ROLE OF TECHNOLOGY TRANSFER FROM ABROAD AND COMMERCIALIZATION ON ENHANCING PRODUCTIVITY GROWTH: THE CASE OF AGRICULTURE IN LAO PEOPLE'S DEMOCRATIC REPUBLIC

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Abstract

Securing food and eradicating poverty are part of the Sustainable Development Goals (SDGs) and the national development goals of Lao PDR. Majority of the poor in Lao PDR live in the rural area and rely on agriculture for their livelihood. Enhancing growth in agriculture therefore is critically important for food security and poverty reduction.

The Lao government achieved its rice self-sufficiency target in 1999. This success was made possible by a significant increase in domestic rice production. This study investigates the role of technology transfer from abroad and commercialization on the growth of rice and maize production. Rice is the main staple crop, while maize is a newly emerging commercial crop in Lao PDR. The results of the study point to the positive impact of imported technology on rice production growth and the positive impact of commercialization on maize production growth.

Yield growth is the main contributor to growth in rice production. Modern rice varieties imported from abroad, along with other technology packages such as irrigation, chemical inputs (i.e., fertilizer and pesticide), mechanical technology, and good farm management practices, are key inputs that enhanced the growth in rice yield. The implementation of the National Rice Research Program (NRRP) in the mid-1980s had strengthened the adaptive research capacity of local rice scientists, enabling them to produce rices that suit local ecological conditions and that meet the quality preferences of local consumers. This has resulted in a wider adoption of modern rices by farmers.

Area expansion is the main contributor to the growth in maize production. The Agricultural Commercialization policy in 2002 facilitated the inflow of foreign direct investment (FDI) in agriculture in the form of contract farming (CF). The spread of CF in maize has resulted in a wider area of land being devoted to maize production for commercial purposes. CF is the major platform for technology transfer from abroad in the form of new seeds, fertilizer, herbicide, pesticide, and farm management know-how. CF also appeared to stimulate the evolution of the credit market, hired farm labor market, capital market, and nonfarm market contributing to rural development in Lao PDR.

This study underscores the importance of irrigation expansion and continued adaptive research capacity to further enhance rice production growth. In maize, CF could be a vehicle to increase yield and production by promoting the use of modern chemical inputs, more importantly, fertilizer.

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I hope this study contributes to agricultural development in Lao PDR.

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List of Abbreviations

AA	Australian Aid
ADB	Asian Development Bank
ACIAR	Australian Center for Agriculture Research
AFTA	ASEAN Free Trade Area
ASEAN	Association of South-East Asia Nations
ATC	Agribusiness Transnational Corporation
CF	Contract Farming
CGIAR	Consultative Group for International Agriculture Research
CIAT	International Center for Tropical Agriculture
CIMMYT	International Center for the Improvement of Maize and Wheat
CPI	Committee for Planning and Investment
CURE	Consortium for Unfavorable Environment
DAFEO	District Agricultural and Forestry Extension Office
EEC	European Economic Community
EU	European Union
IADM	Integrated Agricultural Development and Marketing Program
IITA	International Institute of Tropical Agriculture
IPD	Investment Promotion Department
IPM	Irrigated Pest Management
IRRI	International Rice Research Institute
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
FAF	Faculty of Agriculture and Forestry
FAO	Food and Agriculture Organization
FAOSTAT	FAO online-database

FDI	Foreign Direct Investment
FIAT	Farmer Irrigated Agriculture Training
FNPP	FAO-Netherland Partnership Program
GDP	Gross Domestic Product
GR	Green Revolution
GRIPS-ESP	National Graduate Institute for Policy Studies-Emerging State Project
HDI	Human Development Index
Lao PDR	Lao People’s Democratic Republic
LEAP	Lao Extension for Agriculture Project
LSB	Lao Statistics Bureau
LURAS	Lao Upland Rural Advisory Services
MAF	Ministry of Agriculture and Forestry
MC	Marketing Contract
MPI	Ministry of Planning and Investment
MV	Modern Variety
NAFES	National Agriculture and Forestry Extension Service
NAFRI	National Agriculture and Forestry Research Institute
NARC	National Agriculture Research Center
NERI	National Economic Research Institute
NIER	National Institute for Economic Research
NRRP	National Rice Research Program
NSTDA	Thai National Science and Technology Development Agency
NSV	Netherland Agency for Cooperation and Development
NTN	Namthane 30 Ha Rice Research Station
NUOL	National University of Laos

PAFES	Provincial Agriculture and Forestry Extension Service
PC	Production Contract
PEP	Pilot Extension Project
PEI	Poverty and Environment Initiatives
PNG	Phon-ngam Rice Research and Seed Multiplication Station
PPS	Probability Proportional to Size
R&D	Research and Development
RRC	Rice Research Center
SDC	Swiss Development and Cooperation Agency
SDG	Sustainable Development Goal
TSN	Thasano Rice Research and Seed Multiplication Station
TV	Traditional Variety
UN	United Nations
UNDP	United Nations Development Programme
USAID	United States Agency for International development
USDA	United State Department of Agriculture
USSR	Union of Soviet Socialist Republics
VES	Village Extension Service System
VEW	Village Extension Worker
WB	World Bank
WDI	World Development Indicators

CHAPTER I

Introduction

I. RATIONALE OF THE STUDY

Ending poverty and eliminating hunger are the two most important Sustainable Development Goals (SDGs) to be achieved between 2015 and 2030 (UN, 2015). To date, more than 800 million people in the world remain undernourished and more than 700 million people remain in poverty (UN, 2017). Many of the hungry and the poor live in rural areas. Agricultural development is thus critically important for food security, poverty eradication, and livelihood improvement in developing countries (WB, 2008).

Experience in agricultural development in the world points to the importance of modern agricultural technology in enhancing growth and development. The transfer of technology and management know-how from abroad is believed to be an important pillar of growth and development in developing countries (Hayami and Ruttan, 1985). The Green Revolution in Asia in the 1960s attests to the positive impacts of technology transfer from abroad in securing food, alleviating poverty, and increasing household income in Asian developing countries (Chandler, 1982; David and Otsuka, 1994; Estudillo and Otsuka, 2013; Otsuka et al., 1994).

