21: Estimated models for land productivity (a) and labor productivity (b) as affected by integration level, production area, applied fertilizers and labor

a) Total outputs per ha (baht ha^{-1})	Coefficient	Standard Error
Integration level	178.88	111.25
Production area (ha)	-1134.02	345.48**
Labor used on farm (day ha^{-1})	66.94	13.04**
Applied fertilizer (kg ha^{-1})	2.57	3.58
Constant	7138.08	2218.82**
R-squared = .93; Prob. > F= .000		
b) Labor productivity (baht day^{-1})	**Coefficient**	**Standard Error**
Integration level	9.59	2.60**
Production area (ha)	-29.78	5.68**
Labor used on farm (day ha^{-1})	-.98	.21**
Constant	328.42	34.63**
R-squared = .74; Prob. >F= .000		

*Regression with robust standard errors. ** significant at 1%*

In the model for total output per area (Table 4.21-a), the coefficient for the integration level is positive, and thus in line with the hypothesis, but insignificant. The coefficient for area is negative and significant. This result suggests diminishing returns to the production area. The coefficient for labor worked on farm is positive and the relation was significant. The results suggest that the total output per area tends to increase with labor availability in the farm.

For labor productivity (Table 4.21-b), the coefficient for integration level is positive and the relationship is significant, which confirms the hypothesis. The coefficients for production areas and farm labor are negative and the relationships were significant. These results suggest that labor productivity (baht day^{-1}) tends to decrease when labor worked longer in the same production area (day ha^{-1}), or when the production area increased (ha). These results suggest diminishing returns to labor use on the farm.

Results from the above regression models for total outputs show that the number of working days in the farm had a positive effect with the outputs. It was also observed that the results from the t-test and rank sum for integrated farms are insignificant for hired labor, where as those for labor productivity are significant (see Table 4.20). The results suggest that a larger family labor force on the farm may involve more members in farm-related activities. It was expected that the higher number of family members assigned for different roles is closely related to a larger family labor force available on the farm. The pair-wise correlation coefficient was used to correlate the variables of integration level and size of labor force in the household that were assigned to different roles on the farm. The results are shown Table 4.22.

Table 4.22: Estimated correlation coefficients for integration level and five family labor variables

Labor assignment	Coefficient
Land preparation activities	.91**
Transplanting, nurseries	.91**
Growth improving, crop-animal protection, animal feedings	.74**
Harvesting	.85**
Post harvest activities	.73**

*Pairwise correlation coefficients (Pearson). ** significant at 1%.*

Table 4.22 shows the significant correlation between the numbers of people assigned for all activities on the farm with the size of the available labor force in the household. The results were in the same direction as predicted. The results indicate the dependence of farm activities on the availability of labor on the farm. This implies that integrated farms relied more heavily on family labor.

Gross farm income

Table 4.23 shows average farm accounts for both farming types. The accounts include revenues from sale of farm products, purchased inputs, and fixed farm costs, gross farm income, and net farm income. The mean values of purchased inputs and fixed farm costs on integrated farms were higher than on commercial farms. The overall mean of total fixed costs were 4,787 and 3,806 baht farm^{-1} for the integrated farms and commercial farms respectively.

Table 4.23: Annual costs and returns on a whole farm basis by production system, year 2002-2003, averages

Mean of measurement (baht farm^{-1})	IFS	CFS
A. All outputs (returns)		
Rice grains	18,732	17,813
Vegetables, Fruits/ trees	4,665	2,419
All meat and eggs	41,568	19,239
Fish	2,121	0
Total outputs	*67,086*	*39,471*
B. All purchased inputs	10,819	7,875
C. All fixed farm costs (except depreciation)	4,787	3,806
D. Gross farm income (A-B)	48,327	29,114
E. Net farm income[d] (D-C)	10,620	6,801

[d] measure derived in baht farm^{-1}. An opportunity cost = 120 baht day^{-1}; 7 hours = 1 working day. All fixed costs derived from general charges, all capital items repairs, all capital operation costs, land tax, and water user-fee.

Table 4.24 shows the gross farm income and net farm income for the statistical analysis. The net farm income is converted into a per capita basis (baht capita^{-1}) because farm incomes also depend on the quantity of labor at the farm. The gross farm income was 48,327 and 29,114 baht farm^{-1} for integrated farms and commercial farms, respectively. The average net farm income per capita was 10,620 baht capita^{-1} for integrated farms, i.e., 1.5 times higher than for commercial farms (6,801 baht farm^{-1}). Due to the large number of low values, the distribution curves are slightly skewed to the left.

Table 4.24: Descriptive statistics and statistic results for annual costs and returns on farm generated from plants and animals enterprises by production systems

Measurement (baht year^{-1})	IFS	CFS	Sig.
Mean ± SD			
Gross farm income	48,327 ±8,994	29,114 ±9,765	.001
Net farm income per capita	10,620 ±6,916	6,801 ±1,639	.151
Median (min,max)			
Gross farm income per farm	48,580 (29,235; 57,822)	28,834 (19,655; 50,368)	.006
Net farm income per capita	8,907 (4,110; 25,920)	6,417 (4,992; 9,648)	.208

The significance level refers to a t-test for difference in means and a rank-sum test for difference in medians.

It was tested whether the mean and median gross farm incomes on the integrated farms were higher than those on the commercial farms. This hypothesis was confirmed by both the rank sum and t-tests (Table 4.24). However, with respect to the net farm income per capita, the rank sum and t-tests showed no significant difference between the farming systems.

The result suggests that integrated farms are able to generate significantly higher gross returns than commercial farms. However, the difference in net farm income per capita was not significant, because the integrated farms also had higher fixed costs. A rank sum and t-test were used to test the difference in fixed costs. The results of both tests were consistent; both indicating that the value of total fixed costs on integrated farms is significantly higher than that on commercial farms.

Figure 4.8 plots gross farm income (denoted as I_G) against the integration level (IL). The relationship is approximated by the linear regression model.

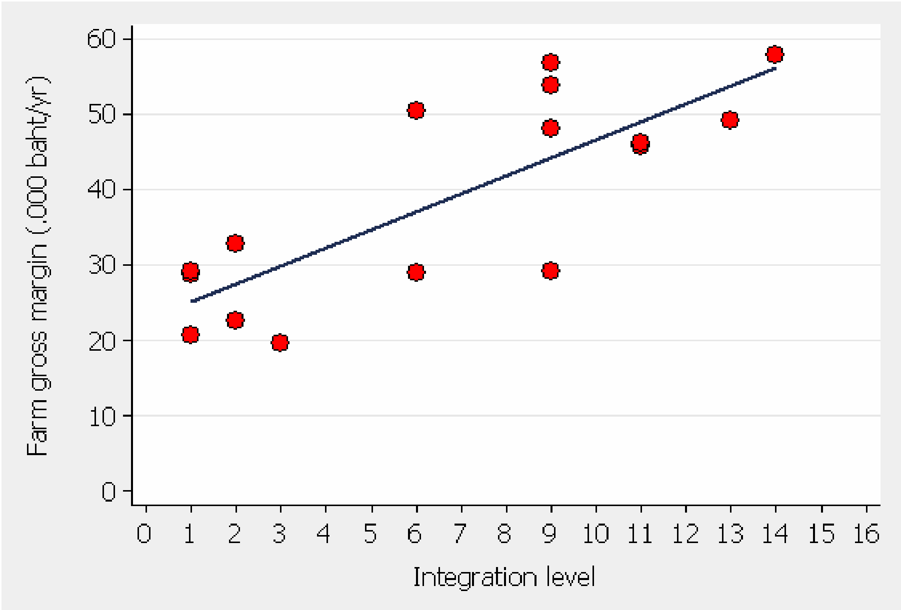

Figure 4.8: Relationship between gross farm income and integration level. Fitted model: $I_G = 22837.24 + 2375.06(IL)$, SE for coefficient = 314.61**; R^2 = .64. Solid line presents fitted values. Regression with robust standard errors. ** significant at 1%.

The parameter in the linear equation shows a positive sign, which was in the same direction as the hypothesis predicted. The line shows an increasing trend of gross farm income at a higher level of integration. This suggests that at a higher integration level farms are generating better returns than farms with a lower integration level.

Constraints to the integration in the farm system

Although the results on gross farm income shows that farms at a higher integration level are generating better returns, however, the correlation between the gross farm income and fixed cost shows a strong correlation (significant at 1%). This suggests that the increasing integration level may be constrained by a high value of fixed cost.

Further results from the qualitative interviews indicate that a low availability of family labor and limited of farming area also constrain the increasing integration level on the farm. A linear regression model was used to determine the relationship between integration level and these variables. The hypothesis is that the higher integration level, the greater the availability of family labor, farming area and investments. Table 4.25 shows the results.

Table 4.25: Estimated regression coefficient for integration level affected by area, labor and fixed cost, and the marginal effects after regress

Explanatory variable	Coefficient	Standard Error	Elasticity $\frac{dy}{dx} * \frac{\bar{x}}{\bar{y}}$
Farm area (ha)	.66	.22*	1.35
Availability of family labor (persons)	1.01	.48*	2.16
Investment costs (.000 baht)	3.50	.00*	5.45
Constant	-13.69	5.66*	

Regression with robust standard errors. R-square = .79; Prob.>F = .001. *significant at 5%. Elasticity explains the % change of variable y on 1 % change of variable. The elasticity derived from the value of [the marginal effect (dy/dx)] time [the mean values of variable y/mean value of variable x].*

The coefficients in the linear equation are positive for the three variables and the sign is the same as predicted. The R-squared (79%) shows an overall good fit of the model. The marginal effects show the relative effect of a one percentage increase in farming area, size of family labor, and fixed costs on the integration level. The results show that a 1% increase in farm area would increase the integration level by 1.35% , while controlling for the effect of all other variables. Similarly, a 1% increase in family size would increase the level of integration by 2.16%; and a 1% increase in investments would increase the level of integration by 5.45%. The results suggest that the integration level is most strongly affected by investments, followed by family labor, and farm area.

5 DISCUSSION

This chapter discusses the results as presented in the previous chapter. It is divided into six sections: Section 1 summarizes the significant findings. Section 2 compares these findings with the literature. Section 3 examines the findings that support the hypotheses. The implications and policy recommendations of the research are highlighted in Section 4. Section 5 outlines the limitations of the present study and the chapter ends in Section 6 with recommendations for further research.

5.1 Overview of significant findings of the study

The quantified ecological and economic attributes are shown in Table 5.1. Selected variables were analyzed and compared for statistical differences between the IFS and CFS based on mean and median.

Table 5.1: Summary of significant findings for the variables in the study, median values and significance of rank-sum test

Variables	IFS (IL≥ 6)	CFS (IL< 6)	Sig.
Food security functions			
Share of home produced food (%)	68	33	**
Species richness as food (number)	38	17	**
Environmental functions			
Diversity of growth habit (number)	8	6	*
Growth performance of tree community			
Basal area (m^2 ha^{-1})	.62	.06	**
Stem density (tree ha^{-1})	463	35	**
Species richness of soil covers (number)	40	8	**
Irrigation months (number)	3	0	**
Soil organic matter (%)	.98	.64	**
Economic functions			
Rice yield (kg ha^{-1})	2,783	2,500	**
Vegetables yield (kg ha^{-1})	6,617	2,223	**
Perennial yield (kg ha-1)	1,893	0	**
Labor productivity (baht day^{-1})	241	168	*
Gross farm income (baht)	48,327	29,114	**
Social functions			
Species richness for local rites (number)	38	21	**
Species richness for medical (number)	16	0	**

*IL integration level of resources on a farm. The significance level refers to a non-parametric test for difference in medians. * significant at 5%. ** significant at 1%.*

Apart from comparing means and medians for the two farm types, the relationship between the variables and the integration level on a farm was explored. The share of home produced food tends to increased with each unit of integration level increase. The increase of species richness used for food, social purposes, and soil covers were positively affected by increasing integration levels on a farm. Availability of trees on the farm was positively correlated with SOM.

Gross farm income was positively affected by additional units of integration level whilst the amount of family labor assigned to farm activities was positively correlated with the amount of family labor available to the household. A regression model suggests diminishing returns to the production area and labor use on the farm.

The constraint for increasing integration level in the farm system was further analyzed. Fixed costs, availability of family labor, and size of farming area were identified as the main constraints.

5.2 Consideration of the findings in the light of existing research

The results of the study revealed a more secure supply of food in terms of the amount and richness of species, and the extent to which preferences for particular foods were satisfied. This was indicated by a lower share of purchased food and a higher share of home consumption on a farm at a higher integration levels. These results confirm the hypotheses in the study undertaken by KKU (2001) that the higher the level of diversification and integration on a farm, the higher the self-sufficiency of the farm household. The KKU study assessed self-sufficiency from 34 farms using three indicators: amount of cash saved through lower amounts of food purchased from the markets; gross farm income; and crop yield. It revealed that households with higher levels of integration were able to save more cash, as they required less food from the market. Lower cash food expenditures were associated with an increase in food diversity on integrated farms.

Dalsgaard and Oficial (1997) assessed the performance of two monoculture rice systems and two integrated farms in the Philippines using selected agroecological and economic indicators. The present finding with respect to the higher species richness for different functions supports their results, showing a large difference in species richness ranging from monoculture to higher integration levels. The species richness increased as the farmers integrated new enterprises into the farm. The lowest income was generated by the monoculture rice system, whereas farms with higher diversity derived most of their income from vegetables instead of rice. The present study also revealed that farms at higher integration levels attained significantly higher crop yields (rice, vegetables and perennial) and that their labor productivity was higher as well. This also confirms the findings of Dalsgaard and Oficial (1997) that the sum of all crop yields and labor productivity was greater at higher levels of integration.

