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Constraints and Opportunities for the Sustainable Development of Rice Production Systems in Laos

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Abstract— Rice has long been the most important food crop cultivated in Laos, and still account for more than 80% of the area under cultivation within the country. Laos is recognized as one of the countries with the highest per capita consumption of rice in the world. In 2012, total rice production in Laos was more than 3.4 million tons which is a remarkable improvement to make a country self-sufficient in rice production. Total production of rice has increased significantly in the past couple of decades with most of the increment in yield occurring in the rainfed lowland (season rice) where production has doubled from 1,502,000 tons in 1999 to 3,489,210 tons in 2012. Further improvement in rice production will depend on higher levels of inputs and continued alleviation of major production constraints. The system of rice production will become less important as alternative, more sustainable technologies and better government policies are implemented.

This paper summarizes the major production constraints in Laos's rice production environments; rainfed lowland (season rice), dry season irrigation and rainfed upland. Major production constraints identified in the rice production system in Laos include unstable temperature, droughts and floods, poor soil fertility, disease and pest infestation. Flood damage is mostly regarded as the major production constraints than drought. Government proposed policy recommendation seeks to adapt the current policy mix to meet socioeconomic challenges in the rice sector by facilitating trade of the products produced both internally and beyond the boundaries of the country. Also strengthen the rice seed and food reserve, improve the efficiency and effectiveness of public investment and finally strengthen the rice seed sector.

Keywords— Constraints, Laos, Rice production, Sustainable, Development

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I. INTRODUCTION

Rice is a major commodity in world trade and has become the second most important cereal in the world after wheat in terms of production, due to a recent decline in maize production[1]. It is widely cultivated throughout the tropics; where flood controls are effective as in South-east Asia, and production is high..

Rice production is the major agricultural activity in Laos, with rice accounting for over 75% of the gross cropped area. An essential part of the Laos diet, rice also accounts for more than 67% of total calorie consumption. Per capita consumption of milled rice is high for the region, at 163 kg. Given the economic importance of the crop in Laos' agriculture, increased rice production is essential for national economic growth. Laos is the most mountainous country in Southeast Asia and rice is the single most important crop for the people of Laos. It is the staple food crop grown in lowland and upland ecologies in this region. Lowland rice is grown in flooded soils in valley bottoms and on terraced hillsides, whereas upland rice is grown in sloping, unbunded fields under slash-and-burn systems by resource-poor farmers for subsistence [2].The rainfed lowland ecosystem is more important in Laos than in other countries in mainland Southeast Asia, accounting for around 70% of total rice area; only 13% of total area is irrigated [3]. Upland rice is typically grown without fertilizer under rainfed condition[4]. Northern part of Lao especially has 67% of its surface area having slopes steeper than 30% [5]. Traditional upland rice cropping accounts for about half of the total rice area in the north of the country. Rice production in Laos faces a number of biotic and abiotic constraints at the farm level, including poor soil fertility, droughts and floods, and various pests and diseases [6]. Furthermore, factors beyond the farm boundary identified such as rising input costs, fluctuating output prices, and uncertain trade policy, continue to limit farmers' incentive to intensify production beyond that required to achieve household self-sufficiency.

II. OBJECTIVE AND METHODOLOGY

In this paper, we aim to identify the constraints affecting rice production systems in Laos and to review the opportunities that exist in Laos's rice production systems. This is a descriptive research based on the documentart study, which was used for summarizing and identifying the constraints affecting rice production in Laos. The study used secondary data by collecting from different sources such as both published and unpublished materials, websites and other sources. Finally, the paper summarizes and also presents the data or sub-themes according to the objectives of this study by using qualitative explanation.

III. Results And Findings

A. Rice Production Systems in Laos

Rice ecosystems in Laos fall into three goups: upland, lowland rainfed (season rice), and lowland irrigated. In 2012, about 85% of rice production came from lowland and upland cropping during the wet season, with the rice season/ lowland ecosystem accounting for about 76% of the total area and 79% of production while the upland system account for about 13% of the area and 6% of production.

Upland rice is grown mostly in the mountainous northern areas under a system of shifting cultivation. Upland rice grows as a rainfed dry-land crop and is usually only grown during the wet season and is often associated with being grown in a slash-and burn system on steep slopes. Upland rice is typically grown without fertilizer under rainfed condition [4]. The low productivity has been attributed to low soil fertility due to increased cropping intensity and insufficient and irregular rainfall [4]. The soils in this region generally have low water-holding capacity as well as low nitrogen and phosphorus availability [7]. Traditional slash-and-burn systems are considered to be sustainable when low population pressure makes it possible to have long fallows between crops [8]. However, rapid population growth combined with government policies aimed to protect forests is resulting in increased cropping intensity. Roder et al., (1997) showed that fallow periods decreased from an average of 38 years during the 1950s to 5 years in 1992. A more recent survey revealed that fallow periods of only 2 or 3 years were common [2]. In such situations, soil nutrients become depleted and rice yield declines. Thus, the current upland rice cropping is not sustainable [3]. Farmers argue that this situation has resulted in increased food shortages and poverty [9].