In Lao PDR, approximately one out of five people still live below the poverty line and majority of them live in the rural areas (ADB, 2015a). The Lao Census of Agriculture in 2010/11 reported that more than 70 per cent of Lao labor force live in rural areas and earn their living mainly from agriculture (MAF, 2011). The rural nonfarm sector, which is an alternative source of livelihood, remains largely underdeveloped (ADB, 2012a; WB, LSB, and AA, 2015). Agricultural development is thus a necessary condition to improve livelihood. Introducing new technology and linking rural smallholder farmers to global markets are essential strategies in enhancing food security, raising the income of the rural population, and reducing poverty of rural households.

The Lao government achieved its national food security target for the first time when total rice production reached 2 million metric tons in 1999 (Douangsila, 2002; Eliste and Santos, 2012; Schiller et al., 2006a). The government sets a new self-sufficiency target of 5 million metric tons of rough rice by 2025 due to high population growth and increasing rice export (MAF, 2015). The country's high population growth at 1.5 per cent per annum, makes it necessary to increase rice production growth by more than 1.5 per cent per annum to ensure domestic food security. Yield growth could be the main source of rice production growth as it has become increasingly difficult to expand the rice area due to scarcity of new land for cultivation. To reduce poverty, it is important to link smallholder farmers to the domestic urban and global markets.

Here, I explore the pathways of technology transfer from abroad to Lao PDR and identify key elements to enable farmers to adopt modern technologies and management know-how. I also explore how commercialization has been transforming the previously subsistence-oriented Lao agriculture to a more market-oriented one. I identify government policies that serve as an important springboard for new technology and commercialization to have positive impacts on productivity growth. This study provides empirical evidence that technology transfer from abroad and commercialization are important strategies for food security and poverty reduction in Lao PDR.

II. EVOLUTIONARY FORCES IN LAO AGRICULTURE

Three evolutionary forces operate in the rice and maize sectors in Lao PDR. They are (1) government policies; (2) technology transfer from abroad; and (3) commercialization.

Rice sector: Important government policies in the rice sector were put in place: (1) collaborative programs with foreign countries and international organizations in agricultural development beginning in 1955; (2) agricultural collectivization program between 1976 and 1985; (3) the National Rice Research Program (NRRP) in collaboration with the International Rice Research Institute (IRRI) after the economic liberalization in the mid-1980s; (4) strengthening of the national rice breeding program between 1991 and 2005 through the Lao-IRRI project; (5) accession of Lao PDR to the Association of South East Asian Nations (ASEAN) in 1997, which strengthened research collaboration with neighboring countries, particularly Thailand and Vietnam; and (6) the Agricultural Commercialization policy in 2002 that facilitated the inflow of foreign direct investment (FDI) into the agriculture sector, thus accelerating commercialized rice production and rice export.

Technology transfer from abroad was made possible by the following: (1) establishment of the first rice research institution (Salakham Station) in 1955; (2) importation of modern rices from abroad between the 1960s and the 1990s; (3) importation of mechanical technology from abroad in the mid-1970s and 1980s; (4) development of large-scale irrigation system between the 1960s and 2000s; (5) development of a national rice research network between the mid-1980s and 1990s; (6) introduction of locally bred modern glutinous rices in 1993; (7) adoption of fertilizers and accelerated use of new mechanical technology since the mid-1990s; and (8) exchange of scientists, scientific work and strengthening of capacity-building programs. The commercialization of the rice sector has evolved after a substantial growth in rice production was achieved in the 1990s through industrialization and urbanization as well as the emergence of rice exports since the mid-2000s.

Maize sector: The important government policies established for the maize sector are as follows: (1) economic liberalization policy in 1986; (2) full membership in ASEAN in 1997, which eased cross-border transactions among countries in the region, particularly the smooth inflow of FDI from Thailand, Vietnam, and China in the form of contract farming (CF); and (3) Agricultural Commercialization policy in 2002, which promoted the 1+4 and 2+3 systems of CF through FDI, where the 2+3 system is a common form of CF in maize.

In the maize sector, technology transfer from abroad has been brought in by CF. New technology brought in by CF consisted of new seeds, fertilizer, herbicide, pesticide, machinery, and management know-how. Under CF, production inputs are provided to farmers in advance on credit. The amount advanced is deducted before payment is given to farmers. The adoption of new technology and management know-how led to the expansion of the maize area and growth in maize yield, eventually leading to growth in total maize production. The new maize technology requires an intensive farming system, which increases the demand for labor and leads to the development of the market for hired labor, which is beneficial to the rural poor. Because of the acceleration in maize production growth, local nonfarm activities such as transport services, maize trading, and small-scale CF also emerged. Some local traders supply maize to domestic livestock industry and some export directly or indirectly through various channels to consumers in foreign countries. The emergence of CF, therefore, appeared to stimulate rural livelihood diversification and development in Lao PDR.

III. OBJECTIVE AND MAIN FINDINGS OF THE STUDY

The main objectives of the study are to qualitatively assess the impact of technology transfer from abroad and commercialization on Lao agriculture and to explore its impacts on productivity growth in the country's rice and maize sectors. Rice is the main staple and source of livelihood of a large number of rural households, while maize has emerged as a new commercial crop when contract farming (CF) evolved. There are five main findings. First, in the case of rice, technology transfer was facilitated by the public sector through collaborative research efforts between the Lao government and the International Rice Research Institute (IRRI) and the governments of Thailand, Vietnam, and China. Adaptive research by local rice scientists took place because of this collaboration. Second, in the case of maize, technology transfer was facilitated by the private sector through CF that emerged with the Agricultural Commercialization policy. Third, production growth in the rice sector took place mainly because of yield growth brought about by the development and dissemination of high-yielding glutinous modern rices with good grain quality, made possible by improved adaptive research capability of local scientists alongside the expansion of irrigation, and improved extension service. Fourth, in the case of maize, total production growth resulted mainly from the expansion of new land for maize cultivation, use of modern maize seeds, and application of modern inputs such as fertilizer, herbicide, pesticide as well as good farm management practices introduced to farmers through CF. Fifth, and finally, commercialization stimulated the development of a hired labor market, credit market, and capital market. Commercialization promoted exports that effectively linked rural smallholder farmers to the larger domestic and global markets, which could be an effective platform for poverty alleviation.

