FACTORS INFLUENCING RICE PRODUCTION EFFICIENCY IN BAN HOME, LAOS

By

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in partial fulfilment of the requirements of the degree

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ABSTRACT

Agriculture remains a dominant economic sector in many developing countries. Rice constitutes a staple food for more than half of the world's population and is the main meal of all Lao people (FAO, 2005). However, rice prodution faces many problems, including the effects of floods, drought and poor soil quality. These challenges combine to reduce rice productivity below what might be possible. However, before new agricultural policies are put in place, it is important to identify the factors associated with rice production efficiency. This thesis analyses technical and socio-economic factors that influence rice production and estimates the level of technical efficiency of individual rice farmers in Ban Home, Laos.

Survey data were collected in the region in 2003, for both wet season and dry season rice production. Using these data, a Cobb-Douglas frontier production function was estimated for each season using two approaches, deterministic and stochastic. During the wet season, several factors were statistically significant and positive in their effect on rice yield: area in rice production, level of fertilizer use, total labour, the use of a modern variety, sandy soil and contact with a professional agricultural advisor. During the dry season, only area in rice production and fertilizer were significant. Based on the frontier production functions, it is possible to conclude that the average technical efficiency of farmers is higher during the dry season than the wet season, for both the deterministic and stochastic approaches.

However, socio-economic factors were unable to explain the level of technical efficiency among farmers, when evaluated using a standard regression approach. By using a simple t-test to compare the mean level of efficiency of different groups of farmers, some significant differences emerged. Farmers who used credit were found to be more efficient than those who did not. Moreover, experienced farmers were more efficient than less experienced farmers. Also, farmers with less than 7 years of education were more efficient than more educated farmers.

RÉSUMÉ

L'agriculture est considérée comme étant un important secteur économique dans plusieurs pays en voie de développement. Le riz constitue l'alimentation de base de plus de la moitié de la population mondiale et représente une ration alimentaire importante de la population laotienne. Cependant, la production rizicole fait face à de nombreux problèmes tels que les inondations, la séchesse et la piètre qualité du sol. Ensemble, ces obstacles réduisent la productivité du riz à un niveau moindre de ce qui est possible dans ce domaine. Par contre, il est important d'identifier les facteurs associés à une production rizicole efficace avant d'instaurer de nouvelles politiques agricoles. Cette étude a pour but de déterminer les facteurs ayant un impact sur la production rizicole du village de Ban Home, au Laos ainsi que d'estimer le niveau d'efficacité technique des fermes rizicoles à partir de données recueillies dans la région sous étude en 2003.

La forme fonctionnelle sélectionnée est la Cobb-Douglas en utilisant l'approche deterministique et stochastique pour les deux saisons. Les résultats démontrent que les facteurs techniques tels que la terre, le fertilisant, la main d'œuvre, la variété du riz, le type de sol et le contact avec un conseiller agricole affectent positivement le rendement du riz durant la saison des pluies alors que seulement la terre et le fertilisant ont un impact significatif sur le rendement lors de la saison sèche. De plus, il s'avère que la technologie de la saison sèche démontre une efficience plus élevée que celle de la saison des pluies, que ce soit par l'approche déterministique ou stochastique.

Cependant, aucun facteur socio-économique n'est statistiquement significatif et ne peut expliquer l'efficacité technique de la production rizicole. En comparant la moyenne d'efficacité de différents groupes d'agriculteurs, il se trouve que ceux ayant emprunté de l'argent pour la culture du riz semblent être statistiquement plus efficaces que ceux n'ayant pas emprunté. De plus, les agriculteurs ayant plus d'expérience en agriculture sont plus efficaces que les agriculteurs avec une expérience moindre. D'un autre côté, les agriculteurs peu éduqués sont plus efficaces que les agriculteurs plus éduqués.

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This thesis is dedicated to my guardian angel Sister Jeannette Lauzier who taught me: when you believe, anything is possible.

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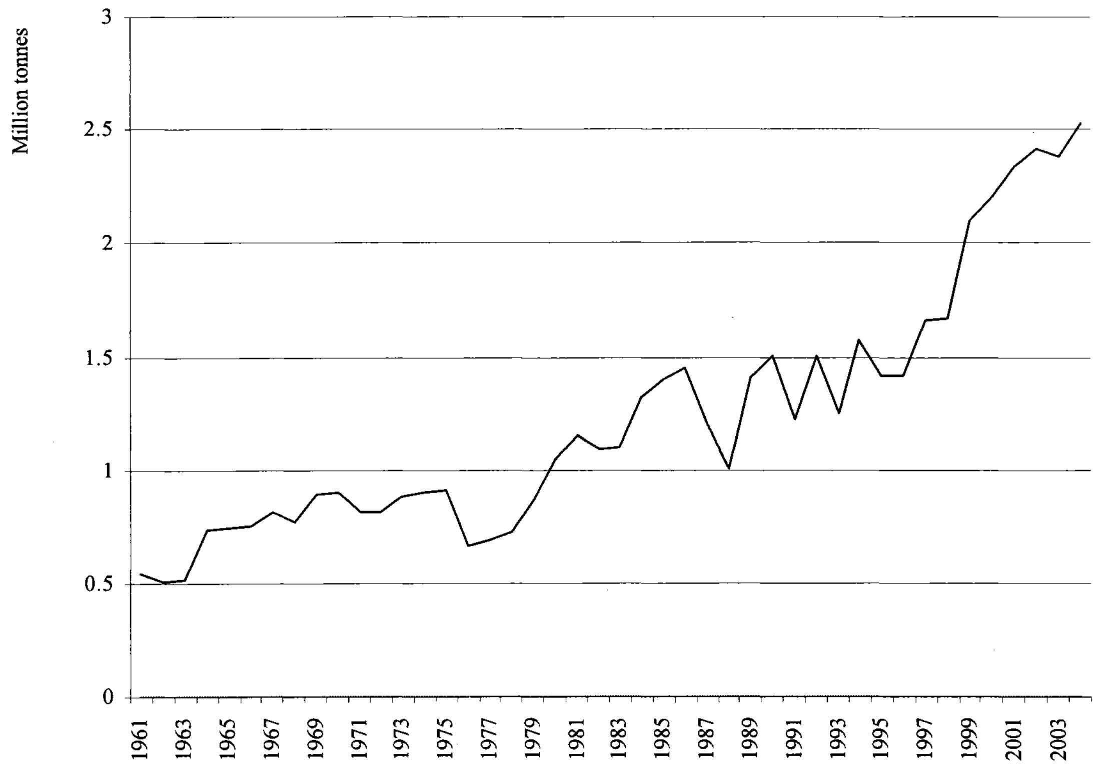
CHAPTER 1: INTRODUCTION

Like many developing countries, the Lao economy relies heavily on agricultural activitities that contribute to the economic and social well-being of the country. However, the agricultural sector faces many constraints that impede its development which often leads to problems in self-sufficiency. In addition to these constraints, Laos faces problems of poverty and malnutrition. According to Schiller et al. (2001), Lao rice production is characterized by low productivity, particularly due to drought, flood and poor quality of soil. The Asian Development Bank (2001) enumerated important institutional and systemic constraints of the Lao agricultural sector.

i. weak public sector institutions and human resources, particularly in the country's remote provinces;
ii. the need to provide a more supportive environment for private sector investment in agricultural development;
iii. poor rural transport, electricity, and communications infrastructure which severely hinders economic development and the integration of markets and public services delivery;
iv. underdeveloped rural credit and savings services;
v. heavy dependence on rain fed agriculture systems;
vi. lack of a marketing system linking producers, wholesalers, and retail buyers;
vii. lack of diversification in agricultural production; and
viii. a declining natural resource base resulting in decreased soil fertility, increased soil erosion, and erratic water supplies.

In 1999, rice production in Laos attained more than 2.1 million tonnes and the country was able, for the first time, to reach self-sufficiency in rice. The FAO (2001) estimated that rice consumption per capita was a little more than 350 kg for a year. Although, self-sufficiency in rice was reached for the first time in 1999, rice was not evenly distributed across the country. Indeed, remote and mountainous areas often encountered food shortages because of a deficient infrastructure.

Figure 1: Rice production in Laos



Source: FAOSTAT 2005

Climate is one of the biggest constraints that hinders agricultural activities and causes high variability in agricultural production. Agricultural production can fall dramatically due to a severe natural disasters such as drought or flood. On the other hand, under the same conditions of production (same type of soil, fertilizers, technologies, etc.), the variance of production and yield is high among farmers. Three categories of factors could explain this variation, as summerized below:

- Technical factors : respect of cultural calendar, technologies used, agricultural extension
- Climatic factors : season, natural disaster
- Socio-economic factors : age, gender, household size, education, second occupation (Mouktari, 1989)

This thesis will attempt to provide some explanation of the fluctuations in production among farmers, and explore the use of efficiency measures, at the level of individual farms.

1.1 Country profile

1.1.1 Geography

Lao People's Democratic Republic (Lao PDR) is a small country in Southeast Asia. With an area of 236800 km^2, Lao PDR is the only Southeast Asian country that is landlocked. The country is surrounded by Thailand to the West, Vietnam to the East, China and Burma to the North and Cambodia to the South (see appendix A). The country is divided into three main areas : Northern, Central, and Southern. Laos consists of 17 provinces and one special zone, and 142 districts that comprise 10752 villages. The country is also characterized by its mountains that cover two-thirds of its area.

These mountains limit transportation and communication among different regions. The altitude varies from 200 to 2820 meters. Another feature of Lao PDR is the proximity of the Mekong river that flows over 1865 km through its territory, from North to South. This river provides a source of irrigation and transportation. (National Statistical Center, 2003)

1.1.2 Climate

The climate is tropical with high rainfall during the monsoon season. The relative humidity is 70-90% and the average daily temperature is 25C-30C. The average annual rainfall is 1500-2000 mm. Heavy rainfall usually takes place between June and September and accounts for 75-90% of the total rainfall. The remaining percentage of rain occurs during the dry season, from November to May. Heavy rainfall during the monsoon season often leads to flooding, especially in the Mekong valley. Historic floods occurred in 1924, 1946, 1966, 1971, 1996 and recently in 2002. This pattern of seasonal rainfall limits agriculture activities, as does its uneven distribution among the regions. (FAO, 2004)

1.1.3 Soil

The type of soil in Laos is characterized as sandy, low fertility, relatively acidic and very sensitive to erosion, especially during the rainy season. During the dry season, drought often occurs because the soil has poor water holding capacity. These features of Lao soil do not make agricultural activity an easy task. (FAO, 2004)

1.1.4 Population

According to the World Bank, Lao PDR had a population of 5.7 million in 2003 and its population density is one of the lowest in Asia, about 20 people per sq km. Nearly 80% of its population lives in rural areas, but it is not equally distributed. Indeed, most of the population lives in the four largest provinces in the country which are Vientiane, Savannakhet, Pakse and Luangprabang. Vientiane, the capital, accounts for more than the third of the country's urban population.

The average growth rate of the population is 2.3% per annum with life expectancy at birth of 54 years. The illiteracy rate is higher in the female population (77%) compared to the male population (55%). Laos is a country ethnically diverse. It is very difficult to classify all the ethnic groups. Prior to 2001, the Lao government categorized different ethnic minorities by topography into three main groups. Lao Loum (lowland), Lao Theung (upland), Lao Soung (highland) including the Hmong and the Yao , and ethnic Vietnamese/Chinese. However, this classification did not capture the diversity of the country and so is no longer recognized as the official terminology. The majority are Buddhist. (World Bank, 2005). Taillard and Sisouphanthong (2000) divided different groups according to linguistic characteristics. According to the government census of 1995, there were 47 tribes recognized in Laos that could be classified into five groups: Tai-Kadai comprising Lao-Phoutai (66.2%); Austro-Asiatic comprising Mon-Kmer (22.7%); Hmong-Yao (7.4%); Tibeto-Burman (2.7%), and Sino-Tibetan including Hor. The largest ethnic group is the Lao (52%). This research is specifically concerned with Lao farmers in Ban Home.

1.1.5 Economy

As mentioned earlier, nearly 80% of Lao population lives in rural areas and depends on agricultural activity. Therefore, agriculture has been and continues to be the mainstay of the economy. Agriculture is practiced mostly by small subsistence farmers. The agricultural sector represents more than 50% of the GDP with a growth rate of 6.3% in 2004. Moreover, it employs more than 80% of the labour force. Although agriculture is one of the country's primary economic sectors, it provides very low incomes. Indeed, the annual per capita income was estimated to be about US$390 in 2004 for the entire population (World Bank 2005). Laos is one of the poorest countries in the world. In 2003, the UNDP ranked Laos as the 133th country out 177 in terms of the human development index. Moreover, the national incidence of poverty is 46% with 53% in the rural areas and 24% in the urban areas. (UNPD, 2005)

The service sector represents 25% of GDP (table 1). Tourism makes an important contribution to this sector, and represents an important source of foreign exchange. The industrial sector commands 20% of GDP. This economic segment has the highest growth due particularly to the textile industries. In 1998, GDP growth fell dramatically to 4% during the Asian crisis, caused by the reduction in foreign investment and construction spending (table 2). Although Laos has been less affected than other Southeast Asian nations by the Asian financial crisis, its indirect impact was marked. Indeed, Laos lost its most important trade and investment partner, Thailand where the Asian financial crisis started. Laos has been a member of ASEAN since 1997. (Bourdet 2002, Yoon 2002).

Table 1. Gross domestic product by economic activity (constant 1990 percent)

Years	1996	1997	1998	1999	2000
Agriculture	**52.2**	**52.2**	**51.8**	**52.2**	**51.8**
Crops	24.9	26.5	27.2	28.7	29.3
Livestock and fishery	20.6	19.7	19.4	18.5	17.8
Forestry	6.7	6	5.2	4.9	4.7
Industry	**20.6**	**20.8**	**21.9**	**22**	**22.3**
Mining and quarrying	0.3	0.4	0.4	0.5	0.5
Manufacturing	15.4	15.7	16.6	16.5	16.8
Construction	3.5	3.4	2.8	2.6	2.5
Electricity and water	1.4	1.3	2.1	2.3	2.5
Service	**24.8**	**25**	**25.3**	**25.2**	**25.3**
Transport,post and telecommunication	5.4	5.5	5.7	5.8	5.9
Wholesale and retail trade	8.6	8.9	9.4	9.4	9.6
Bank, insurance and real estate	1.3	1.3	1.3	1.3	1.2
Ownership of dwellings	3.4	3.2	3.2	3	2.9
Public wage bill	3.1	2.9	2.9	2.9	2.8
Nonprofit institutions	1.2	1.1	0.8	0.7	0.7
Hotels and restaurants	1.7	1.7	1.8	1.9	2.0
Other services	0.2	0.2	0.2	0.2	0.2
Import duties	**2.4**	**2**	**1.1**	**0.6**	**0.6**
GDP (at market prices)	100	100	100	100	100

Sources: National Statistical Center, Laos (2000)

Table 2. GDP growth (% in constant prices)

Years	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
GDP growth (% in constant prices)	**7**	**6.9**	**6.9**	**4**	**7.3**	**5.9**
Agriculture	3.1	2.8	7	3.1	8.2	5.1
Industry	13.1	17.3	8.1	9.2	7.9	7.5
Services	10.2	8.5	7.5	5.5	6.9	6.2

Sources: National Statistical Center, Laos (2000)

Being a landlocked and mountainous country causes difficulty with trade. Furthermore, the lack of infrastructure hinders communication and trade among different regions of Laos. Exports and imports must pass through its neighbours, particularly Vietnam and Thailand. Fortunately, the Mekong river facilitates trade. With an Australian donation, the first bridge across the Mekong between Thailand and Laos was built in 1998 to link the Thai border town of Nong Khai with the Lao capital, Vientiane.

Although, a new economic mechanism (NEM) was implemented in 1986 to improve the Lao economy, imports still extensively exceed exports. This new policy emphasised the stimulation of private enterprise with a decentralization of state control. Thus, the transformation of centrally planned economy to a free market stimulated foreign investment. With a precarious economy, Laos depends heavily upon foreign aid. In some years, foreign aid has corresponded to more than 80% of its annual budget. (UN, 2000)

1.2 Agriculture in Laos

As stated earlier, agriculture that includes livestock, fisheries and forestry forms more than half of the Lao economy. Moreover, agriculture is largely subsistence oriented. Glutinous rice is the main crop in the country and grown over 80% of the cropped land. As a staple food, rice makes up more than 60% of total calorie consumption (Pandey 2001). The other important crops are maize, tubers, sugarcane, and tobacco (table 3). Three main production areas, Savannakhet, Champasak and Louangphrabang have nearly 40% of total harvested land (table 4).

Table 3. Agricultural crop production (thousand tonnes)

CROPS	1996	1997	1998	1999	2000
Cereals	**1,582.30**	**1,832.00**	**1,992.30**	**2,270.70**	**2,305.50**
Rice	1,413.20	1,660.00	1,774.60	2,094.00	2,230.00
Lowland rice paddy	1,075.70	1,303.50	1,349.00	1,502.00	1,635.00
Dry season rice	71.5	113.5	212.1	354	465
Upland rice paddy	266	243	213.5	238	130
Maize	76.6	78	109.9	96.1	23.6
Tubers	92.5	94	107.9	80.6	51.9
Manufacturing products	**146.3**	**158.2**	**241.6**	**239.4**	**246.9**
Sugarcane	87.1	95	170.2	173.6	173.6
Tobacco	26	28	25.6	23.4	39.8
Peanut	11.9	12	15	13	7
Cotton	6.8	7	7.5	4.3	4.7
Others[a]	14.5	16.2	23.3	25.1	21.8
TOTAL	**1,728.60**	**1,990.20**	**2,233.90**	**2,510.10**	**2,552.40**

Source: National Statistical Center, Laos (2000)
[a] Includes mungbeans, soybeans, coffee, and tea.

Table 4. Area of main production zones

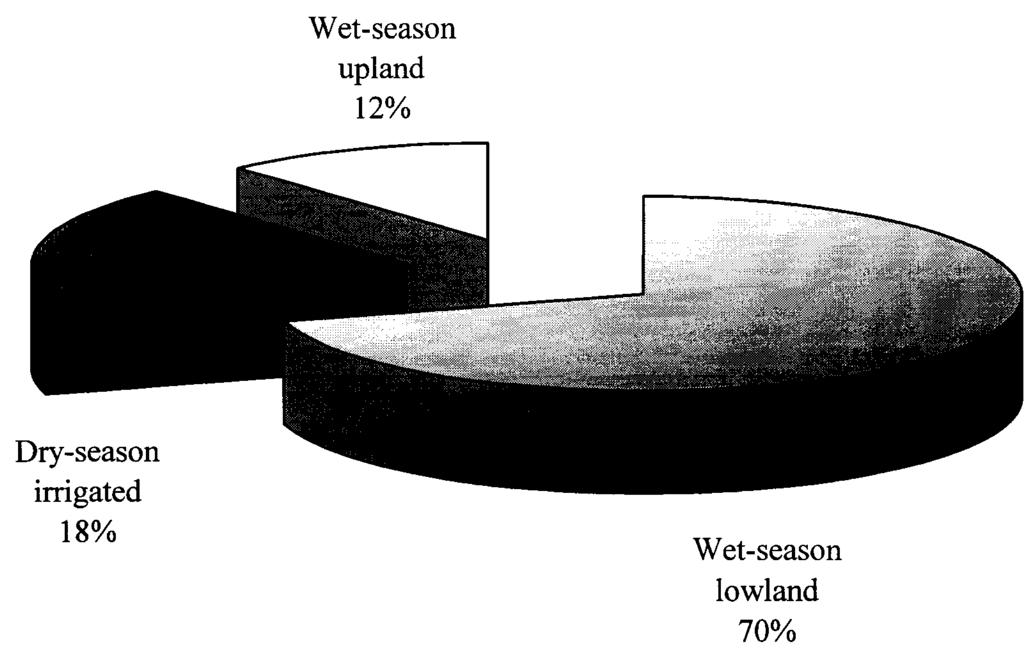
Major Production Zones	**Harvested area** (% total harvested area)
Savannakhet	15.41
Champasak	12.63
Louangphrabang	10.65
Vientiane Municipality	7.83
Salavan	6.90
Vientiane	6.53
Oudomxai	5.65
Houaphan	4.59
Khammouan	4.59
Xaignabouli	4.15
Phongsali	3.83
Bolikhamxai	3.66
Xiangkhoang	3.29

Source : National Statistical Center, Laos (2000).

1.2.1 Rice production

Three production systems can be identified in Lao rice production: wet-season lowland, dry season irrigated, and wet-season rainfed upland (fig.2). The wet-season lowland system is mainly located in the central and the southern areas, particularly in the regions adjacent to the Mekong River. This system is the largest, which accounts for 70% of the cultivated area. The regions of Champasack, Savannakhet and Vientiane Municipality are the biggest producers with the wet-season lowland and irrigated systems while the Northern region dominates the wet-season upland (table 5). (Lao Ministry of Agriculture and Forestry, 2000)

Figure 2: Production in the rice growing environment of Laos, 2000



Source: Lao Ministry of Agriculture and Forestry, Department of Agriculture, Laos 2000

Table 5. General rice production statistics for Laos, 2000

Region and province	2000 Wet-season lowland			2000 Dry-season irrigated			2000 Wet-season upland		
	Harvest area	Yield	Production	Harvest area	Yield	Production	Harvest area	Yield	Production
	(ha)	(t/ha)	(t)	(ha)	(t/ha)	(t)	(ha)	(t/ha)	(t)
Northern Region	**75300**	**3.24**	**243770**	**6580**	**3.52**	**23143**	**108370**	**1.71**	**184926**
Phongsali	5400	3.20	17260	60	3.30	198	16280	1.66	27050
Louang Namtha	7900	3.22	25400	740	3.87	2864	10580	1.69	17931
Oudomxai	9200	3.28	30220	830	3.20	2656	19400	1.70	32980
Bokeo	10200	3.19	32510	220	4.11	904	1560	1.72	2676
Louangphrabang	9800	3.29	32200	1800	4.10	7380	32110	1.75	56100
Houaphan	11400	3.19	36420	980	3.00	2940	14310	1.67	23830
Xaignabouli	21500	3.24	69760	1950	3.18	6201	14130	1.72	24359
Central Region	**267400**	**3.29**	**879280**	**60230**	**4.39**	**264606**	**29340**	**1.68**	**49175**
Vientiane Municipality	50600	3.40	172200	19520	4.60	89792	630	1.74	1098
Xiangkhoang	14500	3.20	46430	330	3.50	1155	10180	1.68	17095
Vientiane	37700	3.24	122300	6970	4.25	29623	2160	1.66	3577
Bolikamxai	25000	3.20	80030	4310	4.27	18391	9180	1.65	15180
Khammouan	34000	3.25	110400	7770	4.27	33210	1390	1.65	2300
Savannakhet	101600	3.30	335100	21250	4.33	92115	3800	1.72	6525
Special Region	4000	3.21	12820	80	4.00	320	2000	1.70	3400
Southern Region	**132800**	**3.24**	**429750**	**24990**	**4.10**	**102401**	**14400**	**1.71**	**24649**
Salavan	46300	3.24	150100	4890	4.00	19580	4870	1.73	8420
Xekong	3000	3.12	9350	420	4.04	1696	3710	1.69	6264
Champasack	71100	3.25	231100	19230	4.12	79280	1350	1.73	2340
Attapu	12400	0.32	39200	450	4.10	1845	4470	1.71	7625
Total	**475500**	**3.27**	**1552800**	**91800**	**4.25**	**390150**	**152110**	**1.70**	**258750**

Source: The Lao Ministry of Agriculture and Forestry, Department of Agriculture, Laos 2000