Lowland rice (sometimes referred to as paddy rice or season rice) grows in bunded and the soil is flooded for at least part of the crop season. Water for rice production comes from either rainfall or irrigation. Lowland environments predominate with more than 75% of production grown in the wet season in the central and southern agricultural areas. Much of this production is rainfed-based, although some areas now have access to supplementary irrigation. Irrigated rice is grown mainly in the dry season, and mostly in provinces along the Mekong River. In recent years, the area under upland rice had diminished as a result of governmental policies on rice production in the uplands.

During the mid-1990s, the Government of Laos launched a program to expand irrigation to increase rice production. Large investments were made to install high-capacity pumps for small-scale irrigation development, pumping directly from the Mekong River and its tributaries.

Table 1. Rice Production and Harvest Area 2002-2012

Years	Product/ Area	Season Rice/wet season	Irrigated Rice	Upland Rice	Total
2002	Rice Products (Ton)	1801200	375000	240300	2416500
	Area(ha)	519471	84000	134553	738024
2003	Rice Products (Ton)	1819800	369100	186200	2375100
	Area(ha)	564953	81360	109999	756312
2004	Rice Products (Ton)	1976000	341800	200500	2518300
	Area(ha)	575520	76840	107619	759979
2005	Rice Products (Ton)	2082100	271100	214800	2568000
	Area(ha)	569750	61030	105240	736020
2006	Rice Products (Ton)	2161400	310000	192300	2663700
	Area(ha)	618820	68500	108225	795545
2007	Rice Products (Ton)	2193400	329200	187450	2710050
	Area(ha)	604147	71400	105696	781243
2008	Rice Products (Ton)	2321110	439200	209600	2969910
	Area(ha)	619950	94072	111523	825545
2009	Rice Products (Ton)	2468750	452050	224000	3144800
	Area(ha)	656471	94309	122116	872896
2010	Rice Products (Ton)	2331330	512430	226880	3070640
	Area(ha)	627865	108410	118839	855114
2011	Rice Products (Ton)	2323195	540315	202250	3065760
	Area(ha)	598358	112210	106682	817250
2012	Rice Products (Ton)	2763150	509920	216140	3489210
	Area(ha)	706028	107967	119772	933767

Irrigated area increased seven-fold from about 12 000 ha in 1990 to about 87 000 ha in 1999. As a result, the share of irrigated rice in total rice output increased to 17%. This share is expected to increase further if the Government’s target of expanding irrigated areas to 130 000 ha by 2003 is realized. Farmers throughout Laos have been building traditional weirs and canals for centuries to provide supplementary irrigation to their wet-season rice crops. A typical traditional scheme would include a weir made of logs, stones and sometimes bamboo and earth, with small hand-dug canals. The command area of these traditional irrigation schemes has varied from a few hectares to about 100ha, governed mostly by the limited areas of flat land within the mountainous watersheds. These small diversion scheme irrigate terraced or valley-floor paddy. As of 2002, thousands of these small weir and canal systems were still in operation in Laos. Overall, the wet-season lowland ecosystem dominates rice production in Laos, accounting for 66% of the rice area and more than 70% of total output. The rainfed lowland system is of similar importance in Cambodia and Thailand, although in Vietnam, it accounts for only 30% of the total rice area. The expansion of irrigated rice production in the Mekong Delta, which is the main rice bowl of Vietnam, has led to a reduced share for rainfed lowland rice. The average yield of rice in Laos during 1991 and1999 was 2.6 t ha-1.

Lowland rice (both rainfed and irrigated) is common in the mountainous northern region and along the eastern border with Vietnam. The terms upland and lowland as used in describing rice production ecosystem, have no relation to the elevation or topography where the rice is grown. Indeed, lowland rice production systems can be found at over 1000m elevation in Xieng Khouang Province. Similarly, upland rice field can be on flat field at low elevation, such as those in Vientiane area.

B. Constraints Identified in Rice Production

i. Temperatures

During the wet season (May to October), temperatures are relatively stable, and within the range (20ºC and 30 ºC) regarded as suitable for rice cultivation. However, in much of the northern agricultural region, the maturity time of varieties normally grown in the central and southern regions can be extended by 20 to 40 days, as a result of significant decline in both night and daytime temperatures in the latter part of the growing period.