Agbonlahor et al. (2003) determined the optimal resources allocation that satisfied productivity requirements and sustained soil fertility in the system for small farm holdings in Nigeria. The present finding regarding improved labor productivity in the IFS corroborates their results that family labor is better utilized than in pure arable crop or animal farming systems.

The finding of improved farm income in the present study also supports the results of a case study undertaken by Alsagoff et al. (1992), KU (2000), and Tabtimoon (1996). Alsagoff et al. (1992) evaluated the financial situation of IFS in central Malaysia and revealed that the integration of aquaculture and trees can augment farm incomes up to 3.3 times as compared to the monthly average income. The FAE, KU (2000) assessed the change in net farm income from three integrated farms in Northeast Thailand and revealed that farm net incomes increased in all cases. The study undertaken by Tabtimoon (1996) reached a similar conclusion. The study assessed the farm gross income from the system in Petchaburi, Thailand, and revealed that income increased from 11,325 baht farm^{-1} in the first year to 26,649 baht farm^{-1} in the second year.

The comparative analysis also showed that the improved quality of soil, tree communities and water resources on the integrated farms were associated with higher levels of integration. The improvement of SOM is more likely to appear at a higher stem density of the tree community on a farm. These findings support the notion that diversity and integration improve the quality of on-farm resources in the degraded environment and foster the resource efficiency (Dalsgaard and Oficial 1997). The findings confirm the results of a recent study undertaken by Whitbread et al. (2002), who reported on the influence of residue from leaf litter and fertilizer management on SOM, nutrient balances, and crop yield in Northeast Thailand and Australia. They found an increase in rice grain yield of 20 to 26% and a large net positive nutrient balance after five seasons of leaf litter application.

The present study concludes that a higher total production and non-harvested production were found at higher levels integration where on-farm water reservoirs were established, and plant and animal species were diversified into a farm. The studies undertaken by Dalsgaard and Oficial (1997), KKU (2001), Agbonlahor et al. (2003), FAE, KU (2000), and Tabtimoon (1996) reported on the impact of integrated farm on crop yield. The studies reached similar conclusions that a higher total production were found at higher integration levels, where on-farm water reservoirs were established and plant and animal species were diversified.

The results of the present study showed that high substantial investment, low availability of family labor, and small farming area were the major constraints to increasing the level of integration on a farm. This finding confirms the results in the studies undertaken by Dalsgaard and Oficial (1997), KKU (2001), Tabtimoon (1996) Kaewsong et al. (2001) and reports by Ligthfoot (1997) and Paris (2002).

Dalsgaard and Oficial (1997) stated in their study that two main factors limit the integration and diversification on a farm were the availability of labor and land tenure. The reviews promoting IFS over the past 15 years by Ligthfoot (1997) supported the finding that labor and land scarcity can be obstacles in the system’s operation. Studies undertaken by KKU (2001), Tabtimoon (1996) and Kaewsong et al. (2001) have reached a similar conclusion that the high investment required for establishing the necessary infrastructure in combination with a small family labor force are the main constraints to integration and diversification on a farm. A study undertaken by Paris (2002) assesses case studies from South Asia, which document the benefits and impacts from the system. This study indicates that initially, the integration in the rice-based system was acceptable to the farmers; however, they stopped the practice because of a lack of seeds and difficulties in establishment.

A study undertaken by Pant (2002), assessed the potential and economic viability of integrated agriculture-aquaculture (IAA) in the Khon Kaen and Buriram provinces in NE Thailand, and reached the similar conclusion that lack of inputs, seeds and technologies were common problems in integrated agriculture-aquaculture in the study area.

Although the analyses in the empirical studies showed many advantages of IFS, a higher level of purchased inputs was observed in the present study. This finding shows that IFS does not support the notion of eliminating external inputs. The empirical results suggest that these external inputs are a necessary ingredient in a regenerative agriculture, and that IFS does not offer a standard combination for diversification and development of the farm (Dalsgaard and Oficial 1997).

5.3 Multiple functions of IFS in the study area

The radar graph in Figure 5.1, as proposed by Garcia (1997) and Coughland and Lefroy (2001), is used to summarize the performance of IFS compared with CFS in various aspects. The graph simultaneously compares the two farming systems in 14 aspects. Values are calculated from the average values per farming system, which are then divided by the maximum. Each value hence shows the performance of one system relative to the maximum performance of both systems. The relatively large area between the two lines shows that the difference between the farming systems is substantial. The graph clearly shows that the IFS outperforms the CFS in every aspect. Each of these variables is discussed in the following.

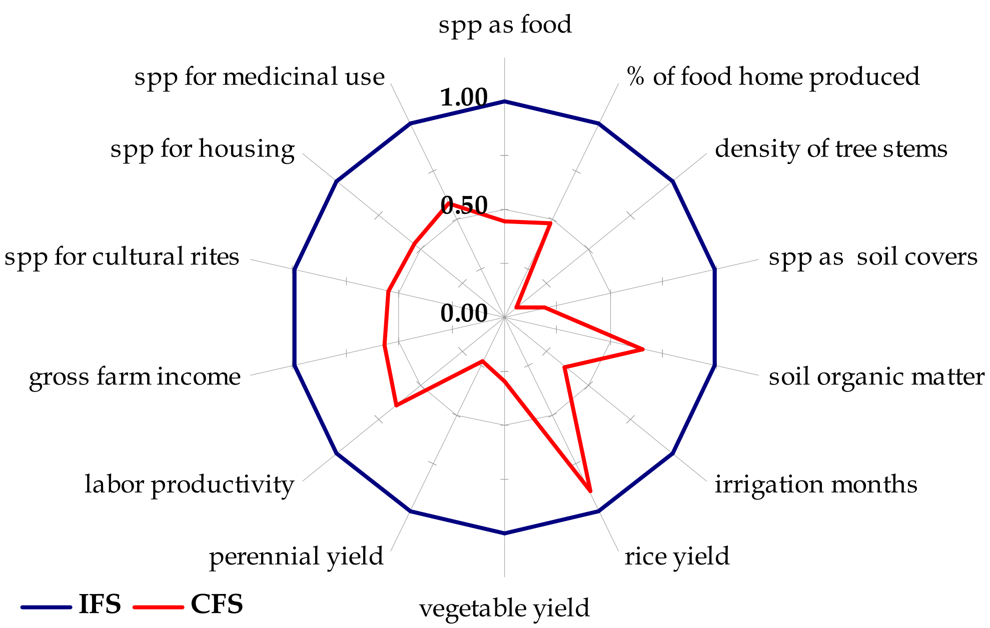

Figure 5.1: Radar graph comparing the IFS with the CFS in 14 aspects. All values are calculated from the averages for IFS and CFS divided by the maximum of these two values.

5.3.1 Food security functions

The situation of food security is equated to the situation of food availability. Based on this, the availability of food can be characterized as type, proportion, and distribution of food in the farm system. The proximity variables are discussed in this part.

Type of food

Figure 5.2 shows the aspects of availability of food species using two regression lines, one for each farming system. The left regression line shows the level of available food species on commercial farms, the line on the right shows the level on integrated farms. A significant and positive correlation was found between richness of food species and integration level.

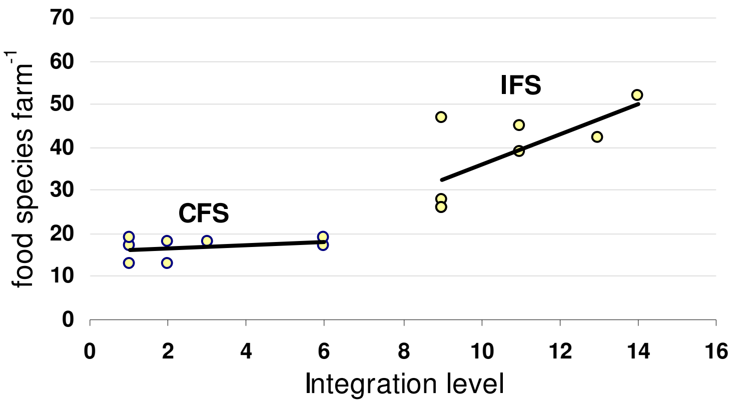

Figure 5.2: Distribution of food species affected by integration level. CFS line presents availability of food species on commercial farms. IFS line presents available food species on integrated farms.

On commercial farms, the number of food species slightly increases with the level of integration. Moreover, on the integrated farms, the number of food species was not only higher, but also increased greatly with the level of integration. This suggests that a few integration activities between enterprises on commercial farms produced fewer food species than on integrated farms. The richness of food species available on integrated farms tends to increase with the integration level on the farm. The richness of food species available on commercial farms tends to be the same if no, or less, food species are introduced into the farm area.

Proportion of food

Figure 5.3 shows the total food consumption for each farm in the sample. The figure show the increased of share of market value of home consumption, and the reduced of share of purchased food from local markets is associated with the increase in integration level. This suggests that the diversified food supply on the farm met the food preferences and diet of the household members.

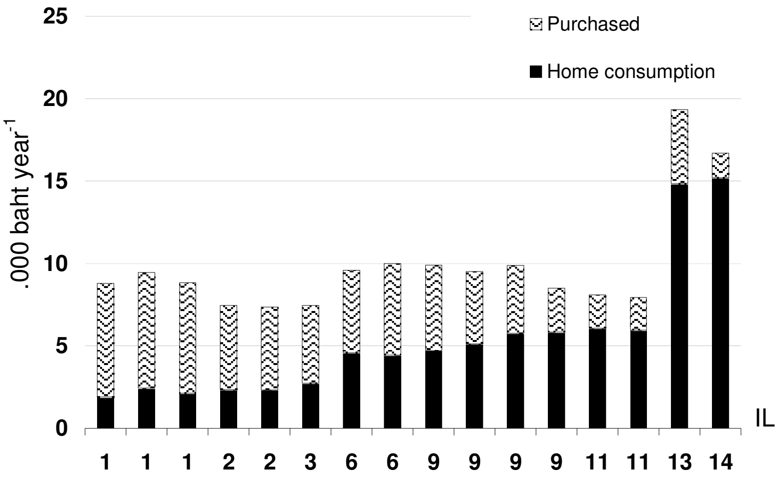

Figure 5.3: Value of home consumption and value of food purchased outside the farm on CFS (integration level 1 to 6) and IFS (integration level 9 to 14)

Compared to the low-integration level farms, few food species are available on the farm to meet the food requirements, and thus the dependency on food from the local market is increased, indicated by the higher share of food purchased from outside the farm. These results support the hypothesis that increasing integration level and diversification on a farm encourages food availability.

Distribution of food

A comparison of food production activities in the IFS and CFS (see Table 4.5) show different land and water uses according to the season and the environmental conditions of the farming system. A more equal distribution of food production throughout the year was observed for the IFS. The farm ponds provide a longer period for crop production and aquaculture. Aquaculture activity substitutes for fishing in the natural lake and stream, which is more difficult between August to October due to the flooding (see also

Table 4.5-c). The fruit trees in the woodland in the IFS offer alternatives for food production throughout the year. A greater diversity of fruit trees, bearing fruit in different periods of the year, diversifies household consumption and sources of income.

Rice still remains a main source of staple food and generates much of the annual income. Compared to rice, few vegetables and meat are required for the daily diet. These requirements can also be met through the local market, whereas introducing more fruit trees, animals and other species demands additional labor and investments. When promoting integration and diversification of on-farm enterprises, priority needs to be given to crops, trees and animals that can be harvested relatively quickly, can be used for food and are accepted in the local diet.

5.3.2 Environmental functions

Recycling of nutrients

The analyses show a tendency toward higher levels of SOM where stem density on a farm increase (see Figure 4.7). This characteristic implies a long-term source of SOM and ensures the availability of a SOM stock at integrated farms (Kang 1993; Kleinman et al. 1995; Palm 1995).

At farms with a higher integration level, products from some enterprises show additional functions in the farm system. An example is feeding the fish in a farm pond with vegetables and poultry manure. Crop residues, rice straw, and leaf litter from the trees are also used for the cultivation of mushrooms as found in integrated farms case 2. In the integrated farm cases 1 to 5, the dry leaves and pods from Acacia trees and the leaves of Leuceana were used for feeding cattle. Tree litter, crop residues, and green manures were used as amendments to the soil in vegetable beds. The value of on farm resources is therefore enhanced when products are used on the farm.

Although application of leaf litter, green manure, and crop residues shows a potential increase in productivity as reported by a number of studies, this requires a relatively large application of residues as well as in terms of labor costs (e.g., Blair et al. 1990; Handayanto et al. 1994; Wonprasaid et al. 1995; Whitbread et al. 2003).

Diversity of soil covers

A significant relationship was found between increasing integration level and the species richness used as soil cover. These cover plants protect the soil surface from incoming radiation, wind and precipitation as well as enhance the SOM level on the farm (Mulongoy and Akbundu 1990; Kleinman et al. 1995).

Regulation hydrology

The additional constructed component, such as farm ponds, provides a range of services that improve the sustainability of the farm. In addition, the farm ponds have functions for the IFS in regulating the storage and flow of surface water (Kapetsky 1997). The more extensive use of farm ponds by households in the IFS showed that the construction of such ponds has the potential to diversify food production by integrating fish culture (see e.g., CIRDAP 1988; FAN 1999; KKU 2001; ICLARM and IIRR 2001).