1.3 Problem statement

Lao agriculture is fragile and dependent on climate. Regions along the Mekong River are affected by flood almost every year. In addition, the Lao population has a high growth rate with a subsistence farming system, predominantly based on rice farming. Indeed, the diversification of agricultural production is very limited. Also, people have preference for glutinous or sticky rice compared to Jasmine rice that is consumed by most Asian people. Nearly 85% of rice production in Laos is characterized by farm technologies which use low levels of inputs and farm mechanization. In general, farm size is very small, less than one hectare. This practice results in a relatively low level of total agricultural productivity. In figure 3, we can see that Laos produces less than its neighbours. Viet Nam and Thailand ranked fifth and sixth in the world in terms of rice production and represented the world largest exporters in 2002/2003 (USDA, Foreign Agricultural Services, 2003). These leaders use mechanical technology while Cambodia and Laos still struggle with subsistence agriculture. Also, political troubles for so many years in Cambodia and Laos have not helped the agricultural sector. (ADB, 2001)

Figure 3: Rice production in Southeast-Asia

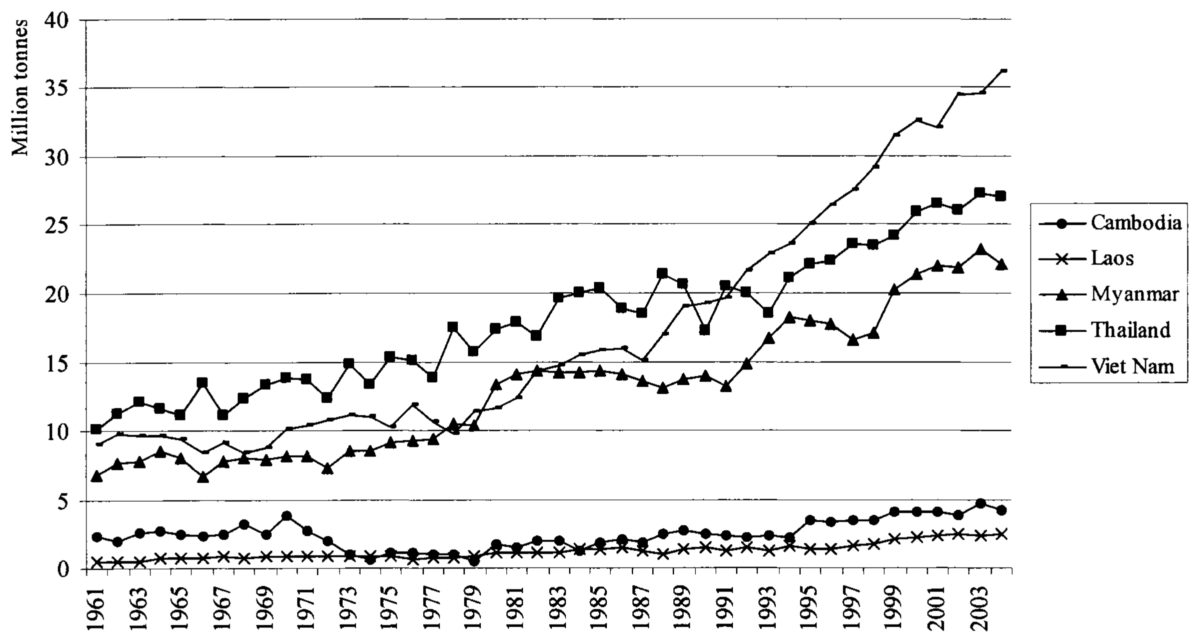
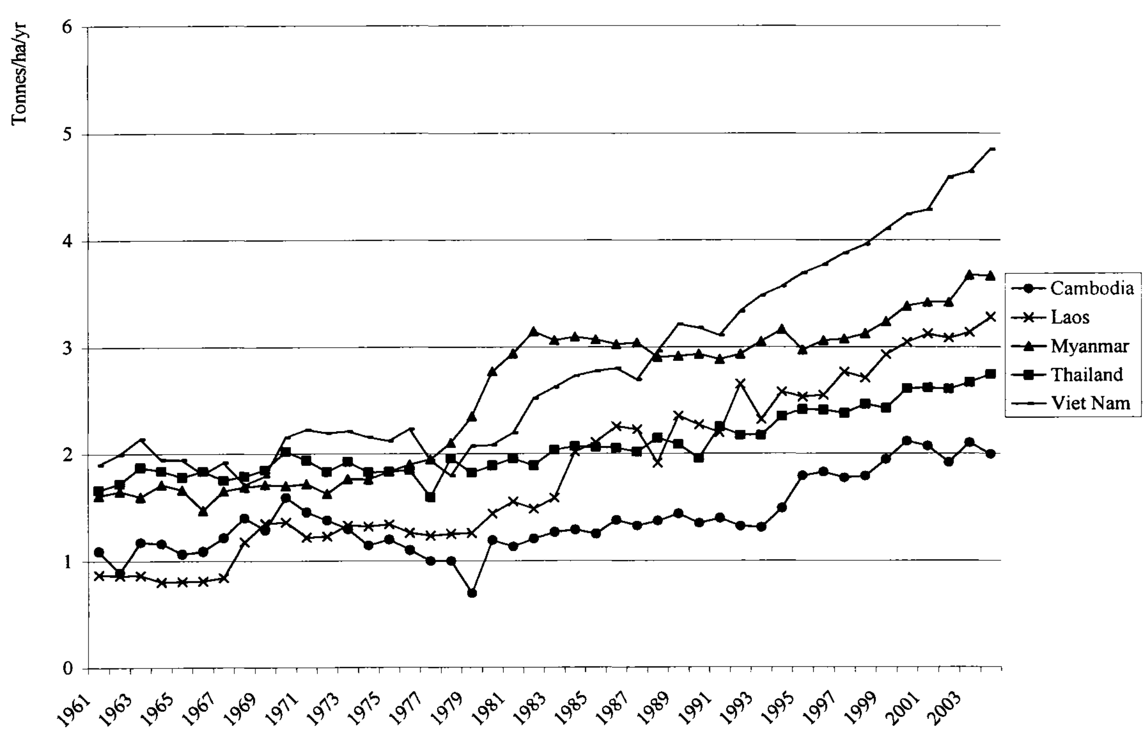


Figure 4: Rice yield in Southeast-Asia



Source: FAOSTAT 2005

Laos may not be a large producer compared to its neighbours, but the average yield in 2004 was 3.28 tonnes/ha compared to 2.75 tonnes/ha of the biggest exporter in the world, Thailand (see fig.4). Indeed, since the early 90's, yield in Laos has exceed Thailand, even though Laos uses a traditional technology and is intensive in labour.

Another problem that Lao agriculture has to confront is the high variability of rice production. Although internal political disturbances and the weather explain this fluctuation, other factors also contribute. The nature of these factors can be technical, climatic and socio-economic. However, the country was able to reach self-sufficiency in rice production in 1999. Besides, many constraints such as lack of available arable land, labour, irrigation, technical expertise, market information, limited access to domestic and international markets for inputs and outputs aggravate the problem. As the backbone of the economy, agriculture faces big challenges to ensure food security (ADB, 2001).

According to the Asian Development Bank (2001), in order to improve the agricultural sector, the Lao government has established a development program covering the period 2000 to 2020. Its main goals are to:

- Increase food production to achieve food security
- Develop and promote production for commerce
- Stop shifting cultivation and provide occupations for permanent settlement
- Expand the irrigation system
- Promote research programs in the area of agriculture and forestry

- Develop human resources (produce agricultural scientists and specialists)

1.4 Objectives

This research is designed to analyse the variability of rice production among Lao farmers in Ban Home, a small village in Vientiane. The main objective is to identify important technical and economic factors in order to suggest strategies of sustainable agriculture in Ban Home and to improve the standard of living of farmers. Also, the technical efficiency of individual farms is estimated.

In order to achieve the main objective, this thesis will specifically try to:

- estimate a production function
- estimate a production frontier function
- estimate individual farmer's efficiency in rice production
- identify factors that influence this variability
- suggest policies and strategies to improve the standard of living and sustainable agriculture of the village

1.5. Structure of the thesis

The second chapter introduces the literature review. It focuses mainly on production theory and the concept of efficiency. Particular attention is given to the concept of efficiency. For a better understanding of this concept, several empirical studies on efficiency, especially in developing countries, are reviewed. The third chapter outlines the methodology used in the estimation of rice production and its determinants. A frontier function is derived from the average production function. Based on two approaches, deterministic and stochastic, the efficiency measures for individual farms are estimated. This section also highlights how the survey was undertaken. Chapter four presents and discusses the empirical results. Finally, chapter five presents the summary of the research. It also discusses limitations of the research, strategies of agricultural development and conclusions.

CHAPTER 2: LITERATURE REVIEW

It is well known that agriculture holds an important place in the economic sector, especially in the economic development of the third world. (Kuznet 1966; Hayami and Ruttan 1985). Indeed, over two-thirds of the world's poorest people live in rural areas, with subsistence agriculture as their main occupation (Todaro and Smith, 2000, p.422). In this chapter, the concept of economic development, the production function, and production efficiency will be examined.

2.1 Economic development theory

In his article "Toward a Unified Theory of Economic Development", Peter H. Calkins (1989) summarized several theories of economic development. According to Calkins, the concept of economic development can be defined verbally or graphically. Expressed in words, the definition of economic development could be :

> *the environmentally sustainable improvement over time in the levels and distribution of national income, human nutrition and the satisfaction of basic needs, as identified and prioritized by the population of a given nation or region.* [1]

Figure 5 provides a conceptual model where Calkins divided the economy into four major sectors: the agricultural, rural, urban sectors and the rest of the world. The shaded area represents the proportion of the poor. Contrary to the urban sector, there are more poor people in the agricultural sector. Calkins described development as a *virtuous*

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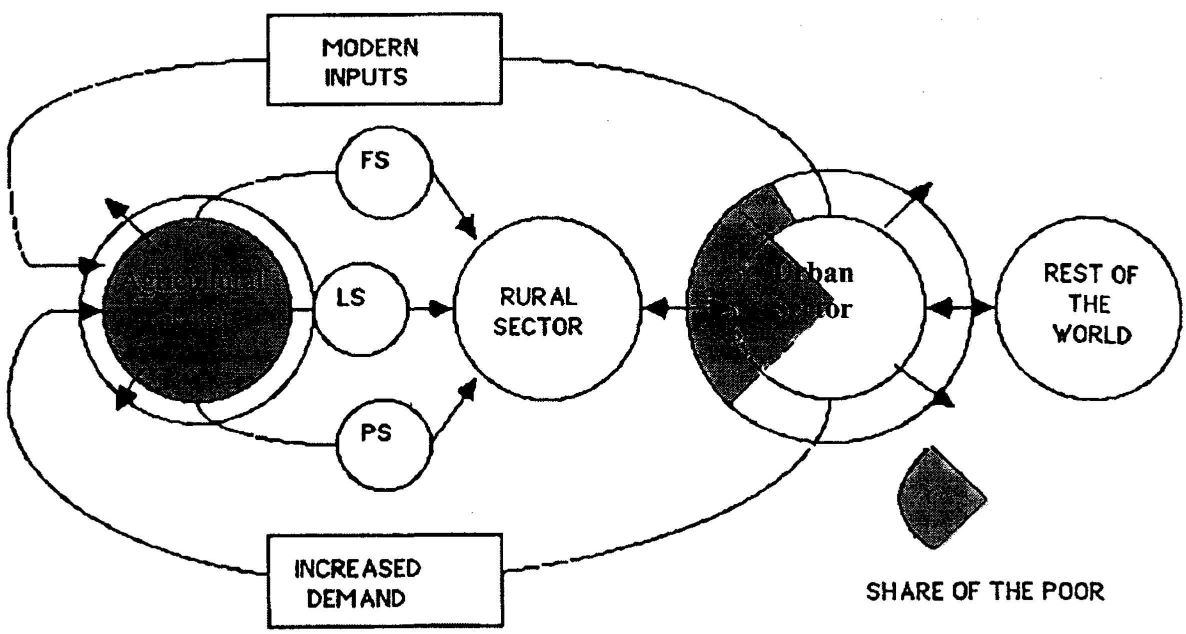
[1] Calkins, (1989), p.922

cycle as opposed to a vicious cycle because the surplus resources of finance, labour and product move from the agricultural sector to the rural sector. This transfer contributes to an improvement in the standard of living (income, employment and food), not only in the agricultural and rural sectors, but also the urban sector. In fact the urban sector increases its demand and injects modern inputs into the agricultural sector. Then, each sector can generate enough surplus to trade with the rest of the world. This illustration could be seen as an electrical circuit where surplus can flow from one sector to another. Each economic sector is interlinked with each other. However, factors that obstruct the flow of surplus contribute to underdevelopment (Calkins 1989 p.924).

Figure 5 : A graphical definition of development



Source : Calkins (1989), p. 924

FS: financial surplus

LS: labour surplus

PS : product surplus

A similar view is expressed by Todaro and Smith (2006) who viewed economic development as:

> *a multidimensional process involving major changes in social structures, popular attitudes, and national institutions, as well as the acceleration of economic growth, the reduction of inequality, and the eradication of poverty.* [2]

As mentioned earlier, agriculture is an important part of economic development and plays a dynamic role. As a development strategy, improving the agricultural sector must include at least three basic complementary elements:

1) accelerated output growth through technological, institutional, and price incentive changes designed to raise the productivity of small farmers;
2) rising domestic demand for agricultural output derived from an employment-oriented urban development strategy;
3) diversified, nonagricultural, labour-intensive rural development activities that directly and indirectly support and are supported by the farming community (Todaro and Smith, 2006, p.423)

Thus, the definition of development is complex and not strictly limited to economics. Development must also include social and institutional aspects. In order to improve the national standard of living, an economy that relies on the agricultural sector has to increase agricultural productivity, hence the importance of understanding the process of agricultural production. In order to analyze the determinants of rice production, as will come later in this thesis, it is important to understand some of the economic theory of production. First, the nature of the production function is considered, with some attention given to the issue of choosing an appropriate functional

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[2] Todaro and Smith, (2006), p.17

form. This is followed by a review of empirical applications of theory to agriculture development.

2.2 Production function theory

Many authors describe production as the transformation of inputs (factors of production) into outputs. The quantity of outputs depends on the technology in use and any constraints on the quantity of inputs. Coelli et al. (1998) referred to the production function or production frontier as the maximum output produced with a given quantity of inputs and given technology. The production function can be defined by a mathematical function or illustrated with a graph. We can express the function mathematically as:

$$Y = f(X_1, X_2, \ldots, Xi) \quad \text{with } i = 1,2, \ldots, n \qquad (1)$$

where : Y represents the quantity of output

X_i is the quantity of the ith variable input that is needed to produce the output

The inputs used in production can be characterized as variable, fixed and random (Doll and Orazem, 1984). Taking into account these categories, the production function can be rewritten as:

$$Y = f(X_1, X_2, \ldots, Xi| \, X_{i+1} \ldots X_m \, || X_{m+1} \ldots X_n) \qquad (2)$$

$(X_1, X_2, \ldots, Xi)$ portray the variable inputs. These inputs can be modified by the entrepreneur as he wishes, in the short run; for example seed, and fertilizer. $(X_{i+1} \ldots X_m)$

represent fixed inputs that the farmer can not change in the short run. Land is categorized as this type of factor. ($X_{m+1}...X_n$) depict factors that are not controlled by the farmer. Although, these factors are out of reach for the farmer, their influence on production is sometimes significant. Climate and social institutions represent this category.

To be considered as a valid production function, f(X) must satisfy several properties, described below: (Chambers 1988, Jehle and Reny, 2000, p.118).

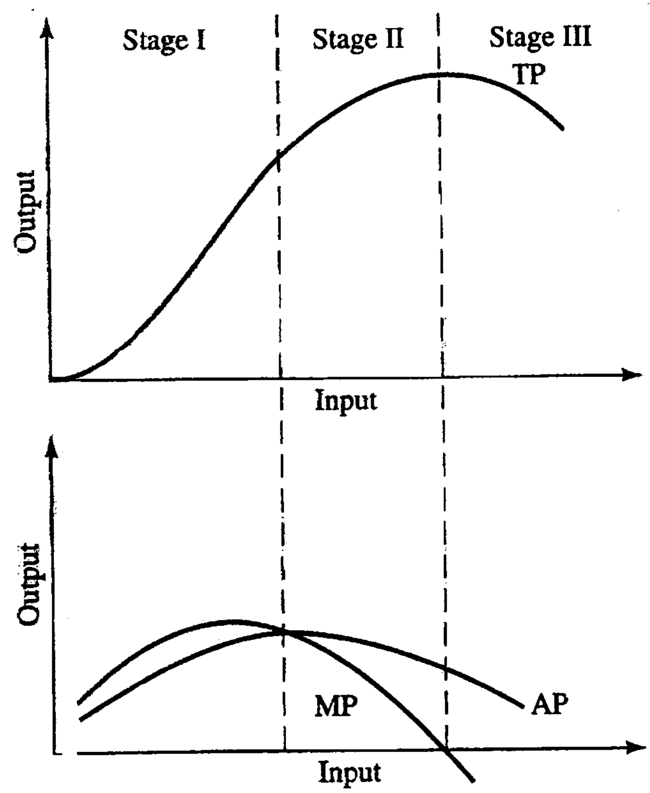
a) $X_i \geq 0$, finite (nonnegative, real inputs)
b) $Y \geq 0$ is finite, nonnegative
c) f(X) is everywhere continuous and twice continuously differentiable
d) f(X) is subject to the law of diminishing returns for all inputs

Properties a) and b) are straightforward, and only mean that output and input are real. Properties c) and d) are related. The law of diminishing returns describes the situation where as an additional unit of input is used, the marginal physical product eventually starts to decline. This requires that the second derivative is negative, at least over some range of input use.

$\frac{\partial Y}{\partial X_i} > 0$, and $\frac{\partial^2 Y}{\partial X_i^2} < 0$ over the economically relevant range of input use.

The production function can also be represented by a graph (fig.6). The figure illustrates three concepts, total product (TP), average product (AP) and marginal product (MP). TP is the production function while AP is the quantity of output produced over the quantity of input. $AP_i = Y/X_i$ where Y is output and X_i the ith input. Marginal product is defined above, as the slope of the production function.

Figure 6: Graphical illustration of the production function



Source: Doll and Orazem (1984), p.38

Figure 6 shows three stages of production. The first stage is terminated where AP is at a maximum. It also shows that MP is greater than AP, while AP is increasing. As more input is employed, more output is produced. The firm is better off to use more input to increase its output. However, less developed countries often face input constraints, so they are not able to produce as much as they want. Many firms in the third world produce in this stage.

In the second stage of production, AP and MP are decreasing but remain positive. The MP curve decreases faster than the AP curve. The second stage begins where AP is a maximum and ends where MP equals zero. It is usually assumed that the producer is maximizing profit or minimizing cost. In order to reach the goal of maximizing its profit, the firm should produce somewhere in the second stage.

The third stage shows a negative MP. Indeed, as extra input is added, output starts to decrease. In other words, the firm uses more input than necessary so a waste of resources occurs. The first and the third stages are not economically efficient. The meaning of efficiency will be investigated subsequently, but first, we consider how to select a functional form for the production function.

2.2.1 Functional form in production theory

A variety of functional forms have been used to represent production, some more often than others. Commonly used functional forms are the Cobb-Douglas, quadratic and transcendental. Less common forms are those developed by Liebig and Mitschelich-Baul. Beattie and Taylor (1985) have described some of those forms along with their properties.

Cobb-Douglas: $$Y = \beta X_1^{\alpha} X_2^{\lambda} \quad (3)$$

Quadratic: $$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 \pm \beta_3 X_1 X_2 - \beta_4 X_1^2 - \beta_5 X_2^2 \quad (4)$$

Transcendental: $$Y = \beta_0 + \beta_1 X_1 \pm \beta_2 X_2 \pm \beta_3 X_1 X_2 + \beta_4 \log X_1 \pm \beta_5 \log X_2 \quad (5)$$

According to Kaneda (1982), Dillon and Hardaker (1993), and Calkins (1998), the choice of a functional form should be based on several criteria:

1. **Economic and physical logic:** The chosen functional form should correspond to economic and physical logic such as the law of diminishing returns, positive marginal product, rates of technical substitution, etc.

2. **Parsimony in parameters:** When estimating the production function econometrically, there should be sufficient degrees of freedom to support the potential for significant statistical tests, for example significant t-tests, F-test and R^2.

3. **Ease of interpretation:** Usually a complex functional form renders the estimation results difficult to analyse. Furthermore, as more variables are added in the production function, there is more chance that multicollinearity occurs.

Now that we have defined the concept of the production function, its properties and criteria for selecting a functional form, we can examine some empirical studies, based on data from experimental farms and farm records from both developed and developing countries.

2.3 Empirical studies of production functions

Significant effort has been directed towards determining which factors influence agricultural production. Some of the early studies focused on the relationship between the amount of feed a dairy cow consumes and its milk output, the amount and composition of hog feed and the rate of gain, the amount of fertilizer applied to a field and the resulting crop yield. (Doll and Orazem,1984, p. 22)

According to Ibrahim (1989), there exist many empirical studies on the production function in developed countries, however, those from developing countries were limited prior to the 60's. More recently, researchers have been more involved and aware of problems in developing countries. Indeed, more than half of the population of the planet lives in poor countries where they face many problems from population pressure, hunger and poverty. Policy leaders agree that the expansion of agricultural production could help these countries, and contribute to economic development. However, studies in developing countries have faced some difficulties. Ibrahim (1989, p.19) provided three examples:

- Lack of quality and quantity of data (labour, capital, fertilizer).
- Agriculture is a multiple output technology, and this makes it difficult to estimate how an input is related to a specific output.
- The area allocated to some crops is often small. In this case, it is not easy to extend the analysis to a larger area.

In the following section, we will examine some empirical studies of the production function both in developed and developing countries, but we will put emphasis on studies in developing countries.

2.3.1 Studies based on experimental sites

In agriculture, data used for empirical research on production functions may be collected from experimental sites or farm records. Researchers have usually used data from experimental sites to determine the effect of a particular input on yield. In other words, they want to find the optimal amount of input in order to reach a maximum yield of output. The concept of a yield function is similar to the production function except that output is divided by the most restrictive variable. For example, the yield function for crop production could be written as Y/ha where Y represents output and ha (hectare) for the unit of land. For dairy production, the yield function could be the amount of milk divided by the number of cows. One characteristic of studies conducted on experimental sites is the limitation on inputs used. Indeed, researchers are inclined to focus on a sole input to analyse its impact on output. (Doll and Orazem 1984). In their book published in 1961, Heady and Dillon presented several studies on the response of output to a specific input.

According to Heady and Dillon (1961, p.10), in 1855 Liebig, famous for his "law of the minimum", introduced the idea of a relationship between nutrient inputs and crop yields. This law supposed that crop yield responded linearly to the quantity of a limiting inputs. At some level, it would not be possible to increase yield anymore because it reached its maximum when some other input became limiting. While Liebig did not represent his idea algebraically, many economists have attempted to represent this law of the minimum. Heady and Dillon (1961) noted that Bondorff and Plessing (1924) suggested the following linear equation:

$$Y = \beta x \tag{6}$$

Where Y is the yield, β represents a coefficient and x the amount of input. So yield would increase proportionally to the input supplied. Yield would be zero without any input used. In 1924 Boresch added a constant β_0 to the previous equation.

$$Y = \beta_0 + \beta_1 x \tag{7}$$

Here β_0 represents yield with no input supplied. Equations (6) and (7) were an attempt to represent Liebig's law of the minimum. However, they did not account for the maximum yield, just the linear response to inputs. Another early study on yield response to nutrient inputs is attributed to Mitscherlich. In 1909, Mitscherlich was probably the first to suggest a nonlinear production function to estimate the relationship between fertilizer and crop production.

$$Y = \beta_1 (1 - e^{-\beta_0 x}) \tag{8}$$

Y = yield

β_1 = maximum possible yield when the input x is not limited

β_0 = constant unaffected by type of crop, climate or environmental factors

x = amount of input added

In 1923, Spillman proposed a similar equation to Mitscherlich. He studied the effect of fertilizer on tobacco, based on research in North Carolina. Contrary to Mitscherlich, Spillman thought that the constant should be affected by environmental factors. (Heady and Dillon 1961, p.11)

$$Y = \beta_1(1 - \beta_0^x) \quad (9)$$

Y= yield

β_1 = maximum possible yield from use of input x

β_0 = coefficient that represents the marginal product

x = amount of input added

According to Mundlak et al. (1997), analysis of agricultural production functions really took off with the works of Tintner (1944) and Heady (1946). Indeed, Heady conducted a wide variety of research on crop, hog, milk and poultry production. Later on, with the cooperation of Dillon in 1961, Heady published a textbook related to agricultural production functions based on field experiments in the US. However, all this work was oriented to production in North America.