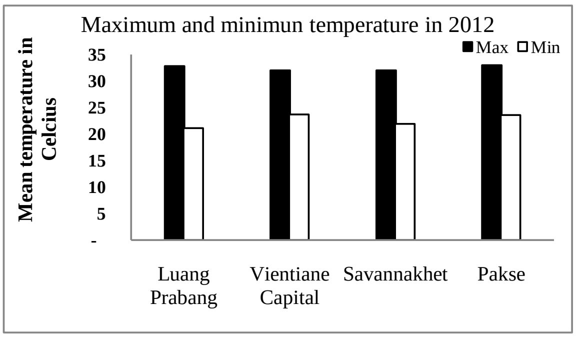

Figure 2. Maximum and minimum temperature in Laos (2012)

The impact is believed to mainly affect maturity time rather than yield potential. However, extended maturity time can prevent the planting of a second crop under dry-season irrigated conditions. This constraint is now being reflected in the varietal improvement program, which is aiming to develop varieties more specifically adapted to the conditions of the northern region. The dry-season temperatures are initially cool, and then increase dramatically toward the end of the season. Critical low and high temperatures for rice are normally below 20°C and above 30 °C, with considerable variability according to the crop's growth stage [10]. The critical high temperature during panicle initiation and grain filling is 30 °C; higher temperatures result in yield loss. The critical temperature for flowering is about 35°–36 °C. Within the critical limits, lower temperatures favour higher yields because of higher net photosynthesis. Low temperatures increase crop growth duration in both the vegetative and reproductive phases and lowers photorespiration. Therefore low dry-season temperatures would likely have a greater effect on rice performance in northern Laos where minimum temperatures can fall below 5°C. In southern and central Laos, high temperatures during late March and April, which can coincide with flowering and grain filling, may result in sterility and smaller grain size.

ii. Seasonal droughts and floods

Majority of planted area of rice is under rainfed conditions, and annual production is highly prone to climatic variability. The rainfall pattern throughout the country is weakly bimodal with a minor peak in May and early June and a major peak in August and September. About 75% of the rainfall is received between May and October and in some of the communities in the Northern provinces (e.g. Sayabouly and LuangPrabang), the total annual rainfall drops to between 1200 and 1300 mm in 2010 to 2012, (Figure 2). In most provinces of the Mekong River Valley, rainfall ranges from about 1500 to 2200 mm. The rainfall pattern can vary from year-to year, causing large fluctuations in rice production. Every year, at least part of the country is affected by either drought or floods or a combination of both. The drought problem in the Mekong River Valley (the main wet-season, lowland-rice-growing area) is aggravated by the permeable nature of the sandy soils that prevail in much of the area. Farmers throughout the central and southern regions regard drought as their most serious constraint. Savannakhet Province has most of its soils in the sandy and sandy-loam categories and, of the provinces, it suffers most from drought either early or late in the season [11]. Early season drought usually occurs from mid-June to mid-July as the monsoons change from south-east to south-west. The effects of this drought can be reduced by appropriate crop practices, particularly by matching crop phenology with water availability [11]. Late-season drought occurs if the regular monsoon rains end early. Fukai et al. (1995) have demonstrated that late-season drought alone can reduce grain yields by an average of 30%. More than 10% of the area planted to wet-season lowland rice in the central and southern agricultural regions is affected by regular flooding of the MekongRiver. During 1991 to 1999 significant areas were affected by flooding on five occasions: 1994, 1995, 1996, 1997 and 1999.

In 1991, more than 21% (about 70 000 ha) of the total rice area was destroyed by floods and in 1995, almost 30% of the planted area in the central agricultural region was lost. Flooding of the Mekong River in 2000 has also resulted in large crop losses, with preliminary estimates of the area destroyed in the central and southern regions being about 61 000 ha (i.e. about14%). As periods of submersion associated with the flooding of the Mekong River can often extend to 2 weeks, total crop loss usually results. Those areas that are particularly flood prone are not cropped in the wet season, rather being used only for dry-season irrigated production. Floods in the northern mountainous agricultural region are

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usually of shorter duration but potentially capable of causing significant levels of soil erosion.

iii. Nature of soil and fertility

The soils throughout the main lowland rice-growing areas in the central and southern agricultural areas are generally infertile, highly weathered, old alluvial deposits that comprise a series of low level terraces with an elevation of about 200m above sea level [12]. Texturally, they are predominantly loams, sandy loams and sands. Systematic studies on the soil nutrient status and potential yield responses from fertilizer application in the wet-season lowland environment began in 1991 with the initiation of the development of a national rice research program. The studies were extended throughout the country as the rice research network expanded during 1992 to 1996.