IV. CONTRIBUTION TO THE LITERATURE

First, in the case of rice, the Asian Green Revolution in the mid-1960s is believed to be an important outcome of technology transfer from abroad to Asian developing countries (Hayami and Ruttan, 1985, David and Otsuka, 1994, Estudillo and Otsuka, 2013, Khush and Virk, 2005, and Otsuka et al., 1994). This phenomenon is the outcome of the "West-to-East" technology transfer, which is a transfer of technology from temperate developed countries to tropical developing countries. Appa Rao et al, (2006), Douangboupha et al. (2006) and Inthapanya et al. (2006), claim that without adaptive research the Green Revolution in Asia had little impact on rice production in Lao PDR. Several studies such as Douangsila (2002), Eliste and Santos (2012), and Schiller et al. (2006) reported that Lao PDR has achieved its first rice self-sufficiency target in 1999 only. This study is the first attempt to identify strategic processes underlying the launch of the Green Revolution in Lao PDR in the 1990s. Here I explore the impact of "East-to-East" mode of technology transfer from tropical developing countries to a tropical developing country in launching a Green Revolution in Lao PDR. In the case of Lao PDR, "East-to-East" means the transfer of technology from Thailand, Vietnam and China. This study also identifies that the main constrain that prevented the Green Revolution to take place earlier is the lack of adaptive research in the 1970s and 1980s, insufficient extension service and slow expansion of irrigation system.

Second, in the case of maize, previous studies show that contract farming (CF) has served as an important vehicle for agricultural modernization and poverty reduction

(Bellamare and Novak, 2017, FAO, 2012, Key, 2005, Ramsundar and Shubhabrata, 2014, Setboonsang et al., 2008, and WB, 2008). Otsuka et al. (2016) however, claim that the benefits of CF in terms of employment and income are limited and many studies on the benefits of CF are inconclusive. This study provides new evidence and analysis based on extensive case studies on how CF has performed an evolutionary role in the development of credit market, hired farm market, capital market, and nonfarm market contributing to rural development in Lao PDR.

Third, and finally, many scholars have pointed that the most important lesson learned from the Asian Green Revolution is the importance of technology-led and policy-support programs that made possible the launch of the Green Revolution in the mid-1960s (Dawson et al., 2016, Estudillo and Otsuka, 2013, Hazell, 2009, Otsuka and Kijima, 2010, and Otsuka and Muraoka, 2017). Based on a qualitative analysis, this study contributes to the existing literature by exploring how government policy, new agricultural technology, and commercialization could work together harmoniously to bring about productivity growth in Lao agriculture.

V. ROADMAP TO THIS DISSERTATION

There are three remaining chapters in this dissertation. Chapter II is an exploration of technology transfer from abroad and productivity growth in the rice sector. Chapter III describes the evolution of the maize economy with a focus on how maize evolved from being a subsistence crop to a commercial crop through CF. Finally, Chapter IV gives the conclusion and policy implications.

Chapter II describes how the so-called Lao Green Revolution was launched through germplasm improvement, establishment of rice research institutions in main rice-producing areas, exchange of scientists and scientific work, local capacity building in research, and extension services. Chapter III explores how maize production has been transformed from a subsistence-oriented to a market-oriented mode and how markets for hired labor, credit, and capital have evolved in the rural villages. CF appeared to be the main conduit of this transformation. Chapter IV, which is the final chapter, provides the overall conclusion of this dissertation, identifies policy implications, and spells out directions for future research.

CHAPTER II
Technology Transfer from Abroad and Productivity Growth in the Rice Sector

I. INTRODUCTION

Poverty and food security are critically important issues for the global community in line with the ratification by the United Nations of its Sustainable Development Goals (SDGs) in September 2015. SDG1 aims to end poverty in all its forms, whereas SDG2 aims to end hunger, achieve food security, improve nutritional status, and promote sustainable agriculture (UN, 2015). Food security in developing countries in Asia could be broadly defined as self-sufficiency in rice, which is the major staple for a large majority of Asian consumers. Enhancing growth in rice production is therefore a necessary condition in achieving food security.

Lao PDR aims to achieve national food security largely through self-sufficiency in rice as it does not have adequate foreign exchange to import a large amount of rice. The government proclaimed that rice self-sufficiency was achieved in 1999 with the production of around 2 million metric tons of rough rice (Douangsila, 2002; Eliste and Santos, 2012; Schiller et al., 2006a). Because of the rapid growth in population, the government increased its target of rice self-sufficiency to around 5 million metric tons of rough rice by 2025 (MAF, 2015). If this target were achieved, it would mean that each Lao person will have 2,600 calories per person per day from rice alone, which is more than sufficient to achieve the standard 2,100-calorie daily nutritional requirement. However, taking into account the situation at the regional level, Eliste and Santos (2012) reported that rice production in some provinces fell short by as much as 25 to 40 per cent of the provincial rice consumption. With the country's high population growth rate of more than 1.5 per cent per year in the last decade, per capita domestic rice production has to increase at a higher rate than population growth rate to achieve rice self-sufficiency.

An important task is to identify strategies in enhancing rice productivity. The spread of modern seed-fertilizer technology is believed to be the main engine of rice productivity growth in Asia in the course of its Green Revolution beginning in the mid-1960s (Barker and Herdt, 1985; David and Otsuka, 1994; and Khush and Virk, 2005). Early generations of modern varieties of rice were developed to suit the lowland irrigated and favorably rainfed ecosystems, which produce 70 per cent of the world rice production. Thus, the adoption of modern rice varieties is significantly affected by the availability of irrigation, as these new seeds were tailored to grow more profitably in irrigated and favorably rainfed environments. In addition to irrigation, farmers are more likely to adopt new rices that have high yield capacity, resistance against multiple pests and diseases, high degree of suitability to various ecosystems, and, more importantly, good grain quality that commands a higher price in the market. In Lao PDR, there is a national preference for aromatic glutinous rice and modern rices that do not meet the market demand for good-quality rices are commonly not popular among local farmers.

Many studies have shown the relationship between agricultural productivity, food security, and poverty. The Asian Development Bank (ADB) (2012b), for example, identifies agricultural productivity improvement as an important factor for achieving food security and reducing poverty in developing Asian countries. Eliste and Santos (2012) argue that low productivity in rice farming is the main reason for high rural poverty in Lao PDR as rural Lao people depend heavily on rice production for their livelihood.

Lessons from the Green Revolution in Asia in the mid-1960s infer that technical innovation has played an important role in the growth in rice yield and rice production. By adopting new technology and connecting to the market, small farmers in Asia were able to enhance growth in rice yield and rice production leading to food security, enhanced income, and reduction in poverty (Chandler, 1982; David and Otsuka, 1994; Estudillo and Otsuka, 2013; and Otsuka et al., 1994).