Habitat value

The farm maps show that the area in the IFS is more diverse than that of the CFS (see Figure 4.1 and Table 4.3). The farm ponds and the tree communities provide additional habitats for other plants and animals.

5.3.3 Economic functions

Figure 5.4 illustrates the level of gross farm income attained in integrated farms and commercial farms. The height of the farm gross income bar in the figure is above the total food consumption for all farms (see Figure 5.3). This suggests that there was sufficient income from the farm for food consumption on all farms. However, average gross farm incomes for integrated farms were higher than for commercial farms as depicted by the dotted regression line in the figure.

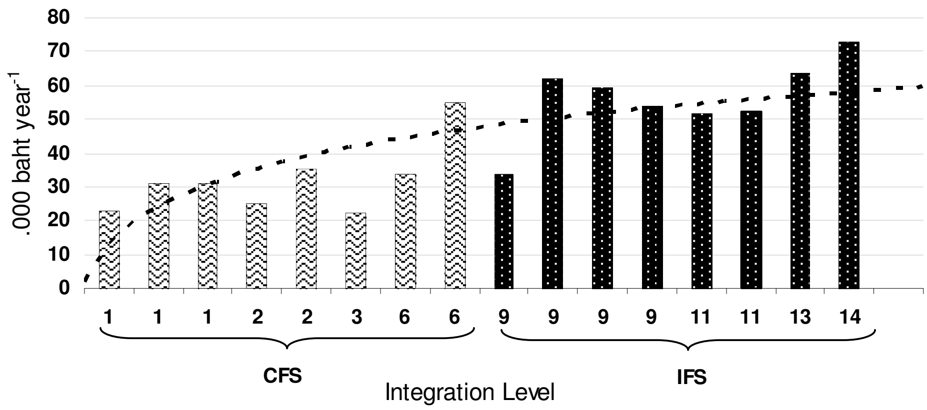

Figure 5.4: Gross farm income by integration level and by farming system

The IFS outperforms in terms of land- and labor-use efficiency than the CFS due to the farmers had alternatives to diversify food species, i.e., from a few cash crops, to different types of vegetables and fruit trees.

5.3.4 Social functions

Diversity of species

The IFS increases species richness used for social purposes. Examples of species used for religious and cultural rituals, i.e. making merits, wedding, and house warming ceremonies are black rice, black sugar cane (case 1, 2, 6 and 7), maddimara tree (*Morinda tomentosa*) (case 1, 2 and 3), and Chinese albizia tree (*Albizia chinensis*) (case 1, 6).

Example of the species used for medical purposes are black sugar cane (in case 2), which is used for clean blood, gonorrhea fever, and headache, and the maddimara tree (case 1, 2 and 3), which is used for astringent, cathartic, diarrhea, dysentery wounds and ulcers. Other examples include the tamarind tree (case 1), and silk cotton tree (*Bombax ceiba*) (case 2 and 4), which are used as astringent, cooking, relieving swellings, skin troubles, stimulant, diuretic, kidney ulcers. Examples of species used for household purposes include the use for firewood for cooking, silk production, charcoal production, making of small tools and temporary constructions (Kongkajan et al. 1990; Prachaiyo 2000).

Although these species often have multiple functions, they have little market value compared with cash crop species such as jasmine rice, chinese lettuce, kale, and water melon. These species were therefore replaced more than a decade ago, resulting in the gradual loss of indigenous knowledge on the uses of these species (Choosakul 1999; Thamrongwarangkul 2000). Besides, the loss of indigeneous knowledge is probably due to the replacement of fuel wood by gas in households of both farming types and the limited experience and skills in using wood for making furniture or permanent constructions (Jamroenpruksa 2001; Thamrongwarangkul 2001). Over time, the households may increase the use of wood species for making small furniture and construction as they accumulate experience.

Diversity of activities

All farm households in the IFS show a more diverse set of activities and a range of products as compared to the farm households in the CFS (see Table 4.4 and Table 4.5). Resource integration is therefore a practice well accepted by the local community.

5.3.5 Constraints to the integrated farming system

Three main constraints on integration and diversification on a farm were identified: high investments and fixed costs, availability of family labor, and the area of the farm. They are discussed in the following.

Larger farm households involved more members in farm-related activities such as preparing the land, transplanting crops, improving crop growth, feeding animals, harvesting, storing and selling the products after harvest. These results suggest that the IFS is likely to be more suitable for farm households with a greater availability of labor, yet also suggest that farm households with a smaller labor force might not be able to switch to integrated farming.

A larger farming area had the expected positive association with integration level. Integrating new enterprise, i.e., farm pond and livestocks requires more land. For example, the integration of animal enterprises, especially cattle, as revealed from the interviews, is the limited the amount of grazing land. The available grazing land is public land, but its forage supply is insufficient to feed these animals (see Saisoong 1989; Shelton and Phaikaew 2001; Intramangala 2001). This suggests that the availability of farming area is an important factor affecting the potential for increasing the integration level on a farm and those smaller farms might be disadvantage when they want to switch to integrated farming.

The fixed costs were mainly the result of the establishment of ponds and area changes. Furthermore, inputs such as animals and seeds are important factors in increasing the integration level on a farm, since purchased inputs are necessary to regenerate and/or continue farm production and occur annually. The farm household may increase the integration level or adopt IFS when the required investment for animals (fish and cattle) is lowered. High costs of animals and seeds reduce the potential for substituting alternative enterprises for rice cultivation.

The integrated farms are more oriented toward on-farm resource use (Jitsanguan 2001) and it is therefore not surprising that integrated farms invested more in on-farm resource improvements. Yet, this might also indicate commercial farms with a limited access to capital cannot easily switch to integrated farming. Competition with rice and vegetable cultivation affects the opportunities to integrate trees and animals, since these activities require the same resources, e.g., land, labor and capital.

Limited availability of family labor, high fixed costs, and high costs of purchased inputs are major limitations to increasing the levels of integration and diversification. When the farm land has been leveled and a farm pond established, then the purchase of genetic resources, such as animals is the next constraint. High availability of family labor and access to finance, such as farmer network group credits, can assist farmers in the construction of farm ponds. Membership in farmer networks can also reduce the cost of genetic resources because of a stronger negotiation position with input providers. The findings suggest that functioning institutions, such farmer groups and the sharing of experiences, are important for practicing IFS in the study area and its promotion can encourage the use of the IFS.

Sustainability of the integrated farm system in the study area

The study defined sustainability of the IFS as the extent to which the integrated farms meet the four requirements of food security, environmental, economic, and social functions; and these four primary requirement must be viewed in a positive light (as mentioned in Chapter 3). The results from eight farms in the IFS illustrate that the four requirements according to the multifunctionality framework were met and performed better than for commercial farms as discussed in the above sections. According to these results, the IFS is considered sustainable.

5.4 Policy implications and recommendations

This study shows that the IFS can be utilized to maintain or enhance productivity and strengthen the environmental services delivery, while reducing the level of production risk to the farmers and improving the quality of soil and water resources. The majority of the farmers in the study area are small-resource farmers. Policy support is needed to assist resource-poor farmers to switch to IFS. It is recommended that policy makers support these farmers in three important ways:

1) Since the issue of sustainable food production is now recognized especially for resource-poor farmers in the lowland rainfed areas, building up farmers' own capacities needs to be a priority. Policies can assist by supporting data collection and information dissemination and facilitating the exchange of experiences among farmers. The formation of farmer networks can be supported and leading farmers can be identified in each community who can act as an example for other farmers to follow. Starting-point for such strategy should be farmers' own self-sufficient philosophy, their culture and traditional agricultural knowledge.
2) Where the IFS is being promoted to resource-poor farmers, especially in degraded environments, policies supporting resource management need to focus on the farm level and concentrate on the development of on-farm surface water and land-use planning tailored to specific agroecosystem.
3) It is obvious that resource-poor farmers, through the IFS, can play an important role in maintaining their agricultural production while maintaining and improving the environmental quality at a local level. Policies can provide the economic incentives for the farmers, whose practice brings environmental benefits to society as a whole. Economic incentives need to focus on credit subsidies to farmers for integrating various enterprises, management unit, and genetic diversity on the farm. Such incentives can include short-term subsidies, tax reduction for genetic resources used in sustainable agriculture, and a community revolving fund to support growth of agricultural networking.

5.5 Limitations of the study

This research also has some limitations, which may affect the validity of the results. While the study looked at enhancing food security in terms of amounts and richness of specie used for food purposes, the share of purchased food from other food sources, and the level of home consumption, it did not consider the nutritional status or actual nutrition requirement of individual farm household members (FAO 2002). It could be expected that household members of IFS are better nourished because of a more diverse diet.

The analysis of non-purchased food only looked at home produced food and did not consider food collected from the vicinity of the farm, like products from the communal native forest, which also influence food consumption. Yet, there is little reason to believe that this would bias the results since the farms are located in the same areas and all households have equal access to the communal areas.

The results on the socioeconomic returns from IFS relied on the analyses of gross farm income, land and labor productivity in the period of investigation. The analysis did not explain the magnitude of change in these indicators over time. The change of these indicators can only be observed when time series data become available. Similarly, with respect to ecology, the study did not consider nutrient flows but relied on soil samples, which capture the current quantity of nutrients but not the change in nutrients over time. Capturing these dynamics was impossible within the limited time available for the study.

With respect to sustainability of the IFS, it is recognized that the interactions between biophysical and socioeconomic factors in the study area determine the sustainability of a system at a given time. Over a future reasonably long time period, a form of IFS may be regarded as sustainable if no permanent or progressive deterioration of it suitability (Smyth and Dumanski 1993).

5.6 Recommendation for further research

Five knowledge gaps have been identified that require further research:

1) Farmers themselves are a crucial factor for the success of adoption IFS. A better understanding of farmers' needs, perceptions about the IFS, structural and behavioral characteristics of the farm households could contribute to a wider adoption of IFS.
2) The IFS satisfy the household needs in term of production and services at the household and local level. However, farm households also have supplementary sources of food and income from the vicinity of the farm, such as native forests. The study of food security and dependency of the farm household from such an area can improve the understanding of survival strategies of the farm households in particular areas as well as help to conserve these resources.
3) The existence of farmer groups and the involvement of GO and NGO agencies giving technical support to the farmers were examples found in the study area. This suggests that relevant institutions are important for promoting IFS. More knowledge is needed about the organization and function of such institutions, i.e., farmer leadership, networking, and involvement of external agencies as well as the functioning of the financial market.
4) To assist farmers in improving the level of resource integration and resource-base management, an understanding of the quantity and quality of residues or by-products from one enterprise to another is necessary. The quantity and quality of different types of by-products on a farm need to be investigated. The assessment of the rate of change of important indicators such as soil organic matter or soil microorganisms in response to management needs further investigation.
5) The key to improving the resource quality through integration and diversification of farm resources lies with the farmers, as they manage the soil, water, and biodiversity through their farming methods. Policies influence resource-poor farmers through economic incentives, and their support is crucial in assisting these farmers in sustaining agriculture and environment. Policy impacts on land-use management by resource-poor farmers, and vice versa, needs to be analyzed.

6 CONCLUSIONS

This study examines the performance of integrated farming systems (IFS) in the lowland rainfed area of the Khon Kaen province, Northeast Thailand. This type of farming integrates vegetables, trees, livestock, and farm ponds into the rice-based system. The concept of agricultural multifunctionality was used as a conceptual framework to assess the extent to which IFS has satisfied its objectives. The performance of the IFS was assessed by selecting a number of integrated farms and comparing these with adjacent commercial farms through farm pairing and using techniques of rapid rural appraisal.

The study showed that the IFS has two management zones in addition to the commercial farming system (CFS): woody lands and farm ponds. This resulted in a higher diversity of management units, higher habitat values, and more on-farm activities.

The IFS had a significantly higher diversity of species used for food, a lower share of purchased food in the total food consumption, and a concomitant higher share of home produced food, indicating a more secure food supply from the own farm. The IFS also showed a higher diversity of plants used for social purposes and on-farm activites, suggesting the acceptance of the system by local communities.

A better growth performance of tree communties implies a longterm source of soil organic matter on the IFS. The higher level of soil organic matter on the integrated farms related to the higher stem density of tree communities. The existence of farm ponds on the IFS, increased the number of months with irrigation in addition to rainfall for crop production and provided additional services that improved the sustainability of the farm. The use and re-use of products in the farm were important for the recycling of nutrients.

The farm ponds on the IFS allowed these farms to increase their land productivity while reducing production risks. The households in the IFS attained significantly higher crop yields, labor productivity, and gross farm incomes.

The findings support the notion that diversification and integration of on-farm resources is feasible in economic terms and can benefit ecological performance of farms. Nevertheless, a low availability of family labor, high initial investments and subsequent fixed costs, and small farm sizes were identified as the three main constraints to a switch from CFS to IFS.

The results suggest that when integrating more enterprises and genetic diversity on a farm, priority needs to be given to food species that can be harvested quickly and fit into the farm households' diets in a particular region. Policy makers could contribute to building up capacity among farmers and support their philosophy, which is oriented toward self-sufficiency. Encouraging the formation of smallholder farmer groups and facilitating their sharing of experiences in the IFS will strengthen the development of sustainable farming. Policies need to provide the right incentives to the farmers. These can include targeted credit subsidies to farmers for integration and diversification of the farming system and support to communities to stimulate the exchange of information.

7 REFERENCES

Aarnink W., Bunning S., Collette L. and Mulvany P. 1999. Opportunities, incentives and approaches for the conservation and sustainable use of agricultural biodiversity in agro-ecosystems and production systems. International Technical Workshop, 2–4 December 1998, FAO, Rome, Italy.