Emphasis on studies in developing countries began in the 1960s (Eicher and Baker, 1985). In 1964, Herdt and Mellor compared rice experiments in developed and developing countries. Indeed, they conducted an experiment of rice yield response to nitrogen application in India and the United States. They only considered rice production under irrigation and the nitrogen effect by holding other nutrients constant.

The authors selected a quadratic functional form to depict the relationship between rice yield and the amount of fertilizer used because this function produced a good fit with the observations. They found that the optimum level of nitrogen use was much higher in the United States than in India. The researchers did not think that biological or physical factors were the cause of this difference. They suggested that the advanced research and technical training in the United States could explain this difference. However, one limitation of this research was that only one input was examined while in reality, many factors under and beyond farmer's control affect rice production. So the optimum level of nitrogen use might be overestimated.

In Asia, the International Rice Research Institute (IRRI) is probably the most important agricultural institution for the study of rice, with activities that began in the early 1960's. Between 1974 and 1976, the IRRI agronomy department carried out experiments on rice production in five regions in the Philippines. The team collected data on farm inputs such as fertilizer, herbicides and insecticides. Environmental variables were also measured in order to define a production function. Based on those data, Herdt and Mandac (1981) studied the economic efficiency of Philippine rice farmers. Their results and concept of efficiency will be discussed in more detail in the next section.

Since then, experiments have expanded and the econometric methods of estimation have also improved. More recently, Ozsabuncuoglu (1998), investigated factors affecting the production function for wheat in the Southeastern Anatolion Project region in Turkey. Data for the period 1963 to 1989 were used for the purpose of this study. The author estimated the wheat production function by using quadratic and Cobb-Douglas functional forms. The variables inserted in those functional forms were area, fertilizers, temperature and rainfall. The effect of those factors on wheat production turned out to be statistically significant at the 5% level.

2.3.2 Studies based on farm records

Contrary to the experimental settings, researchers tend to include more explanatory variables in their studies based on farm records. Commonly used variables include land, labour, capital, fertilizers, machinery, etc. Some authors arrange those variables into categories. For example, Norman (1967) categorized labour according to gender and age. Upton (1967) separated labour into hired labour and family labour. Based on 1973-75 data in Nepal, Calkins (1982) studied the interactions among income, employment, and nutrition. Indeed, Calkins divided labour into three groups: outside, outside co-operative and family labour. He separated land into two components: irrigated and unirrigated. Yadav and Peterson (1993) also decomposed land to irrigated and nonirrigated land for their research on rice yield in Nepal. They found out that irrigated land is a major factor that affects rice production. Earlier research of Barker and Herdt (1985) also found that irrigated area influenced rice production.

Indeed, Barker and Herdt (1985), two former members of IRRI, published a book on the rice economy in Asia, in particular the countries of East Asia, Southeast Asia and South Asia. Based on farm records, they estimated a Cobb-Douglas production function for Asian rice between 1951 and 1975. They used data from five-year averages to lessen the weather effect. They only analyzed technical explanatory variables such as land, irrigation, rice variety, fertilizer, labour and capital and excluded factors that were beyond farmers control like weather. They found out that labour and irrigation were the most important factors affecting rice production. They expected a positive relationship between fertilizer and rice production. Indeed, fertilizer is usually a major factor in the production of any grain. However, fertilizer showed a negative sign in the equation. The authors suspected that the negative sign might be caused by a correlation between fertilizer and some other variable. There was an important correlation between the area allocated to modern varieties and fertilizer. They also explained that the fertilizer applied and irrigated area differed tremendously among Asian countries. The amount of fertilizer varied from zero to 300 kg/ha and irrigated area from zero to 100 percent of rice area. A single equation could probably not capture these differences. So the authors, corrected their estimation by dividing their data into groups, according to the percent of irrigated area: low, medium and high irrigation. Each of the irrigation classes showed the expected results.

As mentioned earlier, studies based on farm level data include more variables for the explanation of production. Thereby, researchers started to include socio-economic variables to assess determinants influencing agricultural production and their effect. Among these kind of factors, there are age, gender, education, among others. According to Eicher et al (1970), socioeconomic variables are as important as technical variables in terms of their influence on production. Moreover, policy makers could establish programs based on the results of the research to stimulate and encourage farmers to improve and increase their production (Ibrahim 1988, Calkins 1998). Contrary to the technical factors, some socio-economic variables are more difficult to quantify. Indeed, it is difficult to measure management quality for example.

There are a number of studies that consider both technical and socio-economic factors in the assessment of production efficiency. In the empirical studies of Griliches (1964), Upton (1967), Hayami and Ruttan (1970), Lockheed et al (1980), education was found to be an important factor that affected agricultural production. However, Phillips (1987) disagreed with Lockheed et al, suggesting that in less developed countries, farmer education had a negative impact on production efficiency. Phillips criticized Lockheed et al by analyzing more carefully their studies. Phillips gave an example showing that education coefficients were often not statistically significant at 5% and in some cases education coefficients were negative. The studies did not explain further about the negative impact of education on efficiency. In the same year, Dhakal et al (1987), investigated the effect of education in Nepal's traditional agriculture. They analyzed the impact of education on agricultural production by using three functions: a gross value function, a value added function and an engineering production function. They found that the education coefficient was highly significant for the gross value and value added functions. However, the engineering function showed that education was not statistically significant. It means that education, through the worker effect, is not likely an important factor that influences productivity. The worker effect is simply the marginal value product of the engineering production function according to Welch

(1970). Results of Dhakal's studies were similar to Pudasaini's (1983) work. Indeed, Pudasaini found that education was statistically insignificant in the traditional agriculture of Nepal.

Based on the previous review, it appears that the most commonly used factors of production in analysis are land, labour, fertilizer and education. Capital is not often included in empirical studies of developing countries because it is not often available to small farmers. The dependent variable estimated is often gross value, physical output, or yield and the most commonly used functional form is a Cobb-Douglas because of its simplicity. These studies on production functions allow us to identify the importance of input factors that affect output. Also, these studies provide the basis for assessing variables that influence farmers' production efficiency. In the next section, we consider efficiency and its determinants, after first defining the concept.

2.4 The concept of efficiency

In general, with the same conditions of production, farmers should obtain a similar production. However, the results vary from one farmer to another probably because farmers' ability to manage their farms differ. Indeed, one farmer may produce more than the average. It is interesting for the less efficient farmer to compare with an efficient farmer so he can increase his production without using more inputs (Ibrahim, 1989). In this section, we will define the concept of efficiency and its methods of measurement. Then, we will examine some empirical studies.

According to Romain and Lambert (1992), early studies on efficiency were attributed to Debreu (1951) and Koopmans (1951). Koopmans defined a producer's technical efficiency as a feasible input-output vector for which it is impossible to increase any output without simultaneously increasing at least one input, ceteris paribus. On Debreu's side, he provided a definition of efficiency as a measure of resource utilization. Debreu evaluated the efficiency measure as one minus the maximum relative reduction in all inputs that still holds the same level of production. For example, if the relative reduction in inputs equals 0.10, the efficiency measure would be 1 - 0.10 = 0.90 or 90%.

Based on the work of Debreu and Koopmans, Farrell (1957) separated this concept into technical and allocative components. He defined these two elements as :

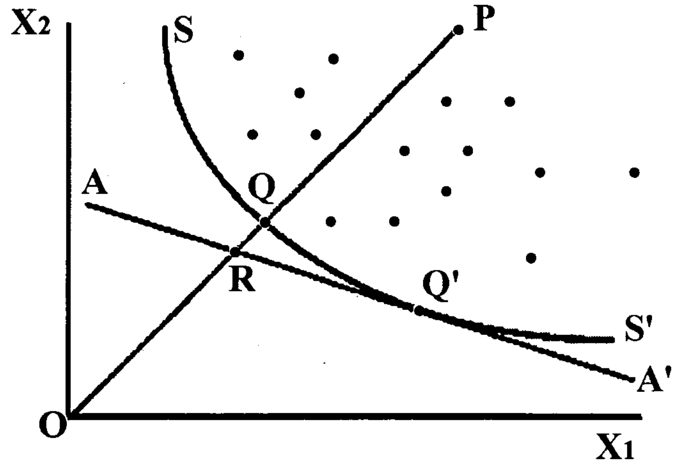
Technical efficiency (TE): is the ability of a producer to reach the maximum output possible from a given sets of inputs or, for a given output, the producer uses the minimum set of inputs possible.

Allocative efficiency (AE): refers to the producer's decision to use an optimal mix of inputs or outputs given their prices and technology in order to maximize profit.

Economic efficiency (EE): is a combination of the other two and results from the product of technical and allocative efficiency.

In order to distinguish the various types of efficiency, we will discuss different efficiency measures relative to a given technology. In figure 7, Farrell provided an example of input-oriented measures of efficiency. This figure presents observations of firms using a combination of two inputs (X_1 and X_2) to produce a single output. Each point represents an observation for one farm, and the amount of the two inputs required to produce the same level of output.

Figure 7: Input oriented measure of technical and allocative efficiencies



Sources: Farrell (1957), p. 254 and Battese and Coelli (1998), p.135,

SS' represents the isoquant of fully efficient firms with a given technology. It means that SS' is a frontier isoquant, and no firm can produce beyond this isoquant, toward the origin. With any combination of inputs along the isoquant, the firm obtains the same level of output. Here, observations at Q and Q' are considered technically efficient while P is not. At Q, the firm uses a combination of inputs in the same ratio as P. So Q and P produce the same amount of output but Q uses only a fraction OQ/OP of inputs. In fact, the ratio OQ/OP is the technical efficiency measure of firm P. This measure takes the value of 1 or 100% if the firm is located along the isoquant. This value decreases indefinitely if the amount of inputs per unit output increase indefinitely. Thus, an increase of the amount of inputs per unit of output leads to a reduction of technical efficiency. However, in order to be considered economically efficient, the firm needs to know if it produces with the best proportion of inputs considering their prices. In figure 7, AA' illustrates the input price ratio. Although Q and Q' are technically efficient, the optimal production is at Q'. The costs of production at Q' are represented by the fraction OR/OQ of those at Q. Therefore, the fraction OR/OQ is the price efficiency or allocative efficiency at Q (Farrell, 1957, p.254). If the firm is operating at point P, the firm is said to be inefficient. The measure of technical efficiency (TE) at P is calculated as the following:

$$TE = OQ/OP \text{ or } TE = 1 - QP/OP \quad (10)$$

The value of TE lies between zero and one. By incorporating the relative prices of inputs, indicated by the slope AA', we can measure allocative efficiency (AE). At P, its allocative efficiency is:

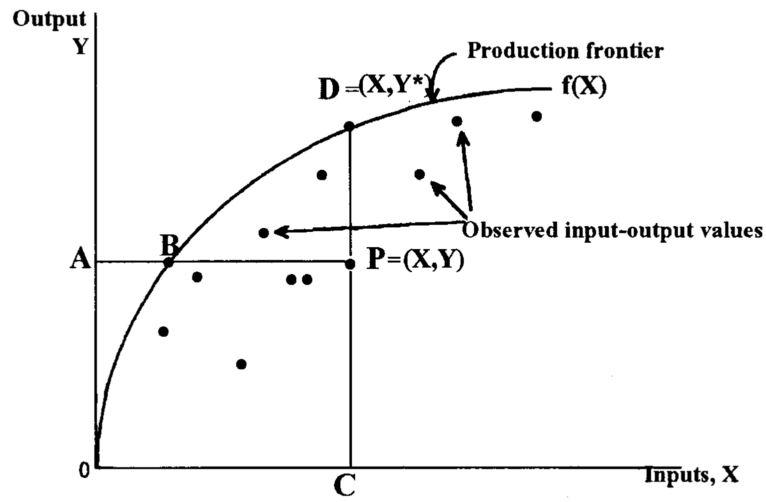
$$AE = OR/OQ \quad (11)$$

So, at P, allocative inefficiency occurs because the firm fails to use inputs in the same proportion to their relative prices. Note that the point Q' represents the least-cost combination of inputs where the marginal rate of technical substitution is equal to the input price ratio (Kumbhaker and Lovell, 2000). Finally, economic efficiency (EE) is the product of TE and AE.

$$EE = TE*AE = OQ/OP*OR/OQ = OR/OP \quad (12)$$

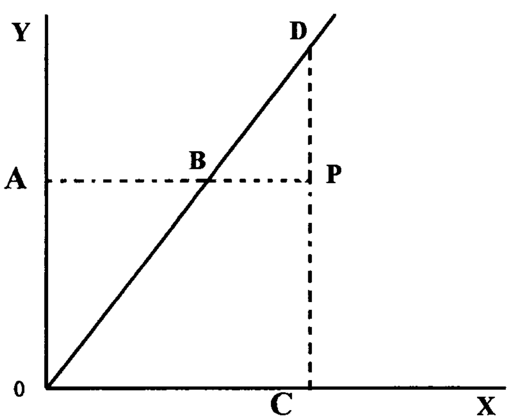
We have seen the measure of different components of efficiency by representing an input-oriented measure, i.e. for a given amount of output, we want to use the minimum set of inputs. However, we can also define an output-oriented measure. In this case, the output orientation reflects, from a given set of inputs, the maximum attainable level of output and it is outlined by the curve f(X) in figure 8. So, f(X) is the best production function where the X axis represents the inputs and the Y axis represents the output, hence Y^* is the estimated output on the frontier and Y^0 is the observed output. Firms located on the frontier are considered 100% technically efficient and inefficient if they produce under the frontier. Thus, the deviation from this frontier is the measure of technical efficiency.

Figure 8: Output oriented measure of technical efficiency with a DRS



Sources: Battese 1992, and Battese and Coelli, p.137, 1998

Figure 9: Output oriented measure of technical efficiency with a CRS



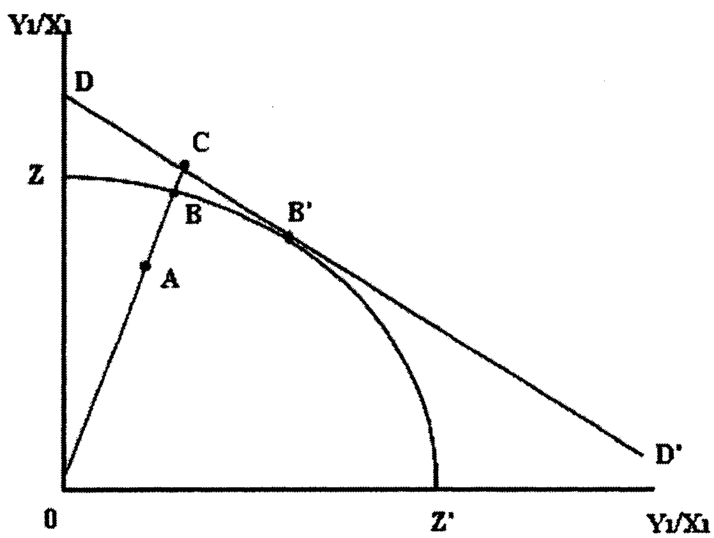
Sources: Battese 1992, and Battese and Coelli, p.137, 1998

$$TE = Y^0 / Y^* \tag{13}$$

where TE represents the ratio of observed output (Y^0) over the best practice output (Y^*) for given inputs. Figure 8 depicts a decreasing returns to scale technology (DRS). It means that when a firm increases its use of all inputs by some proportion, output increases by less than the same proportion. Figure 9 represents a constant returns to scale (CRS) technology. There are constant returns to scale when a firm increases its use of all inputs by some proportion, and output increases by the same proportion. In both cases, at point P, the firm produces inefficiently. The TE is calculated by the ratio CP/CD. However, the input-oriented measure of TE would be AB/AP. The TE measures of those two methods, the input oriented and the output oriented measure, are equal in value only when CRS occurs. Thus, in the figure 9 that depicts a CRS , it would be the case that:

$$AB/AP = CP/CD \quad (14)$$

Figure 10: Output oriented measure of TE



Sources: Battese 1992, and Battese and Coelli, p.138, 1998

Figure 10 illustrates the output oriented efficiency measure for a firm producing two outputs by employing a single input (X_1). The curve ZZ' illustrates the production possibility frontier. Production under this curve is considered inefficient as in point A.

The distance AB is related to technical inefficiency since it would be possible to move along OB and produce more of both outputs, if the firm was efficient. In this case, the measure of TE output-oriented is :

$$TE = OA/OB \tag{15}$$

This measures the proportion of potential output (OB) that is produced at point A.

If information on prices is available, we can determine the point where production is allocatively efficient. The line DD' represents an isorevenue line with a slope that equals relative output prices. Allocative efficiency is measured by:

$$AE = OB/OC \tag{16}$$

The product of technical efficiency (TE) and allocative efficiency (AE) measures economic efficiency (EE).

$$EE = TE*AE = OA/OB*OB/OC = OA/OC \tag{17}$$

This efficiency measure is a radial measure. Radial input and output efficiency are calculated along a ray from the origin to the observed production point. These measures are characterized by constant relative proportions of inputs or outputs. Also, they are unit invariant. This means that changing the units of measurement (for example, measuring quantity of labour in person hours instead of person years) does not change the value of the efficiency measure. (Battese and Coelli 1998, p139)

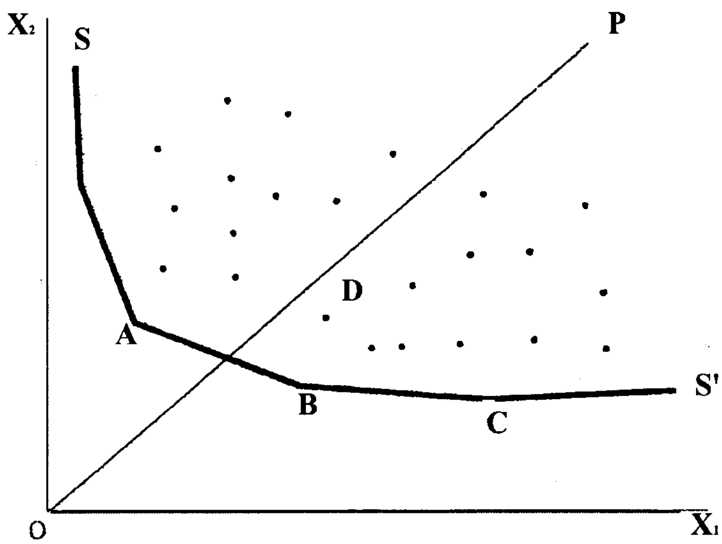
2.4.1 Approaches to estimate efficiency

In order to calculate efficiency, we need to determine a frontier production function, such that no firm can produce beyond this frontier. There exist different approaches to measure efficiency. These approaches can be divided into two categories: deterministic and stochastic. The deterministic approach can be classified into two types: parametric and non-parametric. The first category, parametric frontier is characterized by a specific functional form while non-parametric frontier does not require a particular functional form. (Amara and Romain 2000, Ibrahim 1989, Bravo-Ureta et al 2001).

2.4.2 Deterministic frontier approach

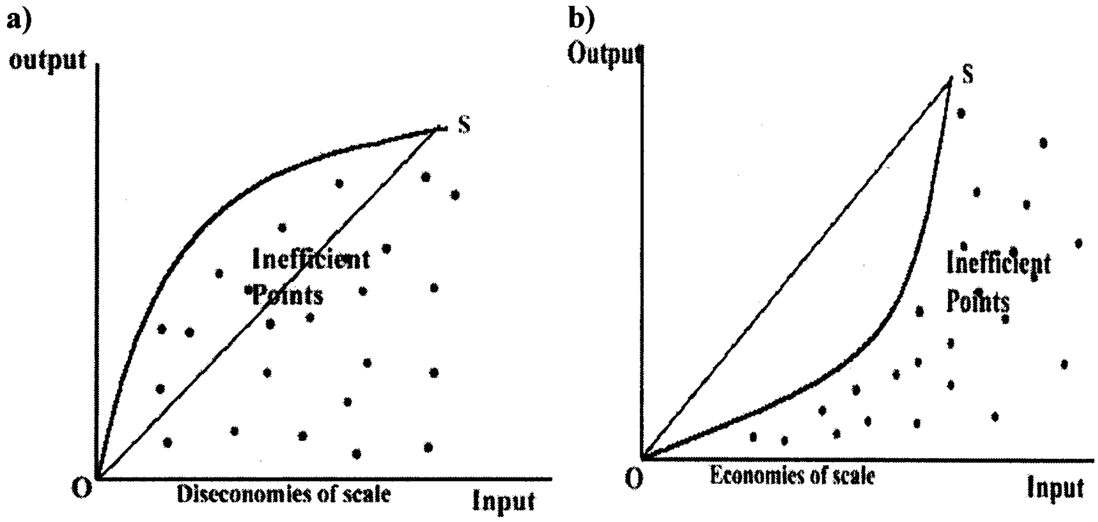
The main feature of this approach is all observations lie on one side of the frontier. Any deviation from the production frontier is assumed to represent technical inefficiency. This approach is attributed to Farrell's (1957) work and no specific functional form is associated with this approach. Farrell estimated an efficient isoquant from a scatter diagram, by using a succession of linear programming models (fig.11). Farrell assumed that this isoquant was convex and had a negative slope in the context of a constant return to scale technology. The assumption of a convex isoquant means that if two points are attainable in practice, then so is any point representing a weighted average of them.

Figure 11: Farrell's measurement of efficiency



Source Farrell (1957), p.256

Figure 12: Effect of diseconomies and economies of scale on efficiency measure



Source: Farrell (1957), p.258

In his study, Farrel estimated the level of agricultural efficiency of 48 American states. He included in his model four inputs (land, labour, materials and capital). Farm income plus home consumption were considered as the output. He estimated an isoquant frontier based on the input-output ratio and calculated the deviation of the observations from the isoquant as the efficiency measure. Thus, he estimated the efficiency for each state with different combinations of inputs. However, Farrell's study had some limitations. As mentioned earlier, Farrell's model of efficiency is fitting only in the case of constant returns to scale. Indeed, the convexity assumption is not necessarily true in cases of variable returns to scale. In figure 12a, a case of diseconomies of scale, points along the OS segment are inefficient while OS in figure 12b is efficient, in the case of economies of scale that involves a non-convex production function. To counter this problem, Farrell and Fieldhouse (1962) made some improvements and analyzed efficiency under increasing returns to scale with the same data used by Farrell (1957). They suggested this method to show that the efficient production function did not necessarily follow the convexity assumption.

2.4.3 Non-parametric models

Non-parametric models are often known as "data envelopment analysis DEA". This method was first introduced by Charnes et al in 1978. They measured efficiency by using a mathematical programming model to construct a piece-wise linear production frontier. Efficiency is measured as the ratio of total output to total inputs. The score varies from 0 to 100%. Two major features of this method are the possibility of efficiency measurement in the case of multiple outputs and when returns to scale are not constant. The DEA method is similar to the Farrell model or a relative measure of decision-making units (DMU) compared to all the other DMU. Measuring efficiency using the DEA method in developed countries has proved to be useful particularly in the public sector such as public schools, hospitals, and extension services. (Sengupta 1989).

In the agricultural sector, Sharma et al. (1999) studied different components of efficiency in swine production in Hawaii. They compared the non-parametric and parametric approaches by using DEA and a parametric stochastic approach. This latter approach will be defined in more detail in the next section. They also assessed efficiency under variable (VRS) and constant returns to scale (CRS). They found that the measure of efficiency under CRS is higher in the parametric models than in non-parametric. However the efficiency measure is similar under VRS using both approaches. Moreover, Sharma et al. (1999) analyzed factors that influenced the efficiency of swine production. The results of their study showed a robust positive relationship between farm size and efficiency. In his research, Helfand (2002) examined in more detail the influence of farm size on efficiency in the Center-West of Brazil. He also investigated the determinants of productive efficiency based on the DEA approach. He found that the main explanatory variables of efficiency are access to institutional credit and modern inputs. In addition, the results of this study showed that the relationship between farm size and efficiency was not linear as expected. Indeed, farms producing under 200 ha showed an inverse relationship but larger farms (over 200 ha) started to show a positive relationship. The author explained that larger farms had more access to credit and modern inputs compared to smaller farms.