The aim of this chapter is to explore how technologies that were transferred from abroad have affected growth in rice production in Lao PDR. Imported technologies are irrigation, mechanical technology, farm management practices, and new rice varieties. I focus on new rice varieties because it is the core component of technology transfer from abroad and it has the most direct impact on rice production growth. The most important finding in the chapter is that new rice varieties imported from abroad and directly disseminated to farmers did not necessarily contribute to rice production growth because adoption rates by farmers were low. In Lao PDR, there is a national preference for aromatic glutinous rice varieties. It is when adaptive research took place and successfully tailored these modern rices from abroad to cater to local market demand that rapid rice production growth was achieved. Large-scale adoption of modern rices and rapid rice production growth took place starting in 1993 with the release of modern Lao glutinous varieties, which is a product of joint adaptive research efforts between the International Rice Research Institute (IRRI) and the local scientists. In addition to adaptive research, improved research capacity of local rice scientists, along with increased availability of local rice germplasm resources, good policy environment such as development of irrigation systems, and providing extension services to farmers are equally important building blocks in launching a Green Revolution in Lao PDR in 1993.

This chapter has six remaining sections. Section II describes the rice economy in Lao PDR. Section III presents the conceptual framework. Section IV investigates the pathways of technology transfer from abroad to Lao PDR. Section V assesses the sources of yield growth. Section VI identifies the factors affecting modern variety adoption, fertilizer use, and rice yield. Finally, Section VII gives the summary and conclusion.

II. RICE ECONOMY IN LAO PDR

2.1. The Lao PDR Economy and Economic Importance of Rice

Lao PDR is known as an agriculture-based country with more than 70 per cent of its labor force in agriculture (MAF, 2011; NIER, 2017). Rice is the main staple and main crop, providing 70 per cent of the daily calorie intake (LSB, 2013). Economic transformation has been taking place. In 1990, agriculture contributed nearly half of the gross domestic product (GDP), but, in 2017, it accounted for only 16.2 per cent of total GDP. In contrast, the share of the industry sector in total GDP has increased from 14.4 per cent (lowest among other sectors) in 1999 to almost 31 per cent in 2017. The share of the service sector remains constant, 40 to 41 per cent in 1990 and 2017, respectively (Figure 2.1).

The recent structural change in GDP has been driven by the large inflow of foreign direct investment (FDI) in the industry sector. Thailand, Vietnam, and China are top three foreign investors in Lao PDR. The inflow of FDI has sharply increased after Lao PDR became a full member of the Association of South-East Asian Nations (ASEAN) in 1997 and after the implementation of the ASEAN Free Trade Agreement (AFTA) in the early 2000s. The FDI has played a significant role in sectoral development, which helped accelerate growth and development. According to World Development Indicators, average growth of Lao PDR's GDP between 2009 and 2013 was more than 8 per cent per year. After that, economic growth rate slightly declined, but, on average, it is still considered robust at 7.5 per cent per year up until 2015. Recently, growth has continued to decline with an annual growth rate of less than 7 per cent per year. In 2017, it was 6.9 per cent (WB, 2018). The high economic growth rate has accelerated the increase in domestic real GDP, from a mere US dollar 1.8 billion in 1984 to US dollar 12 billion in 2017 (Figure 2.2), and GDP per capita has increased from US dollar 203 in 1990 to US dollar 2,457 in 2017[1]. GDP growth has contributed to poverty reduction as poverty has declined by half from 46 per cent in 1993 to 23 per cent in 2015 (ADB, 2015a). The United Nations Development Programme (UNDP) (2018) reported that Lao PDR's human development index (HDI) has improved from 0.400 in 1990 to 0.601 in 2017. The growth in the industry sector is the main driver of aggregate growth in Lao PDR. World Development Indicators stated that average growth of the industry sector between 2000 and 2017 was 12.1 per cent; that of the service sector was 6.6 per cent; and that of the agriculture sector was 3.2 per cent.

Overall economic performance may imply structural change from low-productivity agrarian-based economy to a higher productivity industrial-based one, led by FDI. It was assumed that the growth in the industry sector could deploy more jobs, and the slow growth of the agriculture sector might also be associated with the shift of labor from the agriculture sector to the industry sector. However, the most attractive sectors to FDI inflows are natural resource-based industries, particularly mining and

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[1] World Development Indicators (WDI): http://datatopics.worldbank.org/world-development-indicators/

hydropower, which accounted for more than 60 per cent in total FDI value between 2006 and 2014 (IPD, 2015). According to the National Economic Research Institute (NERI) (2014), between 2012 and 2013, copper and gold were the two main mines receiving high FDI inflow, and 13 hydropower projects were begun, with three projects starting production at that time. This shows that most of FDI projects have concentrated on only a few capital-intensive sectors, which may not necessarily contributed largely to job creation and better income distribution among local people. The Ministry of Planning and Investment (MPI) and the UNDP (2009) reported that the number of workers directly employed in these two sectors between 2008 and 2013 were approximately 8,000 people, implying less contribution to overall income generation and poverty reduction. Furthermore, income gap has been widening due to an imbalance in sectoral development in association with unequal income opportunity and distribution. According to the World Bank, Lao PDR's Gini-coefficient of income inequality has increased from 0.326 in 2002 to 0.364 in 2012[2].

Thus, the slow growth of the agriculture sector, which employed almost three-fourths of the total labor force, implies an urgent task for Lao PDR to devise a comprehensive strategy on agricultural development to accelerate economic growth, create jobs, secure food, and generate income to a large number of Lao citizens. In the agriculture sector, rice is the major food crop and a major source of calories and nutrition. For Lao PDR, food security means having sufficient rice. Thus, rice self-sufficiency is an important target for food security, poverty reduction, and development of the country.

[2] https://data.worldbank.org/indicator/SI.POV.GINI?locations=ZM/

Enhancing the growth of the rice sector is necessary for socioeconomic development of Lao PDR.

The rice sector began to develop only with the launching of its National Rice Research Program (NRRP) after the country undertook liberalization in 1986 (Theppavong and Sipaseuth, 2007). The NRRP aimed to increase rice production by enhancing growth in rice productivity through improvement of rice varieties and farm management. With the establishment of this program, modern technologies, together with farm management practices from abroad (mostly from the International Rice Research Institute) started coming into Lao PDR. Importantly, it was only in 1993, after the release of locally bred glutinous modern rice varieties that satisfy domestic rice preference, that farmers started adopting modern rice varieties over the country. Consequently, rice farming productivity had increased and rice production increased so substantially that, by 1999, the government declared its achievement in national rice self-sufficiency. This implies effective implementation of the NRRP in collaboration with international organizations and foreign countries.

