Input productivity under the System of Rice Intensification: a rice farming technology explored

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Foreword

This is a literature study for a bachelor science thesis. I hope that this study will contribute to the research project 'The System of Rice Intensification as a social movement', which is funded by the Bill and Melinda Gates Foundation and carried out at Wageningen University by Ezra Berkhout and Dominic Glover.

I would like to thank my supervisor Ezra Berkhout for his advice, enthusiasm and support. I would also like to give my gratitude to God and my friends and family, especially Pim Dekkers, for their love and support.

Contents

List of abbreviations

AAN = Alternative Agriculture Network

AIT = Asian Institute of Technology

AVP = average product of labour

BUCAP = Biodiversity Use and Conservation Asia Program

CCHD = Catholic Commission for Human Development

CEDAC = Cambodian Center for Study and Development in Agriculture

CDRI = Cambodia Development Resource Institute

CGIAR = Consultative Group on International Agricultural Research

CIIFAD = International Institute for Food, Agriculture and Development at Cornell University

CPWF = Challenge Program on Water and Food

DAALI = Department of Agriculture and Land Improvement

FAO = Food and Agriculture Organization

EED = Church Development Service

FFS = Farmer Field School

GO = Governmental Organization

GDP = Gross Domestic Product

GTZ = Deutsche Gesellschaft für Technische Zusammenarbeit

HEIA = high-external-input agriculture

HEKS = Swiss Interchurch Aid Organization

IFAD = International Fund for Agricultural Development

ILEIA = Center for Information on Low External Input and Sustainable Agriculture

IO = International Organization

IPM = integrated pest management

IRRI = International Rice Research Institute

ISAC = Institute for a Sustainable Agriculture Community

kg = kilogram(s)

LEIA = low-external-input agriculture

LEISA = low-external-input and sustainable agriculture

MAFF = Ministry of Agriculture, Forestry and Fisheries

MARD = Ministry of Agriculture and Rural Development

MC = marginal cost

MCC = Multiple Cropping Center

MESA = Multinational Exchange for Sustainable Agriculture

MRC = McKean Rehabilitation Center

MRVR = Maekok River Village Resort

MR = marginal revenue

MVP = marginal product of labour

NGO = Non-Governmental Organization

OARD = Office of Agricultural Research and Development

PDA = Provincial Department of Agriculture

PPD = Plant Protection Department of MARD

RISE-AT = Regional Information Center for SEA on Appropriate Technology

RRAFA = Rural Reconstruction Alumni and Friends Association

SAKDI = Sustainable Agriculture Knowledge and Development Institute

SEARCA = Southeast Asian Research Center in Agriculture

SRD = Center for Sustainable Rural Development

SRI = System of Rice Intensification

UNDP = United Nations Development Program

UHDP = Upland Holistic Development Project

t/ha = ton(s) per hectare

TNU = Thai Nguyen University

VND = Vietnamese Dong

Summary

Agriculture is a very important generator of food and income for developing countries. Investment in agriculture will enhance pro-poor growth. In this bachelor thesis the effect of a new rice cultivation technology called the System of Rice Intensification (SRI) on input productivity has been investigated in Thailand, Cambodia and Vietnam. Though most SRI principles go against farmers' traditional rice farming methods, SRI at large is dispersed and promoted by GOs, universities and NGOs and presented as a new way of rice farming. SRI is aimed to a new paradigm of rice farming with more care and attention for the rice plant but increased productivity, but it is found that a higher production curve is not being reached.

In Cambodia, SRI is labour-neutral. In Vietnam, labour productivity is found to be increased compared to conventional methods. For Thailand nothing yet can be concluded on SRI and its impact on labour productivity. On the whole, land productivity is increased under SRI. This is found for all three countries, with good references by Anthofer (2004) and AIT (2005). Furthermore, it is concluded that SRI increases water productivity in comparison to conventional methods in the case of Thailand and Vietnam. For Cambodia there was not enough information to draw any conclusion about water productivity. Increased productivity under SRI may be related to farmers' high opportunity costs of labour, but this explanation is too simplistic yet to account for the dynamics of SRI rice farming within South-East Asia.

After critical review it is concluded that the consulted literature is not of good scientific value to draw any rigid conclusions on SRI and its relation to input productivity. SRI is not exogenous technical change but rather a new idea on rice farming. The attention given to LEIA and LEISA may explain the popularity of SRI among governmental and non-governmental organizations. As SRI requires low external inputs, it is found suitable for small and low-endowed farmers.

It is concluded that SRI has not brought technical change that created a new production function. SRI however does reduce the labour peak during transplanting to the benefit of farmers in Cambodia (Anthofer, 2004). This holds for Thailand and Vietnam as well. This quality can be of significant meaning to farmers who have inadequate access to labour force. It is likely that farmers weigh the trade-offs between achieving higher rice yields with other opportunities for incomes. If farmers obtain technical support from NGOs and GOs in the future, SRI may well be an appropriate technology to enhance their livelihoods.

The impact of SRI as a technology needs to be investigated further. In addition, research is suggested on the adoption processes of SRI and the type of farmer it is presented to. For now it is concluded that SRI is suited to full-time farmers, in other words those farmers with low labour opportunity costs, with enough access to labour force.

1 Introduction to the subject

1.1 Introduction

Recently from the 20^{th} to 22^{nd} of September the UN Summit on the Millennium Development Goals was held. It ended with the adoption of a global action plan to achieve the eight anti-poverty goals by their 2015 target date (UN, 2010). To recall, in September 2000 the first World Summit was held in New York when world leaders agreed to adopt the United Nations Millennium Declaration, committing their countries to a global partnership and setting out targets to reduce extreme poverty by the year 2015. These have become known as the Millennium Development Goals. Ten years later it seems there is still a long way ahead to reduce extreme poverty. How can this be achieved?

Macroeconomists try to understand how the economy functions as a whole. In this way, macroeconomics is able to contribute to effectively stimulating pro-poor growth. In a nutshell, development economics focuses on the causes of growth. One discussion in development economics is in what sectors it is best to invest to stimulate growth in a developing country. This discussion may be divided into two views. The first view is that capital accumulation in the modern sectors is an engine of growth. This has been adverted in, for example, the labour surplus model of Lewis and Ranis-Fei (Ray, 1998). The second view is that improvement in the agricultural sector is a stimulation of growth. It can be argued that investment in agriculture is always a right thing to do because agriculture provides food. The earthquake that hit Haiti on January 12 2010 and its devastating effect on the country's wealth, showed what happens when people have no food security - violence and robbery followed. As Pearl S. Buck (1892-1973) said:
'There will never cease to be ferment in the world unless people are sure of their food.'[1]

The World Bank has published recent empirical findings in support of the second view. In the World development report 2008 the World Bank ascribes to agriculture some fundamental functions. Not only it is argued that agriculture is important for food security because it provides income for the majority of the rural poor, empirical evidence for agriculture as an engine of pro-poor growth is consulted too. It is confirmed that growth in agriculture has more impact on poverty reduction than growth in nonagricultural sectors. In addition, agriculture in such countries also has a comparative advantage in international markets. Finally, agriculture has strong growth linkages with other sectors. Rising farm incomes will increase the demand for non-tradable consumer products and services (World Bank, 2007).

In 2005 the world population estimated more than $6,5$ billion people, of which almost $5,3$ billion live in developing countries (UN, 2007). The agricultural sector in a country at an early development stage employs more people than all industries and sectors put together. Sixty or seventy percent or more of the total workforce are in agriculture in many of the poorer developing countries (Perkins et al., 2006). Together with the evidence provided by the World Bank, this gives reason to invest in agriculture. To conclude, rural development is very important for enhancing the economy of a developing country.

Asia has got the largest number of poor people in the world. Given that Asia leads the world in rice production and consumption, rice is a relevant source of food for the inhabitants as well as a chief export product (Barker et al., 1985). Rice contributes up to fifty percent of agricultural value added and forty to fifty percent of calories eaten by people in the region. As economies have grown agriculture has become a smaller part of total economy, but rice still is the main staple in the Asian diet and the most widely grown crop (Sombilla et al., 2002:2).

Since this millennium, a new method of rice cultivation has found its way into Asian countries called the System of Rice Intensification (SRI). It is claimed that it is sustainable and raises production too. While it requires a reduction in inputs, yields do not lessen. SRI seems a rice farming technology that can facilitate food security.

[1] Quote found at www.thehungersite.com, visited July 30 2010

About SRI is claimed that it produces higher yields than conventional methods (Uphoff, 2002). This claim has triggered many remarks and critical investigations by others. Dobermann (2004) has made comments that the reported yields are not corrected for the amount of fertilizer applied and that other determining factors like climate conditions and soil conditions are not specified. Moreover, John Sheehy, an agronomist at the International Rice Research Institute (IRRI) in the Philippines, has pointed out that most SRI field studies have not been subject to peer review. As SRI originates from Madagascar, it is quite puzzling that in Madagascar adoption rates have been low, while rates of disadoption have been high. Furthermore, most farmers who practice SRI continue to practice traditional methods on some of their land even while they have experienced with SRI for several years (Barett et al., 2004). Perhaps SRI has not met potential in Madagascar but did elsewhere.[2]

SRI has been introduced to various countries in South-America and Asia. For instance in Asia, SRI has been introduced to China, India, Indonesia, Iran, and also smaller countries like Japan, the Philipines, Thailand, Vietnam, , Cambodia and Buthan (Sothy, 2008). Have rates of adoption been substantially higher in these countries than in Madagascar? Is SRI suitable for farmers in less-favourable regions or maybe just applicable to one type of farmer? Who are responsible for its spread? It is of concern if SRI is able to raise input productivity. Three South-Asian countries with a similar profile are Vietnam, Thailand and Cambodia. They are similar for three reasons: they are developing countries with a considerable share of agriculture attributed to the economy, they largely engage in rice production while enduring comparable erratic climate conditions, and all three have been acquainted with SRI for several years.

A major point of interest then is what influence SRI methods have got on economic productivity. The purpose of this study is to research SRI as a technology and its effect on productivity of some key factors of production, namely labour, land and water. Since fertilizer application is not always thought to be a part of SRI, fertilizer productivity will not be investigated. SRI will be compared to conventional methods in Vietnam, Cambodia and Thailand to see whether input productivity is changed under SRI methods. Through the review of existing literature for Thailand, Cambodia and Vietnam on SRI, the spread and impact of SRI will be explored. The next section spells out the research questions that have been raised.

1.2 Research questions

The main question is:

- What does the System of Rice Intensification entail in terms of input productivity for farmers in Thailand, Cambodia and Vietnam?

To be answered for Thailand, Vietnam and Cambodia respectively are the next subquestions:

- What is SRI and who are its advocates?
- Does SRI change labour productivity in comparison with conventional methods?
- Does SRI change land productivity in comparison with conventional methods?
- Does SRI change water productivity in comparison with conventional methods?
- For what type of farmers is SRI suitable?

A case study of SRI in Thailand, Vietnam and Cambodia serves to answer these questions. Before these questions are investigated, the next Chapter will introduce the methodology of the study. Hereafter the theoretical background will be set out in Chapter 3. Chapter 4 that follows after that, will address the background of agricultural trends in Asia and the common rice practices in Thailand, Cambodia and Vietnam respectively. The development

[2]See the Cornell University for further information, http://ciifad.cornell.edu/sri/

and dissemination of SRI will be also be discussed in this section. Chapter 5 serves to answer the subquestions on input productivity of SRI in comparison to conventional farming methods. Finally, in the conclusion the research questions listed above will be reviewed and some suggestions for further research will be included.

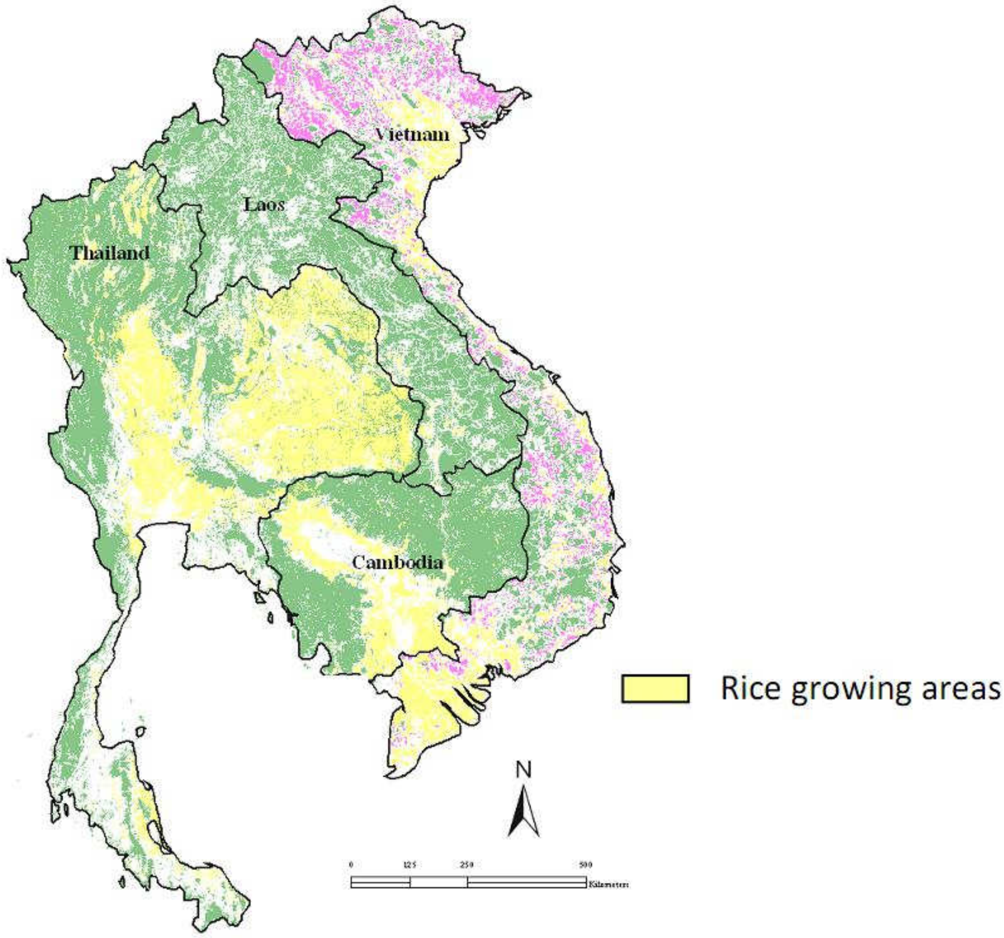

Figure 1: Rice growing areas of South-Asia

2 Methodology

This investigation has largely been done through existing literature. In addition some information was to be conducted from surveys carried through email to NGO's and GO's whom have established experimentation with SRI. Unfortunately, while drawing this case study to an end no replies yet were given so this thesis has strictly been a literature study.

A critical note by the author is that a lot of non-scientific literature has been explored for this research. Though data has been chosen carefully, this may affect the 'trustworthiness' of the presented outcomes. Little scientific articles were available as SRI is mainly documented and reported by NGOs, GOs and universities who can be biased to publish merely positive results. These documents have also not been subject to peer-review. Moreover, farmers could have reported more positive results to NGOs to maintain their support (Dumas-Johansen, 2009). As will become clear, many documents or reports presented by NGOs and other organizations have listed only simple data, for instance on yields, without controlling for differences in soil type, input use etcetera.

Therefore a critical evaluation of the literature will be part of Chapter 5. Attention will be paid to the origin of the documents and of its authors. An important criteria will be if the reported results have been shown to be significant on the basis of a statistical test.

3 Theoretical background on technical change

This chapter gives first of all a model of the farm household by Barnum and Squire (1979), as discussed in Ellis (1993). This model provides a good framework for deriving predictions about the responses of the farm household to changes in domestic variables such as family size and structure, as well as market variables like output prices, input prices, wage rates and technology. Important concepts that are also defined here are opportunity costs of labour and productivity of land, labour and water respectively.

Next a theoretical background on technical change with respect to agriculture in developing countries is considered. It aims to describe economic concepts on technical change and its implications for the farmer's decisions.

In the section hereafter, the focus will be on the dominant ideas of technology in agriculture: low-external-input agriculture and high-external-input agriculture.

In the final section the learning-by-doing and learning-by-observing models of Bardhan and Udry are conferred. Though the topics of these models are not yet well understood, they are shortly presented to gain some additional insights in the adoption of SRI.