Early studies aimed to characterize responses to N(Nitrogen), P(Phosphorus) and K(Potassium) on the major soil groups, followed by quantifying the minimum input levels required to sustain yield improvements for those nutrients shown to be deficient [13]. Studies in the latter part of the 1990s were also aimed at maximizing nutrient-use efficiency (particularly N and P), together with characterizing potential responses to K and S [14]. The agronomic efficiency of applied N in the central and southern regions is generally considerably greater than in the northern region (20 kg kg^{-1} in the former, and 8 kg kg^{-1} in the latter). Phosphate was the second most limiting nutrient and P-deficient soils of the north generally have higher P requirements than in the central and southern regions, probably because of higher clay contents and, possibly, different clay mineralogy [15]. Responses to K and a need for K inputs are expected to increase as production is increased through double cropping (wet-season and dry-season cropping) and as rice yields increase as a result of improved varieties being used in combination with increased fertilizer inputs and improved agronomic practices. The potential for using green manure (GM) crops as an organic source of N in the wet-season lowland production system is limited.

More than 95% of the area for dry-season irrigated rice cultivation is also cropped during the wet-season. The description of nutrient status and nutrient responses of soils used for wet-season lowland rice (Linquist et al. 1998) applies also to the dry-season irrigated areas. Nitrogen and phosphorus are the main limiting nutrients, with soils in provinces in the central and southern agricultural areas within the rice growing areas generally showing more widespread deficiencies and greater responses to nutrient inputs than soils in the northern agricultural area. The levels of nutrient inputs recommended for dry-season irrigated cropping are generally higher than for the main wet-season crop in rainfed lowlands. For example, an application of N at about 60 kg ha^{-1} is recommended for most rainfed lowlands in the wet season, whereas N at 90 kg ha^{-1} is recommended for most areas under dry-season irrigated cultivation. The higher rates recommended for the dry season reflect the lower risk to farmers with the removal of the potential drought constraint.

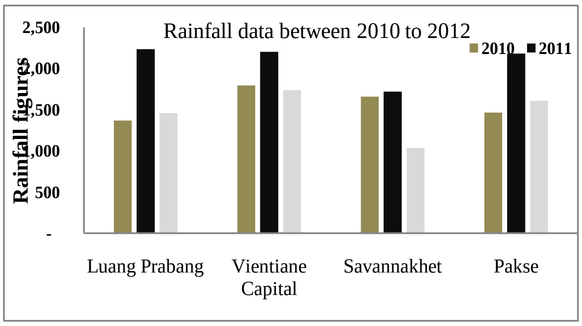

Figure 2. Rainfall data in four provinces in Laos (2010- 2012)

Table 2. Rainfall data in four Provinces (2002 to 2012)

Year	Luang Prabang (Unit: mm)	Vientiane Capital (Unit: mm)	Savannakhet (Unit: mm)	Pakse (Unit: mm)
2002	1,601.80	1,846.70	1,982.00	2,478.00
2003	1,399.00	1,481.00	1,492.30	2,029.10
2004	1,472.70	1,629.60	1,396.70	1,977.90
2005	1,435.00	1,667.80	1,768.20	1,956.10
2006	1,205.60	1,930.30	1,398.70	2,694.50
2007	1,295.00	1,667.50	1,444.70	1,967.50
2008	1,708.70	2,201.60	1,565.70	1,907.60
2009	1,259.40	1,482.80	1,567.60	2,209.60
2010	1,368.60	1,794.20	1,658.90	1,464.30
2011	2,233.50	2,202.40	1,717.90	2,182.50
2012	1,459.40	1,735.60	1,034.90	1,607.40

As with areas cropped during the wet season, an increased need for K inputs is anticipated for dry season irrigated areas as cropping intensifies. Between the 1950s and early 1990s, as population pressure increased, average fallow periods in much of northern Laos dropped from more than 30 to 5 years or fewer [16]. Many areas of Luang Prabang Province, which has the largest area of upland rice of any single province, are currently being cropped, based on a fallow period of only 2 or 3 years. These reduced fallow periods are too short to enable soil fertility to be restored between successive rice crops. Roder et al. (1997b) report that the soil pools of organic C and total N are reduced substantially during cropping and the short fallow period. Fallow periods of 2 years are regarded as being too short to reverse the downward trend, and soil organic C and N levels are expected to decrease further with subsequent cropping-fallow cycles until equilibrium has been reached [17]. The low upland-rice yields being recorded throughout much of northern Laos reflect in part, this continued decline in soil fertility.