According to Bravo-Ureta and Pinheiro (1994), studies on farm efficiency using the non-parametric approach in Asia, especially in developing countries were scarce. Ray (1985) also used a non-parametric approach to estimate efficiency according to farm size in India. Based on a sample of 63 farms, the author divided this sample into three groups according to farm size. He used linear programming to measure efficiency for different groups. The results of his research did not show a significant difference of efficiency across farm size groups. More recently, Krasachat (2003) studied the efficiency measure and factors that affected rice farm efficiency in Thailand by using an input-oriented DEA model based on cross-sectional survey data of 1999 in three provinces of the Northeastern region. The author justified the choice of these provinces because they have a similar climate and soil type and face a similar market environment. The main factors investigated were fertilizer, irrigation, labour, capital, land and other inputs. The results of his research did not reveal that irrigation or farm size affect rice efficiency significantly. However, provincial differences appeared to influence rice efficiency. Krasachat's research did not seem very conclusive with respect to factors influencing rice efficiency. The DEA method may not be an appropriate approach since he estimated efficiency for a single output, in this case, rice. Thus, the non-parametric approach may have some advantages under the condition of multiple output estimation and variable returns to scale, but it also has some limits. Indeed, non-parametric is a deterministic approach, so deviations from the frontier are attributed only to inefficiency and does not allow for random errors that could be attributed to the environment. Furthermore, the estimated frontier is sensitive to outliers. The Farrell model with the isoquant frontier displays this problem. Since the non-parametric approach does not assume a particular functional form, it is difficult to analyze its algebraic proprieties. Due to these problems, Farrell suggested a second method to estimate a frontier production function: the parametric approach.

2.4.4 Parametric frontier approach

Farrell improved his first model by using a Cobb-Douglas functional form although the assumption of constant returns to scale was still retained. As mentioned earlier, the deterministic and parametric approach requires a specific functional form, and in the literature, there are abundant empirical studies with this approach. The Cobb-Douglas functional form is frequently used (Farrell 1957, Lau and Yotopoulos 1971, Jeffrey and Xu 1998, Huang et al. 2001, Nahm et al. 2003). Researchers seem to favour the Cobb-Douglas because of its simplicity although this functional from displays some restrictive properties.

In 1968, Aigner and Chu also used the Cobb-Douglas functional form to calculate efficiency. Contrary to the Farrell models, they did not impose constant returns to scale. Their model is the following:

$$Ln\,(Yi) = Xi\beta - Ui \qquad i = 1, 2, 3, \ldots, N \qquad (18)$$

where Ln (Yi) denotes the logarithm of the ith firm's output

Xi is the log quantity of vector inputs used by the ith firm

$\beta = (\beta0, \beta1, \ldots, \beta k)$ represent the unknown parameter vector to estimate

Ui is assumed to be independently distributed, non-negative and represents unobservable random variables and is related to technical inefficiency

Technical efficiency is estimated by the ratio of production observed and the production frontier.

$$TE = Yi/\exp(Xi\beta) \quad (19)$$

$$= \exp(Xi\beta - Ui)/\exp(Xi\beta)$$

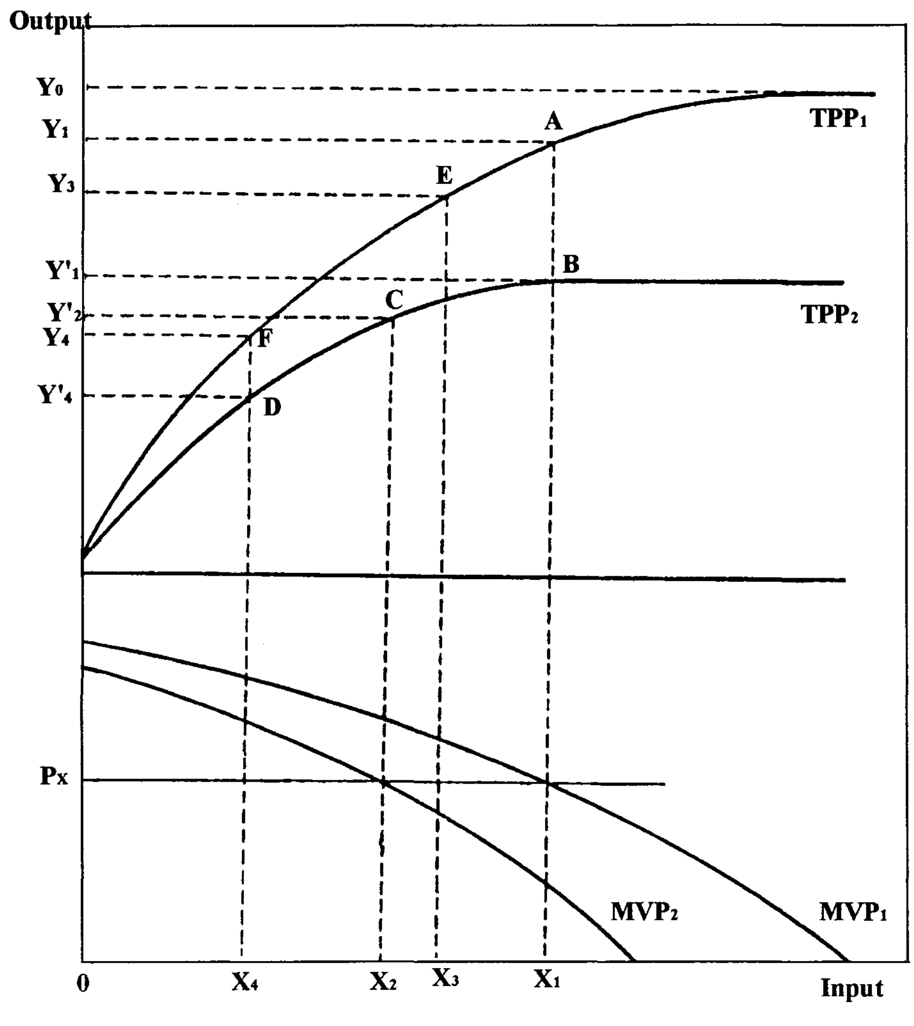
$$= \exp(-Ui)$$

Yi is the observed production of the ith firm and exp(Xiβ) denotes the production frontier. (Amara and Romain 2000)

Based on the Aigner and Chu (1968) model, Timmer (1971) suggested a probabilistic model for Farrell's first model in order to correct for the problem of outliers. In fact, Farrell's model is based only on the extreme observations in the estimation of the efficient isoquant. In the case of data error, the estimated frontier may be upwardly biased and lead to an incorrect efficiency measure. Timmer corrected the problem of outliers by removing some extreme observations and generated a new frontier by using linear programming and ordinary least-squares (OLS). Thereafter, Timmer estimated a sequence of production functions by removing the less efficient observations until only the most efficient observations remained. The frontier function is the result of all these eliminations, when it is no longer sensitive to the outliers. In his study, Timmer assessed the efficiency measure by estimating a Cobb-Douglas production function for 48 American states from 1960 to 1967. He found that technical efficiency varied from 81% to 99% for each state. Six factors of production: gross value of farm production, labour, capital, fertilizer, livestock, seed and miscellaneous were found to be significant.

Another way to understand different components of efficiency measurements is to take a look at an exemple from Herdt and Mandac who investigated the efficiency of Philipine rice farmers in 1981.

Figure.13: Theoretical model of technical and allocative efficiency in the one-variable input case



Source: Herdt and Mandac (1981), p. 378

This figure shows an example of a production function using one variable input where Y depicts the output and X the input. The TPP_1 curve represents a frontier production function, i.e. in case of full efficiency. So, production under this curve is regarded as technically inefficient such as the curve TPP_2. MVP_1 and MVP_2 represent their respective marginal value product functions. Suppose that the producer faces an input price Px. The efficient farmer will decide to use X_1 to produce Y_1 unit of output. Such a decision happens when there is no restriction on input use, profit maximization behaviour, and a competitive market. In other words, the firm operates where the value of the marginal product is equal to its price. So, operating at point A, the firm is technically efficient and allocatively efficient as well. At this point, the value of TE and AE is one because the firm is fully efficient. (Herdt and Mandac, 1981, p. 377)

In the case of technical inefficiency for example, a firm producing below TPP_1 at B, the firm still employs X_1 unit of input. Thus, for the same quantity of input, the firm produces less output Y'_1 instead of Y_1. The enterprise is also qualified as inefficient allocatively because its does not respect economic theory. Indeed, the firm should use X_2 to produce Y'_2 where MVP_2 equals its price. Another point where the firm is inefficient technically and allocatively is at point D by using X_4 input and producing Y'_4 output.

In their studies, Herdt and Mandac measured the rate of efficiency. They attributed a maximum value of one where the firm is fully efficient. So the measure of technical efficiency at point D is :

$$E_t = 1 - (Y_4 - Y'_4)/Y'_4 \qquad (20)$$

and the allocative inefficiency :

$$E_a = 1 - (Y'_2 - Y'_4)/Y'_4 \qquad (21)$$

So the observations F, E and A are technically efficient because they lie on the frontier production curve. However, F and E are not allocatively efficient.

In their research, Herdt and Mandac compared the rice yield obtained by farmers (actual yield) with the experimental yield obtained by researchers (potential yield). They assumed that given the same conditions of production, farmers should obtain the same yield as the researcher's. However, results under a farmer's control were lower than the experimental station. In order to analyse this difference, the authors first estimated a production function based on data from the experiments. The independent variables included were farm inputs such as fertilizer, insecticide, herbicide, farm size, soil type, water stress, and solar radiation. Then, they measured technical and allocative efficiency for each farm. Finally, they regressed variables on farm efficiency in order to explain the efficiency variation among farmers. They found that technical efficiency could be explained by a farmer's ability to apply fertilizers, i.e. the timing and the management skills in the application of fertilizer. They found that farm size was an important variable that affected efficiency. Indeed, larger farms were less technically and allocatively efficient than smaller farms. Lack of labour and management difficulty were probably the cause of this inefficiency.

Several authors have studied efficiency in developing countries. Shultz (1964) focused his research on allocative efficiency. In his study, Shultz concluded that farmers might be poor but they are efficient. They are efficient in the sense that they make efficient use of whatever inputs are available to them, but the income they receive is low. Thus, low productivity of inputs leads to a poor income and not inefficiency of resource allocation. Moreover, Shultz's famous notion of "efficient but poor" is applied only to traditional agriculture under perfect competition and information. He defined this type of agriculture as a stable and unchanged agriculture practiced for generations. In other words, he considered only the communities that practiced agriculture unaffected by external factors such as political change or structural change. Lipton (1968) and Adams (1986) criticized Shultz's theory by arguing that it is nearly impossible to find such a community unless there is a lost tribe to be found. Furthermore, Adams (1986) disagreed with Shultz's theory because he analysed only two communities, one from India and the other from Central America that corresponded to Shultz's definition of traditional agriculture and neglected other parts of the world. So, many developing countries will not meet Shultz's standard of a traditional agriculture. On the other hand, in the absence of a perfect market, which is often the case in developing countries, Schultz's theory is not appropriate even if an individual farm allocates its resources efficiently, but collective results may not be efficient (Ball and Pounder, 1996).

2.4.5 Stochastic approach

Contrary to the deterministic approach, that attributes any deviation from the frontier to technical inefficiency, the stochastic approach acknowledges the fact that factors beyond the producer's control may considerably affect firm efficiency. The first authors who attempted to incorporate variables outside producer's control were Aigner, Lovell and Schmidt (1977), then Meeusen and van den Broek (1977). The stochastic approach includes an independent composed error with a two-sided symmetric term and a one-sided term. (Amara and Romain 2000, Ibrahim 1989)

- The two-sided error term is symmetric and incorporates random effects. In other words, the error term is distributed on both sides of the production frontier.
- The one-sided error, i.e. error distributed on only one side of the frontier, reflects the inefficiency.

The stochastic model can be defined as:

$Y = f(X)\exp(v-u)$

where Y depicts the output vector

X is the input vector

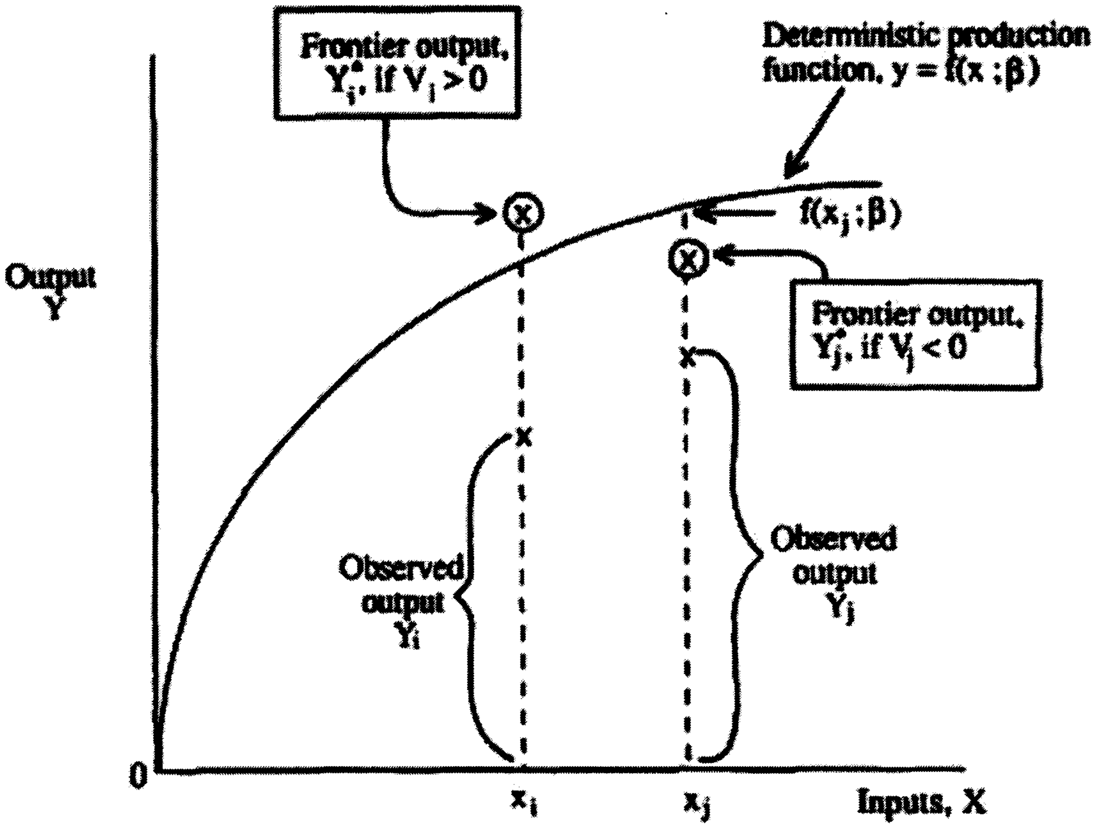
v represents random errors assumed to be independently and identically distributed

u is the error term associated with technical inefficiency and is on or below the production frontier, thus $u \geq 0$

2.4.6 Stochastic empirical studies

For a better understanding of the difference between the deterministic and stochastic approaches, consider figure 14.

Figure 14: Stochastic frontier production function



Source: Battese (1992), p.191

Here we suppose there are two firms : firm i and firm j. These two firms produce Y_i and Y_j quantity of output by using respectively X_i and X_j input. Firm i operates at Y_i^*, a point above the deterministic production frontier. As mentioned earlier, the error term can be on both sides of the production frontier while the error term in the deterministic approach lies on or under the production frontier. In this case, the observation Y_i^* lies above the production frontier. Thus, Y_i^* also depicts the stochastic frontier that can be expressed as $f(X_i)\exp(v_i)$. At this level of production, firm i probably benefits from good conditions of production, and the random error v_i takes a positive value. On the other hand, firm j produces below the deterministic production frontier, at Y_j^* which reflects a negative value of v_j. (Amara and Romain 2000)

There are a number of empirical studies on efficiency that have used the stochastic approach (Rawlins 1989, Wen et al. 2002, Yao and Liu 1998). Sriboonchitta and Wiboonpongse (2000) estimated the technical efficiency of Jasmine and non Jasmine rice for 1999/2000 in Thailand. They used the transcendental logarithmic and Cobb-Douglas stochastic production frontiers. They found an average technical efficiency of 67.93% for Jasmine rice and 71.58% for non Jasmine rice. They also investigated factors that significantly influenced technical efficiency. The determinants of efficiency were age, labour, male-labour ratio in the case of non Jasmine while only one variable significantly affected the technical efficiency of Jasmine : the male-labour ratio. Similar studies have been done on efficiency in rice by employing the stochastic approach. In 1996, Sharif and Dar published their research on technical inefficiency in traditional and high yielding varieties of rice cultivation in Bangladesh. In 1984, Huang and Bagi examined technical efficiency of individual farms in Northwest India.

The stochastic production frontier can be estimated by the method of maximum likelyhood (ML) and corrected ordinary least squares (COLS). Initially, stochastic models did not allow for the separation of the errors terms, U from V, for an individual firm. Indeed, it was only possible to estimate an average efficiency for the entire sample.

In 1982, Jondrow et al, showed that it was possible to measure efficiency for each firm and distinguish the error terms v from u by assigning a known distribution to the two error terms.

CHAPTER 3. METHODOLOGY

The previous chapter showed that many functional forms can be used to estimate a production function, and that there are different approaches to measure technical efficiency. In this chapter, there are three sections that describe the methodology used to estimate a production function, the measure of technical efficiency employed, and the survey data used for this study.

3.1 Specification of econometric models

To estimate technical efficiency of an individual firm, first a parametric and deterministic approach was selected following Timmer (1971). Furthermore, a stochastic approach that includes a random error, based on Aigner et al. (1977), was also used. The results from both methods will be compared.

3.1.1 Estimation of the production function

In order to measure technical efficiency, a production function is first estimated based on data randomly collected in Ban Home village. A mathematical model is defined to capture the relationship between the dependent variable and the explanatory variables by a regression analysis.

Suppose that the relationship between the output and inputs is linear:

$$Y_i = \beta_0 + \beta_k X_k + \mu_i \qquad (22)$$

where Y_i is the ith observation of explained variable (production or yield)

X_k are the explanatory variables (land, fertilizer, labour, etc), they are observed variables without error

β_0 is the intercept when the explanatory variables are zero

β_k is a vector of unknown parameters to be estimated

μ_i is a random variable associated with firm inefficiency

The equation $Y_i = \beta_0 + \beta_k X_k$ implies that a firm produces under the condition that there exist no factors beyond the firm's control. In reality, it's not always the case because it is hardly possible to include all factors to estimate a production function. So including the error term μ_i, also known as the residual, measures the difference between the actual output Y_i and the estimated output $\hat{Y}_i$. This error term might affect positively or negatively the output.

3.1.2 Model and parameter estimation

In this study, the method of ordinary least squares (OLS) was employed to estimate the production function (Gujarati 1995).

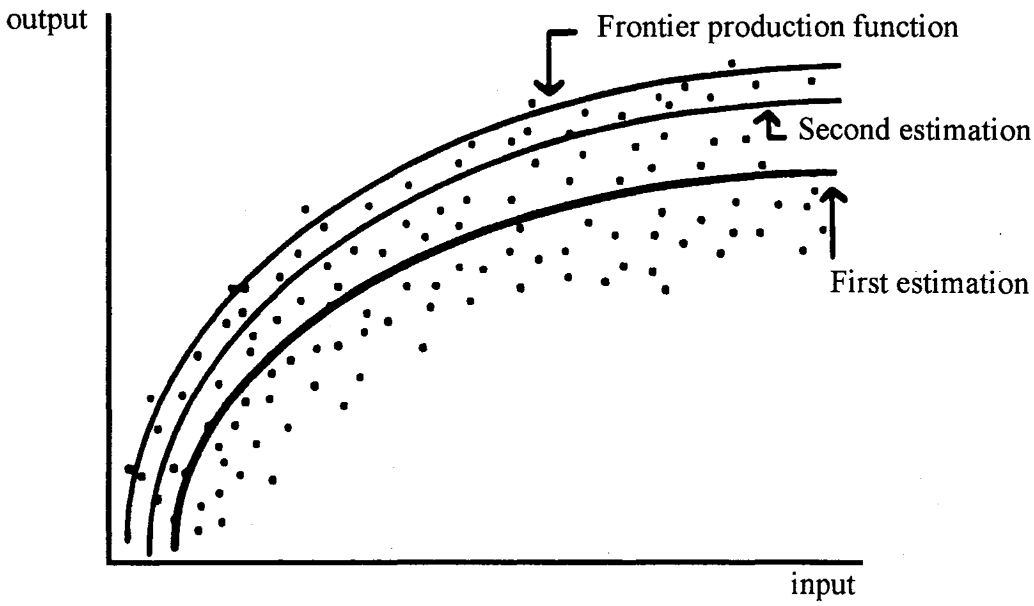
3.2 Estimation of the frontier production function

Stata 9 was used to estimated various econometric specifications. The choice of a functional form is very important because it can significantly affect the results. Several functional forms were estimated and the Cobb-Douglas was chosen because it showed a higher R^2_{adj} and F-test. Moreover, it included several significant explanatory variables.

3.2.1 Deterministic frontier function

Based on the Cobb-Douglas production function, $\ln Y_i = \beta_0 + \sum_i \beta_i \ln X_i + \varepsilon_i$, the frontier production function is calculated by an iterative process. Indeed, the error term is the difference between the production estimated by a regression and the actual production. A positive error term means that the actual production is higher than the estimated production. On the contrary, a negative error term shows that the actual production lies below the estimated production. Since we want to reach the maximum attainable production (frontier), only observations with a positive error term are considered. The first step consists of estimating an average production function for the whole sample, assuming that the OLS properties are satisfied. The first regression showed that more than 50% of the observations lay above the average estimated production function. At this point, we can still do better in order to reach the frontier. In the second step, observations with a negative error term are dropped. So, a second regression estimates the production function with the remaining observations. During this step, the significance of the coefficients might be affected as well as the whole regression significance. This second step is repeated as long as the OLS properties are not violated. This second step allows the production function to move toward the frontier (fig.15).

Figure 15: Frontier production function



source: Romain and Lambert 1992, p. 17

When the production frontier is reached, the potential production Y_i^* for each farm is estimated given the explanatory variables for each farm, and the level of technical efficiency can be estimated for each farm. The technical efficiency (TE) is simply the actual production Y_i over the potential production Y_i^*. When TE is greater than or equal to 1, the firm is considered 100% efficient. The deterministic frontier can give a good indication of technical efficiency. However, it does not take into account that external factors might affect the production frontier, unlike the stochastic approach. Indeed, the stochastic approach provides a better representation of reality.

3.2.2 Stochastic frontier function

According to Jaforullah et al (2003), the stochastic approach is very popular among researchers, because it considers external factors that can affect the production frontier. Moreover, the stochastic frontier is determined in fewer steps than the deterministic frontier. This can lessen errors when the frontier is estimated and avoids violations of the OLS assumptions. To find the stochastic frontier, the first step is similar to the deterministic approach, i.e. estimating the average production function: $\ln Y_i = \beta_0 + \sum_i \beta_i \ln X_i + \varepsilon_i$. Contrary to the deterministic frontier, where the error term ε_i is attributed to inefficiency, the stochastic error term ε_i is now defined as $\varepsilon_i = v_i - u_i$ where v_i is the error term associated with factors beyond farmer's control and is independently and identically distributed as $v_i \sim IIDN(0, \sigma_v^2)$. The error term u_i measures deviations from technical efficiency that are attributed to the farmer. In this study, only technical efficiency is investigated, the technical efficiency measure of an individual farm relative to the stochastic frontier is calculated with the following equation: $TE_i = \exp(-u_i)$. After calculating the farm specific measure of technical efficiency, further analysis can be done to investigate socio-economic factors that influence technical efficiency. The procedure is the same as examining variables affecting the production function, but this time, the dependent variable is TE instead of the production.