3.1 The farm household model

Now follows a brief discussion of the Barnum and Squire model (for further details see Ellis (1993) or Barnum and Squire (1979)). The model is actually three-dimensional because of three pairs of consumption trade-offs and a production function with three resources, but for simplicity's sake it is pictured here in a two-dimensional graph. Its assumptions are: (i) A labour market exists; (ii) Land available to the household is fixed, so there is no land market; (iii) Home activity, in terms of production of Z-goods, and leisure are combined and referred to as G; (iv) Farmers have a choice between own consumption of output (C) and sale of output to purchase non-farm consumption needs (M); (v) Uncertainty and behaviour toward risk are ignored (Ellis, 1993).

The production function is:

$$Y = f(A, L, V) \tag{1}$$

where A is fixed land under cultivation, L the total labour used, and V is other variable inputs for production. The production function refers to farm output which, besides for own use, can be traded. Furthermore the farm household has the option of hiring in labour at the market wage as well as hiring out. The utility function consist of: (i) time for the production of Z-goods and for leisure combined (T_z); (ii) home consumption of output (C); (3) and purchased goods (M). The utility function is thus:

$$U = f(T_z, C, M) \tag{2}$$

Naturally there is:

1. a time constraint given by ($T = T_z + T_w + T_f$, time allocated to Z-goods and leisure, farm work and wage work respectively, and;

2. an income constraint that states that net household earnings should equal expenditure on market goods.

Therefore, there are several equilibrium conditions. One is that in equilibrium the marginal rates of substitution between each pair in the utility function (Tz for C, Tz for M, C for M), should equal the price ratios between them (w/p, w/m, and p/m). The other is that in equilibrium the marginal product of labour equals the wage rate, and that the marginal product of other variable inputs (V) equals their average price (v).

In Figure 3 the Barnum and Squire model for household hiring agricultural labour is illustrated, while not buying goods at the market. The wage cost line ww' represents opportunity cost of alternative uses of labour time: home work (leisure), farm work or wage work. When farmers do off-farm work they receive wages, but they may produce less goods or have less time for leisure. Therefore the *opportunity costs of labour* are defined as the costs of labour of passing up another option when making a decision.

The line OW shows the rise in total cost of labour (in terms of output quantity) as its use increases. For instance, if the wage rate is 6 dollars per day and the price of rice is 2 dollars per bag, the slope of the line w/p is 3. So in equilibrium three bags of rice need to be produced to hire one worker. A represents the equilibrium of farm household in consumption. Here the marginal rates of substitution of consumption and leisure are equal. This position is also equal to the slope of the production function. The level of own consumption is C while total farm output equals Q. The difference $Q - C$ is then for market supply.

In an equilibrium marginal costs are equal to marginal revenue. Equilibrium B represents the point where the marginal product of labour is equal to the average costs of labour. Thus if a change comes about in the ratio w/p, the model predicts its consequences. If the ratio w/p rises, the line ww' becomes steeper, there is a rise in farm work and a decline in use of hired labour. If the ratio w/p declines, output and income rise, use of own labour decreases and use of hired labour rises. However, in both situations it stays ambiguous what the impact is on the household's consumption and sales to the market (Ellis, 1993). Off course one assumption is that when income and output increase, the family farm sales more to the market than before.

Looking again at Figure 3, line OW defines labour productivity. Namely, as the slope of line OW decreases less labour is needed to produce a fixed level of output and so labour productivity is increased. Growth in labour productivity, an increase in output per worker, can be caused by one or more of the following factors: human capital, physical capital and technology. Worker's productivity can increase as they acquire more skill and knowledge (human capital) or work with better equipment (physical capital). However, probably the most important driver of productivity is technological progress. Labour is then able to produce more output with the same skills and input as beforehand (Krugman et al., 2008).

In general, productivity is the ratio of input versus output (Krugman et al., 2008). Furthermore, land productivity is defined as output per hectare, if land units are measured in hectares. If yield is increased, while land under cultivation has remained constant and also no other factors like fertilizer have been increased, it can be spoken of an increase in land productivity.

Finally, a definition of water productivity is obtained from Molden (1997). Water productivity analysis connects the physical input of water with yield or economic output to give an indication of how much value is being obtained from the use of water (Molden, 1997). Water productivity will be reviewed for SRI because its analysis is becoming globally more and more essential in the light of population growth and increasing pressure on water resources (Abdullaev and Molden, 2004).

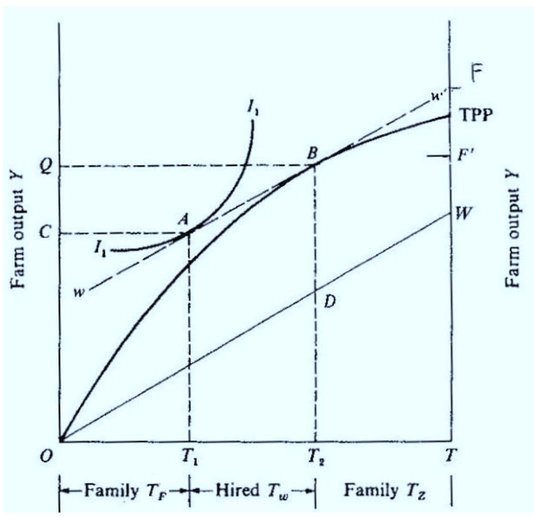

Figure 2: The Barnum and Squire model for hiring labour

One critical reminder is that is some rural areas a labour market may be absent. When this is the case, a farmer's production decisions depend only on the household's demographic structure and responses to higher output prices are not predictable. However if, according to the Barnum and Squire model, a competitive labour market is present production decisions are made separately from consumption decisions. Moreover, households respond positively to higher output prices and welfare of households is higher than without labour markets (Ellis, 1993).

With this model it is possible to predict farm household responses to technological change. Technological change may imply that labour productivity is increased. This would result in more time for the farm household to spend on other things, like wage work or leisure. Technological change may entail a new production function with higher output than before. Like Ellis (1993) points out, technical change can result in higher sales from the farm household to the market than before. An interesting question would be whether SRI implies a shift in the production function curve or if farmers just move along the curve.

3.2 Technical change

First of all a precise description of technical change is provided by Ellis (1993). Technical change means a reduction in the quantity of resources that are required to produce a given output, or in other words, more output for the same level of resources. In practice, an even better definition of technical change is 'the proportional decrease in costs of production achievable by the innovation when both the old and the new techniques operate at their optimal input combination and when factor prices are held constant' (Ellis, 1993; Binswanger, 1978:20). For comparison of the conventional and new technique it is important that relative factor prices are held constant. Technical change, namely, implies a reduction in total production cost for a given output level (Ellis, 1993).

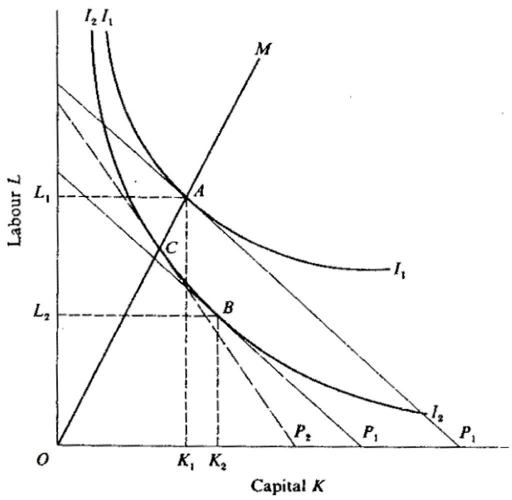

Figure 3: Technical change

Second, what is meant by *technology* is all input-output combinations that have been or can be developed with existing knowledge. It should not be confused with *technique*, which is a specific input-output package (Ellis, 1993).

Technical change can be neutral, but it can also be biased toward either labour or capital. It is neutral when it results in higher output while the same amounts of labour and capital are used prior to the technical change. When the income share of one of labour or capital rises or decreases for constant factor prices, it is spoken of technical change bias. If the income share of labour rises, stays the same or falls relative to that of capital, one speaks of capital-saving, neutral or labour-saving technical change respectively.

If technical change is biased in favour of using more of one resource than another, then different social and as well as economic implications follow technical change (Ellis, 1993). For example, in agriculture labour-saving technical change means lower employment and gross income to direct farm labour. Simultaneously, owners of resources outside the agricultural sector receive higher payments to purchased variable inputs or fixed capital.

In Figure 2 technical change is shown that is biased in favour of capital and against labour. In the equilibrium A, L_1 is labour input and K_1 is capital input. Technical bias is shown at the new equilibrium B, with the same factor price ratio as for the initial equilibrium A. One can also see the parallel shift of the iso-cost line P_1, showing that total costs have been reduced. I_1 and I_2 are isoquants. The isoquant I_2 has a different slope because more labour is displaced for a given increase in capital than on the previous isoquant. Labour is reduced from L_1 to L_2, while capital use is somewhat increased. Thus it is labour saving technical change (Ellis, 1993).

Another way of looking at technical change is given by the ray OM. It exists of the same factor proportions K/L. To keep the factor ratio the same with the new technology at point C, the price of labour w must fall relative to the price of kapital r. This is presented by the new iso-cost line P_2. The fall in the price of labour relative to capital reduces the share of labour wL in the total value of output for a given K/L ratio.

In this figure technical change is exogenous to the agricultural system, which is a neoclassical approach. Technical change is endogenous when changes in relative factor prices induce farms to search for production methods that use less of the factor that has become relatively expensive. This is called the induced innovation theory (Ellis, 1993; Hayami and Ruttan, 1985).

3.3 Technology paradigms: HEIA versus LEIA

The Green Revolution provides an illustration of the advantageous impacts of new technology. It was based on the development of new high-yielding varieties of wheat and rice and their spread through Asia and parts of Latin America, and as a result a country like India has changed from a situation of famines and periodical shortages to a net exporter of wheat and rice (Upton, 1996). The Green Revolution can be labeled under high-external-input agriculture (HEIA), for it depends heavily on chemical inputs, hybrid seed, fossil fuels and often irrigation. HEIA is found in developing countries in areas with high potential. It is most widespread in Asia in its Northern regions and the Green Revolution areas support $2.3 - 2.6$ billion people.

Once a technology has been exhausted, it is only natural another will follow. Throughout history the transition from an old paradigm to the next can be witnessed. Subsequently, in imitation of the Green Revolution, another paradigm has come along. Just as the Green Revolution was born out of growing concern about the pending food crisis in Asia and gained international and national support (Sombilla et al, 2002), the emerging evidence of stagnating yields and concerns about the sustainability of Green Revolution technologies, has caused the focus to be on other technologies in developing country agriculture (Crosson and Anderson, 2002; Pretty, 1995), particularly to help farmers in less-favoured regions in Asia and elsewhere (Pender, 2007).

Completely counter to HEIA is low-external-input agriculture (LEIA), which is described as the intensified use of local resources with few or no external inputs, to the extent of the degradation of natural resources (Reijntjes et al., 1992). A next step of LEIA is low-external-input and sustainable agriculture (LEISA) - agriculture based on ecological principles of farming (Reijntjes et al., 1992).

LEISA is agriculture that makes optimal use of locally available natural and human resources and which aims to be economically viable, ecologically sound, socially just, humane and adaptable. The external use of inputs is not excluded but seen as complementary to the use of local resources given that they meet the above-mentioned criteria. LEISA is a sustainable alternative to agricultural methods that require intensive use of external inputs while also a strategy in resource-poor environments where no or very few external inputs are used (Reijntjes et al., 1992). Examples of LEISA are taken from Reijntjes et al. (1992). They include composting, integrated pest management (IPM), zero tillage, mineral fertilizer, intercropping, green manure, mulching, integrated crop-livestock-fish farming, and multiple cropping. Many of these approaches already exist for centuries in the South and East of Asia and the Pacific. One approach especially common in South-East Asia is forming contour hedgerow systems with leguminous trees, which is prescribed for the intensive open field cultivation that exists there (Pender, 2007).

LEIA does not necessarily have to be sustainable. Indeed, LEIA may lead to over-exploitation of natural resources with adverse effects on the environment and rural populations (Kessler and Moolhuijzen, 1994). Reijntjes et al. (1992) also state that in many LEIA areas sustainable technologies are not known to farmers or have not been developed, causing farmers to exploit their land. However, many LEISA approaches have demonstrated success (Pender, 2007), and if managed properly they can contribute to LEIA. Well-functioning LEIA systems can be like mature natural ecosystems in which nearly all biomass produced is reinvested to maintain fertility and biotic stability of the system (Reijntjes et al., 1992). On the whole, still many potential LEISA approaches have to be identified and promoted according to context (Pender, 2007). To summarize, LEISA is an option feasible for a large number of farmers - especially those who have low access to artificial inputs but have the ability to make efficient use of local resources (Reijntjes et al., 1992).

3.4 Learning-by-doing and learning-by-observing models of Bardhan and Udry

The target input model by Bardhan and Udry (1999) is a model of technological change with the assumption that the new technology is superior, and so farmer's learning has merely to do with discovering the precise shape of the technology. However, this assumption of a superior technology is quite a big one, and it is likely that farmers first have to experiment with a new technology to see whether it is more profitable or not.

Another approach then, would focus on discovering whether or not a new technology is profitable in a particular environment. Moreover, the transition from the old technology to the new one, may happen when the old technology is still more profitable. Bardhan and Udry (1999) have modeled this as well and predict that if the loss in current expected profits is less than the gain in future profitability from the additional trial of the new technology, the new technology will be adopted. Innovation implies adoption; it refers to the first practical use of a new, more productive, technique. Most innovations in agriculture are process innovations in which the output produced remains unchanged (Ellis, 1993).

A farmer's decision to try out a new technology has implications for all neighbouring farmers. Decisions about technology use not only depend on its possible success, but also on the nature of a farmer's interactions with other farmers. Thus, the adoption of technology is a social process (Bardhan and Udry, 1999). The value a farmer attaches to future profits depends not only on own experience with the new technology, but also on the experience of everyone else in the near environment. Bardhan and Udry (1999) claim that the more experimentation the farmer expects his or her neighbors to conduct, the higher own profit is expected to be. In addition, a farmer may be reluctant to experiment himself because he prefers to wait and see how neighbor farmers get on with the new technology. The spread of technology, therefore, depends on social interactions in several ways. First, there is a direct effect of information flow within the community. Farmers might be learning from each other's experiments. Second, the impact of the externality needs to be considered. In other words, is there any social mechanism that rewards experimenters (Bardhan and Udry, 1999).

4 Rice in South-East Asia

This chapter provides the contextual background that will help to explain the findings on SRI. In the first subsection the trends in rice agriculture prior to SRI are illustrated. In the second subsection the context of rice farming is presented for Thailand, Cambodia and Vietnam respectively. This will include data on labour opportunity costs when these are available.

Next, the coming about and spread of SRI is studied. In the light of these facts, decisions of farmers to adopt or not to adopt SRI can be explained. Some conclusions and remarks are put forward in the final subsection 'Discussion and conclusion'.

4.1 Rice demand and supply

Though world rice production grew at almost 3 percent per year from the mid-60s to the mid-80s due to the success of the Green Revolution technologies, slower growth in production, area and yield has been since. In Figure 4 the trend of world rice price can be seen from 1950 to 1998. Two weather events in the mid-1960s and in 1972 ended in a loss in crop production, causing a sharp increase in world rice prices. Still today, drought and the effects of El Niño and La Niña weather conditions are the main cause for annual variation in crop production. Accordingly, a diminished supply in some years and fewer demand in other years caused fluctuations in the world rice price between 1950 and 1980. However, after 1980 the world rice price has been rigid at a lower position. Also, the growth rate of production declined from 3 percent previously to near 1.5. What explanation can be given to this slowdown?

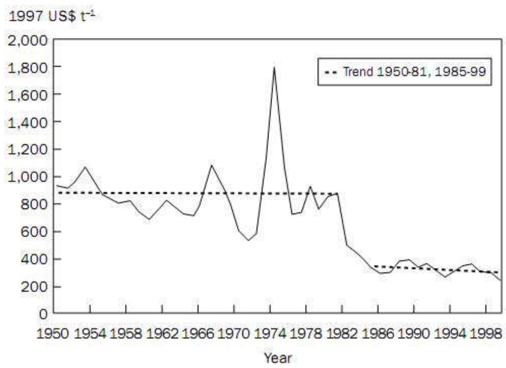

Figure 4: Worldprice of rice

Figure 4 depicts another trend in world rice prices from 1981 to 1985. Due to the booming introduction of Green Revolution technologies, supply grew more rapidly than demand, causing world rice prices to drop sharply. A major cause for the slowdown in growth thus has been the decline in world rice prices. After 1985, a new equilibrium in supply and demand has been reached at a lower price and slower growth rate.