iv. Insect pest and diseases

In the wet-season lowlands, insect pests are rated by farmers as being among the top three production constraints in almost all the rice-producing provinces of the Mekong River Valley[18]. Drought was the only factor to be consistently ranked as being more important than insect pests. Most of the pest problems perceived are those that are highly visible, with most farmers believing that leaf-feeding insects cause yield loss [19]. Few farmers were aware of the presence of beneficial arthropods naturally occurring in their rice fields. Although they were often aware of other insects and animals (spiders, crickets, dragonflies and frogs) in their fields, but not feeding on the rice, farmers generally did not know what the organisms' roles in the fields were.

However, the perception of the importance of insect pests on production is not associated with high levels of pesticide use (Rapusas et al. 1997), even though most farmers strongly believed that insects decrease production and should be controlled with pesticides. The low use of pesticides in Laos is probably due to both the farmers' lack of resources for purchase and the unavailability of pesticides. Although insect pests are believed to significantly limit yield, attempts to demonstrate their economic impact have usually not been successful[13]. One exception is the rice gall midge (*Orseoliaoryzae*), which is economically important in some areas, particularly in the central agricultural region (Inthavong 1999). A screening program is being implemented to identify varieties and breeding lines with potential resistance to those gall midge biotypes that are important in some lowland areas of Laos. The rice bug (*Leptocorisa* spp.) is also becoming increasingly cited by farmers as causing substantialyield loss in the provinces of the Mekong RiverValley [19]. Locally, at least, the rice bug is a problem that appears to be increasing in importance from year to year. Studies are currently under way to better understand the significance of the rice bug problem and develop appropriate control strategies. The brown plant hopper (BPH) has occasionally caused severe damage and was observed for the first time in 1979 when about 2000 ha of paddy fields in Vientiane Municipality, representing almost all the dry-season irrigated area at that time, was severely damaged.

The last severe outbreak of BPH was in the 1990 - 1991 dry season when more than 40% of the irrigated area was damaged. Again, this outbreak centered on Vientiane Municipality believed to be related to a BPH outbreak. Improved varieties with resistance to some of BPH biotypes are now available in Laos. BPH infestations are still recorded where non-resistant varieties are being used, with areas of hopper burn. However, most of the recent damage observed has been on a relatively local rather than general scale. Many farmers in the central and southern regions of Laos believe that the stem borer is economically important in dry-season crops. Although usually observed in most areas of irrigated production, studies undertaken during 1993 to 1997 to monitor infestations in farming areas and to measure yield loss failed to demonstrate any consistent yield loss of economic significance that might require specific control measures studies in Vietnam, Philippines and Indonesia indicated that the levels of dead heart and whitehead (both caused by stem borer activity) need to reach about 30% before control measures can be economically justified. In monitoring studies in most parts of the rice production provinces, the incidence of both dead heart and whitehead has rarely been greater than 5% [14] . Of more recent significance, in dry-season irrigated areas (and areas double cropped in the wet-season) is the golden apple snail (Pomacea spp.). The snail was probably introduced from neighbouring Thailand as an aquatic food to Vientiane Municipality about 1991 [20]. Flooding in Vientiane Municipality in 1992 may have then encouraged its spread into areas of dry-season irrigation, where it quickly became established as a significant pest.

In 1995, the snail was also recorded in Sing District of Luang Namtha Province, with Yunnan Province in China being the probable source. The snail has spread to almost all irrigated areas in the central and southern regions, damaging crops shortly after transplanting, and becoming increasingly difficult to manage. Pesticides are not used for control, their use being actively discouraged by the Government. Farmers are therefore developing their own strategies for collecting and destroying the snail, including water management and the use of 'botanical' lures to attract them for easy collection and disposal. Little research has been undertaken on the role of insect pests and diseases in limiting yield of upland rice crops. Another major insect pest, according to Lao farmers, is the white grub (larvae of scarab beetles), which feeds on living roots. In the tropics, the grubs have a 1-year life cycle, with the adults emerging from the soil after the first heavy rains of the wet season. They lay eggs at the same time as the farmer's seed upland rice. After several months, the long-lived white grubs become sufficiently large so that two or three larvae can denude the root system of a mature rice plant. This intensity of damage is rare but wilting can occur when root loss is combined with moisture stress.In an attempt to quantify potential white-grub damage in the uplands of Laos in 1992 and 1993, their incidence and damage was monitored in farmers' fields in the northern provinces of Luang Prabang and Oudomxay [13]. Although grub damage was observed as early as 3 weeks after seeding (WAS) in Luang Prabang Province and recorded in more than 50% of hills at 7 WAS, the level of damage in both provinces and in both years declined significantly as the rice crops matured. No correlation was established between yield and white-grub damage, although, in drought years, white-grub damage to roots is believed to affect the plants' ability to tolerate moisture stress and to subsequently recover.