3.3 The survey

The data on rice farmers in Ban Home come from Lao municipal statistics and field data gathered during 2002. Municipal statistics provided information on households such as age, gender, household size. The survey was carried out during the months of November to December 2002, the period of the wet season (see questionnaire in Appendix B). Only one village was surveyed because of time constraints. Data on inputs and output were collected from 112 households for the current wet season and 82 households for the previous dry season. Data collected for the wet season may be more reliable than data for the dry season because rice farmers seemed to better remember the most recent harvest. Households were randomly selected, and households that did not produce rice were discarded from the survey. Most of the time, the interview was conducted directly in the field because it was harvest time and easier to find willing rice farmers to be interviewed. The interview took about an hour with the help of two local people to administer the interview. One week of training was given to the field assistants to become familiar with the questionnaire.

3.3.1 Sampling characteristics

The following section describes the sample characteristics for the different technologies adopted by rice farmers, i.e. wet season technology and dry season technology. The main difference is the use of irrigation, particularly during the dry season. The area under study was chosen for its fertile land, particularly suitable for rice production. Ban Home village is located around 20 km from Vientiane, the capital of Laos, and has approximately 1200 inhabitants.

3.3.2 Socio-economic characteristics

Table 6 and 7, show some socio-economic characteristics of the households interviewed. These tables show the gender that manages the household. Usually, the household head makes decisions regarding rice production. However, some household heads are not fully involved in rice production because he might not work the land as a primary occupation. In this case, the wife usually takes responsibility for rice production. There are few women who are in charge of the household. Women who manage a household are generally widowed or single. It is interesting to note that in this particular village, women can inherit land from their parents, yet in 85% of the cases, the household head is a man (Pa Nang, village chief of Ban Home, 2002).

Table 6: Gender of household head for the wet season

Wet season	Freq.	Percent	Cum.
Female household head	17	15.18	15.18
Male household head	95	84.82	100.00
Total	112	100.00	

Table 7: Gender of household head for the dry season

Dry season	Freq.	Percent	Cum.
Female household head	12	14.63	14.63
Male household head	70	85.37	100.00
Total	82	100.00	

Table 8 describes the average age of the household head, number of members and number of females in the household, and quantity of land owed by the family. There exists a wide range of land owed, from less than 1 ha to more than 8 ha. The average area owned in the sample is around 1 ha. However, less than 1 ha is attributed to rice cultivation. As mentioned earlier, Ban Home village has the most fertile land. Usually, farmers work the land for cash crops and produce rice as a staple food.

Table 8: Socio-economic characteristics for the wet season

Wet season	Mean	Std. Dev.	Minimum	Maximum
Age	54.22	14.83	24.00	87.00
Household size	5.64	2.09	2.00	12.00
Nbr of females	2.91	1.35	1.00	8.00
Rice are (ha)	0.76	0.60	0.10	3.94
Other area (ha)	0.28	0.65	0.00	4.48
Total area (ha)	1.04	1.05	0.10	8.42

Table 9: Socio-economic characteristics for the dry season

Dry season	Mean	Std. Dev.	Minimum	Maximum
Age	53.85	15.79	24.00	87.00
Household size	5.52	2.17	2.00	12.00
Nbr of females	2.92	1.26	1.00	8.00
Rice are (ha)	0.63	0.37	0.10	2.03
Other area (ha)	0.45	1.00	0.00	7.22
Total area (ha)	1.08	1.15	0.10	8.42

Table 10 describes the highest education level of family members. 50% of the sample has a secondary diploma with an average of 11 years of formal education. However, few people have over 12 years of education. Usually, members of the household participate in rice cultivation. In this case, it might have been more appropriate to measure the highest education level of family members instead of the household head. (Calkins, 1998)

Table 10: Education for the wet season

Wet season	Obs.	Mean	Std.Dev.	Minimum	Maximum
educ ≤ 6 yrs	38	5.68	0.87	3	6
6< educ ≤ 12	63	11.37	1.27	8	12
educ >12 yrs	11	14.55	0.69	14	16
Total	112	9.75	3.26	3	16

Table 11: Education for the dry season

Dry season	Obs.	Mean	Std.Dev.	Minimum	Maximum
educ ≤ 6 yrs	34	5.44	1.28	1	6
6< educ ≤ 12	44	11.32	1.29	8	12
educ >12 yrs	4	14.50	0.58	14	15
Total	82	9.04	3.36	1	15

Table 12 and table 13 show the extent to which household heads have a second occupation besides agriculture. 75 % of farmers who produce rice during wet season have a second occupation and 67% of farmers for the dry season. Non farm income is usually from crafting, weaving and fishing. Some of them have part time employment as teacher or have a small shop.

Table 12: Second occupation of the household head for the wet season

Wet season	Freq.	Percent	Cum.
No second occupation	28	25.00	25.00
Second occupation	84	75.00	100.00
Total	112	100.00	

Table 13: Second occupation of the household head for the dry season

Dry season	Freq.	Percent	Cum.
No second occupation	27	32.93	32.93
Second occupation	55	67.07	100.00
Total	82	100.00	

3.3.3 Technology adopted by rice farmers

In order to measure efficiency, the farmers should be using the same technology, since different technologies adopted by farmers might affect the efficiency measure (Amara and Romain, 2000). The sample counts 112 households that adopted the wet season technology and 82 households the dry season technology. Usually, households produce rice during the wet season because their land is not irrigated. Also, it is very difficult to produce a cash crop during this season. This technology depends tremendously on weather. Indeed, heavy rain could flood the land and cause real damage to rice production. However, the wet season technology has the advantage that it requires less labour unlike the dry season technology. Since farmers do not have any control of rain during the wet season, they do not spend much time tending their land. The dry season technology needs more attention, particularly to control irrigation, but that usually leads to a higher rice yield. In order to increase rice production, the Lao Ministry of Agriculture wants to implement more irrigation. During the interviews, many rice farmers were not able to produce rice during the dry season because of canal construction near their land initiated in previous years. Indeed, construction materials and excavated land were spread out everywhere on some farmers' land. That is why the survey counted more farmers who cultivated rice during the wet season than the dry season. Once the irrigation project had been completed, with Japanese aid, many Lao farmers were not able to cultivate rice because they could not afford to pay for water that had been free prior to this irrigation project.

3.3.4 Variable definitions

The variables included in the production function are classified in two categories: technical and socio-economic.

3.3.4.1 Technical variables

This category of variables represents factors that directly affect rice production. It includes the output and inputs.

YIELD is the output variable measured in tonne/ha of rice paddy or rough rice, i.e. rice as it comes from the field after harvest. The yield was reported as the number of bags of paddy per unit of area because farmers did not know the exact quantity of rice harvested but they remembered the number of bags they harvested. A bag of rice paddy weighed approximately 80 kg.

RIAREA represents the total area in ha under rice cultivation. Unfortunately, it was not possible to collect data for each plot of land under rice production because farmers did often not remember the quantity of inputs used for different plots. However, they had an idea of the overall quantity of inputs applied.

FERT is the quantity of fertilizer first measured in bags, then converted in kg/ha. A bag of fertilizer weighed 50 kg. Some plots of land are exclusively used for rice production, usually in the case of farmers who own a relatively large amount of land. However, more than 60% of the farmers in the sample have less than one hectare and cultivated more than one crop on the same field

LABT represents the total quantity of labour measured in hours per hectare. The variable labour was divided in two groups: family labour and hired labour.

VARIETY is a binary variable. It takes the value 1 if the farmer used a modern variety of rice and 0 if a traditional variety.

SOILTYPE is also a binary variable with the value of 1 if it is a sandy soil and 0 if it is a heavy soil.

3.3.4.2 Socio-economic variables

Most variables of this category are difficult to measure. Indeed, they often are qualitative variables and are classified as binary variables taking the value of 1 or 0. The expected signs for these variables can be found in table 14. According to Bravo-Ureta and Evenson (1994), there exist two approaches to investigate the relationship between efficiency and socio-economic variables: a simple correlation matrix and a two-step procedure. The two-step procedure consists of measuring the farm level efficiency and then regressing the efficiency by incorporating socio-economic variables as the independent variables. Battese et al (1989) disapproved of the two-step approach because socio-economic variables may have a direct effect on production and should be included during the first step. However, Kalirajan (1991) argued that socio-economic variables have indirect impact on production and that was justifiable to incorporate those variables indirectly. In this study, the two-step procedure is selected because the incorporation of socio-economic variables during the first steps were not statistically significant except for the variable AGREXT (see definition below).

GENDER is a binary variable that takes the value 1 if the household head is male and 0 if the household is managed by a woman. In this particular case, the female household head is usually a widow. Although women inherit land from their parents and carry out most of the agricultural tasks, the household head, usually the man, makes decisions.

FARMEX represents the farming experience in years of the household head. This variable captures the farmer's knowledge of the conditions of rice production. It is expected to positively affect technical efficiency.

SIZE counts the number of household members. This variable is a proxy for the availability of labour since rice production is an intensive labour activity.

EDUC represents the highest number of years of schooling achieved by a member of the household. It does not measure necessarily the household head education. This variable measures the education of the member with the highest level, because most of the household members participated actively in rice production. This variable proxies managerial quality and is expected to be positive (Calkins 2001).

SECOCC is a binary variable with the value 1 if the household head has a second occupation other than agriculture and 0 if the household head practices only agriculture. This variable accounts for the possibility that another source of income can be invested in agriculture and positively influences rice production. On the other hand, it can negatively affect production if the manager has less time to spend on agricultural activity because of this second occupation.

AGREXT represents farmers who have contact with a professional agricultural advisor by taking the value 1 and 0 if farmers do not have access to agricultural extension.

CREDIT variable measures credit accessibility for farmers by borrowing money from banks, relatives or friends. Access to credit also means availability of inputs required for rice production. It takes the value of 1 if farmers have actually borrowed money and 0 otherwise.

Table 14: Expected signs for variables influencing rice production

Explanatory variables	Influence on yield
RIAREA	+/-
FERT	+
LABT	+
VARIETY	+
SOILTYPE	+
AGREXT	+

Table 15: Expected signs for variables influencing technical efficiency

Explanatory variables	Influence on TE
GENDER	+/-
FARMEX	+
SIZE	+/-
EDUC	+
SECOCC	+/-
CREDIT	+

CHAPTER 4: RESULTS AND DISCUSSION

In this section, the results from the frontier production function and the technical efficiency measure will be discussed using both the deterministic and stochastic approaches. It is important to recall that the main goal of this study is to estimate the efficiency of individual rice farms. To reach this goal, the frontier estimation is a crucial step, yet a common problem that arises is heteroscedasticity, the assumption that residuals have the same variance is violated. Therefore, while estimating the production frontier, the problem of heteroscedacity has to be assessed. In order to investigate the production frontier and the heteroscedasticity problem, a production function has first to be estimated.

4.1 Production function results

Several functional forms, Cobb-Douglas, transcendental and quadratic were investigated for the deterministic approach. The Cobb-Douglas function was selected because it included several significant variables and the overall model was also significant. Moreover, the signs attributed to each variable seemed logical. The deterministic production function was estimated by OLS and in the results, the prefix ln means the natural logarithm.

4.1.1 Cobb-Douglas production function for the wet season and dry season

Table 16 presents the production function for the wet season with a significant F-statistic of 39.34 and a coefficient of determination, R^2_{adj} of 67%. Considering the degrees of freedom, 67% of the yield variation is explained by the independent variables included in the model. All variables are statistically significant at 1% except for agricultural extension that is significant at 5%. Also, the variables follow the law of diminishing returns. Indeed, a Cobb-Douglas production function shows a positive and diminishing marginal product if the parameters estimated are less than one but greater than zero. It is the case for all the variables.

Table 16: Deterministic production function for Wet season

Number of observations				112		
R^2	0.69					
R^2_{adj}	0.67					
F(6, 105)	39.34					
Prob > F	0.00					
lnYIELD	Coefficient	Std. error	t	P>|t|	[95% Conf. Interval]	
lnRIAREA	0.64***	0.14	4.51	0.00	0.36	0.93
lnFERT	0.62***	0.16	3.84	0.00	0.30	0.94
lnLABT	0.56***	0.16	3.43	0.00	0.24	0.88
VARIETY	0.38***	0.10	3.66	0.00	0.18	0.59
SOILTYPE	0.45***	0.10	4.48	0.00	0.25	0.65
AGREXT	0.27**	0.11	2.47	0.02	0.05	0.48
constant	-7.24***	1.44	-5.03	0.00	-10.09	-4.38

*** significant at 1% , ** significant at 5%

For the purpose of comparing both technologies, a similar Cobb-Douglas production function was estimated for the dry season (Table 17). The F-statistic and R^2_{adj} are significant and higher compared to the wet season. However, the VARIETY, SOILTYPE AND AGREXT variables are not significant. Moreover, variable FERT has a coefficient greater than one and thus violates the assumption of the law of diminishing returns. This result suggests that yield will increase at an increasing rate, and may have occurred because of poor soil quality.

Table 17: Deterministic production function for Dry season

Dependant variable				lnYIELD		
Number of observations				82		
R^2	0.86					
R^2_{adj}	0.84					
F(6, 105)	73.72					
Prob > F	0.00					
Variables	Coefficient	Std. error	t	P>|t|	[95% Conf. Interval]	
lnRIAREA	0.23***	0.08	2.92	0.00	0.36	0.93
lnFERT	1.73***	0.13	13.83	0.00	0.30	0.94
lnLABT	0.11	0.09	1.19	0.24	0.24	0.88
VARIETY	0.01	0.05	0.14	0.89	0.18	0.59
SOILTYPE	0.05	0.05	0.92	0.36	0.25	0.65
AGREXT	0.20	0.04	0.44	0.66	0.05	0.48
constant	-9.53***	0.81	-11.83	0.00	-10.09	-4.38

*** significant at 1%

4.2.2 Estimation results

lnRIAREA:

The estimation of the production function shows that the variable lnRIAREA is statistically significant in both seasons and follows the law of diminishing returns. In both cases, an increase in area is associated with an increase in yield, but at a diminishing rate. However, during the wet season, the paddy yield has a better response to land. An increase of 1% in rice area leads to an increase of 0.64% in yield compared to 0.23% during the dry season. A priori, rice area could affect positively or negatively yield. It influences negatively, for example, in the case where farmers own a larger area and have less time to spend on the land. In the case of these Lao farmers, they grow rice on a small area, an average of less than one hectare. It might be assumed that it is easier to take care and manage a smaller area than a larger area, however the results suggest that farmers with a larger holding have better yield than farmers with smaller holdings. It probably implies that larger farms use more hired labour and this labour is usually characterized by mechanization.

lnFERT:

Fertilizer has a significant positive effect on rice yield for both seasons. It shows a better response during dry season probably due to flood problems during the rainy season. Although a decreasing marginal productivity is expected, the dry season's technology presents an increasing marginal productivity. It means that as long as the fertilizer is applied, the yield continues to increase at in increasing rate. Better water management during the dry season could explain this case.

lnLABT:

Family labour and hired labour are not significant individually, but when they are grouped as total labour, it shows a significant coefficient with a positive sign as expected for the wet season but not significant during the dry season. It can be explained that during the dry season there is more labour available than during the wet season 4269 hours/ha comparatively to 3253 hours/ha for the wet season. Although more labour is used during the dry season, perhaps it does not increase yield because labour is not well used or managed compared to the wet season

VARIETY:

The use of a modern variety has a significant positive effect on yield during the wet season. Farmers using a modern variety have a yield 46% higher than those who cultivate a traditional variety ($e^{.38} = 1.46$). During the dry season, a modern variety was not statistically significant. Perhaps this difference has to do with the importance of selecting a modern variety for the wet season that is resistant to diseases caused by flooding. So, variety selection during the dry season does not greatly influence yield because farmers have a better control of disease and irrigation.

SOILTYPE:

During the dry season, soil type was not significant, but during the wet season, sandy soil compared to heavy soil gave a significantly higher yield. Heavy soil tends to hold water and potentially damage the plant's roots. Also, fungus often appears during the rainy season. As mentioned earlier, the selection of variety might affect yield when the farmer has difficulty to control the conditions of production. It appears that soil type and variety do not influence rice yield during the dry season because of better water management.

AGREXT:

Contact with a professional agricultural advisor influenced positively and significantly yield during the rainy season but not so for the dry season. Although agricultural advisors visited farmers less often during the wet season, this visit had an impact on yield because this season is considered as a difficult period to grow rice. Advice from a professional might help farmers because the timing of fertilizer application is critical. However, professional visits seemed less important during the dry season, probably because farmers had a good knowledge of the conditions of production. Although in both seasons, farmers had access to a large source of agricultural information for example on television, newspaper and brochures that some farmers received, contact with a professional advisor remains most likely an important source of agricultural information, especially during the wet season.

The socio-economic variables will be analysed further in the section on the production frontier. This thesis uses the two-step procedure following by Kalirajan (1991) in order to estimate a frontier function.

4.2.3 Heteroscedasticity problem

After estimating the production function by OLS, the heteroscedastic problem was assessed. A regression has a heteroscedastic problem if its errors are not constant across observations. There exist different tests to detect heteroscedasticity. For the purpose of this research, the Breusch-Pagan test was used as well as the Cook-Weisberg test. According to Griffiths et al (1993), the Breusch-Pagan test consists of assessing whether μ^2 is a function of the explanatory variables. So, Breusch-Pagan designed a Lagrange multiplier test (LM) of the hypothesis that all the slope coefficients are jointly equal to zero.

$$\mu^2 = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k \quad (23)$$

$$H_0 = \beta_1 = \beta_2 = \ldots = \beta_k = 0 \Rightarrow \text{homoscedasticity} \quad (24)$$

First, we need to obtain the residuals (μ) from the original regression and square the residuals (μ^2). Then, a new variable (NV) is generated, μ^2 divided by its mean. Thereafter, we regress NV on the explanatory variables $X_1, X_2, X_3 \ldots, X_k$. If one coefficient is statistically significant, the assumption of homoscedasticity is probably violated. Finally, we test whether the calculated test statistic LM =ESS/2 is smaller than the critical χ^2 . If this is the case, there is no apparent problem of heteroscedasticity. The Cook-Weisberg test is similar to the Breusch-Pagan test, except that the NV is regressed on $\hat{y}$ instead of the explanatory variables. The table below shows that both seasons, wet and dry, do not have a heteroscedasticity problem since the calculated LM is smaller than the critical χ^2. At 1% and 5% levels of significance, the critical χ^2 is respectively 16.81 and 12.59. Also the F-stat for both seasons is smaller than the critical F-stat. It means that the null hypothesis of constant variance cannot be rejected and it is unlikely that there is a heteroscedasticity problem.

Table 18: Breusch-Pagan test for heteroscedasticity, wet season

Dependant variable	NV	Source	SS
Nbr of obs.	112	Model	16.76
F(6, 105)	1.04	Residual	281.52
Prob > F	0.40	Total	298.28
variables	Coef.	t	P>| t |
lnRIAREA	-0.12	-1.36	0.18
lnFERT	-0.14	-1.49	0.14
lnLABT	-0.12	-1.20	0.23
VARIETY	0.01	0.09	0.93
SOILTYPE	-0.05	-0.75	0.45
AGREXT	-0.02	-0.32	0.75
constant	1.80	2.09	0.04
LM	8.38		

Table 19: Breusch-Pagan test for heteroscedasticity, dry season

Dependant variable	NV	Source	SS
Nbr of obs.	82	Model	5.97
F(6, 75)	0.42	Residual	176.44
Prob > F	0.86	Total	182.41
variables	Coef.	t	P>| t |
lnRIAREA	0.01	0.67	0.51
lnFERT	0.00	0.08	0.93
lnLABT	0.02	0.89	0.38
VARIETY	-0.01	-0.50	0.62
SOILTYPE	0.01	0.73	0.47
AGREXT	0.01	0.10	0.92
constant	-0.15	-0.73	0.47
LM	2.99		

The Cook-Weisberg test for heteroscedasticity leads to the same conclusion as the Breusch-Pagan test for the dry season. However, during the wet season, the Cook-Weisberg test shows different results. Indeed, the critical χ^2 at 5% and 1% is respectively 3.84 and 6.64. It implies that the null hypothesis of homoscedasticity is rejected at 5%, but not at 1%. Thus, at 1% level of significance, the Breusch-Pagan and the Cook-Weisberg test suggest that there is probably no heteroscedasticity problem.

Table 20: Cook-Weisberg test for heteroscedasticity

	Wet season	Dry season
χ^2	5.51	0.67
Prob > χ^2	0.02	0.4134

4.2.4 Multicollinearity problem

Another problem that is common in multiple regression is multicollinearity. This occurs when the independent variables are highly correlated. One problem is that the t-test for the individual coefficient may not be statistically significant, yet the overall R^2 is. The second problem is that the confidence intervals are so wide that it can affect the stability of the parameters estimated. Indeed, the decision to include or exclude a variable in the regression could radically affect the coefficients or even change their signs (Green 2000). Tables 21 and 22 present correlation matrices among variables. A positive sign designates a positive relationship between two variables and a negative sign indicates a negative relationship.

Area under rice cultivation has a surprisingly strong negative correlation with family labour and fertilizer. As the area under rice cultivation increases, it would be expected that there would be an increase in family labour to work the land. However, that is not the case, probably because other inputs are used instead of family labour. Fertilizer has a negative relationship with hired labour, variety, soil type and contact with an agricultural advisor. Usually, the application of fertilizer is done manually by family labour and hired labour consists of hiring people who own tractors to do harder work on the land, especially during tilling and harvest time. On the other hand, the use of a modern variety probably requires less fertilizer during wet season as well as cultivation in sandy soil. Frequent visits of professional agricultural advisors allow rice farmers better fertilizer management especially during critical periods for fertilizer application.

Family labour also has a negative relationship with hired labour, variety, soil type and visits by an agricultural advisor. As the number of family members involved in agricultural activities increases, the household head tends to employ less hired labour. Moreover, family members prefer to cultivate traditional varieties compared to modern varieties because they like its taste and have a better knowledge of the conditions of production of this variety even if a modern variety has a higher yield. In the case of soil type, heavy soil probably requires more labour than sandy soil. Indeed, it requires more care, so more family labour is needed.

Hired labour is positively correlated with variety, soil type and visits by an agricultural advisor. As mentioned earlier, hired labour is usually characterized by the use of tractors. Here, a modern variety is probably more resistant than a traditional variety during handling, so there is not much loss when rice is mechanically harvested compared to the harvest done manually by family labour. Also, when tractors are used in heavy soil, they often cause problems of soil compaction. Modern varieties tend to perform well in sandy soil, and are extensively promoted by agricultural advisors.

Table 21: Correlation between variables during the wet season

Wet season	lnYIELD	lnRIAREA	lnFERT	lnFAMILY	lnHIRE	VARIETY	SOILTYPE	AGREXT
lnYIELD	1.00							
lnRIAREA	0.50	1.00						
lnFERT	-0.21	-0.63	1.00					
lnFAMILY	-0.24	-0.88	0.56	1.00				
lnHIRE	0.46	0.38	-0.35	-0.20	1.00			
VARIETY	0.65	0.49	-0.38	-0.29	0.51	1.00		
SOILTYPE	0.64	0.48	-0.38	-0.31	0.38	0.45	1.00	
AGREXT	0.67	0.49	-0.35	-0.28	0.41	0.63	0.59	1.00

During the dry season, yield and fertilizer have a strong positive relationship. It is not surprising since the regression shows that yield has a positive response to fertilizer probably due to better water management. Unlike the wet season, area under rice cultivation and fertilizer are positively correlated. By comparing the use of fertilizer in both seasons, it is interesting to note that the signs of the correlation are opposite. It is believed that flooding problems during the wet season is the main cause of this difference. On the other hand, family labour is strongly and negatively correlated with area in both seasons. However, hired labour is less correlated during the wet season compared to the dry season, possibly because during the dry season rice farmers hire more people than the wet season.