IRRI found that the slower growth has been caused by both supply and demand factors. On the production side, in many areas of Asia the yield gains from the adoption of the Green Revolution technologies have reached their potential and 'intensification of rice production has been leading to the overexploitation and degradation of soil and water resources' (Sombilla et al., 2002:8). Also, farmers have found rice production to be less profitable due to lower domestic rice prices and rising wage rates. A production growth rate at $2.5 - 3$ percent per annum can no longer be achieved. Finally, the growth in demand for rice has been falling in many places because of a simultaneous rise in incomes and a fall in population growth rate (Sombilla et al., 2002).

On the contrary, there is also concern that rice production may not keep pace with the growth in demand (Sombilla et al., 2002). Pinstrup-Andersen and Cohen (1999) project that demand for rice and wheat continues to grow. Apparently, there is some debate upon this topic. However one comforting fact is that rice is an inferior good (IRRI, 2010), such that as income increases demand for rice decreases. It is therefore not likely that demand for rice will exceed its supply when countries develop further.

The development and spread of new technology is crucial for the continuing growth of agricultural production and incomes. In the past some agricultural growth has been achieved by expanding the area of land under cultivation. Hence, by increasing the amount of inputs made use of. Nowadays most of the available land has been brought into use, especially in Asia. It is now acknowledged that most of the desired growth in output must come from increasing productivity of the land, labour and other inputs (Upton, 1996).

4.2 Agriculture in Thailand, Cambodia and Vietnam

It is now a good moment to reflect upon the rice economies of Vietnam, Thailand and Cambodia. Some recent statistics on rice production have been summarized in the Table below, dating from 2009 or otherwise where it is indicated. In addition, Figure 5 presents the net trade status of rice for all three countries. Next, rice cultivation is described for Thailand, Cambodia and Vietnam respectively. In the next subsection the spread of SRI is explored separately for all three countries.

Table 1: Rice statistics (dating from 2009)

	Cambodia	Thailand	Vietnam
Total export quantity (2008, million)	0.4	5.2	9
Female labour force in agriculture (1000 persons)	2665	8687	15064
Male labour force in agriculture (1000 persons)	2519	10541	2519
Agricultural GDP share (2007)	10,406,316	967,518	232,188,000
Agricultural population (1000 persons)	9811	28384	56007
Rough rice production (2008)	7,175,470	30,466,920	38,725,100
Rough rice yield (t/ha, 2008)	2.75	2.97	5.22
Agricultural labor force (1000 persons)	5184	19228	29695

4.2.1 Thailand

Rice is a dominant part of Thailand's crop income and has long been a major source of export earnings. (Barket et al., 1985). After a financial crisis in 1997 the role of rice and the

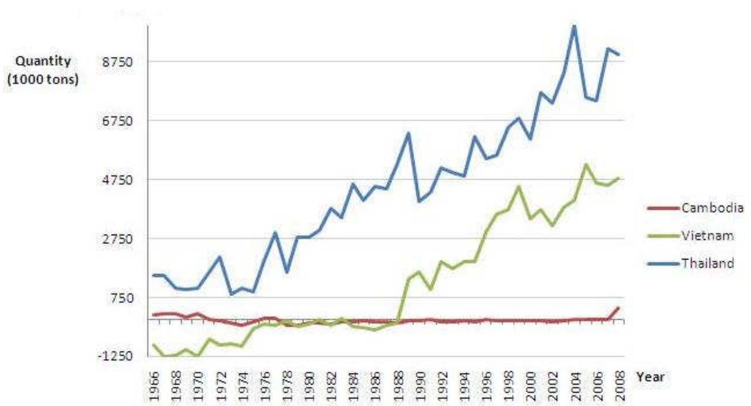

Figure 5: Net trade status

agricultural sector diminished, but rice continues to be the largest economic activity in rural Thailand. Agriculture still employs nearly 56 percent of the total labor force (IRRI, 2010).

Thailand is the world's largest rice exporter, currently exporting about 6.5 million tons of milled rice per year. Some more recent figures of 2008 show that exports of rice had grown more than 10 percent in the first 10 months of 2008 compared to the same period the year previous, and that the export value per ton of rice increased about 60 percent in that period (World Bank, 2008). The exports continue to grow despite the stagnation in domestic production because of the declining trend in the domestic demand for rice. Thailand has a reputation for high-quality, long-grain white rice, which usually has a substantial price advantage over lower types.

Thailand lies in Southeast Asia and shares borders with Myanmar in the West, Laos and Cambodia in the North-East, and Malaysia in the South. Thailand has a land area of 51 million hectares, of which one-third is cultivated for annual crops and about 7 percent is used for permanent crops. Rice is the most important crop of the country. Though rice production is declining in relative importance, it still covers about 55 percent of the total arable land (IRRI, 2010). From the 1970s to the late 1990s, growth in rice production was stimulated by an increase in rice cropping intensity, farm mechanization, modern rice varieties and short-duration rice varieties (Sombilla et al., 2002).

The average rural person in Thailand has a low education level because most of the highly educated people migrate to cities in search for better living conditions. Rice farmers in Thailand are very poor. Rice farmers in the North-East, which is the main rice-growing region, are mostly subsistence farmers. They sell only their excess production. The main surplus of rice comes from the Central region and the North. Here the average farm size is three times larger than in the North-East and the production environment is more favourable (Sombilla et al., 2002).

In Thailand, most insecticides and herbicides are free from import taxes. This has led to their excessive use. In recent years, though, the integrated pest management (IPM) method has come up as a sustainable alternative, but so far it is not adopted widely. Rice yield is relatively low, with an average yield in 2008 of 2.8 tons per hectare (t/ha) (FAO, 2010).

The following information about Thailand's climate is obtained from IRRI (2010). Thailand's climate is characterized as warm sub-humid tropics. The country experiences four seasons, which are the South-West monsoon from May through September, a transition period from the South-West to the North-East monsoon during October, the North-East monsoon from November to February, and a pre-monsoon hot season during March and April.

Thailand is divided into four regions, each region having different rice-growing environments.

- The *North-East region* occupies nearly one-third of Thailand's land. Almost one-half of the rice land is located in this region but the average size of the rice farm is smaller than in other regions. The water-holding capacity of the soil is very poor. Harsh climatic conditions like floods and droughts are often present in this region. Soil erosion and drought during the dry season are quite severe. Less than twenty percent of irrigated land is found in the north-East region, and many crops other than rice are grown there.

- The *central region* is an intensively cultivated alluvial area. It accounts for about one-fifth of the total cultivated rice land of the country in the wet season. During the rainy season, rice covers the major part of the region. The average farm size is large, and a larger proportion of the rice land has access to irrigation facilities that allow many farmers to grow rice twice during the year. Almost three quarters of the dry-season rice grown with irrigation water is located in this region. Farm operations are nearly completely mechanized. Also, farmers apply the direct-seeding method to save labour.

- The *northern region* captures about one-fifth of the total rice land in the country. Upland rice is grown in the lower parts of high hills and in upland areas. Lowland rice is grown mainly in lower valleys and on a few terraced fields where water is available.

- The *southern region* comprises just six percent of the total rice land. A negative environmental factor is that the soil is acidic. Because of a limitation of rice fields that can be cultivated, there is always a deficit of rice for local consumption.

In northern Thailand the average farm size is small, namely 0.8 hectare (Gypmantasiri, 2002). In this region, the main cropping pattern is to grow a single rice crop with traditional high-quality rice varieties. The average rice yield is quite low. Market production is mostly present in the Central and lower Northern region. Recall that a substantial area is irrigated here. Modern rice varieties are known to be grown often in these regions (Sombilla et al., 2002).

The average rice yield in the wet season is stuck at a level of two t/ha. Even at this low level it is of some concern to maintain productivity of the system. An even larger constraint is scarcity of labour during peak periods. This is especially true for the central region where industrial employment is higher than elsewhere. In summary, besides the climatic problems, the main production problems that farmers face are stagnating yields and labour shortages (IRRI, 2010). Unfortunately, there is not much data to be found on the opportunity costs of Thai farmers so these are not included here.

Rice is grown in Thailand mostly under rainfed conditions. The rainfed area accounts for almost 80 percent of the total rice area. Due to water scarcity, development of irrigation systems to allow for rice cultivation during the dry season has not been possible. Not surprisingly, dry season irrigated rice occupies only one-tenth of the total rice area in Thailand and contributes to approximately 19 percent of total rice production (Sombilla et al., 2002).

Farmers who practice conventional methods, prepare the land by puddling the soil and flooding the field. To ensure sufficient water, most rice farmers try to maintain their fields flooded. Lowland rice is grown in bunded fields (paddy fields) that are continuously flooded from crop establishment to close to harvest (IRRI, 2010). Transplanting is done under flooded conditions. Rice transplanting during the rainy season is done under a shared labour system. In the lowlands of Thailand, farmers grow modern high-yield rice. In the uplands, the ethnic minority of Karen farmers grow traditional rice varieties and do not practice slash-and-burn agriculture. The farmers aim to preserve their crop's genetic diversity by exchanging and selecting seeds for the next year.[3]

Conventional management practice is to use seedlings of about 34 days old (Gypmantasiri, 2002). AIT (2009) reports a slightly younger rice plant of about 25 days old. These seedlings are then placed at three to four per hill. Overall, the plants are closely spaced (AIT, 2009). Lowland rice farmers are used to broadcasting seed in a prepared space near the fields. A large quantity of seed is needed this way (Gypmantasiri, 2002). In the Chang Mai region of Thailand most farmers use chemical fertilizers and pesticides.[4]

4.2.2 Cambodia

After years of war and conflicts, Cambodia became a rice exporter again in 2004 (Guimbert, 2008). With the country running democratic elections and a turning toward an open economy, agriculture had the change to flourish (Nesbitt, 1997). Now around 2 million tons are exported every year. Although the share of agriculture in the economy is steadily diminishing, in 2005 the sector accounted for almost one third of gross domestic product.

Like in Thailand, agriculture in Cambodia employs most of the country's labour force (IFAD, 2010). Still 56 percent of employment is in agriculture. As rice is the dominant crop in Cambodia, eighty percent of farmers grow rice, of which sixty percent of them are subsistence farmers (Guimbert, 2008). So far agriculture is the only sector in the economy sustaining growth, with progress in rice yields in 2008. In conclusion, rice production largely grants food security and is like a safety net to the country (World Bank, 2009).

Located in South-East Asia, Cambodia shares borders with Thailand, Laos and Viet Nam. The vast Mekong river flows through flat lowland plains in the middle of the country.

[3]See article called 'Genetic diversity of rice', from http://www.sciencedaily.com /releases/2010/01/100104181535.htm by ScienceDaily. Visited September 8 2010.

[4]See http://www.mesaprogram.org/global/hcp/farmer-field-school-sustainable-rice-production, visited August 9 2010

The lowland plains next to the Mekong make way to upland plains. Further beyond there are hilly and mountainous uplands, primarily along the northern border and the coast. Rice is mainly cultivated in the fertile, irrigated land of the Mekong River basin.[5]

The following is taken from a book titled ‘Rice production in Cambodia’, published by IRRI and edited by Nesbitt (1997). Rice farming practices vary considerably between the rainfed lowland, upland, deepwater, and irrigated areas but for practical reasons farm methods will be only briefly discussed.

Figure 6: Rice field in Cambodia

Since Cambodia is situated in the tropics, the climate is hot and humid with distinct wet and dry seasons. Cambodia is not in the typhoon belt, but droughts and floods are common in all rice ecosystems. Cambodia’s topography influences the distribution of rainfall . On high altitudes more rainfall is expected than on the lower areas on which rice is more often grown. Unfortunately, the unpredictable nature of rainfall severely restricts both the potential for considerable rice yields and the patterns for farming diversity. Yields are low at 2.7 t/ha (FAO, 2010) compared to an average of $3.5 - 4.0$ t/ha in the rest of Asian countries (Guimbert, 2008). In general, soil fertility increases from the high to the low fields. All fields are exposed to periods of drought and flood.

Farm households in Cambodia are engaged in a range of activities to secure food and income. These activities include rice production, other field crop and garden production, livestock production, hunting and gathering, fishing, wage labour and small business (Nesbitt, 1997; Helmers and Bleakley 1996). Rice is the staple food for these households and a very important crop for food security.

Average farm sizes vary across the country. In the most densely settled provinces near Phnom Penh, fields on alluvial soils may be 20 m^2 or less (Nesbitt, 1997). More usual farm sizes are in the range of one to two hectares in southeastern provinces such as Takeo, Svay Rieng, and Prey Veng. In areas with low population densities such as the northwestern provinces, farm sizes may reach two up to four hectares (Nesbitt, 1997; Rickman et al. 1995).

Since farm sizes are not very huge in rural Cambodia, household labour is not restricted to staying in the villages (Resurreccion et al., 2008). However, off-farm income may also

[5]See website http://www.ruralpovertyportal.org/web/guest/country/geography/tags/cambodia, visited July 30 2010.

depend on the distance to the cities and on the availability of adequate infrastructure to these cities. As an example, Resurreccion et al. (2008) found that there are higher standards of living in Kandal province, which is more urbanized and closer to the capital city Phnom Penh; compared to in Kampong Chhnang province, which is less urbanized and farther from the capital city. The higher standards of living in Kandal seem to be an outcome of on the one hand, a more diversified portfolio of multi-local livelihoods, particularly higher involvement in urban-based industrial and service activities; and on the other hand, higher yields in rice cultivation. The relatively high rate of landlessness and near landlessness in Kandal seems not to be a relevant factor constraining standards of living (Resurreccion et al., 2008).

If farmers are very dependent on off-farm income for their livelihood, it can be expected that they have high opportunity costs of labour. For provinces Prey Veng, Kampong Speu and Kandal the relative importance of household income source is presented in Table 2. For Prey Veng the most important income source is agriculture, while for Kampong Speu and Kandal the largest income source is non-agriculture. Thus farmers in these two provinces have higher labour opportunity costs than farmers in Prey Veng.

Table 2: Relative importance of household income source (in percentage)

Source	**Prey Veng**	**Kampong Speu**	**Kandal**
Huntering/gathering	14	10	18
Non-agriculture	15	45	50
Agriculture	42	13	13
Home gardens	9	3	6l
High opportunity costs of labour	No	Yes	Yes

Rice productivity in Cambodia is the lowest in Asia. This is mainly due to the low productivity of all rainfall-dependent rice ecosystems. Rice produced in the current rainfed lowland system is mainly used for consumption. Serious production constraints are erratic rainfall, pests, poor soils, low levels of technology, rice varieties and associated issues, recurrent floods and droughts and socioeconomic constraints (Nesbitt, 1997). Food shortages are common in many areas (IRRI, 2010).

Since the Cambodian farmer depends heavily on weather conditions, the rainfall pattern determines at large the farming activities. Heavy rains in September and October are essential for these flood the fields to a depth that will kill weeds but allow the rice to flower and develop seed. Too much rain causes flooding in the lower fields and too little results in the crop running out of water before the crop reaches maturity. The wet season in Cambodia generally stops abruptly some time in November and the fields dry quickly, thereby reducing the prospect of planting a second crop. Rice matures at different times over the next few months and is harvested by hand.

A dry season lies between half November and April. This dry period allows the first rice crops to be harvested. Cambodian farmers mostly manage to grow just one rice crop. Below a production scheme is given for when a second crop is grown as well. Of course, such a scheme does not show the complex reality. Farmers may grow various varieties, from short-duration to long-duration crops, and adapt their farming activities to their specific rice ecosystem.

At the end of the dry season rice seedbed preparation begins as the first set of rains fall. This is between March and May. At the break of the season, when 100 millimeter or more of rainfall can be expected, deepwater rice farmers plow and broadcast their rice crops, and rainfed farmers complete their nursery preparation. Rainfed lowland rice is cultivated in all provinces of Cambodia. A possible early end to the rains compel farmers to diversify their range of varieties by maturity, reducing thereby the potential for high yields.