Although diseases are reported and recorded throughout the main rice-growing areas (leaf and neck blasts, bacterial leaf blight, brown spot and *bakanae* or "foolish seedling" disease), they are generally not of economic significance under the relatively low-input production systems that still prevail in the lowlands of Laos. However, some exceptions do occur. Parts of Phiang District of Xayaboury Province where the soils are K deficient, brown spot disease (*Helminthosporium oryzae* Bredade Haan) can significantly limit yield when inappropriate varieties are used, or the K deficiency is aggravated through the use of chemical fertilizers without a K component [13]. The main disease encountered in upland rice crops is blast *(Pyricularia oryzae* Cav.), which is aggravated by high fertility

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(mainly N) and dry conditions. Although no reports of quantifying the economic significance of blast are known, in some years of on farm testing of upland varieties, little yield is harvestable because of blast [14].

v. Weed control

The need for weed control provides the single greatest demand on labour inputs during the cropping cycle, and the greatest constraint to labour productivity. Between 40% and 50% (140 to 190 days ha–1) of an average labour input of about 300 days ha–1 is used to control weeds [16]. This compares with an average of less than 10 days ha–1 through much of the lowlands [18]. The most common weed in the upland environment is *Chromolaena odorata*, which was introduced to Laos in the 1930s. Other important weeds are *Ageratum conyzoides*, *Lygodium flexuosum* and *Commelina* spp. [16]. Although *C. odorata* is the most abundant weed species, its growth habit allows a much easier control by hand than do other species such as *L. flexuosum* and *Commelina* sp. [13]. Many of the constraints cited by farmers are interdependent (weeds, lack of land, insufficient labour, low soil fertility and soil erosion). Reduced fallow periods have been clearly associated with increased weed problems (Roder et al. 1995). In some areas, the average fallow period has shrunk from 38 years in the 1950s to about 5 years in 1992.

vi. Input cost and uncertain trade policies

Recent years labour and capital have been redirected into a range of other farm and non-farm activities rather than into intensifying rice production [21]. With high levels of yield- and price-risk, and limited opportunities for consumption smoothing through market mechanisms (credit, insurance), households adopt income-smoothing strategies by adopting low-input production systems and income diversification, most notably through migration of family members to earn wages. Despite the achievements of these green revolution technologies in terms of increased output, lowland rice production remains an economically marginal activity, providing limited economic incentive for farmers to intensify production beyond household consumption needs. This poses a challenge for the Government that seeks to keep the price of rice affordable for urban consumers (and net buyers of rice in rural areas), while providing incentives for farmers to intensify production to achieve food security objectives. Attempts to maintain national food security, equated with rice self-sufficiency, have included the setting of official yield targets – 4 tons/ha for the rainfed wet-season crop and 5 tons/ha for the irrigated dry-season crop – that are high relative to the current situation, as well as ad hoc trade restrictions prompted by seasonal shortfalls and price spikes.

The Lao PDR borders on two of the largest rice-exporting countries in the world (Thailand and Viet Nam). Both of these nations are also significant producers and exporters of glutinous rice. They also have highly competitive milling and transport infrastructures, which makes their milled rice cheaper compared with that of the Lao PDR. The main constraint for the export of Lao milled rice in the short and medium term would be the high cost of milled rice relative to its quality. While the Lao PDR still has lower production costs of paddy than its competitors, its rice prices become increasingly uncompetitive as the rice is priced ex-rice mill, and is delivered to the regional markets or overseas destinations. Lao milled rice suffers mainly from low milling quality, which makes it unattractive to consumers in the neighbouring countries. These same issues would also affect the potential export of non-glutinous rice. While there has been increasing investment in the milling capacity in the Lao PDR over the past years, a vast majority of the commercial mills are still small and operate with obsolete milling equipment.