Table 22: Correlation between variables during the dry season

Dry season	lnYIELD	lnRIAREA	lnFERT	lnFAMILY	lnHIRE	VARIETY	SOILTYPE	AGREXT
lnYIELD	1.00							
lnRIAREA	0.52	1.00						
lnFERT	0.89	0.36	1.00					
lnFAMILY	-0.23	-0.85	-0.09	1.00				
lnHIRE	0.57	0.61	0.48	-0.37	1.00			
VARIETY	0.46	0.36	0.44	-0.14	0.42	1.00		
SOILTYPE	0.44	0.38	0.35	-0.11	0.39	0.36	1.00	
AGREXT	0.25	0.12	0.24	-0.04	0.04	0.08	0.28	1.00

4.3 Technical efficiency measure of individual rice farm

This section presents the results of the measures of technical efficiency for individual rice farms. Based on the deterministic and stochastic approaches, technical efficiency was calculated with an emphasis on the deterministic approach. Moreover, socio-economic characteristics of farms that produce on the frontier are described. In order to estimate technical efficiency, it is necessary to first estimate a production frontier.

4.3.1 Production frontier estimation based on the deterministic approach

During the wet season, three regressions were needed to determine the frontier compared to only two for the dry season. Only nine observations were left if a fourth regression was estimated although R^2_{adj} and F were statistically significant as well as some independent variables. It is interesting to observe that R^2_{adj} increased as the frontier was reached on the third regression. Almost all the independent variables are statistically significant at 1% except lnLABT and lnRIAREA that are still significant, but at 10% and 5% respectively. Coefficients lnRIAREA, lnLABT, AGREXT and the constant decrease from step one to the last step. However, coefficient VARIETY increases, suggesting that the modern variety has an important effect on yield for farmers who produce on the frontier. On the other hand, coefficients lnFERT and SOILTYPE decrease during the first iteration and then increase during the last iteration (table 23).

Table 23: Deterministic frontier production function during the wet season

Dependant variable	lnYIELD					
Regression	1		2		3	
Nbr of obs.	112		61		23	
R^2_{adj}	0.67		0.84		0.92	
F	39.34		53.11		43.19	
d.f.	6 ;105		6 ;54		6 ;16	
Variables	Coef.	t	Coef.	t	Coef.	t
lnRIAREA	0.64	4.51***	0.41	3.61***	0.27	2.12**
lnFERT	0.62	3.84***	0.44	3.50***	0.60	3.33***
lnLABT	0.56	3.43***	0.41	3.33***	0.20	1.44*
VARIETY	0.38	3.66***	0.43	6.20***	0.51	5.52***
SOILTYPE	0.45	4.48***	0.42	6.21***	0.55	6.67***
AGREXT	0.27	2.47***	0.24	3.51***	0.21	2.78***
constant	-7.23	-5.03***	-4.93	-4.16***	-4.07	-2.71***

			t(105)	t(54)	t(16)
Level of significance:	***	1%	2..326	2.403	2.583
	**	5%	1.645	1.676	1.746
	*	10%	1.282	1.299	1.337

During the dry season, around 41% of the farmers produce on the frontier compared to 21% for the wet season. This implies that during the dry season, more farmers are efficient than during the wet season. One iteration was enough to estimate a production frontier for the dry season (table 24). On the third regression, there are 14 observations left and with 6 degrees of freedom. Thus, there are not enough observations to allow for the estimation of a production frontier. From the first to the second regression, R^2_{adj} and F increase and are highly significant. Some variables that are not significant from the first regression become significant for the second. This is the case for lnLABT and SOILTYPE. The magnitude of the coefficients of the significant variables also increase as the frontier is reached. Although coefficients VARIETY and AGREXT are not statistically significant for both regressions, their signs change negatively at the second regression.

Table 24: Deterministic frontier production function during the dry season

Dependant variable	lnYIELD			
Regression	1		2	
Nbr of obs.	82		34	
R^2_{adj}	0.84		0.95	
F	73.72		97.73	
d.f.	6 ;75		6 ;27	
Variables	Coef.	t	Coef.	t
lnRIAREA	0.23	2.92***	0.30	3.40***
lnFERT	1.73	13.83***	1.78	14.60***
lnLABT	0.11	1.19	0.23	2.13**
VARIETY	0.01	0.14	-0.72	-1.05
SOILTYPE	0.05	0.92	0.14	1.93**
AGREXT	0.02	0.44	-0.01	-0.13
constant	-9.53	-11.83***	-10.55	-12.12***

			t(75)	t(27)
Level of significance:	***	1%	2..381	2.473
	**	5%	1.667	1.703
	*	10%	1.294	1.314

So, the deterministic frontier production functions during the wet season and the dry season are the following :

LnYIELDw = -4.07 + 0.27 lnRIAREA + 0.60 lnFERT + 0.20 lnLABT + 0.51 VARIETY + 0.55 SOILTYPE + 0.21 AGREXT (25)

$$LnYIELDD = -10.55 + 0.30\ lnRIAREA + 1.78\ lnFERT + 0.23\ lnLABT - 0.72\ VARIETY + 0.14\ SOILTYPE - 0.01\ AGREXT \quad (26)$$

4.3.2 Socio-economic characteristics of the deterministic frontier

Based on the frontier production functions, the next step in the research was to determine if the efficiency of individual farms could be related to socio-economic factors. Individual farm efficiency was regressed on socio-economic variables. This step represents the second stage of all efficiency investigation according to Kalirajan (1991). The socio-economic variables were not included during the first stage, because they were not statistically significant, except for the variable AGREXT. This situation could occur when socio-economic variables have an indirect impact on technical efficiency. Tables 25 and 26 compare the gender of the household heads of efficient rice farmers and the rest of the farmers in the sample. In both seasons, there are fewer female household heads that produce on the frontier. However, the difference is small in the wet season compared to the dry season.

Table 25: Gender of household head for the wet season, deterministic frontier

Wet season	Deterministic Frontier		Rest of the sample	
Nbr of observations	23		89	
Gender	Freq.	Percent	Freq.	Percent
Female household head	3	13.04	14	15.73
Male household head	20	86.96	75	84.27
Total	23	100.00	89	100.00

Table 26: Gender of household head for the dry season

Dry season	Deterministic Frontier		Rest of the sample	
Nbr of observations	35		47	
Gender	Freq.	Percent	Freq.	Percent
Female household head	2	5.71	10	21.28
Male household head	33	94.29	37	78.72
Total	35	100.00	47	100.00

Table 27 describes the socio-economic characteristics of efficient farmers and the rest of the sample for the wet season. The average age of farmers on the frontier is virtually identical to the rest of the sample. The number of family members and number of females in the household are slightly higher for the efficient household compared to the rest of the sample. However, efficient farmers seem to be less educated than the rest of the sample. Also, they own less land and allocate less area to rice cultivation. Thus, there are some slight differences but these would not be statistically significant.

Table 27: Socio-economic characteristics for the wet season

Wet season	Deterministic Frontier		Rest of the sample	
Nbr of observations	23		89	
Variables	Mean	Std. Dev.	Mean	Std. Dev.
Age	54.61	13.97	54.12	15.12
Household size	6.13	2.43	5.52	1.98
Nbr of females	3.04	1.07	2.88	1.41
Education (yrs)	8.78	3.64	10.00	3.13
Rice are (ha)	0.74	0.58	0.76	0.61
Other area (ha)	0.16	0.24	0.31	0.72
Total area (ha)	0.91	0.68	1.07	1.13

During the dry season, most of the socio-economic factors of efficient farmers are lower than to the rest of the sample except for education level (table 28). It could suggest that educated farmers are more efficient than farmers who are less educated. Thus, the difference between the two groups, efficient farmers and the rest of the sample, is small and not statistically significant.

Table 28: Socio-economic characteristics for the dry season

Dry season	Deterministic Frontier		Rest of the sample	
Nbr of observations	35		47	
Variables	Mean	Std. Dev.	Mean	Std. Dev.
Age	52.06	15.12	55.19	16.30
Household size	5.40	2.13	5.62	2.22
Nbr of females	2.74	1.09	3.06	1.37
Education (yrs)	9.63	3.34	8.60	3.34
Rice are (ha)	0.65	0.44	0.61	0.32
Other area (ha)	0.54	1.33	0.39	0.67
Total area (ha)	1.19	1.52	1.00	0.78

Tables 29 and 30 show technical characteristics for the wet and dry seasons. Both tables present similar results. Yield in both seasons is higher for the farmers producing on the frontier. Indeed, it is expected to have a higher yield for the efficient farmers compared to the rest of the sample. Also, efficient farmers used less fertilizer per hectare and more total labour per hectare in the wet season, while using less labour in the dry season. Based on these results, it would be appear that there is no systematic relationship between any of the socio-economic variables and efficiency.

Table 29: Technical characteristics for the wet season

Wet season	Deterministic Frontier		Rest of the sample	
Nbr of observations	23		89	
Variables	Mean	Std. Dev.	Mean	Std. Dev.
Yield (t/ha)	2.97	1.76	2.06	1.35
Fert. (kg/ha)	219.95	76.19	232.89	87.68
Total labour (hr/ha)	3327.36	2383.14	3234.74	1869.38

Table 30: Technical characteristics for the dry season

Dry season	Deterministic Frontier		Rest of the sample	
Nbr of observations	35		47	
Variables	Mean	Std. Dev.	Mean	Std. Dev.
Yield (t/ha)	3.58	1.67	2.73	0.90
Fert. (kg/ha)	282.01	60.34	289.81	43.99
Total labour (hr/ha)	4245.83	2414.95	4287.85	2591.93

4.3.3 Production frontier estimation based on the stochastic approach

Tables 31 and 32 show the stochastic production frontier for both seasons. All variables included in the wet season have the expected sign and are statistically significant, as in the deterministic approach. However, during the dry season, the stochastic frontier does not incorporate as many significant variables, perhaps because of the functional form selected, the Cobb-Douglas. Only area and fertilizer are significant.

Table 31: Stochastic frontier for the wet season

Dependant variable			lnYIELD	
Number of observations			112	
Wald chi2(6)			218.57	
Prob > chi2			0.00	
Variables	Coefficient	Std. error	z	P>| z |
lnRIAREA	0.59	0.14	4.24	0.00
lnFERT	0.56	.016	3.55	0.00
lnLABT	0.50	0.15	3.29	0.00
VARIETY	0.39	0.09	4.13	0.00
SOILTYPE	0.43	0.09	4.69	0.00
AGREXT	0.26	0.10	2.72	0.01
constant	-6.14	1.45	-4.23	0.00

Table 32: Stochastic frontier for the dry season

Dependant variable			lnYIELD	
Number of observations			82	
Wald chi2(6)			483.61	
Prob > chi2			0.00	
Variables	Coefficient	Std. error	z	P>| z |
lnRIAREA	0.23	0.08	3.06	0.00
lnFERT	1.73	0.12	14.47	0.00
lnLABT	0.11	0.09	1.24	0.21
VARIETY	0.01	0.04	0.15	0.88
SOILTYPE	0.05	0.05	0.96	0.34
AGREXT	0.02	0.04	0.46	0.65
constant	-9.53	0.78	-12.17	0.00

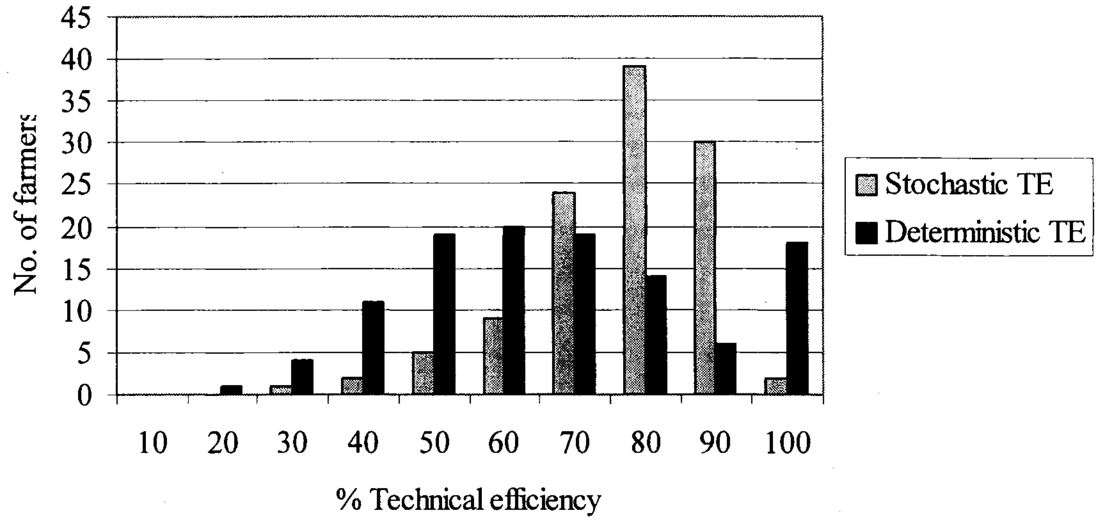
4.3.4 Technical efficiency estimation

Tables 33 and 34 compare the deterministic and stochastic technical efficiency methods for both seasons. The stochastic approach should improve the technical efficiency measure because it incorporates factors beyond the farmer's control. For individual farmers, the stochastic TE ranges from 29% to 91% in the wet season. Fleming and Villano (2004) who studied the stochastic TE of small farmers in the Philippines obtained a similar result. They estimated a stochastic TE that varied from 39% to 91%. Although the mean of the stochastic technical efficiency is higher than in the deterministic approach for the wet season, its TE maximum does not reach full efficiency. So the average deterministic and stochastic TE is respectively 63% and 72%. It implies that rice farmers produced only 63% and 72% of the maximum attainable output from a given sets of inputs. Figure 16 shows the distribution of technical efficiency for both approaches during the wet season. The deterministic approach counts more farmers who produce on the frontier than the stochastic approach because there were only two iterations for the frontier estimation. A third iteration leaves only 9 observations for 6 degrees of freedom. So, the deterministic frontier estimated might include farmers that are not really fully efficient.

Table 33: Deterministic and stochastic technical efficiency for the wet season

Wet Season	Mean	Std.Dev.	Min.	Max
Deterministic TE	0.63	0.22	0.14	1
Stochastic TE	0.72	0.12	0.29	0.91

Figure 16: Distribution of deterministic and stochastic TE for the wet season

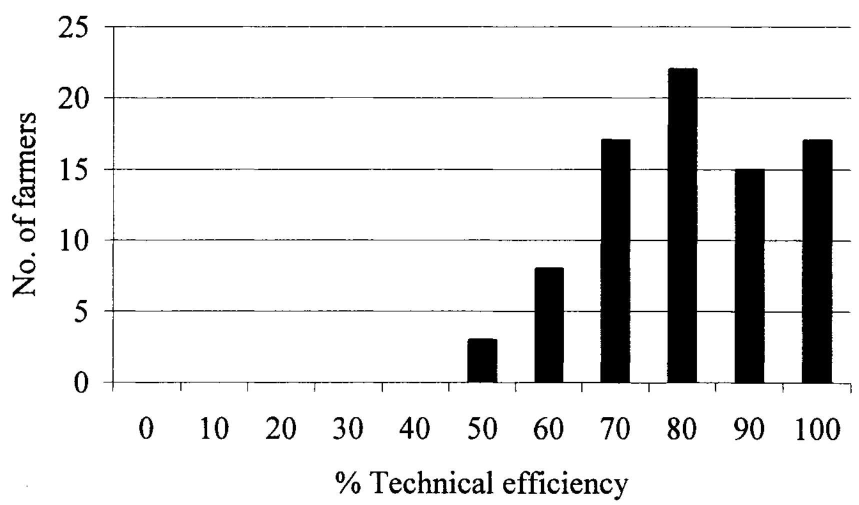


During the dry season, both approaches demonstrate higher technical efficiency than during the wet season. It is expected to have higher technical efficiency during the dry season because rice farmers have better management in production, especially for water control. Indeed, the lowest deterministic TE during the wet season is 14% compared to 46% for the dry season. The dry season shows a distribution of deterministic TE more clustered in the upper half (figure 17). However, the stochastic approach shows that all farmers in the sample are fully efficient. While it might seem unlikely that efficiency for the whole sample is 100%, it's not unusual to obtain full efficiency. Indeed, in Krasachat's studies (2003), he found that in the south of Thailand, the mean TE was 99% for the agricultural sector during the period of 1972-77. More recently, Nahm et al. (2003) found that in some regions in central Thailand, agricultural producers were 100% efficient. This full efficiency could be explained by a high level of management skills of the farmers, and favourable conditions of production during the dry season.

Table 34 : Deterministic and stochastic technical efficiency for the dry season

Dry season	Mean	Std.Dev.	Min.	Max
Deterministic TE	0.76	0.15	0.46	1
Stochastic TE	1.00	0.00	1.00	1.00

Figure 17: Distribution of deterministic TE for the dry season



Although the deterministic and stochastic approaches show different levels of technical efficiency, some of the efficiency rankings are quite similar. These results are consistent with the findings of Bravo-Ureta and Rieger (1990). They measured technical efficiency by using data from six states of the USA on 404 dairy farms for 1982 and 1983. They compared the deterministic and stochastic methods and found differences. However, the ordinal technical efficiency ranking for both approaches was comparable.

According to Bravo-Ureta and Rieger, the approach used to estimate technical efficiency was not that critical since the ordinal ranking were similar.

4.3.5 Factors influencing technical efficiency (TE)

Earlier in this section, we investigated factors that influenced the production function. This time, factors that affect technical efficiency are analysed, using simple linear regression. Tables 35 and 36 present factors that affect deterministic and stochastic technical efficiency during the wet season and tables 37 and 38 for the dry season. Instead of the yield as the dependant variable, socio-economic factors are regressed on technical efficiency. Both approaches show similar results.

Regression results in tables 35 to 38 do not show any statistically significant variables, except the variable credit that is barely significant in two cases. So nothing stands out as an explanation of who is efficient and who is not.

Table 35: Socio-economic factors influencing deterministic TE for the wet season

Dependant variable	Deterministic TE			
Nbr of obs.	112			
R^2	0.04			
R^2_{adj}	-0.01			
F	0.75			
d.f.	6 ;105			
Variables	Coef.	Std. error	t	P>| t |
Gender	0.014	0.061	0.24	0.813
Farming experience	0.000	0.001	0.30	0.762
Household size	-0.002	0.010	-0.23	0.822
Education	-0.005	0.005	-0.79	0.434
Second occupation	0.023	0.048	0.48	0.633
Credit	0.084	0.048	1.75	0.083
constant	0.623	0.109	5.73	0.000

Table 36: Socio-economic factors influencing stochastic TE for the wet season

Dependant variable	Stochastic TE			
Nbr of obs.	112			
R^2	0.04			
R^2_{adj}	-0.02			
F	0.72			
d.f.	6 ;105			
Variables	Coef.	Std. error	t	P>| t |
Gender	0.001	0.035	0.03	0.974
Farming experience	0.000	0.001	0.40	0.690
Household size	-0.005	0.006	-0.80	0.424
Education	-0.005	0.005	-1.28	0.203
Second occupation	0.010	0.004	0.36	0.721
Credit	0.032	0.028	1.14	0.255
constant	0.767	0.063	12.21	0.000

Table 37: Socio-economic factors influencing deterministic TE for the dry season

Dependant variable	Deterministic TE			
Nbr of obs.	82			
R^2	0.09			
R^2_{adj}	0.01			
F	1.17			
d.f.	6 ;75			
Variables	Coef.	Std. error	t	P>| t |
Gender	0.058	0.049	1.18	0.240
Farming experience	-0.001	0.001	-1.14	0.258
Household size	-0.006	0.008	-0.74	0.459
Education	-0.003	0.005	-0.63	0.530
Second occupation	0.000	0.036	0.01	0.991
Credit	0.055	0.039	1.40	0.164
constant	0.805	0.077	10.44	0.000

Table 38: Socio-economic factors influencing stochastic TE for the dry season

Dependant variable	Stochastic TE			
Nbr of obs.	82			
R^2	0.09			
R^2_{adj}	0.02			
F	1.26			
d.f.	6 ;75			
Variables	Coef.	Std. error	t	P>| t |
Gender	4.59e-06	3.43e-06	1.34	0.185
Farming experience	-5.64e-08	7.57e-08	-0.75	0.458
Household size	1.68e-07	5.66e-07	0.30	0.768
Education	1.70e-07	3.47e-07	0.49	0.625
Second occupation	-1.70e-06	2.50e-06	-0.68	0.497
Credit	5.19e-06	2.77e-06	1.88	0.065
constant	0.998	5.41e-06	.	0.000

Because the regressions reported in tables 35 to 38 are not significant, we can not really say that those socio-economic factors influence technical efficiency. As an alternative, we can test if the technical efficiency of certain groups of rice farmers is statistically different, using a t-test. A t-test consists of assessing whether the means of two groups are statistically different from each other. The t-test statistic is represented by the formula (27). The numerator represents the difference between group means and the denominator represents the variability of groups, where σ^2 is the variance of groups and N is the number of observations in each group (Green, 2000).

$$t = \frac{\overline{X}_0 - \overline{X}_1}{\sqrt{\left(\frac{\sigma_0^2}{N_0} + \frac{\sigma_1^2}{N_1}\right)}} \qquad (27)$$

Here, we want to test the following null hypothesis:

$$H_0 = \text{mean (group 0)} - \text{mean (group 1)} = 0 \qquad (28)$$

Table 39: t-test of technical efficiency by gender during the wet season

Approach	Deterministic			Stochastic		
Group	N	Mean	Std. Dev.	N	Mean	Std. Dev.
Female	17	0.63	0.19	17	0.74	0.11
Male	95	0.63	0.22	95	0.72	0.13
t-test	0.00			0.45		
$P > \|t\|$	0.99			0.65		

For the wet season (table 39), the deterministic and stochastic approaches do not show a statistically significant difference between male and female household heads. This is consistent with previous research. In their research on production efficiency, Moock (1976), Bindlish and Evenson (1993), Saito et al. (1994) and Udry et al. (1995) found that gender did not significantly affect efficiency.

Table 40: t-test of technical efficiency by farming experience during the wet season

Approach	Deterministic			Stochastic		
Group	N	Mean	Std. Dev.	N	Mean	Std. Dev.
< 40 yrs Exp.	17	0.60	0.23	17	0.70	0.14
≥ 40 yrs Exp.	95	0.66	0.20	95	0.74	0.10
t-test	-1.51			-1.73		
P > | t |	0.13			0.08		

Table 41: t-test of technical efficiency by education during the wet season

Approach	Deterministic			Stochastic		
Group	N	Mean	Std. Dev.	N	Mean	Std. Dev.
< 7 yrs educ.	38	0.68	0.22	38	0.76	0.10
≥ 7 yrs educ.	74	0.60	0.21	74	0.71	0.14
t-test	1.79			2.10		
P > | t |	0.08			0.04		

Table 42: t-test of technical efficiency by credit level during the wet season

Approach	Deterministic			Stochastic		
Group	N	Mean	Std. Dev.	N	Mean	Std. Dev.
No credit	82	0.60	0.21	82	0.71	0.13
Credit	30	0.69	0.21	30	0.75	0.11
t-test	-1.92			-1.35		
P > | t |	0.06			0.18		

During the wet season, farming experience in number of years shows a slight statistically significant difference between farmers who have more than 40 years of experience (table 40) versus those with less than 40 years of experience. Indeed, rice farmers with more than 40 years of experience are statistically more efficient than farmers who have less than 40 years of experience for the stochastic approach at 10% level of significance. It is important to note that farmers in Ban Home start to farm at an early age. Also, farmers who have less than 7 years of formal education tend to be more efficient than farmers who are more educated (table 41). Saito et al. (1994) found that education had a significant negative impact on technical efficiency. Educated people are more inclined to find work off-farm. It would be expected that in subsistence agriculture, education does not have as much impact as in modern agriculture where it is required to have qualified labour. Bindlish and Evenson (1993) also found that education has a negative coefficient, but insignificant. Other studies obtained insignificant results of the impact of education on efficiency (Kalirajan 1984, 1991, Kalirajan and Shand 1985, Phillips and Marble 1986, Bravo-Ureta and Evenson 1994). On the other hand, there is no statistically significant difference of efficiency between farmers who have a second occupation and farmers who do not as well as different household size. Moreover, farmers who borrow money are not statistically more efficient than farmers who do not (table 42). Farmers tend to borrow money to buy fertilizer. However, when the interest rate is high, many farmers cannot reimburse their loan. That is why banks are reluctant to lend money to farmers, especially since farmers often have no collateral, except the land they own.