At the beginning of the wet season, farmers who own land appropriate for deepwater rice plow their soil and broadcast rice seed. Ideally, these crops receive sufficient local rainfall to allow six or more weeks of growth before mid-July. Then they are at an advanced stage of maturity allowing them to grow fast enough to keep up with the rising floodwaters coming from the Mekong River. Some of these rice plants can grow $20 - 30$ centimeter per day and grow to be up to 4 meters tall.

Most of the times the rice crop is grown with manual labour and simple tools. Cattle or buffalo are the foremost source of power for plowing and harrowing, although agricultural machinery has been spreading (Nesbitt, 1997; Rickman et al., 1995). More than 90 percent of the labour demand is concentrated in the nine-months wet season from May to January. Within this season, labour demand is deeply compressed into short periods during transplanting and during harvest (Nesbitt, 1997; Nesbitt and Phaloeun 1991). Households frequently experience labour shortages during these periods and usually labour is hired or exchanged to meet these peak demands. Some spread in these labour peaks occurs on farms because of the usage of rice varieties of diverse durations.

Several studies have been made of the amount on labour required to cultivate one hectare of rice. Results indicate large variations between the amount of labour required among farm households.

4.2.3 Vietnam

Vietnam's rice economy has gone a similar path of that of Thailand. In Vietnam rice is not only a primary staple food but also a significant source of foreign exchange earnings. Since 1990 Vietnam became a net exporter of rice. While initially exports amounted 1.4 million tons in 1989, in 1999 they were maintained at $3.5 - 4.0$ million tons. With these figures Vietnam's share of the world rice market reached nearly twenty percent in 1999. Vietnam is the second largest exporter of rice on the world market today (IRRI, 2010). Rice accounts for 75 percent of the Vietnamese diet (Sombilla et al., 2002). Due to macroeconomic and institutional reforms since 1986, called Doi Moi in Vietnam, the rice distribution system became more liberal. In addition international trade was made more tolerant - hence farmers were stimulated to produce more rice. The effect of Doi Moi on output growth lasted only for a while. Additional growth in total factor productivity would have to come from technological change (Sombilla et al., 2002:185).

Vietnam is surrounded by Cambodia, Laos, China, and the South China Sea. Eighty percent of the population is rural. On the whole, the rural population is concentrated in the two rice-growing deltas: the Red River Delta in the North and the Mekong River Delta in the South.

Rice is the single most important crop. This is demonstrated by the fact that it is cultivated on 4.2 million hectares out of 5.7 million hectares of arable land. The average farm size in Vietnam is very small. In 1994 the number of farm households was estimated at 9.5 million, with 8.4 million having a size of less than one hectare (IRRI, 2010).

Vietnam went from a collective agricultural production system, to the introduction of a group-oriented contract system of production in 1981. From 1986 onwards, the production system changed to individual contracts. Through sincere investment in flood control, drainage, irrigation in the Mekong River Delta, and the development of short-duration rice varieties, an increase in rice area and crop intensity was made possible. Therefore, an impressive growth in rice production was achieved after 1986. Furthermore, rice yield grew from 2.70 t/ha in 1987 to 5.2 t/ha in 2008 (FAO, 2010).

Vietnam's climate is characterized as warm humid tropics, but it can be subdivided into three types. In the northern part of Vietnam (covering NMM, RRD, and NCC), the temperatures are subtropical. The shifting seasonal wind patterns create dry winters and wet summers. In the zones SCC, CH, and eastern NES, exists a tropical monsoon climate with high temperatures and plenteous precipitation. In the South-West (on the map MRD and western part of NES), there are distinct wet and dry periods, but temperatures are higher than in the North. In the North temperatures are low during winter. Because of this, farmers in the South can grow three rice crops per year while farmers in the North can grow only two rice crops (Sombilla et al., 2002).

Vietnam has two monsoon seasons: the northeastern winter monsoon and the southwestern summer monsoon. During hot weather, typhoons may develop over the South China Sea.

Figure 7: Rice field in Vietnam

Rainfall is usually evenly distributed in June to October or November. In the Mekong Delta, however, October is the wettest month (IRRI, 2010).

Climate is the main factor influencing rice farming systems and rice yield. The agro-ecological differences between northern and southern Vietnam, together with differences in history, farm-holding size, irrigation system, and cultural practices, give rise to different farming systems (Sombilla et al., 2002).

In general, rice farming in the North is very labour intensive. This is due to its long history of rice cultivation, well-established irrigation systems, high population density, and small farm size. In contrast, the favourable agroclimatic conditions in the South, opportunity for land expansion, larger farm size, and newly developed irrigation systems, offer better opportunities for increasing rice production (Sombilla et al., 2002). In most locations of northern Vietnam where irrigation systems are available, farmers can make two rice crops per year (Dung and Minh, 2008).

About 52 percent of Vietnam's rice is produced in the Mekong River Delta and another eighteen percent in the Red River Delta. Soils in the Mekong River Delta are very variable, but the alluvial soil is especially important since two to three crops can be grown on it every year (IRRI, 2010).

The Red River Delta, which is extremely densely settled and has very small landholdings, has long been practicing double rice cropping with highly labour intensive rice cultivation methods. The winter and spring season rice crops cover almost the same area of $530,000$ hectares, with a yield of 5.2 and 5.7 t/ha respectively.

The Mekong River Delta has three cropping seasons: spring or early season, autumn or midseason, and winter or the long-duration wet-season crop. The largest rice area is cropped during the autumn season, equivalent to 1.95 million hectares, and only a small area is cropped in winter, equal to 0.6 million hectares. The rice yield is highest in the spring season estimated at 5.3 t/ha, and lowest in the winter season estimated at 3.3 t/ha. Farmers in this region adopt a direct-seeding method to save labour costs. 52 percent of the rice in the Mekong River Delta is grown in irrigated lowlands, the remaining is grown under rainfed conditions.

Other major rice-growing regions are the North-East and the North-Central coast. The northern provinces of Vietnam have a total rice area of 2.5 million hectares or about a third of the total rice planted area. Almost 85 percent of the total rice area is irrigated lowland, the rest is rainfed. The main cropping pattern is spring-summer rice. The soils of the RRD and MRD are often fertile, but the soils in the uplands are generally poor as a result of leakage of nutrients from the ground by the rainfall (Sombilla et al., 2002).

Some data on farm household income for the year 1993 gathered by van de Walle and Cratty (2004) have been summarized below. It is also indicated whether these farmers are

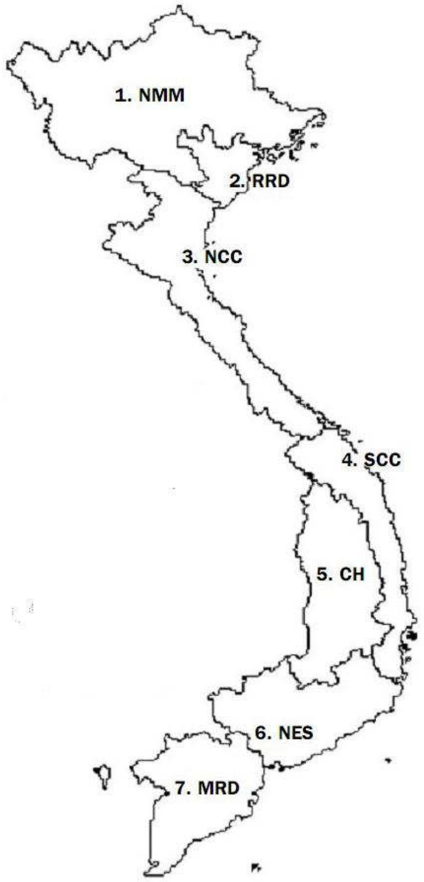

Figure 8: Agro-ecological zones of Vietnam; NMM = North Mountain and Midland, RRD = Red River Delta, NCC = North Central Coast, SCC = South Central Coast, CH = Central Highlands, NES = Northeast South, MRD = Mekong River Delta.

like to experience high labour opportunity costs or not. It is clear that in regions MRD and NES farmers are more dependent on off-farm income than those in other regions. Furthermore in the other five regions farmers, especially farmers in region NMM, derive a high proportion of their income from their farm. These farmers can be called full-time farmers and higher rates of adoption of SRI can be expected under such farmers.

Table 3: Percentage of income 'farm only' of farm households in Vietnam in 1993

	NMM	**RRD**	**NCC**	**SCC**	**CH**	**NES**	**MRD**	**Total**
Farm only	91.5	74.5	80.2	75.3	81.8	42.5	48.3	74.8
High labour opportunity costs	No	No	No	No	No	Yes	Yes	No

Production constraints are numerous for Vietnamese rice farmers. In addition to the major climatic constraints of flooding and drought, small farm size poses a serious limitation. This problem may even increase further because of population pressure.

Furthermore, current infrastructure in Vietnam is not able to sustain possible increases in agricultural production. Two-thirds of the farms have no access to drying areas and so most of the crops are sun-dried. Also transportation for moving the crop to the market, and energy are in short supply. Although electricity is available in most provinces, the majority of rural households does not have access to it (IRRI, 2010).

Farmers' traditional transplanting is 15.5 by 14 centimeters (PPSD, 2007). Furthermore farmers do transplanting with seedlings of about thirty days old and five to seven plants per hill (Uphoff, 2007). Deepwater rice farmers, maintain the water level in the fields during panicle growth and flowering stages. In principal, rice fields are flooded until near harvest time. Fields are only dried before the ripening and harvest (PPSD, 2007).

4.3 The dissemination of the System of Rice Intensification

When Norman Uphoff became acquainted with the method in 1997, he began promoting SRI throughout Asia. On the Cornell University website developments of SRI are recorded (CIIFAD, 2010). The website has published a lot of articles and summaries of workshops that have been held on SRI. Uphoff has made several fieldtrips since and has also written about the findings of SRI experiments. It is likely that through his efforts the practice has become more widespread (Surridge, 2004), although it may have spread also through others.

SRI consists of six components that when applied together, should result in higher yields. First, seedlings should be transplanted when young, before they age fifteen days. Second, only one seedling should be planted per hill. Third, seedlings should be planted with at least 25 by 25 centimeters of space. Fourth, land should not be wet all the time, but soil should be alternated dry and wet. Fifth, weeding should happen more frequently. Sixth, seeds are planted in rows. In addition, organic fertilizer is preferred above other fertilizer but it is not clear whether this is necessarily a component of SRI (Berkelaar, 2001).

So far, the method of SRI has received extensive criticism and contradicting claims have been made. Could it be that SRI is just a utopia delivered by biased parties or is SRI indeed promising and unjustly being under attack by skeptic scientists? Although the Cornell University and other promoters of SRI inform that SRI is spreading widely among farmers, it remains ambiguous what number of farmers apply SRI and whether these farmers adopt all components of SRI. Then again, SRI is sold as a fixed set of practices but farmers are free to experiment. Uphoff claims that SRI is not a technology but a set of principles that needs to be adapted to local conditions (ECHO, 2001). Possibly, this can make it difficult for investigators to define whether SRI is practiced or not.

SRI adoption in Thailand

A clue to how SRI entered Thailand is hinted at Cornell University website. A briefing of a meeting of the Multiple Cropping Center (MCC, Faculty of Agriculture of Chiang Mai University) and other parties was displayed at the country profile site of the Cornell's University SRI webpage (CIIFAD, 2010). It mentions acquaintance started in the year 2000 (MCC, 2005) when Mr. Prinz of the MRC Rehabilitation Institute (MRC) first learned about SRI. Prinz participated a workshop organized by the International Institute for Rural Reconstruction in the Philippines where SRI was discussed. The MCC was informed and on-station study was initiated. Contacts were made with CIIFAD and Association Tefy Saina (Gypmantasiri, 2002). The Agriculture Division of the MRC became interested in SRI in 2001 and began field experiments with farmers in the provinces of Phrae and Chiang Rai, but yield data have not been reported (Gypmantasiri, 2002).

Furthermore, the briefing informs the meeting was between representatives of the MCC, the Alternative Agriculture Network (AAN), Rainbow Farm, the Phrae Rice Research Center, the MRC, the Office of Agricultural Research and Development in Chiang Mai (OARD), and Sansai Resettlement Cooperative. In the meeting is agreed upon by the parties that in the future the central office of the AAN will take over the coordination of matters of SRI from the MRC (MCC, 2005). Five years from then, it is likely that this network of NGOs and GOs has grown. SRI research is done by the AAN, MCC, Rainbow Farm and OARD.

Stewards from MESA created the Farmer Field School (FFS) on Sustainable Agriculture in December 2007 to teach local rice growers to farm while using sustainable methods, to enhancing the health of Thai people and the environment. The FFS on Sustainable Agriculture bases its method on the life cycle of the rice crop in Tambon Bo Ngen, which is in the Ladlum Kaew District in Central Thailand. Farmers come together at a demonstration rice paddy once a week, where topics include seed saving, soil fertility, water management, and weed management. Volunteers also learn to produce compost and herbal pesticide as a means to enrich the soil and reduce their costs. FFS methods are also used to teach farmers about SRI. The FFS receives, beside the financial support from MESA, administrative support from the local government of Bo Ngen Tambon and academic input from the Healthy Public Policy Foundation, a research organization in Thailand.[6]

In Thailand, the following components of SRI are recognized by authorities:

- Using young, two-leaf seedlings, preferably under fifteen days old
- Transferring seedlings from the nursery carefully
- Planting only one to two seedlings per hill
- Giving wider space to the seedlings
- Controlling water: alternate dry and wet soil conditions
- Eliminating weeds regularly
- Increasing nutrients in the soil by organic fertilizer

(MCC, 2003).

In Thailand SRI is tied to organic rice cultivation (MCC, 2005). Apparently the usage of organic fertilizer is thought to be a component of SRI. One principle that is missing in this list is the notion of planting in rows, perhaps because this is found to be too labour-intensive. Other published documents may show this is incorporated too in SRI teachings.

SRI adoption in Cambodia

The Cambodian Centre for Study and Development in Agriculture (CEDAC) was established in August 1997. It is a NGO specializing in ecological agriculture and rural development. In February 2008 CEDAC provided assistance to approximately 75000 farming families in 2000 villages throughout Cambodia (Hoering, 2008). In 2000 CEDAC introduced SRI in Cambodia, by training a selection of 28 farmers spread over four provinces. CEDAC has introduced SRI as a 'toolbox' with many parts and pieces that can be combined. Farmers are stimulated to adopt SRI principles according to their abilities and risk preparedness. Farmers may then gradually extend the implementation of the SRI principles (Hoering, 2008). The basic SRI ideas or principles CEDAC promotes include:

- Growing healthy, vigorous and younger seedlings for transplanting by using healthy, full-grained seeds which are sown in the upland nursery bed, similar to that of a vegetable bed
- Wider spacing between each rice plant, preferably with one seedling per hill and with wider and equal spacing between each hill
- Shallow transplanting at $1-2$ centimeters deep
- Improving soil aeration by avoiding continuous field saturation with flooded water
- Doing frequent weeding to control weed competition and for active soil aeration
- Increasing organic matter in the soil through application of compost to enhance soil biological activity (Koma, 2008).

CEDAC encourages farmers to try natural pest management and weeding, either by hand or with mechanical weeders (Hoering, 2008).The president of CEDAC, Dr. Yang Saing Koma, asserts that farmers should reflect on how they can help the rice to grow better. 'Success does not only depend on natural or external conditions but also on the attitude of the farmers themselves. It would be a mistake to reduce SRI to a question of technology, it is an idea. An idea that comes close to approaching rice cultivation with attention, care and sensitivity, like a mother' (Hoering, 2008:8).

[6]See http://www.mesaprogram.org/global/hcp/farmer-field-school-sustainable-rice-production, visited August 9 2010

When Dr. Koma witnessed stagnating rice yields in Cambodia in the 1990s, he went to look out for alternatives. Apparently, he came across an article on SRI in one of the issues of LEISA magazine, which is published by the Centre for Information on Low External Input and Sustainable Agriculture (ILEIA). CEDAC has made contact with CIIFAD in the United States. From the Cornell University website can be learned about SRI in Cambodia. It is informed that besides CEDAC there are as many as 47 NGOs and GOs working with SRI in Cambodia (Sothy, 2008). CEDAC works together with the Church Development Service (EED) since 1998. From the year 2001 onwards cooperation included financial support of the rural development program, which also involves SRI (Hoering, 2008).