Since then, rice production has increased over time, with substantial surplus from rice consumption requirement strengthening rice export potential. The FAOSTAT released rice export statistics from Lao PDR for the first time in 2008, reporting a total of 13,000 metric tons. Rice exports increased to 75,000 metric tons in 2017, an almost sixfold increase in 9 years. Eliste and Santos (2012), however, reported that there are some informal cross-border rice exports to Thailand and Vietnam in particular, which was estimated at 100,000 metric tons per year, and they calculated that, in 2015, the total rice export to its neighboring countries would be around 300,000 metric tons. This means that the rice export is about three times more than what is officially reported. By considering the current low world rice price, Lao rice export could still bring in foreign currency to the country between US dollar 100 – 120 million per year. Thus it would not only ensure national food security, but it would also improve farmers' income through foreign exchange earnings and develop their livelihood as a whole. The Asian Development Bank (2012c), Khush and Virk (2015), and Papademetriou (2000) estimated that world rice demand is expected to further increase in the future, confirming that the strengthening of the rice sector would provide more income opportunities to farmers and help them move out of poverty.

However, Lao PDR's current rice production growth rate, which has averaged 0.5 per cent per year since 2000, is about 1 per cent lower than its population growth rate. The slow growth of the rice sector may not necessarily have a negative impact on calorie intake, considering that, with rising income and increased urbanization, the Lao people may get calories from food sources other than rice. Rice, however, may be used for other purposes. Shrestha (2012), for example, reported that rice is increasingly being used as inputs for domestic industries. The FAOSTAT shows that the proportion of rice used for domestic processing industries is increasing, accounting for approximately 53 per cent of total rice use in 2013, while the use of rice for consumption has declined to 47 per cent. However, in reality, majority of the people still live in the rural areas (approximately 75 per cent) as urbanization was slow, being dampened by poor infrastructure, particularly the domestic road connectivity (ADB, 2012a, MPI and UNDP, 2009). The proportion on rice spending accounted for one-third of total household food expenditure, which is still considered high (LSB, 2013). In absolute terms, rice consumption has increased from a mere 0.5 million tons in 1961 to 1.5 million tons and 2.3 million tons in 2000 and 2013, respectively. It is clear that demand for rice has been rising for both consumption and industrial input purposes, and there is thus a need to accelerate domestic rice production. An alarming issue in the rice sector is the severe effect of climate change. Droughts and floods have occurred very frequently in recent time, bringing about severe losses in rice production. The Mekong River Commission (2012) has reported that total crop losses in Lao PDR due to natural disasters between 1981 and 2008 was approximately equal to US dollar 10.7 million. Severe droughts in 2004/05 had reduced dry-season rice production by 25 per cent (FAO, 2005). A series of flooding along the Mekong River affected rice crop areas (approximately 56,000 hectares in 2005 and 28,500 hectares in 2008); 45 per cent of the damaged areas were in the capital Vientiane (MRC, 2012). Xangsayasane et al. (2012, 2015) reported that, in the Xebangfai plain of Khammuane and Savannakhet provinces, 100 per cent loss of paddy rice due to severe flooding was experienced.

2.2. Where Rice is Grown

In Lao PDR, rice is grown under three main ecosystems: (1) rainfed lowland, which refers to rice grown in bunded fields using water from rainfall; (2) irrigated lowland, which refers to rice grown in bunded fields using water from irrigation system mainly in the dry season; and (3) upland, which refers to rice grown in unbunded fields and usually in sloping fields associated with slash-and-burn systems, using water from rainfall (Linquist et al., 2006a). The rainfed lowland ecosystem, occupying 79 per cent of the total rice area, produced 82 per cent of total rice production in 2016. The corresponding numbers for the irrigated lowland ecosystem are 10 per cent for total rice area and 13 per cent for total rice production. Those for upland rice are 11 per cent for area and 5 per cent for production.

The irrigated lowland ecosystem has been expanding because of the development of large irrigation schemes. Before the early 1990s, the irrigated area accounted for approximately 2 per cent of total rice area. The first large-scale irrigation was constructed in the mid-1960s; the second and third schemes were constructed in Vientiane during the 1970s and 1980s (Nam Houm Schame and Nam Souang Scheme). Later schemes were gradually constructed in the 1990s and 2000s in the central and southern regions along the Mekong River Valley (Schiller et al., 2006a). With the expansion of the irrigation system, the irrigated lowland areas gradually increased from 7,700 hectares in 1980 to 12,000 hectares in 1990 to 102,000 hectares in 2000 to 112,200 hectares in 2010. It slightly declined to 99,000 hectares in 2015 (FAOSTAT; LSB, 2016; Schiller et al., 2006a). However, total irrigated area accounted for only approximately 10 per cent of total rice area planted in 2015.

Schiller et al. (2006a) reported that almost 95 per cent of irrigation expansion during the 1990s and 2000s and the majority of irrigation schemes occurred in the lowland area along the Mekong River Valley of Vientiane Capital and the provinces of Vientiane, Khammuane, Savannakhet, Saravane, and Champasak. As irrigation became available, farmers in these provinces were able to practice double cropping.

Rice is grown in two seasons, wet season and dry season. While upland rice is grown primarily during the wet season, it is reported separately under a different seasonal category as upland rice. Wet-season rice consists of rainfed and irrigated lowland rice that is grown in the wet season; dry-season rice refers to irrigated lowland rice grown in the dry season (the second round of rice cropping in a year); upland rice is grown during wet season. Wet-season rice produces 82 per cent of total rice production, dry season rice, 13 per cent; and upland rice, 5 per cent. The dry-season crop has a high potential to increase total rice production through double cropping.

At present, there are 18 provinces[3] in Lao PDR, but because Xaysomboun province was newly established in 2017 and there are no data of the province available earlier than 2017, only 17 provinces are reported[4] in this study. Table 2.1 shows Savannakhet province occupying the largest area of rice lands. There are six main rice-producing provinces in the country: Savannakhet, Champasak, Saravane, Khammuane, Vientiane Province, and Viantiane Capital. Altogether, these six provinces occupy almost 70 per cent of total rice area, producing more than 85 per cent of total rice production in 2016 (LSB, 2016). They have a strong comparative advantage in growing rice because they have plenty of water mainly coming from the Mekong River Floodplain and because labor is cheap. Xayaboury, which occupies about 5 per cent of the total rice land, benefited from the first large-scale irrigation system as it occupies only 2 per cent of the total rice land (900 ha out of 46,000 ha).