Adireksarn P. 2001. Thailand: Economy, politics and government. Business Intelligence Report: Thailand, pp. 1-55.

Agbonlahor M.U., Aromolaran A.B. and Aiboni V.I. 2003. Sustainable soil management practices in small farms of Southern Nigeria: a poultry-food crop integrated farming approach. J. Sustain. Agr. 22(4): 51-62.

Alsagoff S.K., Kuperan K. and Hussein M.A. 1992. A linear programming analysis of integrated agriculture-aquaculture mixed farming. Pertanika, 15(3): 271-278.

Altieri M.A., Rosset P. and Thrupp L. A. 2004. The potential of agroecology to combat hunger in the developing world. University of California, USA.

Arunin S. 1992. Strategies for utilizing salt-affected lands in Thailand. Land Development Department, Bangkok, Thailand.

Ashby J. A. 2001. Integrating research on food and the environment: an exit strategy from the rational fool syndrome in agricultural science. Ecol. Soc. 5(2).

Asian Institute of Technology (AIT). 1994a. Partners in development, the promotion of sustainable aquaculture. Pathumthani, Thailand.

Asian Institute of Technology (AIT). 1994b. Study of potential development of water resources in the Mekong River Basin. The Office of National Economic and Social Development Board, Bangkok, Thailand.

Banerjee B.N., Sarker S.C. and Maity A.K. 1990. Impact of resource optimization on cropping pattern and income on crop-dairy mixed farm. Indian Journal of Dairy Science 43(3): 295-301.

Barthelemy D. and Nieddu M. 2004. Multifunctionality as a concept of duality in economics: an institutionalist approach. Paper presented in 90th EAAE seminar multifunctional agriculture: policies and markets, understanding the critical linkage, Rennes, France, October 28-29, 2004.

Blair G., Catchpoole D. and Horne P. 1990. Forest tree legumes: their management and contribution to the nitrogen economy of wet and humid environments. Adv. Agron. 44: 27-54.

Bunyawechewin S. 1983. Canopy structure of the dry dipterocarp forest of Thailand. Thai Forest Bulletin (Botany) 14: 1-132.

Bunyawechewin S. 1985. Analysis of the tropical dry deciduous forest of Thailand II. Vegetation in relation to topographic and soil gradients. Natural history bulletin of the Siam Society 33: 3-20.

Bunyawechewin S. 1986. Ecological studies of tropical semi-evergreen rain forest at Sakaerat, Nakhonratchashima, northeast Thailand. Vegetation pattern. Natural history bulletin of the Siam Society 34: 35-57.

Centre on Integrated Rural Development for Asia and the Pacific (CIRDAP). 1988. Report of the regional workshop Integrated farming system. CIRDAP Newsletter, 34, pp. 3-4.

Chambers R. 2002. Relaxed and Participatory Appraisal: notes on practical approaches and methods for participants in PRA/PLA-related familiarization workshop. Institute of Development Studies (IDS), UK.

Choosakul S. 1999. Challenging crisis with sustainable farming. Sustainable resource management project, northeast region, Mahasarakham, Thailand.

Coughland K.J. and Lefroy R.D.B. 2001. Assessment of sustainable land management using the FESLM: The IBSRAM experience. Issue in sustainable land management 8. International Board for Soil Research and Management (IBSRAM), Bangkok, Thailand.

Craswell T. E. 1998. Sustainable crop and soil management on sloping lands. Paper presented at the international symposium on Asian agriculture in the 21st century. Food and Fertilizer Technology Center for the Asian and Pacific, Taipei, Taiwan, ROC, 9-12 June.

Craswell T. E. 2002. Maintaining soil and water quality: the foundation of sustainable land management. The International Commission for Earth Sciences in Africa (ICESA).

Crawford I. 1997. Rapid rural appraisal. In Marketing Research and Information Systems. FAO, Rome, Italy.

Csavas I. 1992. Regional review on livestock-fish production systems in Asia. In: Mukherjee T.K., Moi P.S., Panandam J.M. and Yang Y.S. (Eds.), Proceedings of the FAO/IPT Workshop on integrated livestock-fish production systems, 16–20 December 1991, Institute of advanced studies, University of Malaya, Kuala Lumpur, Malaysia.

Curtis J. T. and Macintosh R.P. 1951. An upland forest continuum in the prairie-forest border region of Wisconsin. Ecology Bulletin, 32: 476-496.

Dalsgaard J.P.T. and Oficial R.T. 1997. A quantitative approach for assessing the productive performance and ecological contributions of smallholder farms. Agr. Syst. 55(4): 503-533.

Daly B. 1992. Recommended methods for soil and plant analysis. International Board for Soil Research and Management (IBSRAM), Bangkok, Thailand.

de Wit J., Oldenbroek J.K., van Keulen H. and Zwart D. 1995. Criteria for sustainable livestock production: a proposal for implementation. Agr. Ecosyst. Environ. 53: 219-229.

Department of Mineral Resources (DMR). 2000. Geological map to Thailand scale 1:2,500,000. Bangkok, Thailand.

Dhamanonda P. 2001. Report study of potential of watershed. Water source development in Tung Kula Ronghai project. PDC development consultant Limited, Bangkok, Thailand. Dillon J. and Hardaker J.B. 1993. Farm management research for small farmer development. FAO farm systems management series 6. FAO, Rome, Italy.

Dillon J. and McConnell D.J. 1997. Farm Management for Asia: a systems approach. FAO farm systems management Series 13. FAO, Rome, Italy.

Donner W. 1978. The five faces of Thailand: An economic geography. London: C. Hurst & Company (For the Institute of Asian Affairs, Hamburg).

Edwards C.A., Grove T.L., Harwood R.R. and Colfer C.J.P. 1993. The role of agroecology and integrated farming systems in agricultural sustainability. Agr. Ecosyst. Environ. 46(1-4): 99-121.

Edwards C.A., Lal R., Madden P.R.H. and House G. 1990. Sustainable agricultural systems. Soil and Water Conservation Society, Iowa, USA.

Edwards P. 1997. Sustainable food production through aquaculture. Aquaculture Asia, Vol. 2(1). School of Environment, Resources and Development, Asian Insitute of Technology (AIT), Pathumthani, Thailand.

Edwards P. 1999. Aquaculture and poverty: past, present and future prospects of impacts. A discussion paper prepared for the fifth fisheries development donor consultation, Rome, Italy, 22-24 February, 1999.

Electricity Generating Authority of Thailand (EGAT). 2001. Annual report 2001. Nonthaburi, Thailand.

Eswaran H., Lal R. and Reich P.F. 2001. Land degradation: An overview. In: Bridges E.M., Hannam I.D., Oldeman L.R., Penning de Vries F.W.T., Scherr S.J. and Sombatpanit S. (Eds.) Response to land degradation. Oxford & IBH Publishing, New Delhi.

Faculty of Economics (FAE). 2000. Sustainable agriculture: Case study in northeast Thailand. Research report. Kasetsart University, Thailand.

FAO. 1999. FAO Aquaculture Newsletter (FAN), December, No. 23.

FAO. 2002. Measurement and assessment of food deprivation and undernutrition. International scientific symposium, 26-28 June 2002. Summary of proceedings, FAO, Rome, Italy.

Food and Fertilizer Technology Center (FFTC). 2002. Multifunctionality of agriculture. International FFTC seminar on the multifunctionality of agriculture, October 17-19, 2002. The Japan International Research Center for Agricultural Sciences (JIRCAS), Tsukuba, Japan.

Gliessman S.R., Garcia R. and Amador M. 1981. The ecological basis for the application of traditional agricultural technology in the management of tropical agro-ecosystem. Agro-Eecosystems. 7: 173-185.

Gold M.V. 1999. Sustainable agriculture: definitions and terms. Alternative Farming Systems Information Center (AFSIC), National Agricultural Library, MD, USA.

Govindan R., Chinnaswami K.N., Chandrasekaran B., Budhar M.N. and Prince J. 1990. Poultry-cum-fish culture in rice farming in Cauvery delta region of Tamil Nadu. Indian J. Agron. 35(1/2): 23-29.

Groenfeldt D. 2005. Multifunctionality of agricultural water: Looking beyond food production and ecosystem service. Paper prepared for the FAO/Netherlands international conference on water for food and ecosystems, The Hauge, January 31- February 5, 2005.

Halvorson J.J., Smith J.L. and Papendick R.I. 1996. Integration of multiple soil parameters to evaluate soil quality: a field example. Biofertil Soil, 21: 207-214.

Handayanto E., Cadisch G. and Giller K.E. 1994. Nitrogen release from pruning of legume hedgerow trees in relation to quality of the pruning and incubation method. Plant. Soil. 160: 237-248.

Hediger W. and Lehmann B. 2003. Multifunctional agriculture and the preservation of environmental benefits. Contributed paper selected for presentation at the 25th International Conference of Agricultural Economists, August 16-22, 2003, Durban, South Africa.

Hoffman C. and Carroll C.R. 1995. Can we sustain the biological basis of agriculture. Annual Review Ecology System 26: 69-92.

Hussain M.J. and Doane D.L. 1995. Socio-ecological determinants of land degradation and rural poverty in northeast Thailand. Environ. Conserv. 22(1): 44-50.

Imaizumi M., Sukchan S. and Palopkern K. 1999. Current situation of water resources and proposal for construction subsurface dam in northeast Thailand. JIRCAS journal, 7: 45-67.

Intramangala S. 2000. Buffalo development in Thailand. Paper presented in the international workshop on development strategies for senior animal scientist, 23–25 July 2001, Khon Kaen Province. Department of Livestock Development, Bangkok. Thailand.

Jamroenprucksa M. 2001. Problems and strategies for agroforestry development in the Korat basin. In: Kam S.P., Hoanh C.T., Trébuil G. and Hardy B. (Eds.) Natural resource management issues in the korat basin of northeast Thailand: An overview, pp. 27-37.

Jayanthi C., Rangasamy A. and Chinnusamy C. 2000. Water budgeting for components in lowland integrated farming systems. Agricultural Journal 87(7/9): 411-414.

Jitsanguan T. 2001. Sustainable agricultural systems for small-scale farmers in Thailand: implications for the environment. Food and Fertilizer Technology Center (FFTC). Taipei, Taiwan.

Johnson R.B. 1997. Examining the validity structure of qualitative research. Education, 118(2): 282–292.

Kaewsong B., Suwannimitara A. and Suraseang S. 2001. Sustainable farming development for small scale farmers in south Khon Kaen - north Korat. Assessment report. Sustainable agriculture charity, Thailand.

Kang B.T. 1993. Changes in soil chemical properties and crop performance with continuous cropping on an Entisol in the humid tropics. In: Mulongoy K. and Merckx R. (Eds.) Soil organic matter dynamics and sustainability of tropical agriculture. J. Wiley & Sons, UK, pp. 297-306.

Kapetsky J.M. and Barg U. 1997. Land quality indicators from the view point of inland fisheries and aquaculture. In: Land quality indicators and their used in sustainable agriculture and rural development. Proceedings of the workshop, 25-26 January 1996. FAO Land and water bulletin 5. FAO, Rome, Italy.

Khon Kaen University (KKU). 1998. Preparation of master plan for national water resource development project (19 north eastern provinces). Khon Kaen, Thailand.

Khon Kaen University (KKU). 2001. New theory: water and land management for agriculture. Study report on agriculture following the king concept. Khon Kaen, Thailand.

Kleinman P.J.A., Pimentel D. and Bryant R.B. 1995. The ecological sustainability of a slash-and-burn agriculture. Agricultural Ecosystem Environment 52: 235-249.

Kobayashi H. 1996. Current approach to soil and water conservation for upland agriculture in Thailand. JARQ, 30: 43-48.

Kohgo Y., Tamrakar S.B. and Tang H.G. 2000. Saturated and unsaturated mechanical properties of typical soils distributed in northeast Thailand. JIRCAS journal, 8: 75-91.

Konboon Y., Wijnhound J.D. and Lefroy R.D.B. 2001. Nutrient management in rainfed lowland rice-based systems in northeast Thailand. In: Kam S.P., Hoanh C.T., Trébuil G. and Hardy B. (Eds.), Natural resource management issues in the Korat basin of northeast Thailand: An overview. IRRI Limited Proceedings No. 7. IRRI, Manila, Philippines, pp. 137-146.

Kongkajan V., Kheoying K. and Prachiyo B. 1990. Extension of firewood plantation for rural people consumption. Khon Kaen University, Khon Kaen, Thailand.

Laar V.A. and Akca A. 1977. Forest mensuration. Cuvillier Verlag, Göttingen.

Lampercht H. and Pancel L. 1993. Silviculture in the tropical natural forests. In: Pancel L. (Ed.) Tropical forestry hand book Vol. 1. Springer-Verlag, Berlin Heidelberg, pp. 727-810.

Land Development Department (LDD). 2003. Soil classification in Thailand. Bangkok, Thailand.

Lauer W. 1993. Climatology. In: Pancel L. (Ed.) Tropical Forestry Handbook. Vol. 1. Springer-Verlag, Berlin Heidelberg. 158-161, 95-164.

Le Bissonnais Y. 1996. Soil characteristics and aggregate stability. In: Agassi M. (Ed.) Soil erosion, conservation, and rehabilitation. Marcel Dekker: New York, USA.

Lightfoot C. 1997. Promoting low external inputs agriculture (LEIA) from LEIA to intensive integrated farming systems. In: Dolberg F. and Petersen P.H. (Eds.) Maximizing the influence of the user: alternatives to the training and visit system. Proceedings of a Workshop April 7-11, 1997, Tune Landboskole, Denmark.