In 2003 Uphoff reported that more than 2,600 farmers in ten provinces were using SRI (Uphoff, 2003). Until 2007 the rural development program was supported with funding from the German federal government. Since 2008 the program has been financially supported by the European Union and EED (Hoering, 2008). JICA has partnered with CEDAC in Takeo Province to implement the Project for Improving Livelihood of Small Farmers. The project is promoting SRI to improve yields and community finance activities by farmers. Assistance has been given for forming a farmers' association that emphasizes autonomy for farmers (JICA, 2008).

The government of Cambodia officially commenced promoting SRI in 2005. Possibly, the leadership of the Minister of Agriculture of the Ministry of Agriculture, Fisheries and Forestry (MAFF) has been prominent. Becoming an advocate of SRI, he visits SRI farmers regularly, attends workshops and lectures, has produced field guides, and instructed the administration at the regional level to promote SRI through extension work (Hoering, 2008:13). All Provincial Departments of Agriculture (PDA) plan SRI in their rice programs (Koma, 2008). Also, Koma (2008) reports that since 2004 a national SRI Secretariat is hosted by MAFFs Department of Agronomy and Agriculture Land Improvement (DAALI) with technical support from CEDAC and financial support from the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Oxfam America, Oxfam UK, Food and Agriculture Organization (FAO) and HEKS (a Swiss NGO). The SRI Secretariat is a permanent working group of local organizations providing training in SRI (Oxfam America, 2008).

SRI appears to be a success story in Cambodia. Many farmers are still organic – the Green Revolution technologies have been mainly adopted for dry-season rice (Koma, 2008). As a LEIA method SRI has got an opportunity there. Mr. Chhay, the director of the Rice Department of MAFF who made a PowerPoint presentation (CIIFAF, 2010) for a national SRI workshop held in Hanoi, January 20 – 21 2010, reports there are 110,530 farmers using SRI methods in Cambodia on 59,785 hectares in 4,534 villages. According to Hoering (2008) SRI not only helps farmers to increase their yields while using less seed, labour and external inputs, it also helps to secure adequate food supply and reduce poverty. In the next chapter input productivity for Cambodian farmers will be assessed to see whether these claims are correct.

SRI adoption in Vietnam

It seems that SRI made its announcement in Vietnam in the year 2000 too. In that year in September during an UPWARD Conference in Beijing Uphoff discussed SRI concepts with Mrs. van de Fliert, who is FAO's Vegetable IPM Program Development Officer in Vietnam. Mrs. van de Fliert agreed to explore possibilities for assessing SRI within a UNDP project in Northern Vietnam. Separately, Uphoff supplied literature on SRI to the Vice-Minister for Agriculture at his request in 2002.

In a report of 2009 by the Asian Institute of Technology (AIT) the coordinator of the National IPM Program in Vietnam, Mr. Chung, sums up that in 2005 SRI had been applied in fourteen provinces across the country, whereas in the following year 3,450 farmers participated across seventeen provinces. Since 2003 the National IPM Program has been introducing SRI to IPM farmers for experimentation (AIT, 2009). Mr. Dung started SRI activities in Farmer Clubs at twenty sites over three provinces - Hanoi, Hoa Binh, and Thai Binh - conducting SRI trials in the 2003 spring (January-May) and summer (June-October) seasons. Further try-outs were conducted during the 2004 spring season in the provinces Hanoi, Hoa Binh, Thai Binh and Quang Nam (Whitten, 2004). These SRI experiments in

Vietnam have been coordinated by the Plant Protection Department (PPD) of MARD under the supervision of Mr. Dung, and facilitated by IPM trainers from the Plant Protection sub-Departments (Whitten, 2004). One of the NGOs that has worked with the IPM program, is said to have been interested in SRI in 2006. Its name is LÚA, which means rice in Vietnamese, but its activities with SRI have not been reported until now (Uphoff, 2006b).

After examination of the results from the National IPM Program in April 2007, the Ministry of Agricultural and Rural Development (MARD) recognized SRI as a technology that should be applied in rice production in the Northern provinces. This decision of MARD makes possible that provinces and research institutes get financial support for SRI. The National IPM Program and the PPD received support for expansion of SRI in the North of Vietnam. Support came from various IOs and NGOs such as the Biodiversity Utilization and Conservation Asia Program (BUCAP), the Danish International Aid Agency called DANIDA, Agriculture Support Program Sector (ASPS), the FAO Vegetable IPM Program in Asia, the Japan International Volunteer Center (JVC), and World Vision (AIT, 2009).

SRI principles are believed to be (Vietnam, 2010):

- The use of younger seedlings
- Single plant transplantation
- Wider spacing of plants
- Timely drainage of water
- Frequent weeding

Other SRI promotion and dissemination in Vietnam is done by FFSs, the Centre for Sustainable Rural Development (SRD) and the Farmer-to-Farmer training approach (AIT, 2009). The FFS program in Vietnam spread had spread swiftly between 1992 and 2001. During the spring season of 2003, the estimated number of FFSs on rice and vegetables in Vietnam was around 2, 000 (Whitten, 2004). FFSs are used to teach farmers SRI methods. After their training, many become leading farmers whom are responsible for promoting SRI and assisting neighbour farmers in its implementation (AIT, 2009).

Finally, halfway 2007 Oxfam America began supporting Vietnamese organizations in promoting SRI in Vietnam. These partners are the PPD under MARD, Oxfam Quebec and SRD (AIT, 2009).

The total area used for SRI, partial and full applications, accounted to 70 hectares in 2006 and increased to 270 hectares in 2007. In 2008 this number even increased to 71, 241 hectares, which belonged to 232, 269 farmers (AIT, 2009). According to Uphoff, Vietnam has become one of the leading countries for SRI utilization. An official SRI Vietnam website[7] is maintained by SRD. In 2009, MARD figured that 422, 000 farmers were using SRI methods. For 2010, Uphoff estimates that of the farmers who apply SRI, 80 percent do a part of SRI and 20 percent practice SRI fully.

4.4 Discussion and conclusion

It can be summarized that until the present, growth in rice production has been achieved through investment in irrigation and infrastructure, utilization of short-duration and high-yielding varieties, and policy reforms. Farmers in all three countries are faced with serious production constraints due to variable weather conditions and farm size. High opportunity costs of labour are associated with part-time farmers who have good reach to urban areas.

SRI is exogenous technical change (Ellis, 1993), because it has not been developed by farmers themselves but rather been brought to them through GOs and NGOs. It can thus be depicted in a graph like Figure 3. SRI can be viewed as a new technology in the category of LEISA. The components of SRI fall well into the ecological principles of LEISA. SRI could therefore be compared to other LEISA technologies. Unfortunately, LEISA technologies have not been studied well in the past (Reijntjes et al., 1992). The attention given to

[7] http://www.srd.org.vn/?a=vgsid=20g=41

LEIA and sustainable agriculture may explain the popularity of SRI among governmental and non-governmental organizations. As a low-external-input technology SRI seems very attractive and suitable for small farmers. As 'a set of principles' it is attractive because of its flexibility to be adapted to various rice ecosystems. SRI seems a welcoming technology for rice agriculture in Vietnam, Thailand and Cambodia.

The impression of SRI so far is foremost that it promotes more care and adequate space to enhance growth of the rice plant. Overall, the SRI principles of its inventor are adopted by organizations. The emphasis lays on the preparation of nursery beds, careful transplanting, less water input and frequent weeding. The notion that rice plants should be treated singularly while transplanted, is in contradiction with farmer's common belief that the more rice plants are transplanted, the more chance at least one will hedge. Also contradictory to traditional farming methods is that with SRI young rice plants should be used for transplanting. Nevertheless, SRI at large is dispersed and promoted by GOs, universities and NGOs. After seemingly successful trials, adoption of SRI under farmers has been reported to spread because of increased training of farmers by GOs and NGOs like OARD and AAN (Thailand), MAFF and CEDAC (Cambodia), and MARD and JICA (Vietnam).

What remains to be answered is what the net impact is of SRI. Bearing in mind what has been discussed here and in Chapter 3, the following chapter will assess the effects of SRI on input productivity in comparison to conventional farming methods.

5 Input productivity

Now follows a thorough examination of SRI and its influence on input productivity. This chapter will proceed as follows: the findings on labour, land and water productivity respectively, are discussed in separate subsections with respect to Thailand, Cambodia and Vietnam. In the beginning of each subsection the findings are briefly discussed and summarized in a table. The results are discussed in the context of Chapter 3 and 4. Moreover, the literature is reviewed to determine how trustworthy the reported results are.

5.1 Labour

Nothing can be concluded about the impact of SRI on labour productivity in comparison to conventional methods. This is due to the low trustworthiness of the literature. In Table 4 it is exactly indicated if an increase has been found or when it was not so clear, and according to what source of information. For detailed descriptions of the results per country the reader is referred to the subsections below.

In all three countries low adoption of some SRI principles was found to be due to their intensive labour requirements at just the time farmers want to go work elsewhere (Resurreccion et al., 2008). The opportunity costs of labour are too high for most farmers to adopt all SRI methods. Adoption constraints range from opportunity costs due to heavier labour inputs in weeding and difficulty in water and soil management. Under these conditions, the extent of adoption of SRI is largely contingent on the capacities, time and opportunities of rural women and men to secure food through diversifying their farming and livelihood activities as was found in Madagascar (Resurreccion et al., 2008; Moser and Barett, 2006).

Farmers, mostly in Thailand, are still in a phase of reluctance to apply the SRI technology. Many do not believe it works and are afraid to take the risk. It is repeatedly mentioned that neighbouring farmers could not be convinced to try SRI, until they witnessed the flourishing SRI fields of key SRI farmers with their own eyes (Hoering, 2008; CEDAC, 2008; Uphoff, 2006a). Adoption of SRI can certainly be seen as a social process (Bardhan and Udry, 1999). SRI clearly is not recognized as a superior technology. The adoption of SRI as a LEISA technology, reminds of the model Bardhan and Udry (1999) described for technologies that are not profitable yet compared to the traditional technology.

Taking the Barnum and Squire model into account, SRI does not seem to result in a higher production curve. Rather, it seems for most farmers that SRI is moving them just along this curve. This is concluded from the fact that farmers sell more to the market because they are gaining higher yields. Yet, this cannot be rigidly concluded on the basis of the literature that has been researched. The impact of SRI as a technology remains something to be investigated upon.

Though not much is known about Thai farmers' labour opportunity costs, farmers from Chiang Mai have put forward high opportunity labour costs to be a constraint to adopt SRI (AIT, 2009).This could explain why they find their labour productivity increasing. If they would have experienced otherwise, they would not adopt SRI since they depend for the most part on off-farm income (Dumas-Johanson, 2009). It is not known if Thai farmers from Roi Et, Chachoengsao and Surin experience high opportunity costs of labour.

In Cambodia, high opportunity costs of labour go hand-in-hand with reports on increased labour productivity in those areas. In Vietnam too, an increase in labour productivity was experienced in regions RRD and NMM where high opportunity costs of labour prevail. However, this relationship needs to be explored more.
For now the context of the documented results will be discussed. First Gypmantasiri (2002) will be reviewed. The author is from MCC of Chiang Mai University. Although the conclusions on the experiments seem eligible, no statistical test is mentioned to confirm these conclusions. However, it is admitted that 'our results do not show convincing evidence of SRI'. For reference MCC (2003) the same thing holds (no author is specified). The report by MCC is mainly informatory. Discussions are described as well as some results, but significance of results is not shown by a statistical test.

Resurreccion et al. (2008) is an in-depth study of SRI adoption in Kandal and Kampong

Table 4: Labour productivity

	Province	Reference	Productivity
Thailand	Chiang Mai	Gypmantasiri (2002)	Cannot be concluded
	Chiang Mai	MCC (2003)	No increase
Cambodia	Kandal, Kampong Chhnang	Resurreccion et al. (2008)	Increase
	All 24 provinces	Sothy (2008)	Increase
	Prey Veng, Kampot	Uphoff (2003)	Neutral
	Kampong Thom, Kampong Cham, Kampong Chhnang	Uphoff (2006a)	Cannot be concluded
	Kampong Chhnang	Lyman et al. (2007)	Increase
	All 24 provinces	Anthofer (2004)	Neutral
	Takeo	Hoering (2008)	Increase
	Prey Veng	Dumas-Johanson (2009)	No increase
Vietnam	Phu Tho (NMM)	SRD (2008)	Increase
	Ha Tay (RRD)	Uphoff (2007)	Increase
	Northern upland areas (NMM)	AIT (2009)	Increase
	Hanoi (RRD)	Whitten (2004)	Increase

Chnnang province. The writers are from AIT and Royal University of Phnom Penh. A survey is the basis for this study. A good number of farmers have been interviewed and their responses have been categorized and presented in Tables. These descriptive statistics seem quite alright for usage, but they do not give rigid answers on labour productivity of SRI.

Sothy (2008), on behalf of DAALI, compares data collected from PDAs and NGOs of all 24 provinces. In addition, farmers are interviewed about their perceptions of labour requirements for SRI. Unfortunately, with respect to the significance of reported yield increases and input reductions no statistical test is mentioned. Therefore these results cannot be considered for making sound conclusions.

Uphoff (2003), Uphof (2006a) and Uphoff (2007) are trip reports from Norman Uphoff of Cornell University. Though a researcher himself, Uphoff fails to convince of significant differences between SRI and conventional methods by means of a statistical test. This strikes as rather odd, since Uphoff is known to be a big advocate of SRI. Why are yield increases and such not underscored by a test if thought of to be so relevant? Reported results by Uphoff cannot be said to provide scientific conclusions.

Lyman et al. (2007) are from Latter Day Saint Charities and CEDAC. Both organizations are involved in the 'Familiy Food Production project' in Kampong Chnnang province. CEDAC has been promoting SRI for some years and, because it is interested in its progress, CEDAC is benefited by good results. To conclude, this study of Lyman et al. (2007) is not representative for the true impact of SRI.

Hoering (2008) is from EED and has documented his experiences when visiting CEDAC to learn about its SRI activities. Though he admits that he was at first 'a bit skeptical', after talking to people 'from various backgrounds and levels of involvement', especially with farmers groups, Hoering has been convinced that 'SRI indeed has a promising potential, particularly for small farmers' (Hoering, 2008:19). However, the differences in production of rice under SRI and under conventional methods are not being demonstrated with a statistical test. So, like Lyman et al. (2007), this study is also not found to be of good scientific value.

Anthofer (2004) is a consultancy report from GTZ. The potential of SRI is investigated in Cambodia, including a statistical analysis. This study is the kind of scientific study looked for. Hence, the results of Anthofer (2004) weighed a lot in the final conclusion on labour productivity in Cambodia. Dumas-Johanson (2009), a master thesis, is written by a student of University of Copenhagen. Again, statistical analysis was included and yield increases under SRI were shown to be significant.

SRD (2008), written by the staff of SRD, reports numerous developments in Vietnam. One of the things being reported is a case study of a SRI farmer, but whether this farmer is representative for most SRI farmers is not mentioned. Actually, this farmer's story has been mentioned in AIT (2009) and on the Vietnam SRI site as well. This casts doubt on the credibility of the case study in SRD (2008). One may wonder why this farmer is mentioned again and again and no other farmers are brought forward. The study of SRD (2008) is not considered to be a careful study on SRI.

A workshop report by AIT (2009) lists a lot of issues with respect to SRI. Farmers mention advantages and difficulties. Whether these farmers are representative for their village or district remains unclear. Reported results are not said to have been analyzed with a statistical test. Whitten (2004) actually uses some of Uphoff's results. The data are not examined by means of a statistical test. The two reports just discussed, are both found to lack scientific value.

In summary, for SRI assessment in Cambodia two scientific studies could be used. As for the other listed reports of Thailand, Cambodia and Vietnam, so far no studies were found to be of good scientific value.

Now follows a more detailed report on the impact of SRI on labour productivity per country.

5.1.1 Thailand

Labour productivity assessment is a key strategy to identify whether a new technology has got the quality to enhance the living conditions of rural households engaged in rice production.

Some farmers from North and North-East Thailand who attended a SRI workshop in 2003, documented by MCC (2003), found that labour requirements increase with SRI. This was witnessed in soil preparation, seed selection, water control and weeding. In common practice, Thai farmers puddle the soil and flood the field. Under SRI the land has to be puddled, leveled and then drained before rice transplanting takes place. Gypmantasiri (2002) declares that land preparation for rice production systems in the Lower North and the Central Thai regions is similar to SRI recommendations. The mud conditions in those regions permit better seed-soil contact for broadcast rice and better seedling stand in the use of SRI (Gypmantasiri, 2002).