Table 43: t-test of technical efficiency by farming experience during the dry season

Approach	Deterministic		
Group	N	Mean	Std. Dev.
< 45 yrs Exp.	50	0.78	0.14
≥ 45 yrs Exp.	32	0.72	0.15
t-test	2.03		
P > | t |	0.05		

Table 44: t-test of technical efficiency by household size during the dry season

Approach	Deterministic		
Group	N	Mean	Std. Dev.
< 10	78	0.77	0.14
≥ 10	4	0.62	0.15
t-test	1.93		
P > | t |	0.06		

Table 45: t-test of technical efficiency by credit level during the dry season

Approach	Deterministic		
Group	N	Mean	Std. Dev.
No credit	63	0.74	0.15
Credit	19	0.81	0.14
t-test	-1.69		
P > | t |	0.09		

For the dry season, only the deterministic approach is analysed among different groups of farmers because the stochastic distribution of technical efficiency is uniform at 100%. Unlike the wet season, the dry season does not show a statistically significant difference between elementary educated farmers and farmers who have higher degree of education. Farming experience has a significant difference between farmers with 45 years of experience versus those with less (table 43). Indeed, farmers with over 45 years of farming experience are more efficient than farmers who have less than 45 years. On the other hand, households with more than 10 members are statistically less efficient than smaller households, at a 10% level of significance (table 44). Usually, a household with many family members includes grandparents, parents and children. Elderly people and children do not really count as an important part of the labour force. However, children as young as 5 years old often help their parents with agricultural activities. Since family labour was not divided according to the age of the labour force, it is difficult to tell the exact impact of each category of labour on technical efficiency. As for the wet season, farmers who use credit are statistically more efficient than farmers without any debt, at a 10% level of significance (table 45).

CHAPTER 5: CONCLUSION

5.1 Summary of findings

Agriculture is an important economic sector, particularly in the economic development of poor countries (Kuznets 1966, Hayami and Ruttan 1985). It is common knowledge that agriculture in developing countries such as Laos, is characterized by a subsistence farming system where farms are small, and mainly devoted to rice production. Also, Lao agriculture faces problems such as environmental constraints, lack of infrastructure and lack of crop diversification. Due to these challenges, agricultural productivity has been low, similar to other developing countries (ADB, 2001). Many researchers have investigated the factors that contribute to agricultural productivity as well as the efficiency of farmers. However, most studies have focused on developed countries, with fewer that consider developing countries. The objectives of this research were to investigate the factors that affect rice production and estimate the efficiency of individual Lao rice farmers in Ban Home, Laos.

In order to calculate individual farm efficiency, a production function was first estimated by OLS based on a survey of 112 households for the wet season and 82 households for the dry season. The results indicated that area under rice cultivation, fertilizer, total labour, the use of a modern variety, sandy soil and contact with a professional agricultural advisor had positive impacts on rice yield for the wet season. However, during the dry season, only the area under rice production and fertilizer had a significant effect on yield.

Based on the Cobb-Douglas production function, in order to assess the efficiency of individual rice farmers, a deterministic and a stochastic production frontier were estimated. The problem with the deterministic approach is that it tends to underestimate or overestimate the frontier production function if the farmers face favourable conditions of production or not. Fortunately, the stochastic approach takes this into account and provides a more accurate production function. However, the choice of the functional form does affect the estimation of the frontier. This was observed in the results for the dry season where the deterministic and stochastic frontiers are slightly different compared to the wet season where the results were similar for both approaches.

No matter what approach is used, technical efficiency was higher for the dry season than the wet season. Better water management during the dry season compared to the wet season could explain this result. Although the average technical efficiency was relatively high in both seasons, the distribution of efficiency was very dispersed during the wet season compared to the dry season. In order to determine which socio-economic factors affect efficiency, a simple linear regression was estimated. However, none of the socio-economic variables were statistically significant. Another method to analyse efficiency is to test the mean level of efficiency of different groups using a t-test.

It was anticipated that some farmers would perform better than others under the same conditions of production. So, different groups of farmers were tested to analyse if their technical efficiency was statistically different. For the wet season, the results show that farmers who have more than 40 years of experience are statistically more efficient than less experienced farmers. Also, farmers with an elementary education are more efficient than farmers with more education. On the other hand, farmers who used credit tend to be slightly more efficient than farmers who do not, or cannot borrow money. For the dry season, farmers with over 45 years of experience are more efficient than less experienced farmers. Unlike the wet season, household size influences efficiency, at a 10% level of significance. Households with more than 10 members are less efficient than smaller households. Another factor that affects efficiency is credit, but only at a 10% level of significance. So, there is some evidence that the technical efficiency of farmers who actually borrow money is statistically higher than farmers who do not.

5.2 Policy implications

The common factor that possibly affects efficiency for both seasons is credit. It seems that efficient farmers tend to borrow compared to less efficient farmers. Farmers usually borrow money to purchase fertilizer and the source of their credit is often relatives. As seen earlier, fertilizer affected positively rice yield. Few farmers borrow from banks or merchants because they request collateral and charge a high rate of interest. Although there already exist some agricultural banks, usually located in more highly populated areas, it might be interesting to make credit more accessible to farmers. A micro-credit office close to rural areas where most of the farmers are established, could attract more farmers to use credit. However, the proximity of agricultural banks is not the only important factor, since the interest rate should be at a level that farmers can afford.

The rate of interest depends on the loan's duration and the source of finance. Interest rates from formal sources range between 7% and 30% (GTZ/BAFIS 2001). With relatively high and volatile interest rates, it is unlikely that farmers would take the risk to borrow money, especially when natural disasters can occur that greatly affect the harvest. In this situation, farmers could not repay the banks and it becomes harder for them to have credit in the future. A guaranteed interest rate by the government could draw more farmers to borrow. Since farmers borrow to purchase inputs, an agricultural cooperative where farmers could borrow inputs directly instead of borrowing money to purchase the inputs could be an interesting alternative to banks, if the effective rate of interest is competitive.

We have seen that fertilizer has a significant impact on yield. With the establishment of such a cooperative, it could make fertilizer more accessible to farmers and help them improve their productivity. Farmers could repay the cooperative with their harvest in rice depending on the agreement. Payment with rice has been already observed when farmers hire people who have machinery to harvest their rice. However, past experiences of farming cooperatives have not been successful. The collectivisation of the agricultural sector after 1975 was not managed in a fair and equitable manner according to farmers. The system was not successful, and indeed, agricultural production fell dramatically (Bourdet 2000 and Evans 1988). It still might be interesting to promote cooperative behaviour because farmers are not often aware of the potential advantages of cooperatives. If well managed, cooperatives could be effective. Another means that could make fertilizer more accessible to farmers is a government subsidy, but it could be difficult because the Lao government relies heavily on international aid.

Another factor that significantly affects yield is the use of modern varieties compared to the traditional varieties. Although modern varieties have a higher yield, farmers are reluctant to adopt high yielding varieties because they do not know much about their conditions of production. Farmers prefer to cultivate traditional varieties because they have better knowledge of their conditions of production and can better predict yield which is important, because as subsistence farmers, rice forms a substantial part of their diet (Pa Nang, 2002). However, new varieties could be a better choice than traditional varieties because their properties may be more interesting when farmers face difficult environmental conditions of production. Indeed, modern varieties are known to be more resistant to various diseases. A free trial of new varieties coming from a research center could encourage farmers to adopt these varieties.

One of the characteristics of Lao agriculture is that there is little crop diversification. Indeed, 87% of the harvested area is allocated to cereal cultivation and rice production alone accounts for 78%. The remaining land is shared between vegetables and industrial crops such as coffee, peanut, cotton and tobacco (LMAF 2000). Such a heavy reliance on rice monoculture could deplete the soil. To counter this problem, crop diversification could be beneficial for the soil and for farmers as well. Indeed, a wide range of crops could prevent a complete loss of family income when disasters occur, such as a disease that affects a particular crop. When farmers encounter such a difficulty, they could turn to other crops. With a more diversified agriculture, farmers could also practice crop rotation in order to preserve their soil and practice a more sustainable agriculture. Farmers have little academic background on agricultural practices except the agricultural knowledge that is passed from generation to generation. Implementation of a program where farmers could consult agricultural experts could be an interesting avenue to help farmers take better care of the soil and follow a more environmentally respectful agricultural practice.

5.3 Limitations and future research

As mentioned earlier, agriculture is very sensitive to environmental conditions, such as climate, pests, diseases and poor soil quality. However, this study did not include such variables, yet it would be useful to incorporate environmental variables in future research.

Also, the data were limited in detail in some respects, especially the labour data. Labour is an important factor of production, especially in agriculture that is labour intensive as is often observed in developing countries. Thus, the way the labour data were collected might have affected the estimation of the production function. In order to have a better estimate of the production function, it might be useful to collect data for each working day by taking notes of the numbers of hours of labour and even specify the kind of task performed for each working person. It would be interesting to analyze the effect of different types of labour and categorize them according to age or gender.

Another limit of this research was the lack of input and output prices. Within the same village, input and output prices can vary substantially. So, it is difficult to establish representative prices. Having prices would have allowed for the evaluation of allocative efficiency, in addition to technical efficiency. In many developing countries, the goal of survival may be more important than maximizing profits. Nevertheless, it would be of interest to investigate the issue of economic efficiency. Knowing that a particular variable significantly affects profit, policy makers could put more emphasis on that variable and intervene. We could also test Shultz's hypothesis and assess whether or not rice farmers efficiently allocate their resources. Schultz's (1964) famous hypothesis "Poor but efficient", seems to be verified in the case of rice farmers in Ban Home at least with regard to technical efficiency. With a technical efficiency average of over 70%, Lao rice farmers are not that inefficient considering the rudimentary means they use to produce rice. However, a deeper analysis of allocative and economic efficiency is required.

In addition, it would be interesting to extend the research to other geographic areas to determine if there are regional differences. Finally, this research was carried out only for rice. Thus, if other crops were included, then a profit function of the whole household could be analyzed.

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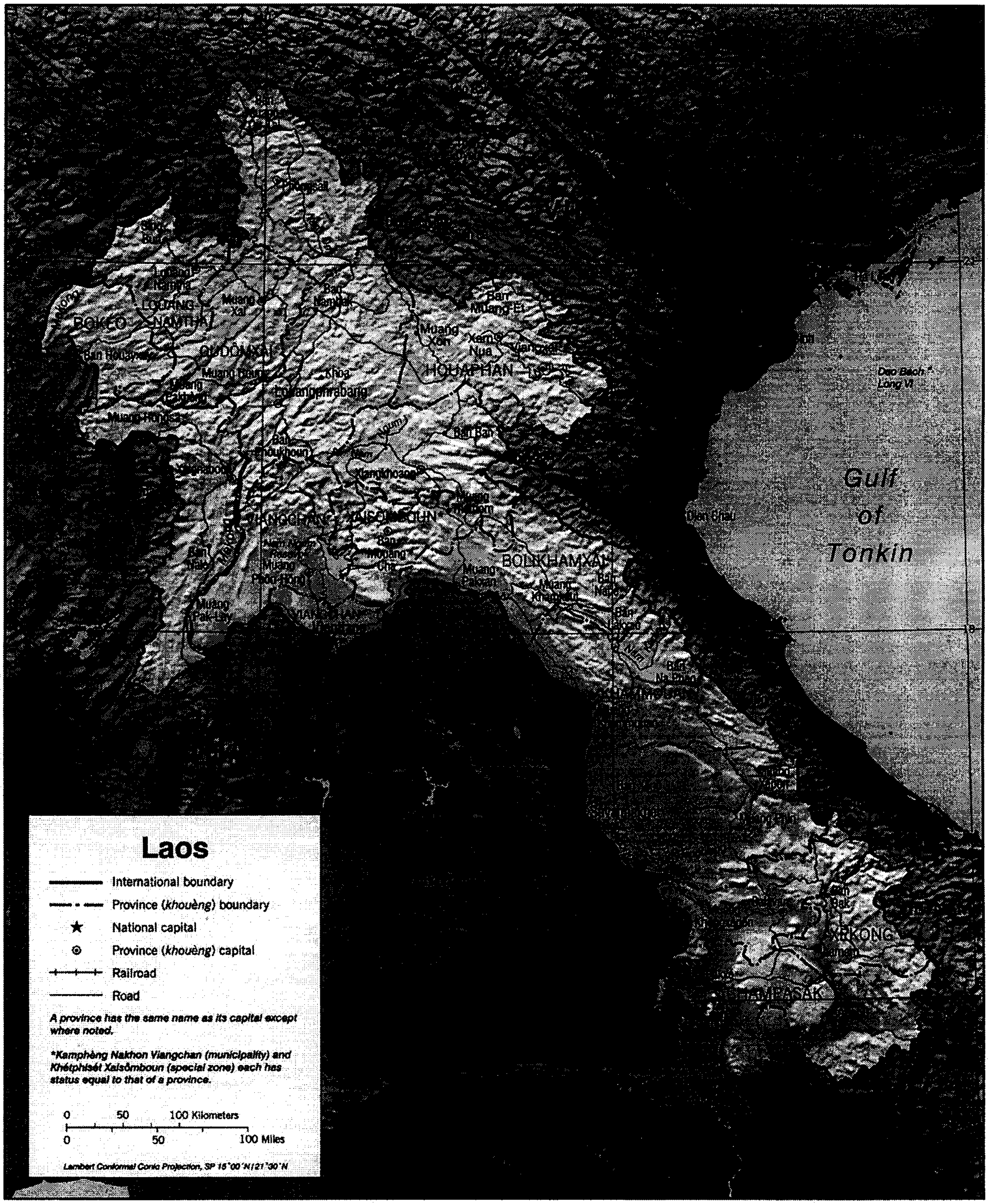
APPENDIX A

Map of Laos



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APPENDIX B

Survey

SURVEY ON RICE PRODUCTION IN BAN HOME (LAOS)

Date of survey : ________________ **Municipality :** ________________________

Householdhead's code: ________________ **Village :** ________________________

Commune : ________________________

1.Demographic : Household information

- What is your status ? MARRIED ( ) DIVORCED ( ) WIDOWED( ) SINGLE ( )
- Have you always lived in this village? YES ( ) NO ( )
- If not, where did you live before?________________________
- When did you move to this village?________________________
- What is your first occupation?________________________
- Do you have a second occupation: YES ( ) NO ( )
- If yes, what is your second occupation?________________
- How long have you been a farmer?________________
- How long have you been growing rice? ________________
- What is your formal education (number of years)?

0__1__2__3__4__5__6__7__8__9__10__11__12________________________

2. Land (1 ray = 0,16 ha)

Field type	Location	Distance from home (km)	Owned area (ray)	Rented area (ray)	Irrigated area (ray)	Other use (ray)	Primary crop	Other crop

On the column of Field type:
What is the type of your soil? SANDY SOIL (A) HEAVY SOIL (B) OTHERS (C)

For rented area:

- How much do you pay in rent per year?________________
- If you don't pay in cash, how do you pay the rent?________________________________
- From whom do you rent the land? RELATIVES ( ) NEIGHBOR ( ) OTHERS ( )________

3. Income (1$ canadian = 5000 kips)

- What is the total annual non agricultural income of the entire household?________________
- For each agricultural product, how much did you sell and how much income did you receive?

Agricultural product	Sale (kg)	Income (kips)

4.Rice production

Year of rice production : __________ **Wet** **Dry**

- What was your total rice production for each season (current year)?(kg) _______ _______
- What was your total rice production of the previous year? (kg) _______ _______
- Total area of production for each season (ray) _______ _______
- What seeding rate did you use for rice production? (kg) _______ _______

- What quantity of chemical fertilizer did you use? (kg) _______ _______
- When did you apply it? ____
- Why did you apply it, or not?____

- What quantity of manure fertilizer did you use? (kg) _______ _______
- When did you apply it? ____
- Why did you apply it, or not?____

- What quantity of molluscicide did you use? (kg) _______ _______
- When did you apply it?____
- Why did apply it, or not.____

- What was the quantity of herbicide? (kg) _______ _______
- When did you apply it?____
- Why did you apply it, or not?____

- What was the quantity of insecticide? (kg) _______ _______
- When did you apply it?____
- Why did you apply it, or not?____

- What was the rice variety did you use? _______ _______
- What was the quality of your rice (paddy) based on humidity, cleanliness and purity of variety?
- EXCELLENT( ) GOOD( ) FAIR( ) POOR( ) BAD( )

- Did you hire people to work on rice production during the last calendar year?

YES( ) NO( ) YES( ) NO( )

- How many days did you hire them? _______ _______
- How much did you pay them per day? _______ _______
- Where was the hired labor coming from?
  - LOCAL LABOR( ) NOMAD LABOR( ) OTHER( )_______________

- How much labor did you get from your family (in days for each season)?
  - male labor _______ _______
  - female labor _______ _______
  - child labor (under 15 yrs old) _______ _______
  - elderly labor (over 65 yrs old) _______ _______

- Did you use motor power (tractor)? YES( ) NO( ) YES( ) NO( )
- If yes, what is the force power? ______________________________
- Did you use animal power? YES( ) NO( ) YES( ) NO( )

- How would you rate the following sources of agricultural information in terms of usefulness to rice production ?

  (1) NOT IMPORTANT AT ALL, (2) NOT SO IMPORTANT, (3) FAIR, (4) IMPORTANT, (5) VERY IMPORTANT

  AGR. ADVISOR ( )
  TELEVISION ( )
  NEWSPAPER ( )
  OTHER ( )_______________________

- Which of the following sources provide the largest quantity of agricultural information, regardless of whether you find it useful or not? AGR. ADVISOR ( )
  TELEVISION ( )
  NEWSPAPER ( )
  OTHER ( ) _______________________

- How many times an agricultural advisor visits you during each season? __________
- What kind of information do you get from an agr.advisor? ______________________________

- How well informed are you of rice market price?
    - VERY WELL ( ), WELL ( ), NOT SO WELL ( ), NOT WELL ( )
- How many time do you go to the

LOCAL MARKET ? ________ ________

CITY MARKET ? ________ ________

Agricultural capital assets for rice production

What assets do you have and their value? If you do not have them do you have access to them?

Assets	Quantity	Value per unit	Access
land			YES ( ) NO( )
tractor			YES ( ) NO( )
oxen			YES ( ) NO( )
irrigation pomp			YES ( ) NO( )
			YES ( ) NO( )
			YES ( ) NO( )

Credit

- Did you borrow money for agricultural purposes for each season? YES ( ) NO ( )
- If yes, who lends you the money?

BANK ( ), NGO ( ), RELATIVES ( ), BUSINESSMAN ( ), OTHER ( )__________

- Was the loan made in cash? ( ) Yes.____________(value) ( ) No
- If not, can you describe the conditions of the loan?____

____

____

- Was a collateral required by the lender? YES ( ) NO ( )
- If a collateral was required, what type of collateral?____________________________
- What is the duration of the loan?____________________
- You might not have used the loan as initially intended, for instance, due to an unexpected medical emergency in your family. Did you actually use the loan for the agricultural purpose?

YES, ALL ( ) YES, PARTLY ( ) NO ( )

- If the money was not all used as initially intended, what was the motive?______________
- Will you repay the loan in cash? YES ( ) NO ( )
- If the loan will be repaid in cash, how much is due?__________
- If not, how will you pay back the loan?____

____

____

____

____

- Last year, did you receive remittances from relatives living outside the village?

YES ( ) NO ( )

- If yes, how much did you receive? ______________________________

APPENDIX C
Data

Data on rice production during the wet season

Household	gender	age	farmex	size	educ	secocc	variety	yield	riarea	otherarea
1	0	70	57	4	10	0	1	2.5	1	1.00E-10
2	1	57	39	4	6	0	1	7.142857	0.56	0.57
3	1	80	66	6	6	1	1	2.806186	0.8018	1.00E-10
4	1	30	16	4	6	1	0	1.99551	0.8018	1.00E-10
5	1	53	38	8	8	1	1	2.5	0.3	1.00E-10
6	1	65	47	2	6	0	1	4.9	1.4	1.00E-10
7	1	35	17	6	6	0	0	1	0.45	1.00E-10
8	1	64	49	4	6	1	1	4.102273	0.88	0.2745
9	1	68	52	7	6	1	0	2.093023	0.43	1.00E-10
10	1	61	47	6	3	0	0	1	0.35	1.00E-10
11	1	62	46	6	6	1	0	2.013575	0.442	0.255
12	1	40	24	5	12	1	1	4.2	1	1.00E-10
13	1	66	47	6	6	1	1	3.5	0.75	0.2
14	0	85	71	2	6	1	0	1.111111	0.27	1.00E-10
15	1	29	15	5	6	1	1	2	0.71	1.00E-10
16	1	56	39	9	6	0	0	2.206694	0.8157	1.00E-10
17	1	37	19	7	12	1	1	5.5	1.8	0.48
18	1	55	39	6	12	1	0	4	1.715	1.00E-10
19	1	42	26	4	12	1	0	1.40625	0.32	0.162
20	1	47	29	4	12	1	0	0.625	0.12	1.00E-10
21	1	55	40	6	6	0	1	2.302632	0.76	1.00E-10
22	1	50	34	10	12	0	0	2.505747	0.435	0.12
23	1	72	57	8	6	1	1	2.097824	0.8914	1.48
24	1	55	42	9	12	1	0	1.003113	1.7346	1.8
25	1	67	52	12	6	1	0	2	0.4	1.00E-10
26	1	43	29	9	14	1	1	2.310924	1.4756	1
27	1	55	37	9	12	0	1	2.609375	0.64	1.00E-10
28	0	29	12	3	12	1	1	4.991024	2.785	0.48
29	0	46	28	6	6	1	0	2.1	0.8	1.00E-10
30	0	87	74	3	12	0	0	2.45	0.6	2.58
31	1	71	54	3	12	1	1	2.463768	0.69	1.00E-10
32	1	39	21	3	12	1	0	0.7022472	0.89	0.56
33	1	40	24	6	12	0	0	1.573034	0.32	1.00E-10
34	1	41	22	5	12	0	0	0.703125	0.32	1.00E-10
35	1	54	38	3	12	0	0	2.453125	0.64	0.4
36	1	60	43	7	12	0	1	6.614786	2.57	0.4
37	1	68	54	6	12	0	0	2.869159	2.14	0.13
38	1	67	54	5	12	1	1	2.8	0.7	1.00E-10
39	1	29	14	4	12	0	0	0.75	0.16	1.00E-10
40	1	34	19	4	9	0	0	1.006109	0.5566	1.00E-10