C. Opportunities

i. Technological issues

Drought and submergence are major constraints in rainfed areas of Laos. Accordingly, superior germplasm and better crop management practices to reduce the yield depressing effects of these abiotic stresses are needed. Such technologies will help stabilize yield and encourage farmers to invest in inputs. When the traits that impart drought tolerance have been incorporated into improved rice varieties, further testing, with farmer participation, of germplasm can help rapidly identify lines with those attributes (such as taste, quality and straw yield) that farmer's value. Results from experimental work and farm-level surveys indicate that the gap between the yield that can be obtained from farmers' fields and the current average yield is substantial. The strategy of closing the yield gap may be more relevant for Laos than trying to increase the yield ceiling. One reason for high variability in yield among farmers is poor fertilizer management. As explained earlier, fertilizers are often applied in quantities that are too small to generate a good yield response. The marginal response to fertilizer application varies among farmers from 9 to 17 kg per kg of nutrient applied. We must understand the reasons for such a high variability in yield response to nutrients such as timing of fertilizer application [22]. Such scientific knowledge could then form the basis for making site-specific recommendations that are more suited to particular environmental conditions. Relative to other Asian countries in the region, Laos, with its population density of 20 hb person's km^{-2},is still sparsely populated. Accordingly, labour intensive methods of rice production such as those practiced in the Red River Delta of Vietnam are not appropriate for Laos. With current average farm size being 2 ha (versus 0.3 ha in the Red River Delta), the agricultural system of Laos is likely to remain somewhat extensive for the foreseeable future. In labour scarce environments, farmers are more interested in maximizing returns to labour than returns to land. Hence, rice technologies that increase labour input are likely to be less attractive to farmers (even if they increase yield). This has major implications for technology design and evaluation. Agricultural research in labour-surplus areas is generally oriented towards increasing the yield per unit area. Research approaches developed in these labour-surplus areas are inappropriate when labour is a constraining factor. Similarly, evaluation of technology should not be based merely on yield per unit area but also on yield per unit labour applied, or on other measures that reflect total factor productivity.

Mechanised land preparation, direct seeding and more efficient weed control methods may be suitable to Laos as they help save labour. However, the use of mechanical land preparation and chemical weed control methods may require policy support as poor farmers cannot acquire such technologies due to limited purchasing power. Efforts to improve the effectiveness of existing tools and implements for land preparation and development of varieties that are more competitive with weeds are also desirable. Another area of research of potential relevance to Laos is breeding for high-quality rice. As consumers with increased income switch from low to high quality rice, the demand for such rice will increase with the country's economic growth. In addition, high-quality rice can also have an export market. The environmental conditions in the southern plains of Laos are similar to those in Northeast Thailand where high-quality export rice is produced. Laos will have to face stiff competition, given that Thailand has established itself as a major exporter of high quality rice. Nevertheless, benefits to Laos could be substantial, even if it captures only a small share of the export market.

ii. Policymaking: towards self-sufficiency

What kinds of technologies and policies are needed to achieve this goal? Let me first turn to the issue of policy. Policies can be considered at two levels: macro-economic policy and agricultural policy. The macro-economic policies are designed to manipulate the exchange rate, interest rates and international trade. These parameters affect the agricultural sector in directly by influencing its comparative advantage vis-a-vis other countries and other sectors. Agricultural policies directly affect the choice of crops grown, the levels of input used and types of technology adopted mainly by altering input/output prices for a small country like Laos, its macro-economic parameters are largely driven by the macro-economic policies of countries with which it has strong economic linkages. Thailand is a major trading partner for Laos and, as a result, the macro-economic fluctuations in Thailand are easily transmitted to Laos. This is shown by the recent economic crisis in Thailand and the resulting rapid devaluation of the Lao currency by almost 700%. Although a higher price for rice in Thailand benefited those Lao farmers in the bordering areas who had surplus rice to sell, the devaluation of the Lao currency also increased the price of inputs (such as fertilizers),which were mostly imported from Thailand. This eroded economic incentives to adopt yield-increasing inputs. Obviously, being a small country, Laos cannot do much to influence these macro-economic shocks that arise outside its borders. Nevertheless, because these shocks do adversely affect incentives to adopt improved technology and the performance of agriculture, compensatory policies are needed to prevent erosion of agricultural incentives. One factor closely tied with regional food security in Laos and its economic growth is infrastructure. Although initiatives have been put in place during the 1990s to improve transport infrastructure, the economies of the northern and southern areas remain somewhat fragmented because of high transport costs. These costs also create a barrier to moving surplus grain from production areas of the southern and central plains to deficit areas in the mountainous northern regions. While farmers in the southern and central plains lack incentives to increase rice output, due to excessive production, people in food-deficit areas of northern regions may find it cheaper to purchase rice produced in Thailand. Poor marketing infrastructure reduces the farm gate price of rice and increases the cost of inputs. This cost-price squeeze obviously makes it difficult to persuade farmers to adopt improved technologies even though such technologies may increase yield and output.