If followed through, SRI leaves its mark on labour allocation. Farmers who grow rice using SRI principles experience more weeds in comparison to conventional methods (Gypmantasiri, 2002). Since the rice plant has to compete with weeds for nutrients, space and water, weeds is a major yield constraint for Thai farmers who practice SRI (AIT, 2005). Normally, a flooded field will prevent most weeds from growing, while the young rice plants are not harmed by water. With SRI principles like alternate wedding and drying and more spacing, weeds have more chance to grow. Though in conventional practice, farmers may only weed once, the SRI principle is to weed more frequently and preferably on time (MCC, 2003). As a result weeding requires more labour than with conventional methods . For this reason, Thai farmers do not follow these SRI practices on a larger scale (AIT, 2005).

Transplanting and uprooting, on the contrary, take a lot less time due to single seedlings per hill with a maximum of one centimeter of the seedling into the soil (MCC, 2003). The record shows that a few farmers have accepted the principle of a single plant per hill, but they are skeptical about using young seedlings of ten to fifteen days old (Gypmantasiri, 2002).

Other farmers, in response, have invented new practices to manage the weed problems. Some intercrop a green manure crop in inter row spaces, to create mulch to cover the exposed soil surface at the early growth stage of rice. This reduces weed problems and conserves soil moisture as well. Furthermore, at the later growth stages the mulch appears to enrich soil fertility because rice yield is increased by almost its double compared to conventional methods (AIT, 2005). AIT (2005) concludes that the mulch concept has stayed yet within the domain of a small number of farms. Farmer-to-farmer learning thus seems to have been limited. In 2009, the AIT again reported that farmers intercropped mung bean in between the rice rows to minimize weed competition. It is not clear from the report how many farmers engage in intercropping mulch. It is articulated though, that rice yield was increased at about 1.5 times compared to the conventional method. In summary, this modified SRI method has allowed farmers to save water and minimize weed completion (AIT, 2009).

In the Mae Rim District of the province Chiang Mai, some farmers were witnessed to apply methods alike the SRI principles. These examples indicate that these farmers from Mae Rim District were triggered after their acquaintance with SRI principles to investigate and innovate on their own. As some SRI trials have been held in Chiang Mai, it is likely that farmers have started to adapt SRI principles to their own circumstances. In addition, the increasing international demand for organic rice and its higher price on the market have compelled farmers to seek alternative crop management options using LEISA concepts. This has attracted farmers to grow their rice using principles of SRI (Gypmantasiri, 2002). The examples also show that these Thai farmers are willing to test SRI and are creative and capable enough to adapt the technology to their own environment.

The alternate wetting and drying principle of SRI demands a good drainage system. In Chiang Mai Valley, the management of irrigation systems at the field level is community-based. If an individual plans to use water differently, this will affect the schedule of others (AIT, 2009). Common practice of rice transplanting during the rainy season is a shared labour system. With SRI principles, transplanting will take less time so this will certainly affect the shared labour system as it now exists under Thai farmers (Gypmantasiri, 2002).

In Thailand SRI adoption has not been so broadly spread as it may have in other countries. Especially in North-Thailand, few SRI trials were held so far (Gypmantasiri, 2002). AIT (2009) confirms that though SRI has grown rapidly elsewhere in the region, it is uncommon in northern Thailand. Causes for this lack of development are assumed to be the high labour requirements for weeding SRI fields and the lack of institutional support by the state and other stakeholders (AIT, 2009). Thus again, SRI adoption is constrained by high opportunity costs of labour. Given that conventional farmers weed their rice fields not so much, they are able to leave their farm to apply for a job elsewhere to generate off-farm income. Apparently these northern farmers mentioned in AIT (2009) are such farmers who rely heavily on off-farm income for their livelihood

After critical assessment of the literature it is clear that a firm conclusion cannot be drawn about SRI and labour productivity in Thailand. In summary, it cannot be concluded that SRI changes labour productivity in comparison to conventional methods. It remains ambiguous whether SRI influences labour productivity for Thai farmers.

5.1.2 Cambodia

In a detailed study of Anthofer (2004), SRI adoption and input productivity were assessed for Cambodia in all 24 provinces. He found that there are two major labour peaks in both conventional rice production and SRI. The first one is when the rice seedlings are uprooted and transplanted to the field, and a second peak is for harvesting. For most Cambodian farmers the second peak is of less significance because it is at the end of the rice season and most of the times no second crop follows. The first peak is nonetheless a major labour bottleneck, that can truly affect the overall productivity of the farm.

As mentioned before, weeding was thought to be time consuming by the Thai farmers. What do Cambodian farmers do with this SRI principle? CEDAC recommends farmers timely weeding and the use of mechanical weeders (Hoering, 2008). The outcome of Anthofer (2004) is that 93 percent of the SRI fields were weeded at least once, and also quite soon at about nineteen days after transplanting. In comparison, only forty percent of the same farmers under the conventional practice weeded the same fields just once and much later.

Adopters have cited more weeding, heavier land preparation tasks and more complicated water management and transplanting procedures as disadvantages of SRI. Some female heads of households are particularly deprived if they have less access to male labour for land preparation and rely heavily on reciprocal exchange labour arrangements in farming. These arrangements may not always guarantee an exchange labour party of knowledgeable farm co-workers in SRI methods (Resurreccion et al., 2008).

Off course differences exist among provinces. In those areas where weeds are common, weeding is integrated in farmer's practices. In such areas it may be easier for farmers to adopt the SRI principles. For instance, in Kampong Thom 6 percent of the SRI farmers were accustomed to weeding their fields, while in Takeo 83 percent of the farmers weeded under conventional practices. For that reason it can be assumed that there is an adoption constraint due to weeding in Kampong Thom rather than in Takeo (Anthofer, 2004).

Many farmers practice SRI principles like younger seedlings, on average 17 days old, one to two seedlings per hill and wider spacing of 26 by 26 centimeters (Anthofer, 2004). In 2004, a large number of farmers were struggling with planting in rows, the alternation between flooding and drying during the vegetative period of the rice crop, and timely and frequent weeding. Group discussions with farmers in 2004 confirmed that several farmers found it too time consuming to plant seedlings in rows (Anthofer, 2004). Conversely, in 2008 farmers were found to carry out the planting in straight rows (Dumas-Johansen, 2009).

In October 2008, Dumas-Johansen (2009) interviewed a project coordinator of CEDAC on some aspects of SRI. Most farmers were said to stop with SRI after three to four years because they are used to working with traditional methods. Farmers will start to mix the two systems and stop with full application of SRI. SRI is explained to be more work for them and so they gradually move back to traditional rice farming (Dumas-Johanson, 2009). This phenomena can be explained within the contextual frame in Chapter 3. Farmers with high opportunity costs of labour are not attracted to SRI. These opportunity costs may vary among provinces, but the closer the farm household is to a major city and adeqaute infrastructure is present, the more likely farmers will depend largely on off-farm income and hence the more likely they experience high labour opportunity costs.

Both female and male adopters agreed that higher yields, lesser labour inputs in transplanting and uprooting and the reduction of risk in crop failure in view of longer dry periods were noteworthy benefits. In a survey performed by CEDAC, 87 percent out of 643 SRI farmers agreed that with SRI farmer tasks were lighter than with conventional methods (Resurreccion et al., 2008). Were these farmers typical farmers? It is likely that most of the farmers CEDAC interviewed were farmers that received training and support in SRI adoption, but this is not clear.

It may be possible that households practicing SRI do not have an adequate labour force to weed early and so have to hire labour. Households with few or- elderly members are to be considered here. If applied on all their land, such households would find no additional income is to be derived from SRI. In addition, if this should be the case, SRI could no longer be considered a low external input technology since it requires external input (hired labour). It is therefore likely that those households will only apply SRI to a proportion of their total production area (Anthofer, 2004).

Since CEDAC brought SRI to the country, some farmers are following many but not all of the SRI twelve steps CEDAC prescribes (Uphoff, 2006a; Oxfam America, 2008). As a partner of CEDAC, Oxfam America reported the progress SRI has made so far. Farmers were said to willingly accept the simpler steps, like weeding, selecting fewer but higher-quality seeds, and collecting manure for compost instead of buying chemical fertilizer, but were reluctant to do the wider spacing for the seedlings or the water management (Oxfam America, 2008).

Despite the extra time necessary for weeding and compost preparation, it is reported that many farmers thought SRI decreases labour, and especially as farmers gain more experience with SRI (Uphoff, 2003; Uphoff, 2006a). To a survey in Prey Veng province, 90 percent responded that SRI reduces labour requirements. In Kampot province, farmers estimated the reduction to be 25 percent (Uphoff, 2003).

A rather positive record is listed by Sothy (2008). Farmers commented that SRI methods use less labour force and are simpler than usual methods of cultivation. This included transport, seeding, removal from nursery, transplanting, and preparation of soil. Farmers noted that SRI methods are similar to customary practice with regard to harvesting (Sothy, 2008).

While additional labour is necessary for weeding and compost preparation, scores of farmers mentioned a labour saving effect during uprooting and transplanting (Anthofer, 2004; Hoering, 2008; Lyman et al., 2007). The reasons for the labour saving effect of SRI for these activities are: (1) it is easier to uproot the much younger seedlings and, (2) transport and transplanting of the much lower quantity of seedlings planted at wider spacing is time-saving. After some experience SRI is able to diminish the most critical labour peak by ten man-days per hectare, a reduction of 26 percent. The shift in labour allocation predominantly benefits female household members, since usually they are responsible for uprooting and transplanting (Anthofer, 2004).

Consequently, with SRI methods labour allocation between transplanting and harvesting is more available. One exception is the case when farmers leave their farm for other income opportunities. This holds true for poorer farmers or for farmers whose main income is derived from off-farm activities. Such farmers may find it hard or even unappealing to apply SRI due to high opportunity costs of labour. Conversely, full-time farmers with enough labour supply ought to be able to manage the necessary weeding (Anthofer, 2004).

A study of the overall labour demand of SRI showed that SRI is labour neutral with respect to family labour (Anthofer, 2004). This is confirmed by farmers who were visited by Uphoff on one of his field trips (Uphoff, 2003). Moreover, SRI reduced the need for hired labour significantly, although the amount of hired labour needed was at a fairly low level (Anthofer, 2004). The figure below, taken from Anthofer (2004), depicts the labour neutrality of SRI.

In general, it seems that SRI does not increase labour requirement and, in most cases, does not reduce it either. Rather, a female farmer said that labour is now more evenly spread over the season (Hoering, 2008). With increased yields because of SRI, the ratio of labour input and rice output will decrease. This means that SRI increases labour productivity. Data from the study of Anthofer (2004) confirm that the gross margin man-day^{-1} for conventional practice was just 1.6 US dollars, while for SRI it was 2.5. However, because only the report of Anthofer (2004) was found to be of good scientific value, rigid conclusions on SRI and its possible influence on labour productivity in Cambodia cannot be drawn.

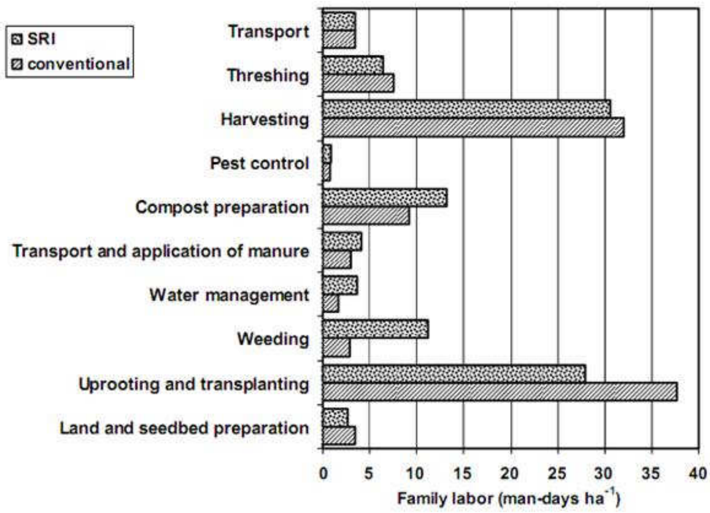

Figure 9: Family labour demand for individual rice management activities with common rice cultivation practices and with SRI practises (N=176)

5.1.3 Vietnam

Before labour productivity is examined for Vietnamese farmers, it will be investigated to what extend farmers have been adopting SRI. Since SRI is not promoted as a 'fixed' package and has only been promoted in Vietnam since 2004, it is possible that Vietnamese farmers have followed a different pattern of adoption of SRI principles so far. As was already laid down in Chapter 4, irrigation is more available to Vietnamese farmers compared to Thailand and Cambodia, which can make it easier for farmers to adopt the water management of SRI. Actually, it was found that farmers are prepared to experiment with water management (Whitten, 2004).

SRI has been applied in seventeen provinces in Vietnam as part of a national IPM program coordinated by PPD. SRD has cooperated with the PPD and Oxfam Quebec to develop a project which goal is to support small-scale rice farmers through SRI implementation. The initial implementation of the SRI program in Vietnam took place in twelve communes, distributed among six provinces: Ha Tay, Yen Bai, Phu Tho, Thai Nguyen, Nghe An and Ha Tinh. This initiative is part of Oxfam America's broader Livelihood and Income Security program in the Mekong Sub-region, including Cambodia, Laos, and Vietnam (SRD, 2008:52).

Seed use of the farmers who tried SRI has fallen by 75 percent. In addition, pesticide use has fallen by 50 to 100 percent , while rice yields have increased by $13 - 29$ percent and net profits between 8 and 32 percent because of SRI. Finally, labour for transplanting was reduced by one half (SRD, 2008).

Uphoff, on a visit to Vietnam in 2007, was told how Vietnamese farmers had rice plants transplanted aged 16 days and positioned at three per hill. Although this is not exactly like SRI methods prescribe, influence of SRI is evident since formerly farmers would do transplanting with seedlings of 30 days old and five to seven plants per hill (Uphoff, 2007).

Farmers are said not to be easily convinced about young seedlings, wider spacing and no flooding, because these SRI principles go straight against their traditional practices. In addition, persuading farmers to stop burning their rice straw and to use it as compost or mulch instead was a challenge too. Uphoff (2007) estimates that Vietnamese farmers are applying half or two-thirds SRI, with no regular spacing and no mechanical weeding yet. Nor were they using as much organic matter as is desired.

An alternate version of SRI seems to be emerging known as direct-seeding. Vietnamese farmers carrying out the direct-seeding method do not prepare seedlings in a nursery bed or do transplanting. Instead, they sow the seeds directly on the fields. This method is thus like broadcasting rice and saves farmers on labour, while yields do not seem to be reduced by it. In fact, the method of direct-seeding has been evaluated in India and a 40 percent reduction in labour was calculated to be feasible, with no or few loss of yield (Uphoff, 2007). Innovations like these are very encouraged by SRI advocates (Uphoff, 2007; AIT, 2009 and Oxfam America, 2008).

Another alteration made with SRI is to transplant two seedlings per hill instead of just one, to help reduce risk during the frequent colds of the Winter/Spring season in Thai Nguyen (Vietnam, 2010).

In Vietnam, farmers apply the SRI principles to keep the soils only moist and do wider spacing (Uphoff, 2007). Like Cambodian and Thai farmers, farmers in Vietnam are unpleased with the increase in weeds. Though CIIFAD recommends mechanical weeders, they were not used by SRI farmers yet simply because they did not have any in their possession (Uphof, 2007).

On the whole, farmers see their labour requirements go down by about fifteen percent. Moreover, female farmers respond that less labour is required from them for transplanting (Uphoff, 2007).

SRI is being recommended for rice production in some Northern ecosystems, whereas potential for Southern ecosystems still needs to be evaluated (Dung, 2006). Professor of agronomy Dr. Phu at Thai Nguyen University (TNU) proposes that SRI is particularly feasible for northern upland areas (Uphoff, 2007). Dr. Phu reported on TNU's work with SRI, starting in Spring 2004 on university plots. Those first trials illustrated yield improvement of twenty percent despite of less inputs. The year after, TNU continued with SRI in Bac Giang province. Yield increases were between 16 and 25 percent. The effects of the application of SRI in the midland and mountainous areas of North Vietnam from Spring season 2004 to Spring season 2009 are: seed use was reduced by 60 percent, water use by 40 percent, and labour for transplanting by 50 percent (AIT, 2009).

