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.