While marketing infrastructure is essential for the physical movement of goods, marketing institutions that permit inputs and outputs to flow freely from surplus to deficit areas are also equally important. Laos has made substantial progress in removing inefficiencies associated with the supply of credit and fertilizers by state-owned agencies. The private sector is now entering these areas. Further actions are needed to free these markets for efficient distribution of agricultural inputs and outputs. Rice production in Laos is currently subsistence oriented. Only a small proportion of rice produced is sold on the market. Because of the limited possibilities of obtaining food from the market, households follow the strategy of being as self-sufficient in rice as possible. However, the strategy of such self-sufficiency has its economic cost because it limits opportunities for income gains that could be realized through marketing and crop diversification. In a diversified and commercialized agriculture, rice may be grown more intensively in certain areas (such as the more favourable central and southern plains), while other income-generating activities (livestock, horticulture) are adopted in areas less suitable for rice. Such a vision of agriculture implies that it may not be necessary to develop rice production technology for marginal environments where the possibilities for technological breakthroughs are more limited.

iii. Trade policies

While there has been increasing investment in the billing capacity in the Lao PDR over the past years, a vast majority of the commercial mills are still small and operate with obsolete milling equipment. Overcoming milling constraints would require significant private sector investments (from domestic or foreign sources) in large modern mills and polishing factories. Experiences from neighbouring, emerging rice exporters, such as Cambodia, show that such changes in the milling sector will occur once the Lao PDR starts to produce a sizable surplus of paddy, which potentially could be turned into milled rice exports. In order to facilitate trade in paddy, the first best policy option would be to eliminate export bans and create a transparent trade (export) environment for both rice and paddy, with clear and easily monitored rules at the border. The analysis conducted in this study indicates that buffer stocks would be effective for only a short period of time at best, given the Lao PDR's integration with larger regional rice markets. Furthermore, their effectiveness is contingent upon closure of the border/trade restrictions that has proven difficult to enforce in practice. Thus, the current Lao policy of having limited buffer stocks seems reasonable although it may not be able to achieve its intended objectives in reality. Focusing on strengthening the other two pillars of the Lao rice reserve programme– emergency rice seed and paddy reserves for those portions of the population affected by natural disasters and a targeted food aid/safety net for vulnerable groups – may be a better way for achieving the government's political objectives.

i. Improve the efficiency and effectiveness of public investments

In terms of improving the efficiency of the allocation of budgetary funds to agriculture, the analysis suggests a need for a more balanced approach to allocating scarce public resources to extension activities, technology development and transfer (including good seed), and irrigation. The simulations performed show that, while investments in irrigation are an important component of a comprehensive investment package, the highest incremental production volumes and returns on public spending come from "best practice" extension packages, which contribute 60–80 percent of total incremental paddy production depending on the scenarios. The key component to this investment package is availability of good quality R3 seed, along with functioning extension and access to fertilizer. The seed sector in the Lao PDR, however, faces significant challenges. Addressing these challenges requires the allocation of dedicated government funding for seed multiplication, as well as necessary institutional reforms that improve the efficiency of seed production systems at all levels and encourage establishment of a viable private sector-driven seed distribution system.

CONCLUSION

Loas has made good progress in increasing rice production during the 1990s. It became self-sufficient in rice with the production of 2.1 million tons in 1999.Despite this achievement, resulting mainly from improved technologies and policy reforms, the challenge to adequately feed its rapidly growing population still remains. While there are possibilities for increasing rice output through expansion of area planted, yield growth must be the ultimate source of output growth. Technologies are needed to increase and stabilize rice yield in the dominant wet-season lowland environments and good progress is being made in this regard.

Given the overall labour scarcity of Laos, improved technologies should not be too too labour intensive. Labour-saving technologies for land preparation, crop establishment and weeding suit the labour scarce environments of Laos well. Emphasis should be placed on reducing the substantial gap in yield between the 'best-practice' farmer and the average yield through better crop management technologies. Research could help develop recommendations that are suitable to specific environmental conditions. Some of these recommendations have now been developed and are being actively disseminated.

The new possibilities opened up by improved technologies cannot be exploited fully without an enabling policy environment. Poorly developed marketing infrastructure and marketing institutions remain a major handicap in commercializing the subsistence-oriented agricultural sector of Laos. As a result, the Lao agricultural economy remains somewhat fragmented, and opportunities for regional specialization based on comparative advantage are being lost. Although the Government of Laos has taken initiatives to improve the marketing system, more remains to be done. With appropriate policies in place and with the technologies that are currently being developed, Laos can indeed be self-reliant in its most important staple crop.

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