Some major outcomes from farmers who have held SRI trials are that (1) there were increased weed problems, but only in those areas where weeds were already present, (2) water management was a problem but farmers felt confident that they could overcome the transition problem, (3) pest and disease prevalence and severity were lessened, (4) and finally, SRI farmers have verified that transplanting younger seedlings with wider spacing, leads to greater tiller production, more grains per tiller and as a result to a higher yield (Whitten, 2004).

Based upon the above results it may be reasonable to conclude that labour productivity is increased under SRI. Yet, since the discussed sources were not found to be of good scientific value, it cannot be concluded that SRI influences changes labour productivity in Vietnam in comparison to conventional methods.

5.2 Land

Does SRI change land productivity in comparison to conventional methods? On the whole, land productivity is increased under SRI. In the Table an overview is shown where exactly these increases have been detected per country.

Table 5: Land productivity

	Province	Reference	Productivity
Thailand	Chiang Mai	Gypmantasiri (2002)	Increase
	Yasothon, Chiang Mai	MCC (2003)	Increase
	Chachoengsao	AIT (2009)	Increase
Cambodia	Kampong Thom, Kandal, Prey Veng, Takeo, Kampot	Anthofer (2004)	Increase
	All 24 provinces	Sothy (2008)	Increase
	Kampong Chhnang	Lyman et al. (2007)	Increase
Vietnam	Yen Bai; Phu Tho; Thai Nguyen (NMM), Nghe An; Ha Tinh (NCC), Ha Tay (RRD)	Dung and Minh (2008)	Increase
	Ha Tay (RRD)	PPSD (2007)	Increase
	Hanoi (RRD)	Uphoff (2006b)	Increase
	Ha Tay (RRD)	Uphoff (2007)	Increase

Studies that have not been discussed in the previous section will be reviewed now. Dung and Minh (2008) have calculated a lot of reductions in input use and increases in rice yield under SRI. There is no statistical test used to show significant differences between SRI and conventional methods. Dung is the SRI project coordinator of MARD and Minh is from the East Asian Regional Office of Oxfam America. It is a pity these authors have not taken more effort to present trustworthy results. As a consequence, this study cannot contribute to rigid conclusions on SRI in Vietnam.

PPSD (2007) is a study of the PPSD in Ha Tay province that is part of MARD. It is concluded that under SRI rice plants produce more tillers and economic returns are higher. No statistical test is named to confirm this conclusion. It seems plausible to conclude that economic returns have been increased, but to make sound conclusions about SRI more is required than is presented in PPSD (2008).

Now follows a more detailed report on the impact of SRI on land productivity per country. Uphoff (2006b) is similar to the other reports by Uphoff. Since no statistical test has been used, this report is rejected to representing a rightful impact of SRI.

5.2.1 Thailand

A report from the Chiang Mai University documents the first SRI trials completed in Thailand. The MCC conducted studies in 2001 in the dry season from February to June and in the rainy season from August to November. For these first trials by the MCC, yields of SRI plots in the dry season were 4.35 t/ha, which is slightly less than the average yield of 4.81 t/ha of conventional practice. Seedlings aged 17 days were used against seedlings of 34 days old. Plant spacing was 25 by 25 centimeters with a single plant per hill. The overall effect of younger seedlings was promising: younger ones gave an average yield of 4.76 t/ha against 4.39 t/ha for the older ones.

In the rainy season experiment, green manure crops were combined with seedlings of ten days and transplantation of a single plant per hill. The SRI rice method performed less with an average yield of 2.19 t/ha against 3.04 t/ha of that of the conventional method. Another trial gave even a worse result: with SRI practice of 25 by 25 spacing and seedling age of 10 days yield accounted 2.59 t/ha, while the conventional method produced 4.16 t/ha.

From flowering to maturity, the water management of both methods was the same. The alternate wetting and drying prior to flowering, as recommended by SRI principles, could hardly be maintained in the rainy season. It could be that because the soil was not kept as dry as required, SRI proceeds were disappointing (Gypmantasiri, 2002).

A positive point for SRI was that the first trials learned that seedling preparation worked best when rice seed was sown in a line on a nursery bed. This method is already been practiced by farmers in Karen, who live on the highland where water is limited (Gypmantasiri, 2002). Lowland rice farmers are used to broadcasting seed in a prepared space near paddy fields. A large quantity of seed is needed this way. In contrast, with a dry nursery bed with a single plant per hill less seed is needed (Gypmantasiri, 2002). This finding confirms some principles of SRI, convincing that SRI belongs to LEIA.

According to CIIFAD (2010) differences in the positive effects of SRI involve soil biological factors. It seems that when rice paddies are not kept flooded in Thailand as well as in Laos, nematode pest problems become harsher. Such a constraint has not been detected yet elsewhere in South-East Asia. It may be that in a certain way SRI mobilizes soil fertility. Yet there is a potential risk that the soil aeration SRI technology seeks, will lead to increased mineralization of soil organic matter in the long run. In the short run, mineralization may lead to increased yields, although soil aeration may lead to soil fertility decline in the end (Dobermann, 2004).

Though this possible peril has to be monitored further, in the meantime, there seems to be prospective for SRI to enhance soil quality. The conventional method of transplanting puts the roots of a thirty days, or older, seedling deep into the soil. It is believed that nutrients could not be used to the full because of this. Counter to tradition, the SRI method plants seedlings younger than fifteen days about one centimeter deep. In this way roots of the seedling are enabled to spread easily to consume nutrients. An experience in the North-East of Thailand also showed that younger seedlings, seven to fifteen days, gave more tillers than older ones (MCC, 2003).

According to MCC (2003), the benefits farmers experienced because of SRI was quite a list. SRI was found to have no adverse effects on the environment and lead to: higher production, cost saving due to seed and- water saving, improvement in soil quality, a reduction in need for external inputs and increased food quality. It was therefore found to be suitable for small farmers (MCC, 2003).

AIT (2009) reports that the Chachoengsao Rice Research Center has evaluated SRI practices from both their own fields and in a farmer's field. The SRI practices were compared with those of the conventional rice production system using a split plot design with three variables tested. The main variable was method of water management: continuous soil submergence or only saturated soil. The subplot variable was different rice varieties. The sub-sub plot variable was seedling age and number of seedlings per hill: seedlings aged 25 days at three per hill from the conventional practice, and seedlings aged 12 days at one per hill from SRI.

Higher rice yield was not obtained with the SRI method of less water input, but young seedlings transplanted at one seedling per hill gave higher yield, 5.3 t/ha, than the older seedlings transplanted at three seedlings per hill, which was 4.8 t/ha.

The principle of the nursery bed and transplanting younger seedlings under wider spacing is approved by conducted research, as it seems to produce more yield under equal employment of inputs. Apparently the principles of SRI indeed enhance soil fertility, at least in the short run. This is confirmed by research like that in MCC (2003), where results from experiments with conventional and SRI principles under same circumstances confirmed that SRI increases yields. Based upon the above results it may be said that land productivity is increased under SRI in Thailand. Yet, since the discussed references were not found to be of good scientific value, no such thing can be concluded.

5.2.2 Cambodia

Considerable differences were revealed between farmers practicing SRI and farmers practicing only conventional rice cultivation methods in Cambodia. SRI farmers on average:

- had a significantly higher educational level than non-SRI farmers.
- had a much better resource endowment, including more rice cultivation area per household member and more livestock.
- were well organized by farmer associations, with technical assistance of CEDAC
- were usually innovative farmers willing and able to take the risk of potential crop failure when trying a new technology

(Anthofer, 2004).

A study of Anthofer (2004) reveals that rice grain yields increased from 1629 kg per hectare with conventional practices to 2289 kg per hectare with SRI. This is an increase of 41 percent, or 660 kg per hectare. This is concluded over a wide range of farming environments and several years. Despite of miscellaneous farmers' locations, average grain yields achieved with SRI plainly outperformed the conventional methods (Anthofer, 2004).

The potential of SRI to increase yields in poor environments is low (Anthofer, 2004). Rather, SRI rice fields were usually located closer to the home-stead and regarded by farmers to be of higher soil quality. However, what if farmers in poor environments cannot opt for such a choice? Those farmers are probably not likely to adopt the new technology, though a portion may attempt so on a small piece of their land (Anthofer, 2004 and Lyman et al., 2007). Analysis conducted separately for each Cambodian province exposed highest yield increases can be expected under favourable environmental conditions. Such conditions are high soil fertility, sufficient and well distributed rainfall, minimal risk of crop losses due to flooding or drought, and good crop management (Anthofer, 2004).

Yet, after some years gone by SRI seems not to be only suitable for more endowed farmers. SRI farmers can also be farmers who own little land, have no cattle and no irrigation facilities. Farmers reported by Hoering (2008) are such farmers, who are tied to rainfed agriculture with their own labour as their major asset.

In Kampot province where GTZ worked with farmers, higher yields were reported and farmers see that their soil fertility is improved with SRI (Uphoff, 2003).

Calculations derived from Anthofer (2004) reveal the economic benefit of SRI. Gross margin calculations demonstrated a clear advantage of SRI over conventional methods. On average, gross margins increased from 120 US dollars per hectare to 209 US dollars per hectare. Two factors contributed to this large difference. First, farmers saved 23 US dollars per hectare on variable costs like seeds and mineral fertilizers. Second, SRI considerably increased rice yields leading to an increased gross benefit by 66 US dollars per hectare, bringing the total increase to 89 dollars.

Other results are from Sothy (2008) of DAALI, who reports that with SRI average rice production has increased from $1.5 - 1.8$ tons per hectare to $2.5 - 4.0$ t/ha. According to data from 120 farmer households collected by CEDAC every year since 2003, farmers can increase their incomes by $58 - 172$ US dollars per hectare with SRI practices (Sothy, 2008).

The experiment done by Latter Day Saint Charities under de heading of 'Family Food Production project', can contribute to this list of success. The Family Food Production project was funded by CEDAC and started in October 2006. The SRI yields that were recorded are from 39 villages in the districts of Kampong Tralach and Samaki Meanchey

(Kampong Chhnang province). SRI farmers used much less seed, less water, less labour, no chemical fertilizer and no insecticide. Young rice plants were given more space, but it is not specified how much (Lyman et al., 2007).

The total of 146 SRI farmers who supplied yield data, all had good results compared to the previous year when they used traditional methods. The average yield was 4.02 t/ha, with a lowest yield of 2.00 tons and a maximum of 10.00 t/ha. Before the Family Food Production started, CEDAC did a survey under the farmers in the area and found the average rice yield of last year to be 1.06 t/ha (Lyman et al., 2007), which is even below the national average (Guimbert, 2008). Average yields in Cambodia are in quite low, even with the use of fertilizer and well-performing varieties (Uphoff, 2003).

In his experience of SRI in Cambodia, Koma (2008) has seen that higher productivity per unit of land permits farmers to convert some of their land for other destinations, such as the growing of fruits and vegetables to diversify their diets and amount to their incomes.

Land productivity under SRI seems to change in comparison to conventional methods. If SRI is able to increase the average range even by one hectare, it will mean a huge improvement to the livelihood of subsistence farmers and their food security. Furthermore, improved yields will contribute to the economic welfare of the country. However, based upon the poor scientific value of the literature it cannot be concluded that SRI changes land productivity in Cambodia.

5.2.3 Vietnam

In four SRI demonstration plots in the Spring season of 2008, the results have been very positive. Rice yields improved by about 20 to 60 kg per sao, seed inputs decreased by 75 percent, pests and diseases were almost absent, and profits increased by 110,000 to 120,000 Vietnamese Dong (VND) per sao (SRD, 2008).

Cost reduction can be substantial. Farmers in Dông Trú village (Hanoi province) who were visited by Uphoff, where they have used SRI since 2004, told him they had gotten a 21 percent increase in their yields with a 24 percent reduction in costs. This resulted in an increase of 65 percent in net income per hectare (Uphoff, 2006b).

A more recent success story was placed on the website of Vietnam SRI wordpress (Vietnam, 2010). Though farmer Nguyen Huy Lieu was doubtful about SRI even after his training, he participated in the SRI trials for the 2008 spring crop and applied SRI on one sao.[8] As he followed the SRI principles, he comprehended he needed only one-fifth of the quantity of seeds and one-half of the labour for transplanting compared to conventional methods. Furthermore he did not use pesticide and only half as much as fertilizer. His resulting yield was 260 kg, when formally he got 200 kg from one sao. Translated to tons per hectare this is an increase from 1.25 to 1.62 t/ha. Lieu's calculated that because of SRI his profits would increase by 120,000 VND per sao, or 1250 US dollars per hectare.

Oxfam America started an implementation of SRI in September 2007 in six provinces in North Vietnam, namely Ha Tay, Yen Bai, Phu Tho, Thai Nguyen, Nghe An, and Ha Tinh. Oxfam America did not rigidly follow the twelve steps of SRI that have been worked out by CEDAC. Instead, it went for an open attitude toward adapting these twelve steps to the local conditions and so it promoted the campaign of MARD for sustainable agriculture known as 'the 3 gains and 3 reductions', which stands for reduction in seeds, fertilizer, and pesticides and herbicides, with gains in yield, rice quality, and net profit (Dung and Minh, 2008).

The winter-spring season 2008 was the first rice season in which the program could promote SRI in North Vietnam. Thirteen FFSs for 390 core farmers were organized as the first step to learning. The area in which SRI was applied summed 33,306.4 hectares including 96,544 farmers. The results were compared to conventional practices. Farmers reduced the amount of seeds 75 percent and pesticide use at least 50 percent. Rice yields rose between 13 percent and 29 percent and net profits rose between 8 percent to 32 percent (Dung and Minh, 2008).

[8]One sao is equal to 360 m^2.

Data from 2006 by Plant Protection Sub Department (PPSD) showed that due to SRI application, seed volume can be reduced by 70 or even 90 percent. Furthermore, nitrogen fertilizer was lowered by$20-25$ percent and average yields increased by $9-15$ percent. SRI rice crops were healthier compared to those from conventional practices, and were therefore discovered to be more resistant to pests and diseases. Pesticide use was reduced accordingly. Profit rose on average by more than 104 US dollars per hectare because of SRI (PPSD, 2007).[9]

An interesting point, like that for Thailand and Cambodia, is if SRI is able to mobilize soil fertility. About SRI is believed that it raises yields and factor productivity because it changes the management of plants, soil, water and nutrients in a way that (i) root systems become larger and function well throughout the growth cycle, and (ii) populations of soil biota are increased in size, activity and diversity (Uphoff, 2007:8).

Up until 2007, the yield increases have been between 10 and80 percent, with simultaneously a reduction in both labour inputs and costs of production (Uphoff, 2007). The largest percentage gains have come on poorer soils, which can be explained by another comment of Uphoff being: 'A big part of the yield improvement has been the evident reduction in pests and diseases, which have become quite common on rice grown with conventional practices' (Uphoff, 2007:6).

The reported results above, all proclaimed that SRI methods are able to increase rice yields without additional fertilizer or compost. However, because the discussed sources were not found to be of good scientific value, it cannot be concluded that SRI changes land productivity in Vietnam in comparison to conventional methods. The exact extension of land productivity SRI can achieve, remains an exploratory option for scientific research.

5.3 Water

Overall, it cannot be concluded that SRI influences water productivity because the literature was not found to be of good scientific value. This was found to be the case in Thailand and Vietnam. For Cambodia there was not enough information to draw any conclusion about water productivity. Below the findings have been summarized per country.

Research shows that two major principles of SRI, alternate wetting and drying during the vegetative stage and the use of organic fertilizer, have potential to increase rice yield with less demand for water than conventional practices (Yang et al., 2004). This definition of productivity is however not in accordance with the definition of water productivity described in chapter 2. None of the documents were found to use a similar definition of water productivity. Actually, water input was simple said to be reduced. Yet, when seed input is reduced water input can also be reduced.

A survey conducted by AIT on farmer's perception on SRI concluded that farmers are willing to adopt SRI - mainly due to less seed and water requirements - if they receive training and technical support for managing weed and water so that they are able to pursue their interests with the available resources they have (AIT, 2005). Anthofer (2004) concludes that SRI requires an intensive training and dissemination process with a high request for human and financial resources. Up until now few Asian research institutions have attempted to explore SRI and validate its potential for rice fields in Thailand (AIT, 2005).