41	0	62	45	4	6	0	1	2.098837	1.72	1.00E-10
42	0	75	59	6	16	1	1	2.798439	1.3579	1.00E-10
43	1	66	48	6	14	1	1	5.564857	2.0306	1.00E-10
44	1	57	41	3	12	0	1	6.25	0.096	1.00E-10
45	1	49	32	6	14	1	0	2.098522	1.015	1.015
46	1	36	19	4	14	1	0	1.395833	0.48	0.6
47	1	64	45	4	14	1	0	1.458333	0.48	1.00E-10
48	1	45	28	4	9	1	0	0.3571429	0.56	1.00E-10
49	1	45	28	9	12	0	0	0.9791667	0.24	1.00E-10
50	1	42	26	5	15	1	1	1.701754	0.57	1.00E-10
51	1	79	64	6	9	1	0	2.09375	0.64	0.8
52	1	58	39	6	12	1	0	0.375	0.8	1.00E-10
53	1	71	54	9	15	1	0	0.625	0.32	1.00E-10
54	1	25	10	4	12	1	0	1.7	0.4	1.00E-10
55	1	72	59	5	6	1	0	2.098214	1.12	1.00E-10
56	0	66	51	5	3	1	0	1.479167	0.48	1.00E-10
57	1	37	20	8	9	1	0	0.7073171	0.41	1.00E-10
58	1	52	37	8	6	1	0	1.25	0.32	1.00E-10
59	1	69	51	5	6	1	1	2.083333	0.48	1.00E-10
60	1	57	40	6	12	1	1	4.812834	1.122	1.00E-10
61	1	53	36	7	12	1	1	3.005347	0.935	1.00E-10
62	1	53	38	7	12	1	0	0.7030178	0.2916	0.64
63	0	57	41	3	6	1	1	2.098214	1.12	1.00E-10
64	1	60	46	5	12	1	1	1.053396	1.6518	0.56
65	0	47	30	6	3	0	1	3.006536	0.459	1.00E-10
66	1	37	24	5	6	1	0	2.100084	0.8333	0.8
67	1	59	46	6	12	1	1	2.8	1	1.00E-10
68	0	79	62	6	6	1	0	1.09375	0.32	1.00E-10
69	1	44	29	5	12	1	0	0.6935123	0.447	1.00E-10
70	1	62	47	5	12	1	0	2.1	0.7	1.00E-10
71	1	55	40	8	12	1	0	0.7258065	0.124	0.64
72	1	30	14	4	6	1	1	2	0.5	1.00E-10
73	1	40	22	4	12	1	0	0.5	0.7	1.00E-10
74	0	41	24	6	12	0	0	1.40625	0.32	1.00E-10
75	0	62	46	6	9	1	0	1.5	0.32	1.00E-10
76	1	61	45	6	6	1	0	2.8	0.4	0.5
77	1	56	41	6	6	1	0	1.5	0.16	0.1656
78	1	72	58	7	5	1	0	1.5625	0.32	1.00E-10
79	1	25	9	5	9	1	0	2	0.6	1.00E-10
80	1	33	15	3	6	1	1	5.6	1	1.00E-10
81	1	70	57	5	4	0	1	2.109375	0.64	1.00E-10
82	1	26	13	3	9	0	0	0.9166667	0.24	1.00E-10
83	1	65	49	5	12	1	0	2.5	0.32	1.00E-10

84	0	66	52	3	6	1	1	2.10687	0.655	2.22
85	1	55	40	4	12	1	0	1.40625	0.32	1.00E-10
86	1	42	26	4	12	1	0	1	0.18	1.00E-10
87	1	76	58	11	12	1	1	3.5	1	1.00E-10
88	1	59	44	7	12	0	0	1.217391	0.46	1.00E-10
89	1	34	21	4	6	0	1	2.103929	0.789	1.00E-10
90	0	43	27	5	12	1	0	0.71875	0.16	0.3
91	1	67	48	8	12	1	1	4.896552	1.45	0.5
92	1	75	57	6	12	1	1	5	1.45	2.0295
93	1	45	28	5	15	0	1	4.203125	1.28	1.00E-10
94	1	33	17	12	6	1	0	1.006109	0.2783	1.00E-10
95	1	66	51	4	12	1	0	1.758242	0.91	1.00E-10
96	1	24	10	5	6	0	0	1.75	0.28	1.00E-10
97	1	51	37	4	12	1	0	1.375	0.32	1.00E-10
98	1	43	25	5	12	1	0	0.7009346	0.4494	1.8324
99	1	43	28	6	6	1	0	1	0.32	0.16
100	1	72	55	11	6	1	0	3.5	0.66	0.28
101	0	65	53	3	9	1	0	1.190476	0.21	1.00E-10
102	1	66	52	4	12	1	0	2.036199	0.442	1.00E-10
103	0	40	26	5	12	1	0	1.802083	0.48	0.32
104	1	58	42	6	8	1	0	1.388889	0.36	1.00E-10
105	1	65	47	4	9	1	1	4.888889	1.44	1.00E-10
106	1	53	39	5	14	1	0	2	0.64	1.00E-10
107	1	65	48	8	15	1	1	5.220588	1.36	0.35
108	1	48	30	4	12	1	1	3	1	0.36
109	1	53	38	5	12	1	1	2.109375	0.64	1.00E-10
110	1	83	67	6	12	1	0	1	0.8	1.00E-10
111	1	52	37	11	9	1	0	0.2083333	0.12	2
112	1	53	36	5	12	1	0	0.5101523	3.94	4.4772

soiltype	agrext	fert_ha	seed_ha	famlab_ha	Hire_ha	credit	labt_ha
1	1	180	170	1200	0	1	1200
1	1	178.5714	107.1429	2678.572	178.5714	1	2857.143
1	1	187.0791	137.1913	1746.071	0	0	1746.071
0	1	199.551	249.4388	1247.194	0	0	1247.194
1	1	333.3333	133.3333	3000	0	0	3000
1	1	178.5714	142.8571	1785.714	142.8571	1	1928.571
0	0	333.3333	111.1111	2666.667	0	0	2666.667
1	1	181.8182	170.4545	1704.545	102.2727	0	1806.818
1	0	279.0698	162.7907	3720.93	0	0	3720.93
0	0	285.7143	171.4286	4285.714	0	0	4285.714
0	0	271.4932	135.7466	2714.932	226.2443	0	2941.177
1	1	200	200	1500	100	0	1600
1	1	186.6667	106.6667	2266.667	266.6667	0	2533.333
0	0	370.3704	222.2222	4444.444	740.7407	1	5185.185
0	1	183.0986	84.50704	2112.676	281.6902	1	2394.366
0	0	183.8911	183.8911	2451.882	0	0	2451.882
1	0	183.3333	152.7778	1666.667	0	1	1666.667
1	1	180.758	233.2361	932.9446	0	1	932.9446
0	0	406.25	93.75	2500	0	0	2500
0	0	250	208.3333	10000	0	0	10000
1	1	184.2105	230.2632	1842.105	131.5789	0	1973.684
1	1	183.9081	114.9425	4597.701	0	0	4597.701
0	1	179.4929	280.4577	2580.211	0	1	2580.211
0	0	187.3631	247.8958	980.053	0	0	980.053
0	0	250	175	5000	0	0	5000
1	1	189.7533	155.8688	1694.226	0	0	1694.226
1	1	187.5	125	3125	156.25	0	3281.25
1	1	179.5332	143.6266	825.8528	71.81329	1	897.666
1	1	187.5	187.5	2125	0	0	2125
1	1	166.6667	133.3333	3000	333.3333	0	3333.333
1	1	181.1594	130.4348	2318.841	579.7101	1	2898.551
0	0	179.7753	101.1236	1348.315	112.3596	0	1460.674
0	0	224.7191	224.7191	4687.5	0	0	4687.5
0	0	187.5	93.75	3125	0	0	3125
1	1	187.5	109.375	2031.25	156.25	1	2187.5
1	1	182.8794	155.642	1167.315	0	1	1167.315
1	1	182.243	163.5514	1028.037	0	1	1028.037
1	1	185.7143	171.4286	3571.428	142.8571	0	3714.286
0	0	250	156.25	8750	625	0	9375
0	0	179.6622	179.6622	2155.947	0	0	2155.947

1	1	180.2326	290.6977	1337.209	58.13953	0	1395.349
0	1	184.1078	117.829	1767.435	73.64313	0	1841.078
1	1	177.2875	177.2875	1575.889	49.24653	1	1625.135
0	1	520.8333	260.4167	12500	0	0	12500
1	1	187.1921	197.0443	2660.099	0	0	2660.099
0	1	187.5	83.33334	2708.333	0	0	2708.333
0	0	208.3333	83.33334	2291.667	0	0	2291.667
0	0	142.8571	107.1429	1785.714	0	0	1785.714
0	0	208.3333	125	4166.667	0	0	4166.667
0	0	175.4386	105.2632	2105.263	0	0	2105.263
1	1	187.5	125	2343.75	0	1	2343.75
0	0	187.5	250	1625	0	0	1625
0	0	187.5	187.5	3750	0	0	3750
0	0	175	125	3000	0	0	3000
0	0	178.5714	357.1429	1875	89.28571	1	1964.286
0	0	208.3333	145.8333	2500	0	0	2500
0	0	195.1219	121.9512	2926.829	0	0	2926.829
0	0	406.25	156.25	4687.5	0	0	4687.5
1	1	166.6667	125	3750	208.3333	1	3958.333
1	1	178.2531	200.5348	2049.911	178.2531	1	2228.164
0	1	181.8182	187.1658	2780.749	106.9519	0	2887.7
0	0	274.3484	137.1742	4458.162	0	0	4458.162
0	0	178.5714	178.5714	1696.429	89.28571	0	1785.714
0	1	181.6201	230.0521	1029.18	60.54002	0	1089.72
0	1	174.2919	108.9325	3703.704	0	1	3703.704
0	1	180.0072	150.006	2640.106	120.0048	1	2760.11
0	1	180	165	2000	100	0	2100
0	0	250	218.75	3125	0	1	3125
0	0	178.9709	111.8568	2684.564	0	0	2684.564
1	0	185.7143	285.7143	2857.143	142.8571	0	3000
0	0	322.5807	241.9355	8870.968	0	0	8870.968
0	0	200	300	3200	200	0	3400
0	0	185.7143	100	1714.286	0	0	1714.286
0	1	406.25	125	6250	0	0	6250
0	0	468.75	187.5	3125	0	0	3125
1	0	175	150	4750	250	0	5000
0	0	312.5	187.5	6250	0	0	6250
0	0	468.75	187.5	4062.5	0	0	4062.5
1	0	183.3333	166.6667	2833.333	0	0	2833.333
1	1	200	200	2800	300	0	3100
0	1	187.5	125	3125	312.5	0	3437.5
0	0	333.3333	104.1667	6250	0	0	6250
0	1	312.5	187.5	6875	0	0	6875

0	0	167.9389	137.4046	2748.092	305.3435	0	3053.435
0	0	468.75	156.25	4687.5	0	0	4687.5
0	0	277.7778	138.8889	6666.667	0	0	6666.667
0	1	180	170	2500	0	1	2500
0	0	326.0869	108.6957	4347.826	217.3913	0	4565.217
1	1	190.1141	164.7655	2534.854	126.7427	1	2661.597
0	0	250	156.25	6250	0	0	6250
1	1	179.3103	275.8621	2137.931	206.8965	1	2344.827
1	1	179.3103	206.8965	2068.966	137.931	1	2206.896
1	1	179.6875	171.875	2421.875	156.25	1	2578.125
0	0	287.4596	107.7973	4671.218	0	0	4671.218
0	1	181.3187	164.8352	1978.022	109.8901	0	2087.912
0	0	535.7143	107.1429	3571.428	0	0	3571.428
0	1	406.25	156.25	3750	0	0	3750
0	0	178.0151	111.2595	2670.227	0	0	2670.227
0	0	250	125	3125	0	0	3125
1	1	181.8182	166.6667	2878.788	151.5152	1	3030.303
0	0	380.9524	119.0476	6190.476	0	0	6190.477
0	0	271.4932	135.7466	2262.443	294.1176	0	2556.561
0	0	250	104.1667	2708.333	0	0	2708.333
0	0	416.6667	166.6667	3333.333	0	0	3333.333
1	1	180.5556	159.7222	1805.556	208.3333	1	2013.889
0	0	187.5	125	2812.5	0	0	2812.5
1	1	183.8235	183.8235	2205.882	147.0588	1	2352.941
0	1	180	200	2800	200	0	3000
0	1	187.5	125	2812.5	0	0	2812.5
0	0	187.5	200	1625	0	0	1625
0	0	208.3333	208.3333	8333.33	0	0	8333.334
0	0	177.665	152.2843	253.8071	0	1	507.6142

Data on rice production during the dry season

Household	gender	age	farmex	size	educ	secocc	variety	yield	riarea	otherarea
1	0	70	53	4	10	0	1	3	0.48	0.52
2	1	57	41	4	6	0	1	7.5	0.56	0.57
3	1	80	61	6	6	1	1	3.492143	0.8018	1.00E-10
4	1	30	14	4	6	1	0	2.993265	0.8018	1.00E-10
5	1	53	36	8	8	1	1	4	0.3	1.00E-10
6	1	35	19	6	6	0	0	2	0.32	0.13
7	1	64	46	4	6	1	1	5	0.88	0.2745
8	1	68	51	7	6	1	0	2.27907	0.43	1.00E-10
9	1	61	48	6	3	0	0	1.59375	0.32	0.03
10	1	62	46	6	6	1	0	2.104072	0.442	0.255
11	1	40	24	5	12	1	1	4.5	1	1.00E-10
12	1	78	63	2	6	0	0	2	0.175	0.8
13	1	29	16	5	6	1	1	3	0.71	1.00E-10
14	1	56	38	9	6	0	0	3.224225	0.8157	1.00E-10
15	1	42	26	4	12	1	0	2	0.32	0.162
16	1	47	30	4	12	1	0	2	0.12	1.00E-10
17	1	55	38	6	6	0	1	2.565789	0.76	1.00E-10
18	1	50	35	10	12	0	0	2.988506	0.435	0.12
19	1	57	39	2	3	0	1	3.814103	0.624	1.00E-10
20	1	72	59	8	6	1	1	2.5	0.48	1.8914
21	1	50	34	8	12	1	1	4.21875	0.96	1.00E-10
22	1	55	38	9	12	1	0	5.073216	0.8673	2.6673
23	1	67	54	12	6	1	0	2.5	0.32	0.08
24	1	55	38	9	12	0	1	3	0.48	0.16
25	0	29	12	3	12	1	1	5	1.6	1.665
26	0	46	33	6	6	1	0	2.5	0.48	0.32
27	0	87	68	3	12	0	0	3	0.6	2.58
28	1	71	54	3	12	1	1	3	0.69	1.00E-10
29	1	39	25	3	12	1	0	1.573034	0.89	0.56
30	1	41	26	5	12	0	0	4.6875	0.32	1.00E-10
31	1	54	36	3	12	0	0	3	0.45	0.59
32	1	60	45	7	12	0	1	4.038462	1.04	1.93
33	1	68	52	6	12	0	0	4.047619	0.84	1.43
34	1	67	48	5	12	1	1	3	0.7	1.00E-10
35	1	29	12	4	12	0	0	1.5	0.16	1.00E-10
36	1	41	25	3	6	0	1	2.083333	0.48	1.00E-10
37	1	34	20	4	9	0	0	2	0.46	0.0966
38	0	62	47	4	6	0	1	2.142857	0.56	1.16
39	1	36	23	5	6	1	0	1.2	0.4	1.00E-10
40	1	66	50	6	14	1	1	6.008077	2.0306	1.00E-10

41	1	57	41	3	12	0	1	3.958333	0.096	1.00E-10
42	0	64	47	2	6	0	1	3	0.16	0.4767
43	1	45	31	4	9	1	0	1.5	0.32	0.24
44	1	45	31	9	12	0	0	1.5	0.24	1.00E-10
45	1	79	66	6	9	1	0	2.8125	0.64	0.8
46	1	58	40	6	12	1	0	4.375	0.8	1.00E-10
47	1	71	55	9	15	1	0	3.125	0.32	1.00E-10
48	1	25	11	4	12	1	0	2	0.4	1.00E-10
49	0	66	51	5	3	1	0	2.083333	0.48	1.00E-10
50	1	69	56	5	6	1	1	2.8125	0.48	1.00E-10
51	1	57	39	6	12	1	1	4.991087	1.122	1.00E-10
52	1	53	39	7	12	1	0	2.057613	0.2916	0.64
53	0	47	32	6	3	0	1	2.5	0.392	0.067
54	1	37	18	5	6	1	0	3.00012	0.8333	0.8
55	1	59	40	6	12	1	1	3	1	1.00E-10
56	0	79	63	6	6	1	0	2.1875	0.32	1.00E-10
57	1	44	31	5	12	1	0	1.118568	0.447	1.00E-10
58	1	30	15	4	6	1	1	4	0.5	1.00E-10
59	1	25	10	5	9	1	0	2	0.6	1.00E-10
60	1	33	18	3	6	1	1	6.3	1	1.00E-10
61	1	70	56	5	4	0	1	2.8125	0.64	1.00E-10
62	1	26	10	3	9	0	0	1.083333	0.24	1.00E-10
63	0	66	50	3	6	1	1	3.050109	0.459	2.416
64	0	68	54	6	9	0	1	4.181449	0.7892	0.2108
65	1	67	51	8	12	1	1	5	1	0.95
66	1	58	41	5	12	1	1	4	1.45	1.00E-10
67	1	75	58	6	12	1	1	6	1.45	2.0295
68	1	33	18	12	6	1	0	2.155947	0.2783	1.00E-10
69	1	66	51	4	12	1	0	1.868132	0.91	1.00E-10
70	1	24	7	5	6	0	0	3	0.28	1.00E-10
71	1	43	29	5	12	1	0	2.803738	0.4494	1.8324
72	1	43	29	6	6	1	0	1.5625	0.32	0.16
73	1	72	54	11	6	1	0	4	0.19	0.75
74	1	32	17	4	9	1	1	0.9375	0.16	1.00E-10
75	1	55	39	8	1	1	1	4	0.79	0.04
76	0	40	23	5	12	1	0	2	0.48	0.32
77	1	65	46	4	9	1	1	5	1.44	1.00E-10
78	1	53	34	5	14	1	0	5	0.64	1.00E-10
79	1	65	52	8	15	1	1	2.794118	1.36	0.35
80	1	53	39	5	12	1	1	2.5	0.64	1.00E-10
81	1	83	70	6	12	1	0	1	0.8	1.00E-10
82	1	53	36	5	12	1	0	4.75	1.2	7.2172

soiltype	agrext	fert_ha	seed_ha	famlab_ha	Hire_ha	credit	labt_ha
1	1	270.8333	291.6667	4166.667	208.3333	0	4375
1	1	357.1429	214.2857	3928.572	178.5714	1	4107.143
1	1	311.7985	280.6186	2743.826	1.25E-11	0	2743.826
0	1	299.3265	286.8546	2494.388	1.25E-11	1	2494.388
1	1	300	266.6667	6000	3.33E-11	0	6000
0	0	250	250	4687.5	312.5	0	5000
1	1	295.4546	250	3409.091	136.3636	1	3545.455
1	1	279.0698	290.6977	4651.163	2.33E-11	0	4651.163
0	1	187.5	218.75	6562.5	3.12E-11	0	6562.5
0	1	271.4932	248.8688	3846.154	2.26E-11	1	3846.154
1	0	300	250	2000	200	0	2200
0	1	285.7143	228.5714	13142.86	5.71E-11	0	13142.86
0	0	281.6902	295.7747	2816.901	140.8451	0	2957.747
0	1	306.4852	281.9664	2942.258	122.5941	0	3064.852
0	1	250	250	4062.5	3.12E-11	0	4062.5
0	1	250	250	13333.33	8.33E-11	0	13333.33
1	1	289.4737	289.4737	2500	131.5789	0	2631.579
1	1	298.8506	287.3563	5747.126	229.8851	1	5977.012
0	1	320.5128	272.4359	3205.128	160.2564	1	3365.385
0	1	270.8333	291.6667	3541.667	208.3333	0	3750
0	0	364.5833	250	2083.333	104.1667	0	2187.5
0	0	299.7809	207.5406	2651.908	115.3004	0	2767.208
0	0	250	281.25	6250	3.12E-11	0	6250
1	1	291.6667	312.5	4375	208.3333	0	4583.333
1	1	356.25	250	1562.5	62.5	1	1625
1	1	270.8333	291.6667	4166.667	208.3333	0	4375
1	1	300	300	4166.667	500	0	4666.667
1	0	289.8551	289.8551	4057.971	289.8551	1	4347.826
0	0	224.7191	224.7191	1797.753	112.3596	1	1910.112
0	1	312.5	250	5312.5	3.12E-11	0	5312.5
1	1	288.8889	288.8889	3555.556	2.22E-11	0	3555.556
1	1	346.1538	250	2980.769	96.15385	0	3076.923
1	1	321.4286	250	3452.381	119.0476	0	3571.428
1	1	285.7143	300	3571.428	142.8571	0	3714.286
0	0	187.5	187.5	9375	6.25E-11	0	9375
0	0	270.8333	270.8333	4166.667	2.08E-11	0	4166.667
0	0	260.8696	239.1304	3260.87	2.17E-11	0	3260.87
1	1	267.8571	232.1429	3571.428	1.79E-11	0	3571.428
0	1	175	200	3750	2.50E-11	0	3750
1	1	339.8011	221.6094	1723.629	147.7396	1	1871.368

0	1	416.6667	312.5	12500	1.04E-10	0	12500
0	1	312.5	312.5	9375	6.25E-11	0	9375
0	1	187.5	218.75	3125	3.12E-11	0	3125
0	1	208.3333	208.3333	4166.667	4.17E-11	0	4166.667
1	0	296.875	281.25	3125	156.25	0	3281.25
0	1	312.5	250	2500	125	0	2625
0	1	312.5	312.5	5312.5	3.12E-11	0	5312.5
0	1	250	250	3750	2.50E-11	0	3750
0	1	270.8333	270.8333	2083.333	2.08E-11	0	2083.333
1	1	291.6667	291.6667	5000	2.08E-11	0	5000
1	1	329.7683	249.5544	2673.797	267.3797	1	2941.177
0	0	274.3484	274.3484	9259.259	1371.742	0	10631
0	1	280.6122	280.6122	5102.041	2.55E-11	0	5102.041
0	1	300.012	300.012	3000.12	1.20E-11	0	3000.12
0	1	300	300	2400	100	1	2500
0	0	281.25	250	3125	3.12E-11	0	3125
0	0	178.9709	201.3423	2237.136	2.24E-11	0	2237.136
0	0	340	280	4000	200	0	4200
1	1	266.6667	250	3333.333	166.6667	0	3500
1	1	350	220	3000	400	1	3400
0	1	312.5	281.25	3593.75	156.25	0	3750
0	0	166.6667	208.3333	5000	4.17E-11	0	5000
0	0	305.0109	283.2244	4793.028	217.8649	1	5010.893
0	1	354.7897	253.4212	3167.765	126.7106	0	3294.475
1	1	320	250	3500	300	1	3800
0	0	296.5517	275.8621	1862.069	137.931	1	2000
1	1	358.6207	206.8965	2413.793	206.8965	1	2620.69
0	1	287.4596	251.5271	4311.894	3.59E-11	0	4311.894
0	0	219.7802	219.7802	2527.472	1.10E-11	0	2527.472
0	1	285.7143	285.7143	3571.428	3.57E-11	1	3571.428
0	0	289.2746	289.2746	3337.784	2.23E-11	0	3337.784
0	0	218.75	218.75	3125	3.12E-11	0	3125
1	0	368.4211	263.1579	10526.32	5.26E-11	0	10526.32
0	0	187.5	156.25	8125	6.25E-11	0	8125
0	1	341.7722	278.481	2278.481	126.5823	0	2405.063
0	1	270.8333	250	3333.333	2.08E-11	0	3333.333
1	1	347.2222	208.3333	2222.222	138.8889	0	2361.111
0	1	343.75	218.75	3906.25	156.25	0	4062.5
1	1	294.1176	294.1176	2500	73.52941	0	2573.529
0	0	281.25	281.25	3750	1.56E-11	0	3750
0	1	150	150	1625	1.25E-11	0	1625
0	1	350	250	1333.333	83.33334	1	1416.667

APPENDIX D

Certificate of ethical acceptability for research involving humans

McGill

Certificate of Ethical Acceptability for
Research Involving Humans

Project Title: Factors influencing rice production efficiency in Ban Home village, Laos

Applicant's Name: Khamla Hem Inthavong
Supervisor (if applicable): Dr. John Henning

Type of Review: Expedited

Decision: **APPROVAL HAS BEEN GRANTED**

Paula Ribeiro
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Research Ethics Committee
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February 21, 2003