Lightfoot C. and Minnick D.R. 1991. Farmer-first qualitative methods: farmers' diagrams for improving methods of experimental design in integrated farming systems. Journal for Farming Systems Research-Extension, 2(1): 57-69.

Lightfoot C. and Noble R. 1993. A Participatory experiment in sustainable agriculture. Journal for Farming Systems Research and Extension, 4(1): 11-34.

Limpinuntana V. 2001. Physical factors related to agricultural potential and limitations in northeast Thailand. In: Kam S.P., Hoanh C.T., Trébuil G. and Hardy B. (Eds.) Natural resource management issues in the Korat basin of northeast Thailand: An overview. IRRI Limited Proceedings No. 7. IRRI, Manila, Philippines, pp. 3-17.

Limpinuntana V., Trelo-ges V., Vityakon P. and Patanothai A. 2001. Sustainability analysis of existing land-use systems in northeast Thailand. In: Simmons

R.W., Noble A.D. and Lefroy R.D.B. (Eds.) International workshop on nutrient balance for sustainable agricultural production and natural resource management in Southeast Asia, 20-22 February 2001, Thailand.

Linda W., Swatman P. and Castleman T. 2004. Faster, richer, better: rapid appraisal techniques for the study of IS implementation in virtual communities. The qualitative report Vol. 9(1). An on-line journal.

Little D.C. and Edwards P. 2003. Integrated livestock-fish farming systems. FAO, Rome, Italy.

Little L. 2004. Agriculture in northeast Thailand. In: Farmers' world network briefing. Briefing papers. Retrieved from: http://www.fwn.org.uk/pdfs

Low External Input and Sustainable Agriculture (ILEIA). 1996. Integrated farming in the lowland. Leisa magazines (Low External Input Sustainable Agriculture) Vol. 12(2).

Maxwell D. and Wiebe K.D. 1999. Land Tenure and Food Security: Exploring Dynamic Linkages. Dev. Change. 30(4): 825-849.

McGowan Pty.Ltd. 1983. Tung Kula Ronghai. Thai-Australia Project. Land Development Department (LDD), Bangkok, Thailand.

Ministry of Interior (MOI). 2001. Annual statistics of Khon Kaen 2001. Department of Provincial Administration, Bangkok, Thailand.

Moncharoen L., Vearasilp T. and Eswaran H. 1987. Benchmark soils of Thailand. Land Development Department (LDD), Bangkok, Thailand.

Moncharoen P., Vearasilp T. and Eswaran H. 2001. Land resource constraints for sustainable agriculture in Thailand. In: Stott D.E., Mohtar R.H. and Steinhardt G.C. (Eds.) Sustaining the global farm. Selected papers from the 10th International soil conservation organization meeting, May 24-29, 1999, pp. 179-185.

Motulsky M. 1995. Intuitive biostatistics. President, GraphPad Software Publisher: Oxford University Press, New York, USA.

Mullee M.A. 2002. Non-Parametric Statistics. Research and Development Support Unit, University of Southampton, Southampton, U.K.

Mulongoy K. and Akobundu I.O. 1990. Agronomic and economic benefits of N contributed by legumes in live-mulch and alley cropping system. IITA Research No. 4. International Institute of Tropical Agriculture (IITA), UK.

Mundy V. 1997. Sustainable agriculture: only goals, not definitions. Horizon, Vol. 10(2). Virginai's Rural Economic Analysis Prograom (REAP), USA.

National Statistic Office (NSO). 1998. National statistic year 1998, Bangkok, Thailand. Retrieved from http://www.nso.go.th/eng/indicators/eco

National Statistic Office (NSO). 2000. National Statistic year 2000. Bangkok, Thailand. Retrieved from http://www.nso.go.th/pop2000

Nelson D.W. and Sommers L.E. 1996. Total carbon, organic carbon, and organic matter. In: Sparks D.L. (Ed.) Methods of soil analysis. Part 3-Chemical methods. SSSA Book Series, No.5, pp. 961-1010.

Ngambeki D.S., Deuson R.R. and Preckel P.V. 1992. Integrating livestock into farming systems in northern Cameroon. Agr. Syst. 38: 319-338.

Noble A. D. and Randall P.J. 1998. How trees effect soils. A report for the Rural Industries Research and Development Corporation (RIRDC). RIRDC Publication No 98/16. Australia.

Noble A.D. and Ruaysoongnern S. 2002. The role of indigenous technology and science in rehabilitating degraded light textured soils using high activity clays and bioremediation. International Water Management Institute (IWMI) and Khon Kaen University (KKU), Thailand.

Noble A.D., Gillman G.P. and Ruaysoongnern S. 2000. A cation exchange index for assessing degradation of acid soil by further acidification under permanent agriculture in the tropics. European Journal of Soil Sciences, 51: 233-243.

Norman D., Janke R., Freyenberger S., Schurle B. and Kok H. 1997. Defining and implementing sustainable agriculture. Manhattan Kansas: Kansas Statue University, USA.

O'Donnel A.G., Syers J.K., Vichiensanth P., Vityakon P., Adey M.A., Naninpiery P. and Sriboonlue W. 1994. Improving the agricultural productivity of the soils of northeast Thailand through soil organic matter management. In: Syers J.K. and Rimmer D.L. (Eds.), Soil sciences and sustainable and management in the tropics. Wallingford (UK): CAB International and British Society of Soil Science, pp. 192-205.

Office of Agricultural Economics (OAE). 1998. Agricultural statistic of Thailand crop year 1997/1998. Center for Agricultural Statistic, Ministry of agriculture and co-operative, Bangkok, Thailand.

Office of Agricultural Economics (OAE). 2000. Agricultural statistic of Thailand crop year 1999/2000. Center for Agricultural Statistic, Ministry of agriculture and co-operative, Bangkok, Thailand.

Office of Agricultural Economics (OAE). 2002. Agricultural statistics of Thailand. Centre for agricultural information, Ministry of agriculture and co-operative, Bangkok, Thailand.

Okigbo B.N. 1995. Major farming systems of the lowland savanna of SSA and the potential for improvement. In: Proceeding of IITA/FAO workshop, Ibadan, Nigeria.

Onduru D., Gachini G.N. and Nandwa S.M. 1998. Experiences in participatory diagnosis of soil nutrient management in Kenya. Managing Africa's Soils 3.

Organization for Economic Cooperation and Development (OECD). 2001. Multifunctionality: towards and analytical framework. Paris Cedex, France.

Othman K. 2004. Integrated farming system and multifunctionality of agriculture in Malaysia. Acta Hort. (ISHS) 655: 291-296.

Palm C.A. 1995. Contribution of agroforestry trees to nutrient requirements of intercropped plants. Agroforest. Syst. 30: 105-124.

Palmer M.W. 2003. Ordination methods for ecologists. Botany Department, Oklahoma state university. Oklahoma, USA.

Panichapong S. 1988. Soil and water resources in northeast Thailand. In: Pairintra C., Wallapapan K., Parr J.F. and Whitman C.E. (Eds.) Soil, water and crop management systems for rainfed agriculture in northeast Thailand. USDA, Washington, DC, pp. 2-13.

Pant J. 2002. Integrated agriculture-aquaculture systems in the context of socio-economic transformation in NE-Thailand. Ph.D. Thesis. Asian Institute of Technology (AIT), Pathumthani, Thailand.

Paopongsakorn N., Ruhs M. and Tangjitwisuth S. 1998. Problems and outlook for agricultural in Thailand. In: Horiuchi H. (Ed.) Sustainable agricultural development compatible with environmental conservation in Asia. JIRCAS International Symposium Series. Proceedings of the 4th JIRCAS International Symposium, Tsukuba, Japan, pp. 45-61.

Paris T. R. 2002. Crop-animal systems in Asia: socio-economic benefits and impacts on rural livelihoods. Agr. Syst. 71(1/2): 147-168.

Patamatamkul S. 2001. Development and management of water resources in the Korat basin on northeast Thailand. In: Kam S.P., Hoanh C.T, Trébuil G. and Hardy B. (Eds.) Natural resource management issues in the Korat basin of northeast Thailand: An overview, pp. 115-118.

Peden D.G. 1998. Agroecosystem management of improved human health. IDRC, Canada.

Prachaiyo B. 2000. Farmers and forests: A changing phase in northeast Thailand. Tonan Ajia Kenkyu (South Asian Studies), 38(3): 271-446.

Prachaiyo B., Chinthaganan V., Kenvises P. and Srisak P. 1995. A case study: Don Pu Ta Forest, Ban Kok Kreau Village, Kalasin. The community forest study project, Regional forest Division, Khon Kaen, Royal Forest Department (RFD), Thailand.

Praphan N. 2001. Resilient of indigenous knowledge, fight to world crisis. Isan alternative framings network, Uboratchathani, Thailand.

Preisinger H. 2001. Paper prepared for interdisciplinary course for doctoral program, Center for Development Research, Bonn, Germany.

Price T. 2000. Cultivation our futures. Final paper. OECD Publications No. 2. Organisation for Economic Co-operation and Development.

Radhamani S., Balasubramanian A., Ramamoorthy K. and Geethalakshmi V. 2003. Sustainable integrated farming systems for dry lands: a review. Agricultural Reviews, 24(3): 204-210.

Rangasamy A., Venkitaswamy R., Purushothaman S. and Palaniappan S. 1996. Rice-poultry-fish-mushroom integrated farming systems for lowlands of Tamil Nadu. Indian J. Agron. 41(3): 344-348.

Ratanawaraha C., Daladom A. and Pisone U. 1989. Rainfed agriculture in Thailand. In: Rainfed agriculture in Asia and the Pacific. Asian Development Bank (ADB), Manila, Philippines.

Reijntjes C., Haverkort B. and Waters-Bayer A. 1992. Farming for the future: an introduction to low-external-input and sustainable agriculture. Macmillan, London, UK.

Royal Forest Department (RFD). 2002. Preliminary forest land use assessment in 2000. In: Forestry statistical Data 2002. Bangkok, Thailand.

Royal Irrigation Department (RID). 1995. Annual report year 1994. Bangkok, Thailand.

Ruaysoongnoen S. 2002. Biography of Mr. Boontem Chaila. 2. Unpublished.

Ruaysoongnoen S. and Suphanchaimart N. 2001. Land-use patterns and agricultural production systems with emphasis on changes driven by economic forces and market integration. In: Kam S.P., Hoanh C.T., Trébuil G. and Hardy B. (Eds.) Natural resource management issues in the Korat basin of northeast Thailand: An overview, pp. 67-77.

Saisoong C. 1989. Crop-Livestock integration in Northeast Thailand: problems and prospects. In: Grasslands and forage production in Southeast Asia. Proceeding of first meeting of regional working group on grazing and feed resources of Southeast Asia, 27 Feb.-3 March 1989, Serdang, Malaysia, pp 123–127.

Schiere J.B., Ibrahim M.N.M. and van Keulen H. 2002. The role of livestock for sustainability in mixed farming: criteria and scenario studies under varying resource allocation. Agr. Ecosyst. Environ. 90(2): 139-153.

Senanarong N. 2002. Watershed Management for minimizing land degradation in northeast Thailand. In: Improving management of natural resources for sustainable rainfed agriculture. Proceedings of the training workshop on on-farm participatory research methodology, Khon Kaen, Thailand, 26-31 July 2001.

Shelton H.M. and Phaikaew C. 2001. Mixed crop-livestock farming: a review of traditional technologies based on literature and field experience. FAO animal production and health papers 152. FAO, Rome, Italy.

Smitinand T., Kanjunt C., Oberhauser U. and Ramsiri B. 1994. Study on forest structure of different stages of succession on old farm plots of mixed deciduous and hill evergreen forest. Namsa Research Paper. Royal Forest Department (RFD), Bangkok, Thailand.

Smyth A.J. and Dumanski J. 1993. FESLM: an international framework for evaluating sustainable land management. World Soil Resource Reports 73. FAO, Rome, Italy.

Sombroek W.G. and Sims D. 1995. Planning for sustainable use of land resources: towards a new approach. FAO, Rome, Italy.

Srisuk K. 1994. Genetic characteristics of the ground water regime in the Khon kaen drainage basin, northeast Thailand. Ph.D. Thesis. University of Alberta, Canada.

Sukwong S. 1974. Deciduous forest ecosystem in Thailand. A paper presented at the UNESCO seminar on deciduous forest ecosystem, Nov. 25-30, 1973. Nakhon Ratchashima, Thailand.

Sunthornhao P. 1999. Supply of eucalyptus material under private sector in Thailand. Master Thesis. Graduate School, Kasetsart University, Bangkok, Thailand.

Sustainable agriculture charity. 2002. Abstract of the pilot project for sustainable agricultural for small-scale farmers. Sustainable agriculture charity (Thailand), Nonthaburi, Thailand.

Swanson B.E., Bentz R.P. and Sofranko A.J. 1997. Improving agricultural extension. A reference manual. FAO, Rome, Italy.

Syers J.K. and Craswell E.T. 1995. Role of soil organic matter in sustainable agricultural. In: Lefroy R.D.B., Blair G. and Craswell E.T. (Eds.) Soil organic matter management for sustainable agriculture. ACIAR Proceedings 56, pp. 7-14.

Tabtimorn P. 1996. Integrated farming following the new theory concept in the development study center Huai-Saai. The 11th seminar on farming system: farming system for farmer, environment and sustainability. Department of Agriculture, Thailand.

Tanaka H. 1997. Hydrology programs and related activities of the Mekong River Commission. Rural Environ. Eng. 33.