It is likely that farmers weigh the trade-offs between achieving higher rice yields with other opportunities for income. Hoering (2008) confirms that Cambodian SRI farmers do a cost-benefit analysis for themselves to figure whether SRI can profit them. Farmers may benefit from SRI because it reduces the labour peak during transplanting. However, SRI requires more labour for seedbed preparation, water management and weeding. Thus SRI is found suitable for full-time farmers, who are not so dependent on off-farm income for their livelihood but who have good access to labour in general (Resurreccion et al., 2008).
The studies AIT (2007) and Dung (2006) are the last ones to be reflected on. For the other studies, the author refers to the previous sections. Beginning with AIT (2007), this report from AIT is actually not resembling to AIT (2009). Statistical test are carried out on the data and reveal significant differences. Thus the results of AIT (2007) can be used with confidence.

[9] 2 million Vietnam Dong, as was mentioned in PPSD (2007), is exactly 104.71 US dollars.

Table 6: Water productivity

	Province	Reference	Productivity
Thailand	Chiang Mai	Gypmantasiri (2002)	No increase
	Roi Et, Surin	AIT (2009)	Increase
	Roi Et	AIT (2007)	Increase
	Chiang Mai	MCC (2003)	Increase
Cambodia	–	–	No information
Vietnam	Phu Tho; Yen Bai (NMM), Nghe An (NCC), Ha Tay (RRD)	AIT (2009)	Increase
	Ha Tay (RRD)	PPSD (2007)	Increase
	Ha Tay, Ha Nam, Nam Dinh, Ninh Binh, Hung Yen, Hai Duong, Hai Phong, Thai Binh (all RRD)	Dung (2006)	Increase
	Quang Nam	Uphoff (2007)	Increase

Dung (2006) reports on behalf of the IPM program of MARD. This report is not found to be of good scientific value because it does not include a statistical test. As the SRI coordinator of MARD, it is possible that Dung tends to report positive results to convince stakeholders of the importance of the existence of the IPM program.

In conclusion, after examining the studies and reports on SRI in Thailand, Cambodia and Vietnam nearly all have been found to be of low scientific value. This has been based on the absence of a statistical test and, sometimes, on the bias of the author too. Only three studies were found to be of good scientific value. More scientific studies like these are needed to be able to give rigorous answers to the questions regarding input productivity of SRI in comparison to conventional methods.

Now follows a more detailed report on the impact of SRI on water productivity per country.

5.3.1 Thailand

The CGIAR Challenge Program on Water and Food (CPWF) is a research program that operates through a global network of partnerships. Its goal is to develop innovative ways of producing more food with less water across nine major river basins in the developing world. The MRC is the coordinating institution for CPWF projects in the Mekong River Basin (CPWF, 2010). One of the projects funded by CPWF is that of the AIT titled 'Increasing water use efficiency by using mulch under SRI management practices in Northeast Thailand'. This project was carried out in the provinces Roi Et and Surin.

The project that was undertaken during 2006 and 2007 focused on enhancing water productivity of rice using SRI principles (AIT, 2005). The project involved two seasons of action research, for which five synchronized FFSs were organized. In the action research, seedling ages of 12 days versus 30 days old were compared under non-flooded and flooded conditions. Also green mulch intercropping of three local bean species, being mung bean, jack bean and cow pea, was tested in order to minimize weeds (AIT, 2009).

In both seasons of action research, 12-day-old seedlings gave higher yield compared to 30-day-old seedlings. The positive effect of young seedlings on grain yield was significantly higher under non-flooded soil condition compared to the continuously flooded soil condition. Water productivity was higher with 12-day-old seedlings compared to 30-day-old plants, and the result was more pronounced under non-flooded soil conditions than under flooded ones (AIT, 2009).

The green mulch intercrop experiments show that SRI practice with mung bean as an intercrop gave higher yield together with highest foliage cover to the ground, in comparison to the jack bean and cow pea (AIT, 2009).

In another field trial in Roi Et province, 14-days-old seedlings were used versus 30-days-old seedlings under same water management and other conditions while both plots were kept just moist. The younger seedlings performed better at 3.73 t/ha versus 2.98 t/ha (AIT, 2007). The same conditions were repeated with plots under flooded soil. Again, the younger seedlings performed better with a yield of 3.32 t/ha, as opposed to the older seedlings that produced 2.85 t/ha (AIT, 2007).

With data from AIT (2007), water consumption of the conventional method and SRI method can be contrasted[10]. The conventional system with flooded soil conditions used 4031 m^3 per hectare, while the SRI system with moist conditions used only 1368 m^3 per hectare. If yields of both systems were reported to be the same, water productivity would have increased by about 295 percent in the system of SRI. Yet, yields were even higher from SRI fields so water productivity increased even more in this case.

In the trials with mulch, additional irrigation water use could be reduced more than half with SRI. The conventional practice used 4050 m^3 per hectare while SRI used only 1350 m^3 per hectare (AIT, 2007). This is a reduction of 300 percent, or in other words, SRI increased water productivity at least threefold. Furthermore, yield increase was almost double with SRI: 5.31 t/ha against 2.81 t/ha with conventional practice (AIT, 2007).

Farmers mentioned in AIT (2009) have made some remarks about the water management of SRI that could be useful for productivity assessment. The first remark was that in northern Thailand both rainfed and irrigation farmers face water uncertainties and are therefore reluctant to drain their fields. The second comment made was that labour costs are relatively high in the area, and so the weeding required under moist soil conditions was reported to be a significant barrier. The third one was that flooded paddy fields are a home for many species, and the opportunity costs of just-moist conditions were considered high. Opportunity costs are in the form of duck meat and eggs, fish and other marine animals, and soil improvement aspects (mentioned is rice-algae-earthworm symbiosis) (AIT, 2009).

If these farmers from Chiang Mai have 'high labour costs' it implies they have high opportunity costs of labour. If then SRI is presented as a labour-saving technology, farmers are likely to be attracted to adopt it. On the contrary, in the Section 5.1.2 it has been suggested that SRI is labour-neutral. A reason for farmers to adopt SRI may be because they are rewarded by NGOs or GOs. Though in the literature nothing is mentioned about a rewarding system, it can be at least concluded that so far farmers have been stimulated by NGOs and GOs to experiment with SRI and to become a representative SRI farmer to neighbouring farmers.

In fact, SRI has been shown to demand more labour for weeding. Part-time farmers leave their fields for several months to work elsewhere. With common practice, these farmers did not weed their fields often and so they have the opportunity to leave their farm. To these farmers SRI poses a serious constraint with respect to off-farm income.

A suggestion from Gypmantasiri (2002) is that highland paddy rice on terraces, as practiced by Karen farmers, will have better drainage and water control than the lowland fields. Perhaps SRI has got more potential here in spite of its water management. Indeed, Gypmantasiri (2002) states that SRI used only thirty percent as much water as was consumed with the conventional method. This was measured from transplanting to flowering.

In addition, farmers who have access to farm ponds will be more independent to use SRI water management (AIT, 2009). Farmers are stimulated to construct fish ponds in Cambodia and Vietnam (Uphoff, 2006a and Oxfam America, 2008). In Thailand too, the MCC and the Karen community developed pond agriculture to help boost their food income (Gypmantasiri, 2002).

The above recorded findings indicate that SRI changes water productivity in comparison to conventional methods. All recorded experiments show that SRI increases water productivity, sometimes over 300 percent. Farmers themselves report reduction in water use (MCC, 2003; Uphoff, 2007). A reduction in water input has a significant meaning for Thai farmers, for it relieves them from the usage of scarce water resources and reduces irrigation costs as well as contributes to a higher net return.

Unfortunately, because the literature lacked trustworthy results it cannot be concluded that SRI influences water productivity in Thailand in comparison to conventional methods.

[10] Data was calculated using the fact that 1 hectare is 6.25 rai, the Thai area unit equivalent to 360 m^2, and rounded off to two decimals. Also 1 ton is a thousand kg.

5.3.2 Cambodia

In spite of the positive records on SRI adoption in Cambodia, water management has been alleged by many farmers as difficult or even impossible to apply (Uphoff, 2003; Koma, 2008; Resurreccion et al., 2008 and Sothy, 2008). This can be partially explained by the climatic conditions of rice farming in Cambodia. Since most farmers rely on rainfed rice with only limited possibilities to control the water level, farmers cannot afford to release rainwater after rainfall occurred because there is a constant risk of drought (Anthofer, 2004). During the rainy season they keep the water that accumulates in their fields (AIT, 2009).

Based on the existing literature, it seems that many Cambodian farmers do not follow the SRI principle related to water management. Not much has been reported about a reduction in water use. Therefore, the question whether SRI changes water productivity compared to conventional methods cannot be answered. Future studies will have to provide a definite answer.

5.3.3 Vietnam

Though no precise calculations have been done by farmers in Quang Nam province, they estimate they save about 25 percent on water (Uphoff, 2007).

An update report published on the Vietnam SRI website states that for the Summer-Fall season 2008 an average yield of 6.30 t/ha was reached. In addition, irrigation costs were lowered by 35 percent.

Another study in Ha Tay province reports that farmers can save around one-third of the volume of irrigation water they formerly applied (PPSD, 2007). This outcome is confirmed by AIT (2009). AIT recorded for Vietnamese farmers practicing SRI how they managed water on their fields. After fertilizer had been added, the farmers withdrew all the water from their SRI trial fields for at least five to seven days until there were cracks showing on the field surface. After this, they let water overflow into the field. When raining, they kept the field moist but not flooded until the rice plants grew their first panicles. From the panicle growth stage to the ripening stage, water was held at four to five centimeters deep. Finally, they withdrew all the water fifteen to twenty days before harvesting.

Thus, Vietnamese farmers do apply the SRI principle of water management. In this way, farmers saved at least thirty percent of the usual water volume in comparison with conventional methods. Due to the alternate wedding and drying principle of SRI, the roots of the rice plants develop well. The stems become stronger and more resistant against heavy wind. SRI rice plants can even withstand a typhoon (Uphoff, 2007). In the provinces Yen Bai, Nghe An, and Ha Tay irrigation costs were lowered by forty to fifty percent for the Summer seasons of 2005 and 2006. In the Summer season in 2008, in Phu Tho province irrigation costs were lowered by one third (AIT, 2009). SRD also witnessed water-savings of forty to fifty percent in its SRI trials started in September 2007. Results were in favour of SRI - rice yields improved by $554 - 1,662$ kg per hectare and profits increased by $3,047,000$ VND to $3,324,000$ VND per hectare, or 171 to186.7 US dollars (AIT, 2009).

SRI performance has been assessed in terms of yield, water-saving, pest and disease resistance, and profitability (Dung, 2006 and Oxfam America, 2008). Dung (2006) has reported that farmers saved about thirty percent on water on average, in some cases even with fifty percent. This record included the provinces Ha Tay, Ha Nam, Nam Dinh, Ninh Binh, Hung Yen, Hai Duong, Hai Phong and Thai Binh.

The PPSD from Ha Tay province worked together with Dai Nghia cooperative to carry out an experiment in the Summer season 2007. Financial support came from Oxfam America and the experiment involved over a thousand farmers. Water was mainly regulated during the vegetative stage, as SRI prescribes. The plots were dried out for the first time from the tillering stage until the panicle growth stage. The plots were let dried up for 26 days. This allowed to save two to three times of irrigation supply, in sharp contrast with traditional practices at which irrigation is done three to four times. With conventional methods, the water level was maintained in the fields during panicle growth and flowering stages. Fields were dried out only before ripening until harvest. This experiment is of significance to the local irrigated rice farming as well as for water saving (PPSD, 2007).

From the SRI program of PPSD (2007) data was used to calculate SRI yields in tons per hectare.[11] Yields of seedling at spacing of 30 by 30 centimeters was the highest with 7.64 and-7.29 t/ha, for two different soil types. Yields of seedling at spacing of 15.5 by 14 centimeters was the lowest with 4.82 and- 5.92 t/ha. It was concluded that wider spacing with SRI results in higher input returns and lower production costs. Moreover, SRI showed that rice plants have the capacity to grow a higher number of tillers (id est a higher number than under conventional methods), and transplanting seedlings at wider spacing promotes not only tillering, but increases the number of grains per panicle and reduces pests (PPSD, 2007).

According to the reports just discussed, SRI is able to increase water productivity for Vietnamese farmers. In summary, farmers are reported to save around one-third of the usual volume of water. Combining less water input with higher yields from SRI methods, water productivity rises even more than thirty percent. Nonetheless, because the literature was not found to be of good scientific value it cannot be concluded that SRI influences changes water productivity in Vietnam in comparison to conventional methods.

[11] Yields were calculated using the fact that 1 quintal = 100 kg, then rounded off to two decimals.

6 Conclusion

The purpose of this literature study was to identify the effects of a rice technology called SRI on the productivity of labour, land and water in comparison to conventional methods in Thailand, Cambodia and Vietnam. Rice cultivation is an important source of food and income in Asia. The increase of input productivity is a means to enhance rice production for Asian farmers. Until the present, growth in rice production has been achieved through investment in irrigation and infrastructure, utilization of short-duration and high-yielding varieties, and policy reforms. Farmers in all three countries are faced with serious production constraints due to variable weather conditions and farm size.

The farm household model by Barnum and Squire (1979) has been used as a basic frame to predict farm household responses. The model of technical change by Ellis (1993) provided a theoretical background on technical change with respect to agriculture in developing countries. It aims to describe economic concepts on technical change and its implications for the farmer's decisions.

Two dominant ideas of agricultural production are found to be LEIA and HEIA. SRI has been developed in Madagascar as a fixed set of principles promoting more care and adequate space to enhance growth of the rice plant. SRI requires low external inputs and so the components of SRI fall well into the ecological principles of LEIA. The attention given to LEIA and sustainable agriculture may explain the popularity of SRI among governmental and non-governmental organizations. Most SRI principles go against farmers' traditional rice farming methods. Nevertheless, SRI at large is dispersed and promoted by GOs, universities and NGOs and presented as a new way of rice farming. After seemingly successful trials, adoption of SRI under farmers has been reported to spread because of increased training of farmers.

In the final section the learning-by-doing and learning-by-observing models of Bardhan and Udry are conferred. Though the topics of these models are not yet well understood, they are shortly presented to gain some additional insights in the adoption of SRI.

Part of this literature study was the assessment of the validity of the literature itself. Literature was found to be significant if it had included a statistical test. After critical review it is concluded that the consulted literature is not of good scientific value except the reports of Anthofer (2004), AIT (2005) and Dumas-Johanson (2009). Since there was few literature available of good scientific value, nothing could be concluded about the influence SRI has on input productivity. This is true for Thailand, Cambodia and Vietnam. Increased input productivity, hence a higher production curve, has not been proven. Recalling also what Uphoff said about SRI being more a set of principles than a technology (ECHO, 2001), SRI is concluded not to be exogenous technical change but rather a new idea on rice farming that is implemented by the government, yet applied with reluctance by most farmers.

It is likely that farmers weigh the trade-offs between achieving higher rice yields with other opportunities for incomes. Increased productivity under SRI may be related to farmers' high opportunity costs of labour, but this explanation is too simplistic yet to account for the dynamics of SRI rice farming within South-East Asia. Farmers who have high opportunity costs of labour are mostly part-time farmers with good access to urban areas. For now it is concluded that SRI is suited to full-time farmers, in other words those farmers with low labour opportunity costs, with enough access to labour force (Resurreccion et al., 2008).

Finally, SRI requires an intensive training and dissemination process with a high request for human and financial resources (Anthofer, 2004). Until recently, few Asian research institutions have attempted to explore SRI in a proper scientific way and validate its potential for rice production (AIT, 2005). Suggestions research, also NGOs (before they promote it).

SRI may have the potential of reducing the labour peak during transplanting to the benefit of farmers in Cambodia (Anthofer, 2004). This property can be of significant meaning to farmers who have inadequate access to labour force. It is recommended that NGOs and GOs investigate the impact and possibilities of SRI before its application is promoted.

Therefore, the impact of SRI as a technology, especially referring to the research questions on input productivity, needs to be investigated further. In addition, research is suggested on the adoption processes of SRI and the type of farmer it is presented to.

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