Slash-and-burn agriculture is still being practiced in most provinces in the northern region. Under this shifting cultivation system, land will usually be left fallow for

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[3] According to Lao official administrative map, the 18 provinces in Lao PDR are divided into three regions as follows: seven provinces in the northern region: Phongsaly, Louang Namtha, Oudomxay, Borkeo, Xayabouly, Houapanh, and Luang Prabang; seven provinces in the central region: Vientiane Capital, Vientiane, Xiengkhouang, Bolikhamxay, Khammuane, Savannakhet, and Xaysomboun; and four provinces in the southern region: Saravanh, Champasak, Sekong, and Attapue. Remark: in some studies, Vientiane province and Xiengkhouang province were added to the northern region so there are nine provinces.

[4] Rice information on Xaysomboun province should be included in that of Vientiane province, Xiengkhoung province, and Bolikhamxay province.

2 or 3 years before recultivation (Linquist et al., 2006a & b). It is also a very labor-intensive farming practice, requiring approximately 300 person-days per hectare on average (Roder et al., 1997, Lao-IRRI, 2003). It is a government policy to replace the upland by a permanent system, particularly by the lowland rice system, but, in practice, the process is very slow because of the different geographical environments (Linquist et al., 2006b).

2.3. Growth of Rice Production and Consumption

Growth of Rice Production: Rice production is rising. In 1950, total rough rice production was approximately 0.5 million metric tons. Total rice production increased to 1 million tons in 1980 then to 2.1 million metric tons in 1999, to 3.2 million metric tons in 2009, and to 4 million metric tons in 2014. This growth in rice production has a strong association with the rise in rice yield. Rice yield was 0.7 metric ton per hectare in 1950, rising to 1.2 metric tons per hectare in 1968 to 2.0 metric tons per hectare in 1984 to 3.1 metric tons per hectare in 2000 and to 4.2 metric tons per hectare in 2014. While domestic rice production is rising, population is also growing. In 1960, total Lao population was 2.1 million, increasing to 3.03 million in 1975 to 4.1 million in 1990 to 5.02 million in 1997 to 6.02 million in 2008 and to 6.8 million in 2016. The average growth rate of population between 1960 and 2016 was 2.4 per cent per year, which is higher than the growth rate of rice production at 0.2 per cent in the same period. If population continues to grow faster than rice production, domestic rice shortage looms in the horizon.

Figure 2.3 shows the trends in per capita rice production and per capita rice consumption in Lao PDR between 1960 and 2016. In 1960, per capita rice production was 149.7 kg and per capita rice consumption was 193.3 kg, a rice deficit of approximately 43.6 kg per person per year. Per capita rice production and per capita rice consumption were balanced between 1982 and 2000 after the implementation of the National Rice Research Program in 1986. Since 2000, per capita rice production has been higher than per capita rice consumption with the release of aromatic glutinous modern rice varieties in 1993, which is believed to have propelled growth in rice production. The country achieved rice self-sufficiency in 1999. The surplus in per capita rice production over per capita rice consumption is explained by the growth in rice yield. In 2016, however, per capita rice consumption increased sharply to 303.3 kg, which is higher than per capita rice production (284.8 kg), creating a deficit of 18.5 kg per person per year.

The average growth rate of per capita rice production from 1960 to 2016 was 0.9 per cent per year, while that of per capita rice consumption was 1.3 per cent per year. That is, growth in per capita rice consumption is about 0.4 per cent per year higher than growth in per capita rice production. Reducing this gap is necessary. One strategy should focus on lowering the speed of growth in per capita consumption, by reducing population growth rate either through effective family planning or other related measures. Yet, the more important strategy is to enhance the growth of rice production by increasing yield through varietal improvement in tandem with irrigation projects and extension services. Some believe that the statistics on per capita rice consumption may be overestimated, which may be due to statistical issues (Eliste and Santos, 2012). One controversy centers on the inclusion of rice consumed by foreign workers in the domestic rice consumption data. There has been an increase in the number of foreign workers in Lao PDR in several mega infrastructure projects such as the high-speed railway linking Kunming and Thailand through Lao PDR and the large Mekong River hydropower plants. Yet, even without including the rice consumption of foreign workers, it is clear that population growth is greater than rice production growth.

Toward a More Commercialized Rice Economy

In 1961, 82 per cent of total production was used for food. While domestic rice production was sharply rising over time, especially after 1990, the proportion used for food declined steadily until it reached 47 per cent in 2013--a decline of 35 percentage points from 1961 to 2013. In 2013, the remaining 53 per cent of rice production was used for industrial processing: as inputs for feed production, beer brewing, and packaged food production. The rising proportion of rice used for purposes other than consumption implies increasing commercialization of rice production linked to industrial usage, where demand is steady and rising over time as the household food consumption basket diversifies away from rice as the most important staple.

In terms of rice as a source of livelihood, there are more than 700,000 farm households in Lao PDR, and 92 per cent of them grow rice (MAF, 2011). According to the Lao Census of Agriculture in 2010/11, the percentage of farmers who grow rice on commercial purpose had increased from a mere 6.2 per cent in 1999 to 24.4 per cent in 2011. In 1999, almost all farmers produce rice for home consumption only and not for market sale, but in 2011, 34 per cent of farmers reported having marketable surplus of rice and sold rice to the market. This implies that rice is increasingly produced for market sale, indicating the evolution of a more commercialized rice farming system. The percentage of rice growers using hired labor has increased from 26 per cent in 1999 to 45 per cent in 2011 (MAF, 1999 and 2011), partly indicating a shortage of family labor and a more intensive use of land for rice farming as irrigation expands and double cropping is practiced. Since commercialized rice farming requires extensive management of hired labor to ensure quality and efficiency of output, the emerging rice farming system challenges the entrepreneurial ability of rice farmers.