Thamrongwarangkul A. 2000. Indigenous philosopher in Isarn. Newsletter, 3(4). Khon Kaen, Thailand.

Thamrongwarangkul A. 2001. For our Thailand. Annual report on sustainable community development for good livelihood and environment project, Khon Kaen, Thailand.

The International Center for Living Aquatic Resources Management (ICLARM), IIRR. 2001. Integrated agriculture-aquaculture: a primer. FAO fisheries technical paper No. 407. FAO, Rome, Italy.

Theng B.K.G. 1991. Soil science in the tropics-the next 75 years. Soil Sci.. 151(1): 76-90.

Tokrishna R. 1992. Integrated livestock-fish farming systems in Thailand. In: Mukherjee T.K., Moi P.S., Panandam J.M. and Yang Y.S. (Eds.) Proceedings of the FAO/IPT Workshop on Integrated Livestock-Fish Production Systems, 16–20 December 1991. Institute of Advanced Studies, University of Malaya, Kuala Lumpur, Malaysia.

Tuckson M. 1983. The hydrogeology of an area of saline land, northeast Thailand. McGowan International Technical Report, TKR Project, Khon Kaen, Thailand.

van Brakel M.L., Morales E.J., Turongruang D. and Little D.C. 2003. Livelihood improving functions of pond based integrated agriculture aquaculture systems. MRC Fisheries Programme (FP). Institute of Aquaculture, University of Stirling, Scotland, UK.

Viyakorn P. 2001. The role of trees in countering land degradation in cultivated fields in Northeast Thailand. Southeast Asia Studies. 39(3): 398-416.

Vorasoot N., Jintrawet A., Limpinuntana V., Charoenwatana T. and Virmani S.M. 1985. Rainfall analysis for the northeast Thailand. Faculty of Agriculture, Khon Kaen Univerisity, Khon Kaen, Thailand.

Wattenbach H. and Friedrich K.H. 1996. Farming systems indicators for sustainable natural resource management. In: Land quality indicators and their used in sustainable agriculture and rural development. Proceedings of the workshop, 25-26 January 1996. FAO Land and water bulletin 5. FAO, Rome, Italy, pp 105-116.

Weyerhaeuser H. and Tennigkeit T. 2000. Forest inventory and monitoring manual. Forest Resource Department/ICRAF, Chiang Mai, Thailand and Silvicultural Institute, Freiburge Univerisity, Germany.

Whitbread A., Blair G., Konboon Y., Lefroy R. and Naklang K. 2002. Managing crop residues, fertilizers and leaf litters to improve soil C, nutrient balances, and the grain yield of rice and wheat cropping systems in Thailand and Australia. Agr. Ecosyst. Environ. 100(2/3): 251-263.

Wijnhoud J.D., Konboon Y. and Lefroy R.D.B. 2001. Accounting for environmental and socioeconomic sustainability in northeast Thailand: Towards decision support for farmers and extension workers. In: Simmons R.W., Noble A.D. and Lefroy R.D.B. (Eds.) International Workshop on nutrient balance for sustainable agricultural production and natural resource management in Southeast Asia, 20-22 February 2001, Thailand.

Willett I.R. 1995. Role of organic matter in controlling chemical properties and fertility of sandy soil used for lowland rice in northeast Thailand. In: R.D.B. Lefroy, Blair G. and Craswell E.T. (Eds.) Soil organic matter management for sustainable agriculture. ACIAR Proceedings 56, pp. 109-114.

Wonprasaid S., Naklang K., Khonthasuvon S., Mepetch S., Hemthanon B., Tippayaruk S. and Lefroy R. 1995. Organic residue management in lowland rice in northeast Thailand. In: R.D.B. Lefroy, Blair G. and Craswell E.T. (Eds.) Soil organic matter management for sustainable agriculture. ACIAR Proceedings 56, pp. 98-103.

Wynen, E. 2002. Multifunctionality and agriculture-why the fuss. Current Issues Brief No. 13. Commonwealth of Australia, Australia.

8 APPENDICES

Table 8.1: Species found on all farms and in the natural area

Latin name	Production system			Family
	IFS	CFS	NA	
Abutilon hirtum Sweet	X			Malvaceae
Acacia siamensis Craib		X	X	Mimosaceae
Achyranthus aspera Linn.	X			Amaranthaceae
Achyranthus bidentata Bl.	X			Amaranthaceae
Actephila collinsae Hunter	X			Euphorbiaceae
Adenosma hirsutum Kurz	X			Scrophulariaceae
Aganonerion polymorphum Pierre ex Spire	X		X	Apocynaceae
Aganosma marginata G. Don			X	Apocynaceae
Ageratum conyzoides Linn.	X			Compositae
Aglaonema cochinchinense Engler			X	Araceae
Albizia chinensis Merr.	X			Mimosaceae
Albizia lebbeck Benth.	X	X		Mimosaceae
Albizia lebbeckoides Benth.	X	X		Mimosaceae
Albizia myriophylla Benth.			X	Mimosaceae
Albizia odoratissima Benth.	X		X	Mimosaceae
Albizia procera Benth.	X			Mimosaceae
Allium cepa Linn.	X	X		Alliaceae
Allium sativum Linn.	X	X		Alliaceae
Anaphalis margaritacea Benth.	X			Bromeliaceae
Aniseia martinicensis Choisy	X			Convolvulaceae
Annona squamosa Linn.	X			Annonaceae
Anthocephalus chinensis Rich. ex Walp.			X	Rubiaceae
Antidesma bunius Spreng.			X	Stilaginaceae
Aporusa villosa Baill.			X	Euphorbiaceae
Arachis hypogaea Linn.	X	X		Papilionaceae
Archidendron conspicuum Nielsen	X			Mimosaceae
Ardisia polycephala Wall.			X	Myrsinaceae
Artocarpus heterophyllus Lamk.	X			Moraceae
Aster cordifolius Linn.	X			Compositae
Azadirachta indica Juss. var. siamensis	X		X	Meliaceae
Azima sarmentosa Benth. & Hook.	X			Salvadoraceae
Bamboosa spp1	X			Gramineae
Bamboosa spp2	X			Gramineae
Bambusa arundinacea Willd.	X			Gramineae
Bambusa glaucescens Sieb.			X	Gramineae
Barringtonia acutangula Gaertn. subsp.	X			Barringtoniaceae

Table 8.1: continued

Latin name	Production system			Family
	IFS	CFS	NA	
Basella alba Linn.	X			Basellaceae
Benincasa hispida Cogn.	X			Cucurbitaceae
Biophytum sensitivum DC.	X			Oxalidaceae
Blumea hymenophylla DC.	X			Compositae
Boea glabriflora Barnett	X	X		Gesneriaceae
Bombax ceiba Linn.	X			Bombacaceae
Brassica alboglabra Bailey	X	X		Cruciferae
Brassica pekinensis Rupr. var. laxa Tsen	X	X		Cruciferae
Buchanania latifolia Roxb.	X		X	Anacardiaceae
Canarium bengalense Roxb.	X		X	Burseraceae
Capparis micracantha DC.		X	X	Capparidaceae
Capsicum frutescens Linn.	X	X		Solanaceae
Cardiospermum helicacabum Linn.	X			Sapindaceae
Carica papaya Linn.	X			Caricaceae
Carissa cochinchinensis Pierre	X	X	X	Apocynaceae
Cassia fistula Linn.	X	X	X	Caesalpiniaceae
Cassia garrettiana Craib	X		X	Caesalpiniaceae
Cassia siamea Britt.	X	X		Caesalpiniaceae
Ceiba pentandra Gaertn.	X			Bombacaceae
Centellia asiatica (Linn.) Utban	X			Umbelliferae
Chrozophora rottleri Juss. ex Spreng.	X			Euphorbiaceae
Cinnamomum glaucescens Drury	X			Lauraceae
Citrus aurantium Linn.	X	X		Rubiaceae
Citrus hystrix DC.	X			Rutaceae
Citrus maxima Merr.	X			Rutaceae
Citrus medica Linn.	X			Rutaceae
Citrus spp1			X	Rutaceae
Citrus spp2	X	X		Rutaceae
Clitoria macrophylla Wall.	X			Papilionaceae
Coccinia grandis Voigt	X			Cucurbitaceae
Cocos nucifera Linn.	X			Palmae
Colocasia esculenta Schott	X	X		Araceae
Combretum quadrangulare Kurz	X			Combretaceae
Coriandrum sativum Linn.	X			Umbelliferae
Cratoxylum formosum Byer		X	X	Guttiferae
Crinum wattii Bak.	X			Amaryllidaceae
Crotalaria albida Heyne	X			Papilionaceae
Cryptolepsis buchanani Roem. & Schult.	X			Periplocaceae
Cucumis melo Linn.	X	X		Cucurbitaceae
Cucurbita moschata Decne.	X	X		Cucurbitaceae

Table 8.1: continued

Latin name	Production system			Family
	IFS	CFS	NA	
Cymbopogon citratus Stapf	X	X		Gramineae
Dalbergia oliveri Gamble		X	X	Papilionaceae
Dalbergia paniculata Roxb.		X	X	Papilionaceae
Derris scandens Benth.	X			Papilionaceae
Desmodium auricomum Grah. ex Benth.	X			Papilionaceae
Desmodium gangeticum DC.	X		X	Papilionaceae
Dicliptera chinensis Nees	X			Acanthaceae
Dillenia obovata Hoogl.			X	Dilleniaceae
Diospyros castanea (Craib) Fletcher	X			Ebenaceae
Diospyros mollis Griff	X	X	X	Ebenaceae
Diospyros montana Roxb.		X	X	Ebenaceae
Diospyros rhodocalyx Kurz	X	X	X	Ebenaceae
Dipterocarpus alatus Roxb.	X			Dipterocarpaceae
Dolichos lablab Linn.	X			Papilionaceae
Eclipta prostrata L.	X			Compositae
Eucalyptus citriodora Hook.	X		X	Myrtaceae
Eupatorium odoratum Linn.	X			Compositae
Euphorbia hypericifolia Linn.	X			Euphorbiaceae
Flacourtia indica Merr.	X	X	X	Flacourtiaceae
Flacourtia rukam Zoll. & Mor.		X	X	Flacourtiaceae
Gardenia erythroclada Kurz		X	X	Rubiaceae
Gardenia spp1			X	Rubiaceae
Gardenia spp2			X	Rubiaceae
Gigantochloa albociliata Munro	X			Gramineae
Glinus oppositifolius A. DC.	X			Aizoaceae
Glochidion sphaerogynum Kurz			X	Euphorbiaceae
Gomphia serrata Kanis		X	X	Ochnaceae
Gomphrena celosioides Mart.	X			Amaranthaceae
Gomphrena globosa Linn.	X			Amaranthaceae
Gordonia dalglieshiana Craib	X			Theaceae
Gymnopetalum monoicum Gagnep.	X			Cucurbitaceae
Hedyotis corymbosa Lamk.	X			Rubiaceae
Heliotropium indicum R. Br.	X			Boraginaceae
Holarrhena densiflora Ridl.	X		X	Apocynaceae
Hopea odoratisima Roxb.	X			Dipterocarpaceae
Horsfieldia irya Warb.			X	Myristicaceae
Horsfieldia macrocoma Warb. var. canario		X	X	Myristicaceae
Hydrocera triflora Wight. & Arn.	X			Balsaminaceae
Hylocereus guatemalensis	X			Cactaceae
Imperata cylindrica Beauv.	X		X	Gramineae

Table 8.1: continued

Latin name	Production system			Family
	IFS	CFS	NA	
Ipomoea aquatica Forsk.	X			Convolvulaceae
Ipomoea batatas Lamk.	X	X		Convolvulaceae
Ipomoea pestigridis Linn.	X			Convolvulaceae
Ipomoea purpurea Roth	X		X	Convolvulaceae
Irvingia malayana Oliv. ex A. Benn.	X		X	Ixonanthaceae
Ixora cibdela Craib			X	Rubiaceae
Jatropha curcas Linn.	X			Euphorbiaceae
Kopsia jasminiflora Pitard	X	X		Apocynaceae
Lactuca sativa Linn.	X			Compositae
Laggera pterodonta Sch. Bip. ex Oliv.	X			Compositae
Languas galanga Sw.	X	X		Zingiberaceae
Lantana salvifolia Jacq.			X	Verbenaceae
Leucaena leucocephala de Wit	X			Mimosaceae
Linociera parkinsonii Hutch.	X			Oleaceae
Lithocarpus wallichianus Rehd.			X	Fagaceae
Litsea glutinosa C.B. Robinson	X	X	X	Lauraceae
Ludwigia adscendens (L.) Hara	X			Onagraceae
Lycopersicon esculentum Mill.	X	X		Solanaceae
Mangifera indica Linn.	X			Anacardiaceae
Mangifera longipetiolata King	X			Anacardiaceae
Markhamia stipulata Seem.			X	Bignoniaceae
Marumia dimorpha Craib			X	Melastomataceae
Memecylon geddesianum Craib			X	Memecylaceae
Mentha arvensis Linn.	X	X		Labiatae
Micromelum minutum Wight & Arn.			X	Rutaceae
Millettia pendula Benth.	X			Papilionaceae
Millingtonia hortensis Linn. f.	X	X	X	Bignoniaceae
Mitragyna brunonis Craib	X		X	Rubiaceae
Momordica charantia L.	X			Cucurbitaceae
Morinda tomentosa Heyne ex Roth		X	X	Rubiaceae
Morus indica Linn.	X			Moraceae
Muntingia calabura Linn.	X	X		Elaeocarpaceae
Musa sapientum Linn.	X			Musaceae
Musa spp1	X			Musaceae
Nephelium hypoleucum Kurz		X	X	Sapindaceae
Ocimum basilicum Linn.	X	X		Labiatae
Ocimum sanctum Linn.	X	X		Labiatae
Oenanthe stolonifera Wall.	X	X		Umbelliferae
Olax scandens Roxb.	X		X	Olacaceae
Oroxylum indicum Vent.	X	X		Bignoniaceae
Oryza sativa Linn. Var1	X	X		Gramineae

Table 8.1: continued

Latin name	Production system			Family
	IFS	CFS	NA	
Oryza sativa Linn. Var2	X	X		Gramineae
Oryza sative Linn. Var3	X	X		Gramineae
Passiflora feolida Linn.	X		X	Papilionaceae
Pentace burmanica Kurz		X	X	Tiliaceae
Petroselinum crispum Linn.	X	X		Umbelliferae
Phaseolus atropurpureus DC.	X			Papilionaceae
Phaseolus lathyroides Linn. f.	X			Papilionaceae
Phyllanthus emblica Linn.			X	Euphorbiaceae
Phyllanthus reticulatus Poir.	X			Euphorbiaceae
Phyllanthus urinaria Linn.	X			Euphorbiaceae
Physalis minima Linn.	X			Solanaceae
Piper nigrum Linn.	X			Piperaceae
Pithecellobium dulce (Roxb.) Benth	X			Mimosaceae
Polyalthia evecta Finet & Gagnep.			X	Annonaceae
Polyalthia viridis Craib		X	X	Annonaceae
Pothos macrocephalus Scort.	X		X	Araceae
Psidium guajava Linn.	X			Myrtaceae
Pterocarpus macrocarpus Kurz	X	X	X	Papilionaceae
Randia wittii Craib		X	X	Rubiaceae
Saccharum officinarum Linn.	X			Gramineae
Samanea saman Merr.	X			Mimosaceae
Schismatoglottis calyptrata Zoll. & Mor.	X			Araceae
Schleichera oleosa Merr.	X		X	Sapindaceae
Sesbania grandiflora Desv.	X	X		Papilionaceae
Shorea obtusa Wall.		X	X	Dipterocarpaceae
Shorea siamensis Miq.			X	Dipterocarpaceae
Sindora siamensis Teijsm. ex Miq.		X	X	Caesalpiniaceae
Solanum sanitwongsei Craib	X			Solanaceae
Solanum torvum Sw.	X			Solanaceae
Spathiostemon moniliformis Airy Shaw			X	Euphorbiaceae
Sphaeranthus africanus Linn.	X			Compositae
Spilanthes acmella Wall.ex DC.	X			Compositae
Stachytarpheta indica Vahl	X			Verbenaceae
Streblus asper Lour.	X	X	X	Moraceae
Streptolirion volubile Edgew.	X			Commelinaceae
Strychnos minor Dennst.			X	Strychnaceae
Synedrella nodiflora (L.) Gaertn.	X			Compositae
Syzygium cumini Druce	X	X		Myrtaceae
Tamarindus indica Linn.	X			Caesalpiniaceae
Tectona grandis Linn. f.	X			Labiatae
Telosma minor Craib	X			Asclepiadaceae

Table 8.1: continued

Latin name	Production system			Family
	IFS	CFS	NA	
Terminalia alata Heyne ex Roth		X	X	Combretaceae
Terminalia calamansanai Rolfe	X			Combretaceae
Terminalia catappa Linn.	X			Combretaceae
Terminalia pedicellata Natakorn		X	X	Combretaceae
Themeda triandra Forsk.	X		X	Gramineae
Thunbergia similis Craib	X			Thunbergiaceae
Tiliacora triandra Diels	X		X	Menispermaceae
Tinospora cordifolia Miers	X			Menispermaceae
Triumfetta rhomboidea Jacq.	X			Tiliaceae
Urena lobata Linn.	X			Malvaceae
Vernonia cinerea (L.) Less	X			Compositae
Vigna sinensis Savi ex Hassk.	X			Papilionaceae
Vitex peduncularis Wall. ex Schauer			X	Verbenaceae
Walsura trichostemon Miq.			X	Meliaceae
Zea mays Linn.	X			Gramineae
Zingiber officinale Roscoe	X			Zingiberaceae
Themeda triandra Forsk.	X	X		Flacourtiaceae
unidentified sp10	X			Olacaceae
unidentified spp1	X		X	Rubiaceae
unidentified spp2	X			Compositae
unidentified spp3	X			Papilionaceae
unidentified spp4	X			Apocynaceae
unidentified spp5	X			Rubiaceae
unidentified spp6	X			Compositae
unidentified spp7	X			Papilionaceae
unidentified spp8	X			Apocynaceae
unidentified spp9	X			Compositae

Data collected 2002-2003. IFS integrated farming system. CFS commercial farming system. NA adjacent natural area

Table 8.2: Total tree stems by growth habit on all farms and in the natural area

Growth habit	Integrated farming system	Commercial farming system	Adjacent natural area
BF-broad leaved forb	110	-	-
GR-graminoid, rhizomes	78	1	96
GS-graminoid, stolons	20	-	-
HR-herb, rhizomes	16	6	-
RT-rosette tree	316	11	1054
SC-spread climber	699	3	262
SH-shrub	1371	3	834
ST-sparsely ramified	896	6	214
UH-upright herb	1371	12	834

Table 8.3: Stem density of tree species in 18 stands

Latin name	Density (stem per 0.08 ha)																	
	IFS								CFS								NA	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Acacia siamensis	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	.	.	.
Aganonerion polymorphum	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Aganosma marginata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9
Albizia chinensis	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
A. lebbeck	1	1	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
A. lebbeckoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.
A. myriophylla	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11
A. procera	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Annona squamosa	.	1	.	.	.	11	.	.	.	.	.	.	.	.	.	.	.	.
Anthocephalus chinensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Aporusa villosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	4
Ardisia polycephala	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Artocarpus heterophyllus	.	1	.	.	.	3	9	2	.	.	.	.	.	.	.	.	.	.
Azadirachta indica	.	28	3	.	23	1	.	3	.	.	.	.	.	.	.	.	.	.
Bamboosa spp1	.	.	.	.	.	6	.	.	.	.	.	.	.	.	.	.	.	.
B. spp2	.	.	.	.	2	2	.	.	.	.	.	.	.	.	.	.	.	.
B. arundinacea	.	.	.	.	.	13	.	.	.	.	.	.	.	.	.	.	.	.
Bombax ceiba	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Buchanania latifolia	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
Canarium bengalense	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	5	.
Carica papaya	11	13	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carissa cochinchinensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	8
Cassia fistula	.	1	.	.	.	.	.	.	.	.	.	.	.	1	1	.	1	.
Cassia garrettiana	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
C. siamea	5	.	.	.	.	.	.	.	1	0	.	.	.	.	.	.	.	.
Ceiba pentandra	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Citrus aurantium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.
C. hystrix	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
C. maxima	.	.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.
C. spp2	.	.	.	.	.	.	.	5	1	.	.	.	.	.	.	.	.	.
Cocos nucifera	.	.	1	.	.	1	.	12	.	.	.	.	.	.	.	.	.	.
Cratoxylum formosum	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	1	.

Table 8.3: continued

Latin name	Density (stem per 0.08 ha)																	
	IFS								CFS								NA	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Dalbergia paniculata	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.
Desmodium gangeticum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	14
Dicliptera chinensis	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Diospyros castanea	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Diospyros mollis	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	3
D. Montana	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	1	.
D. rhodocalyx	.	.	.	14	.	.	.	.	.	.	.	.	.	.	.	.	2	.
Dipterocarpus alatus	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Eucalyptus citriodora	.	.	.	.	2	11	.	.	.	.	.	.	.	.	.	.	.	6
Flacourtia indica	2	.	.	.	.	.	.	.	.	.	.	1	1	2	.	1	4	8
F. rukam	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Gardenia erythroclada	.	.	.	.	.	.	.	.	0	.	.	.	.	.	.	.	3	.
G. spp1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
G. spp2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Horsfieldia irya	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Irvingia malayana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.
Jatropha curcas	.	.	.	.	14	.	.	.	.	.	.	.	.	.	.	.	.	.
Kopsia jasminiflora	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.
Lantana salvifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.
Leucaena leucocephala	14	18	2	.	49	6	.	.	.	.	.	.	.	.	.	.	.	.
Lithocarpus wallichianus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Litsea glutinosa	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	23	2
Mangifera indica	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
M. longipetiolata	3	16	.	.	.	7	.	14	.	.	.	.	.	.	.	.	.	.
Markhamia stipulata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Marumia dimorpha	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
Memecylon geddesianum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	14	.
Millettia pendula	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Millingtonia hortensis	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
Mitragyna brunonis	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	7	24

Table 8.3: continued

Latin name	Density (stem per 0.08 ha)																	
	IFS								CFS								NA	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Morinda tomentosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	3	.
Morus indica	.	4	.	.	.	18	.	.	.	.	.	.	.	.	.	.	.	.
Muntingia calabura	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.
Musa sapientum	.	7	.	.	.	12	.	70	.	.	.	.	.	.	.	.	.	.
M. spp1	.	.	.	10	.	.	.	20	.	.	.	.	.	.	.	.	.	.
Nephelium hypoleucum	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	2
Oroxylum indicum	.	1	.	.	1	.	.	.	1	1	.	.	.	.	.	.	.	.
Passiflora feolida	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	39
Pentace burmanica	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Pithecellobium dulce	.	.	.	.	6	.	.	8	.	.	.	.	.	.	.	.	.	.
Polyalthia viridis	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Pothos macrocephalus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Psidium guajava	9	2	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.
Pterocarpus macrocarpus	.	11	7	.	.	1	.	.	.	.	.	1	.	1	.	.	14	5
Randia wittii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	3
Saccharum officinarum	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.
Samanea saman	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Schleichera oleosa	3	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sesbania grandiflora	.	.	2	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Shorea obtuse	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	2	31
S. siamensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Sindora siamensis	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	2	4
Solanum torvum	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.
Streblus asper	.	.	.	5	12	.	3	.	.	1	.	.	.	.	.	.	.	.
Syzygium cumini	1	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Tamarindus indica	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tectona grandis	.	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Terminalia alata	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	4
T. calamansanai	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Terminalia pedicellata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	7	4

Table 8.3: continued

Latin name	Density (stem per 0.08 ha)																	
	IFS								CFS								NA	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Vitex peduncularis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Walsura trichostemon	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Themeda triandra	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.
unidentified spp7	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.

Data collected 2002-2003. IFS integrated farming system. CFS commercial farming system. NA adjacent natural area.

Table 8.4: Important Value Index of trees on integrated farming system

Latin name	Family	RF (%)	RDo (%)	RA (%)	IVI (%)
Azadirachta indica	Meliaceae	6.67	23.88	9.75	40.30
Musa sapientum	Musaceae	7.11	10.71	16.64	34.46
Pterocarpus macrocarpus	Papilionaceae	4.44	20.78	6.09	31.31
Leucaena leucocephala	Mimosaceae	5.78	7.60	14.96	28.34
Cocos nucifera	Palmae	4.44	14.90	2.35	21.70
Mangifera longipetiolata	Anacardiaceae	6.22	4.35	6.72	17.29
Tamarindus indica	Caesalpiniaceae	0.44	16.22	0.17	16.83
Carica papaya	Caricaceae	4.89	1.92	4.03	10.84
Musa spp1	Musaceae	4.89	2.55	3.36	10.80
Mitragyna brunonis	Rubiaceae	0.44	0.00	9.94	10.38
Morus indica	Moraceae	3.56	0.20	3.70	7.45
Pithecellobium dulce	Mimosaceae	3.56	1.30	2.35	7.20
Flacourtia indica	Flacourtiaceae	0.89	2.15	3.85	6.88
Eucalyptus citriodora	Myrtaceae	2.22	2.13	1.92	6.28
Artocarpus heterophyllus	Moraceae	3.11	0.48	2.52	6.11
Tectona grandis	Labiatae	2.67	1.94	1.34	5.95
Annona squamosa	Annonaceae	2.67	0.09	2.02	4.77
Jatropha curcas	Euphorbiaceae	2.22	0.03	2.35	4.61
Solanum torvum	Solanaceae	2.67	0.09	1.85	4.60
Citrus spp2	Rutaceae	1.33	1.03	2.22	4.58
Streblus asper	Moraceae	2.22	0.03	2.22	4.47
Psidium guajava	Myrtaceae	2.22	0.19	2.02	4.43
Cassia siamea	Caesalpiniaceae	1.78	0.09	2.22	4.09
Diospyros rhodocalyx	Ebenaceae	1.33	0.12	2.35	3.81
Cassia garrettiana	Caesalpiniaceae	0.44	3.13	0.17	3.75
Bambusa arundinacea	Gramineae	1.33	0.04	2.18	3.55
Albizia lebbeck	Mimosaceae	0.44	0.85	2.22	3.52
Schleichera oleosa	Sapindaceae	1.78	0.65	0.84	3.27
Bamboosa spp1	Gramineae	2.22	0.03	1.01	3.26
Muntingia calabura	Elaeocarpaceae	0.44	0.44	2.22	3.11
Cassia fistula	Caesalpiniaceae	0.44	1.90	0.32	2.67
Syzygium cumini	Myrtaceae	0.44	0.00	2.22	2.67
Bombax ceiba	Bombacaceae	0.44	1.37	0.17	1.99
Aganonerion polymorphum	Apocynaceae	1.33	0.12	0.50	1.96
Sesbania grandiflora	Papilionaceae	0.89	0.67	0.34	1.90
Oroxylum indicum	Bignoniaceae	0.89	0.54	0.34	1.77
Dicliptera chinensis	Acanthaceae	0.44	1.11	0.17	1.72
Citrus maxima	Rutaceae	0.89	0.02	0.67	1.58
Bamboosa spp2	Gramineae	0.89	0.02	0.67	1.58

Table 8.4 continued

Latin name	Family	RF (%)	RDo (%)	RA (%)	IVI (%)
Albizia chinensis	Mimosaceae	0.89	0.10	0.50	1.49
Terminalia calamansanai	Combretaceae	0.89	0.02	0.50	1.41
Diospyros castanea	Ebenaceae	0.89	0.11	0.34	1.33
Citrus hystrix	Rutaceae	0.89	0.08	0.34	1.30
Samanea saman	Mimosaceae	0.89	0.08	0.34	1.30
Ceiba pentandra	Bombacaceae	0.89	0.08	0.34	1.30
unidentified spp7	Papilionaceae	0.89	0.00	0.34	1.23
Albizia procera	Mimosaceae	0.44	0.61	0.17	1.22
Buchanania latifolia	Anacardiaceae	0.44	0.31	0.17	0.93
Canarium bengalense	Burseraceae	0.44	0.26	0.17	0.87
Millettia pendula	Papilionaceae	0.44	0.10	0.17	0.72
Mangifera indica	Anacardiaceae	0.44	0.06	0.17	0.67
Dipterocarpus alatus	Dipterocarpaceae	0.44	0.00	0.17	0.62

Data collected on year 2002-2003. RF Relative Frequency. RDo Relative Dominance. RA Relative Abundance. IVI Important Value Index.