In terms of export, the FAOSTAT released data on rice export from Lao PDR beginning only in 2008. Eliste and Santos (2012) reported that exportation of Lao rice to Thailand and Vietnam through informal cross-border trade started a long time ago. FAOSTAT figures show that total rice export in 2008 was 13,000 tons, and it was 75,000 tons in 2017 (a sixfold increase in 9 years). The informal rice export data from Lao PDR to Thailand and Vietnam was estimated at 100,000 tons per year, which is higher than the FAOSTAT figure (Eliste and Santos, 2012). Most of the rice exported to Thailand and Vietnam is the glutinous endosperm type, which is consistent with the domestic rice preference of those countries and the type of rice they export. Durevall and van de Weide (2017) point out that the main reason is that production cost of glutinous rice in Lao PDR is lower than those in Thailand and Vietnam. Some entrepreneurial people, including traders and farmers, are engaged in the rice trade, buying cheap Lao rice and selling them at premium price in the domestic market in Thailand or Vietnam or selling them to rice exporters in those countries.

The Ministry of Agriculture and Forestry (2015) reported that the export volume of aromatic non-glutinous rice to China was 8,000 metric tons in 2015, an increased from 6,000 metric tons the previous year. China further increased the import quota of rice from Lao PDR to 20,000 tons per year from 2017 (USDA, 2019). This shows the rising trend of rice commercialization through exports to China, which is a big and promising market of Lao rices. Exporting rice means earning foreign currency. Certainly, farmers who grow rice for export are benefiting. Taking into account the current rice price (FAO, 2018) and including the informal rice export data, the minimum income from rice export would be between US dollar 100 and 120 million per year.

Commercialization is important. It is useful to understand the flow of rice in the national rice value chain. Based on Eliste and Santos (2012), Ingxay et al., (2016), and the World Bank (2018), the Lao PDR rice supply chain can be represented in Figure 2.4. Farmers supply paddy rice to the markets through rice collectors and/or through farmer groups. Rice collectors sell paddy rice collected from farmers and/or farmer groups to local millers (usually small-scale millers). After milling, these small-scale millers sell the rice to wholesalers/retailers or government contracting agencies before milled rice is sold to final domestic consumers. For the domestic market, rice collectors and millers played an important role in connecting rice farmers to the markets. Surprisingly, how rice moves across various sectors in the rice value chain in Lao PDR is fairly similar to what is described by Hayami and Kikuchi (2000, Ch. 8) in the case of the Philippines. The lesson from the Philippines is that the domestic rice market is so highly contestable that no single entity has a monopoly on the rice market. Value added is created along the value chain without creating "economic rents" to any single player.

For export, paddy rice collected from farmers by farmer groups and/or rice collectors is sold to rice miller groups in the respective provinces. The rice miller groups usually sell milled rice to their contracted partners. There are three main contracted partners who engaged in rice export: government agency, foreign subsidiaries (mostly from Thailand and Vietnam), and large-scale rice millers in Vientiane (who reported having connections with foreign buyers). The government agency exports milled rice to foreign countries based on official quota or contracts with them. Foreign subsidiaries export milled rice to their country headquarters for final distribution. The large-scale rice millers in Vientiane sell rice directly to domestic customers or indirectly through rice wholesalers or retailers. The three main customers of large-scale rice millers in Vientiane are 1) wholesalers, who later sell rice in domestic markets; 2) the Lao Brewery Company that uses rice as key input for beer processing and sells the brewery products to domestic consumers as well as for export; and 3) rice export companies that export rice to foreign contractors.

The rice supply chain shows how rice flows and creates value added to relevant players in the supply chain. Rice collectors and farmer groups have played a middleman role between farmers and processing markets. Small rice millers at the village and district levels connect rice producers to retailers and wholesalers before the rice reaches the final consumers in Lao PDR. Miller groups at the provincial level have played a significant role in connecting Lao rice producers to larger domestic markets and export companies. The large-scale millers in Vientiane have made connections with larger domestic markets, the brewery processing industry, and the export market. Rice commercialization is crucial in improving rice production in Lao PDR. Strengthening the capacity of rice collectors and enhancing the quality of service of rice millers, particularly that of miller groups and large-scale millers, are necessary in advancing commercialization.

In summary, Section II shows the economic importance of rice as a staple food, as a source of livelihood, and as an important source of foreign exchange. Rice has increasingly become an important income source for rice farmers and the relevant actors in the rice supply chain. It is necessary, therefore, to identify a comprehensive strategy for rice sector development that focuses on increasing rice yield and improving grain quality to satisfy domestic and export market demand. Varietal improvement is key to this, along with irrigation and extension services. I will discuss these issues in the next two sections.

III. CONCEPTUAL FRAMEWORK

Figure 2.5 frames the evolutionary process of technology transfer from abroad to Lao PDR and shows how transfer of the technology had been translated into growth in rice production. Together with other technology packages such as irrigation, mechanical technology, and management practices, modern rice varieties from international organizations and foreign countries were imported into Lao PDR. The introduced modern varieties from abroad, however, were not popular among farmers because they are not the aromatic glutinous types preferred by domestic consumers even though these imported varieties have high yield capacity, shorter growing period, and resistance to multiple pests and diseases. Technical know-how on varietal improvement had been transferred to local scientists from international experts. Local scientists adapted techniques to develop local modern varieties that are highly preferred by local consumers. These varieties were introduced to farmers for adoption through the national extension service. The national agricultural extension bureau with organizational structure from national to village levels plays the key role in delivering information and know-how to facilitate adoption. Communication media such as television and radio had played an important role in spreading information about locally bred modern varieties. The use of mass media proved effective in getting the message out as Lao PDR is mountainous and direct contact between extension workers and farmers may be difficult in some cases. Irrigation and mechanical technology are also important in convincing farmers to adopt modern rice varieties. Irrigation enables farmers to grow two crops of rice a year, leading to an increase in output per hectare per year. The yield of modern rices is responsive to fertilizer application.

3.1. History of Technology Transfer in Agriculture

The history of technology transfer in agriculture could be divided into two phases: from temperate to tropical countries (I call this "West-to-East"[5]) and from tropical to tropical countries (I call this "East-to-East"[6]).