Table 8.5: Important Value Index of trees on comercial farming system

Latin mame	Family	RF (%)	RDo (%)	RA (%)	IVI (%)
Flacourtia indica	Flacourtiaceae	9.30	36.54	0.34	46.18
Shorea obtusa	Dipterocarpaceae	2.33	24.04	10.58	36.94
Litsea glutinosa	Lauraceae	2.33	13.39	8.01	23.73
Pterocarpus macrocarpus	Papilionaceae	4.65	12.87	3.19	20.71
Acacia siamensis	Mimosaceae	6.98	1.45	6.67	15.09
Terminalia alata	Combretaceae	2.33	7.47	1.60	11.39
Dalbergia paniculata	Papilionaceae	4.65	1.72	4.44	10.82
Oroxylum indicum	Bignoniaceae	4.65	1.34	4.44	10.44
themeda triandra	Flacourtiaceae	4.65	1.11	4.44	10.20
Cratoxylum formosum	Guttiferae	4.65	0.21	4.44	9.31
Morinda tomentosa	Rubiaceae	2.33	1.53	2.22	6.07
Pentace burmanica	Tiliaceae	2.33	1.11	2.22	5.66
Sindora siamensis	Caesalpiniaceae	2.33	1.08	2.22	5.63
Flacourtia rukam	Flacourtiaceae	2.33	1.03	2.22	5.58
Diospyros montana	Ebenaceae	4.65	0.46	0.32	5.44
Polyalthia viridis	Annonaceae	2.33	0.85	2.22	5.40
Millingtonia hortensis	Bignoniaceae	2.33	0.80	2.22	5.35
Albizia lebbeckoides	Mimosaceae	2.33	0.78	2.22	5.33
Citrus aurantium	Rubiaceae	2.33	0.71	2.22	5.26
Kopsia jasminiflora	Apocynaceae	2.33	0.46	2.22	5.00
Streblus asper	Moraceae	2.33	0.57	2.02	4.91
Cassia siamea	Caesalpiniaceae	2.33	1.68	0.84	4.85
Cassia fistula	Caesalpiniaceae	4.65	0.02	0.17	4.83
Nephelium hypoleucum	Sapindaceae	2.33	0.13	2.22	4.68
Sesbania grandiflora	Papilionaceae	2.33	0.04	2.22	4.59
Randia wittii	Rubiaceae	2.33	0.61	0.96	3.90
Diospyros mollis	Ebenaceae	2.33	0.00	1.28	3.61
Albizia lebbeck	Mimosaceae	2.33	0.66	0.34	3.32
Syzygium cumini	Myrtaceae	2.33	0.80	0.17	3.30
Citrus spp2	Rutaceae	2.33	0.01	0.84	3.17
Muntingia calabura	Elaeocarpaceae	2.33	0.11	0.17	2.60
Gardenia erythroclada	Rubiaceae	0.00	0.71	0.96	1.68

Data collected on year 2002-2003. RF Relative Frequency. RDo Relative Dominance. RA Relative Abundance. IVI Important Value Index.

Table 8.6: Important Value Index of trees in the natural area

Latin name	Family	RF (%)	RDo (%)	RA (%)	IVI (%)
Litsea glutinosa	Lauraceae	6.55	28.53	4.44	39.52
Passiflora feolida	Papilionaceae	7.74	1.26	12.50	21.49
Flacourtia indica	Flacourtiaceae	4.17	0.08	11.11	15.35
Pterocarpus macrocarpus	Papilionaceae	5.36	4.48	4.44	14.28
Mitragyna brunonis	Rubiaceae	7.14	3.63	0.17	10.94
Shorea obtusa	Dipterocarpaceae	7.74	0.88	2.22	10.84
Albizia myriophylla	Mimosaceae	4.76	1.17	3.53	9.46
Aporusa villosa	Euphorbiaceae	4.17	2.27	2.88	9.32
Terminalia pedicellata	Combretaceae	4.17	1.35	3.53	9.04
Memecylon geddesianum	Memecylaceae	3.57	0.25	4.49	8.31
Desmodium gangeticum	Papilionaceae	2.98	0.05	4.49	7.52
Diospyros montana	Ebenaceae	0.60	1.57	4.44	6.61
Eucalyptus citriodora	Myrtaceae	2.38	2.03	2.18	6.59
Gardenia spp1	Rubiaceae	3.57	0.99	1.92	6.49
Terminalia alata	Combretaceae	2.38	0.98	2.22	5.58
Aganosma marginata	Apocynaceae	2.38	0.24	2.88	5.51
Cassia fistula	Caesalpiniaceae	0.60	0.27	4.44	5.31
Carissa cochinchinensis	Apocynaceae	1.79	0.71	2.56	5.06
Diospyros mollis	Ebenaceae	1.79	0.71	2.22	4.72
Sindora siamensis	Caesalpiniaceae	1.79	0.82	1.92	4.53
Marumia dimorpha	Melastomataceae	2.38	0.08	1.92	4.38
Randia wittii	Rubiaceae	1.79	0.29	2.22	4.29
Canarium bengalense	Burseraceae	2.38	0.11	1.60	4.09
Horsfieldia irya	Myristicaceae	2.38	0.21	1.28	3.87
Morinda tomentosa	Rubiaceae	1.79	1.03	0.96	3.77
Irvingia malayana	Ixonanthaceae	1.79	0.66	1.28	3.73
Shorea siamensis	Dipterocarpaceae	1.19	1.19	0.64	3.03
Nephelium hypoleucum	Sapindaceae	1.19	1.03	0.64	2.86
Cratoxylum formosum	Guttiferae	0.60	1.39	0.32	2.31
Gardenia erythroclada	Rubiaceae	1.79	0.11	0.00	1.90
Lantana salvifolia	Verbenaceae	1.19	0.00	0.64	1.83
Lithocarpus wallichianus	Fagaceae	0.60	0.63	0.32	1.54
Anthocephalus chinensis	Rubiaceae	0.60	0.28	0.64	1.52
Markhamia stipulata	Bignoniaceae	0.60	0.54	0.32	1.45
Diospyros rhodocalyx	Ebenaceae	0.60	0.00	0.64	1.24
Cassia garrettiana	Caesalpiniaceae	0.60	0.00	0.64	1.24
Walsura trichostemon	Meliaceae	0.60	0.16	0.32	1.07
Gardenia spp2	Rubiaceae	0.60	0.14	0.32	1.05
Pothos macrocephalus	Araceae	0.60	0.12	0.32	1.03

Table 8.6: continued

Latin name	Family	RF (%)	RDo (%)	RA (%)	IVI (%)
Vitex peduncularis	Verbenaceae	0.60	0.01	0.32	0.93
Ardisia polycephala	Myrsinaceae	0.60	0.00	0.32	0.92
Buchanania latifolia	Anacardiaceae	0.00	0.00	0.00	0.00

Data collected on year 2002-2003. RF Relative Frequency. RDo Relative Dominance. RA Relative Abundance. IVI Important Value Index.

9 GLOSSARY OF TERMS

This section introduces the basic terminology used in the study. Important keywords are defined in order to facilitate information exchange among researchers and to improve the understanding of the study for a wider group of readers. The definitions are largely based on methods used in research on the measurement and assessment of sustainable farming systems in Thailand.

Agroecosystem

Agroecosystem is a conceptually constructed unit referring to an ecosystem modified by people to produce food, fibers, fuel and other products for human use. The system is characterized by inputs from both inside and outside the farm such as the landscape, solar radiation, rain, water, energy, human activities, and infrastructure (Agro-ecosystem Health Project 1996; Peden 1998; Aarnink et al. 1999).

Commercial farming system

Commercial farming system is defined here as one production enterprise (e.g., monocropping) or a combination of production enterprises on a farm that include crops and/or animals. The enterprises are not integrated with each other, but managed separately without functional interrelations (Reijntjes et al. 1992).

Farm household

Farm household is defined is defined as a group of persons who regularly share food and shelter. A household includes all regular residents, but excludes short-term visitors or those who had migrated from the farm more than one year previously (Dillon and McConnell 1997).

Food security

Food security is defined as a situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary need and food preferences for an active and healthy life (FAO 2002).

Integrated farming system

Integrated farming system is defined here as the combination of two or more complementary production enterprises in a farm that include both crops and livestock. The production enterprises in the IFS are mutually supportive and depend on each other (Lightfoot and Minnick 1991; Jitsanguan 2001; Radhamani et al. 2003; Csavas 2004).

Resource-poor farmer

Resource-poor farmer refers to farmers who have a farm area smaller than 7 ha, located in mainly rainfed areas. Theses farmers are often poor because of limited to access to and poor quality of production resources (Jitsanguan 2001).

Sustainable agricultural system

Sustainable agricultural system means an integrated system of plant and animal production practices having a site-specific application that will, over the long term: 1) satisfy human food and fiber needs, 2) enhance environmental quality and the natural resource base upon which the agricultural economy depends, 3) make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls, 4) sustain the economic viability of farm operations, and 5) enhance the quality of life for farmers and society as a whole (Gold 1999).

Upland crops

Upland crops refer to annual crops grown in the upland area, grown all year round, irrespective of time of harvest. Important upland crops are maize, cassava, soybean, mungbean, peanut, red bean, watermelon, and upland rice (OAE 2002).

ACKNOWLEDGEMENTS

A lot of people made this study possible, complete and successful. I would like to first thank Mrs. Channuan Ratarasarn and Dr. Horst Weyerhaeuser for their support and encouragement to start this PhD. I am most grateful to my supervisors, Dr. Dietrich Schmidt-Vogt and Prof. Paul Vlek, for their support and inspiration throughout the study.

The field research would have been impossible if it had not been for the cooperation of IWMI regional office in Southeast Asia. My appreciation goes to Dr. Frits Penning de Vries and Dr. Andrew Noble of IWMI for their professional advice during and after the field work. I also wish to express my gratitude to all the staff of IWMI in Bangkok for the cordial working environment they offered me during my stay. I am furthermore much indebted to the former director of IWMI, Mr. Tissa Bandaragoda as well as to Dr. Saweng Ruaysoognoen and Dr. Suraphol Chandrapatya for kindly providing valuable advice and guidance to get through the study area and collect data.

The laboratory analyses would have been impossible without the advice and support from Dr. Buri Boonsompobbhan, Mr. Prasit Phaiklang, Dr. Robert Simmon, Mr. Somsak Sukchan, and Dr. Verasak Veerasilp. I am equally grateful to the staff of the Department of Agriculture, the Land Development Department and the Royal Irrigation Department for their unconditional professional support during data collection.

I thank my invited field assistants, especially Teerapong Chumsangsri, Nopppорn Nontabha, Bhanumaat Chansuwan, and Somya Tangtrakarnpong, who took so much of the load off my shoulders. The participating farm households did much more than just providing data, they also kindly provided food and took care of us like members of the family, and for that I am most grateful.

I thank the German Academic Exchange Service (DAAD), who generously sponsored my study. I am thankful to Dr. Günther Manske for his tutoring and all ZEF staff for their support during my stay in Bonn. My gratitude also goes to Dr. Eric Craswell for his corrections and suggestions that very much inspired me. I thank Ms. Margaret Jend for editing my work.

I thank my friends at ZEF. Denis Aviles, Almut Brunner, Cristina Carambas, Quang Bao Le, Arisbe Mendosa, Kavita Rai, Lulseged Tamene, and Charlotte van der Schaaf I thank for their friendship and encouragement. I thank other friends whom I met during my study and who so much encouraged me, Martha Bonilla, Susanna Gura, Lara Wever, Marcel Endejan, and NL Bud Allison.

Finally, I very much thank Theo and Lizette, and Maurice and Dominique for their encouragement. My big thanks also go to the Tipraqsa family: my mother and three lovely sisters for uncountable reasons. Very finally, I thank Pepijn for his love and for taking care of me.