In the early stage of technology transfer, West-to-East refers to the transfer of technology that has already been developed in western countries to developing countries in the East and elsewhere. This mainstream may refer to the opening up of new continents in the world (Turner, 1920 and Mikesell, 1960 as cited in Hayami and Ruttan, 1985). Agricultural technology transfer from western countries to eastern countries during the mid-20th century was characterized by direct transfer of agricultural technology that was developed in the temperate environment of the west to tropical regions. Yet, because of differences in the ecosystem, the transfer of ready-made technologies under ecological adaptation (the so-called "adaptive research") was less effective in the early phase (Kamarck, 1976 as cited in Hayami and Ruttan, 1985). Experience from this early stage provided valuable lessons for the improvement of technology transfer from the source

[5] Under OECD terminology "North-South" cooperation has been used referring to technical cooperation between developed countries and developing countries in assisting the development in developing countries. In this dissertation I wish to use "West-to-East" to distinguish from that common terminology in order to refer to technology transfer from an agro-ecosystem to a different agro-ecosystem. West-to-East means technology transfer from temperate agro-ecosystem to tropical agro-ecosystem.

[6] Similar to footnote 5. The OECD terminology of South-South cooperation means technical cooperation between developing countries and developing countries. I wish to use East-to-East for technology transfer from tropical agro-ecosystem to tropical agro-ecosystem.

countries to recipient countries. Adaptive research (i.e. tailoring imported technology to local ecological conditions) has therefore been emphasized as the most important element of technology transfer in collaborative programs.

During the colonial period (1920s and 1930s), Japan brought its new rice technology to South Korea and Taiwan. To ensure the success of transferring such technology, priority was given to adaptive research and development of local scientists' capacity in these two recipient countries (Hayami and Ruttan, 1985). Through the transfer of scientific knowledge and know-how, local scientists in Korea and Taiwan were able to effectively adapt the new rice technology from Japan to fit the ecological environment in their respective countries.

It is believed that a crucial factor in technology transfer is the transfer of knowledge and adaptive capacity from scientists in the source countries to local scientists in recipient countries. Local scientists are able to tailor the western technology into the agro-ecological condition of their country. The Asian Green Revolution (GR) phenomenon in the 1960s has confirmed the effectiveness of technology transfer by giving emphasis on the development of the local research system and building the capacity of local scientists for adaptive research (Millikan and Hapgood, 1967 and Schultz, 1964 as cited in Hayami and Ruttan, 1985).

In the mid-20th century, under the auspices of the Food and Agriculture Organization of the United Nations (FAO), an international system of technology transfer in the agriculture sector was established. International research institutions were set up to tailor existing western technology into the agro-ecological systems of developing countries at the time when there is a substantial technology gap between temperate and tropical countries. Several international organizations were mandated to carry out research and development (R&D) to support technology transfer in agriculture at the global and regional levels. The International Rice Research Institute (IRRI) in the Philippines was established in 1960 with the worldwide mandate of improving rice production, with special emphasis on Asia. The International Center for the Improvement of Maize and Wheat (CIMMYT) in Mexico, which was set up in 1966, focused on the improvement of maize and wheat. The International Institute of Tropical Agriculture (IITA) in Nigeria was born in 1967 with the worldwide mandate of improving overall crops in the lowland tropics, with special emphasis on Africa. The International Center for Tropical Agriculture (CIAT) in Colombia created in 1968 tackled the improvement of some cash crops in the lowland tropics, with special emphasis on Latin America. Some other international organizations were established to support technology transfer beyond the crop sector such as those for livestock, mixed farming system, and policymaking. Established in the 1970s and 1980s, these organizations emphasized capacity building in developing countries.

The East-to-East technology transfer evolved with the success of adaptive research under the West-to-East paradigm. Technology transfer from one developing country to another developing country through exchange of scientists, breeding materials, technical know-how, and good farm management practices has become common in recent years with the rise in global collaboration and globalization. The East-to-East transfer of technology in the case of Lao PDR was facilitated because of its close proximity with bordering countries such as Thailand, China, and Vietnam. These countries possess a better stock of technology, some of them brought from abroad and successfully tailored to their respective agro-ecological environment. Because of the national preference for aromatic glutinous rice, Thai rice varieties were more popular among Lao farmers and they were considered the most successful products of adaptive research among all rices brought from abroad.

3.2. Technology Transfer from Abroad to Lao PDR

Technology transfer from abroad to Lao PDR started in the mid-1950s during the period of the Kingdom of Laos (Schiller et al., 2006a; Stuart-Fox, 1980). The earliest international assistance programs in the rice sector were in collaboration with western countries such as France, the United Kingdom, and the United States (Inthapanya et al., 2006; Schiller et al., 2006a). The collaborative program in the late 1960s with IRRI is the first cooperative effort with an international organization[7]. However, formal collaboration with extensive research and development activities with the IRRI began in the early 1990s.

Technology transfer from abroad to Lao PDR consisted of six main forms of assistance: (1) research and development (R&D), (2) capacity building, (3) irrigation system development, (4) institutional development, (5) farm mechanization, and (6) extension system development.

Research and development (R&D): This has been considered the most effective mechanism in technology transfer from abroad to Lao PDR. Under international assistance programs, the establishment of local R&D institutions has played a critical role since the beginning. This included setting up research infrastructure such as research laboratories and related facilities and building local human resources. Following are research institutions developed and established under international collaboration programs: the Salakham Rice Research and Seed Multiplication in Vientiane (thereafter

[7] http://irri.org/our-work/locations/lao-pdr

referred to as Salakham Station); the National Agricultural Research Center in Vientiane (since the mid-2000s, the name of this center has been changed to Rice Research Center, thereafter referred to as Rice Research Center); the Phone Ngam Rice Research and Seed Multiplication Station in Champasak province; the Thasano Rice Research and Seed Multiplication Station in Savannakhet province; the Namthane 30 Ha Station in Xayabouly province; the Louang Namtha Rice Research Station in Louang Namtha province, and the Houay Khot Rice Research Station in Luang Prabang. These rice research institutions played key roles in rice germplasm improvement in the early phase. Rice research facilities and stations have later been established in almost all provinces. These research institutions are under the National Agriculture and Forestry Research Institute (NAFRI), which represents the national organization of R&D in the agriculture and forestry sector in Lao PDR as a whole.

Capacity building: The most common methods of capacity building provided under the international collaboration programs are as follows: (1) on-the-job training, which mostly refers to dispatching experts from international organizations/donor countries to work with and provide instructions to Lao researchers and officers in conducting related research and experiments; (2) joint research between international and local scientists; (3) study grants in foreign countries, by providing scholarship to Lao researchers and officers to obtain technical and/or higher degree programs in foreign countries; and (4) short-term training abroad, enabling Lao researchers and officers to learn and gain international research experience.

Irrigation system: The most important irrigation systems developed under these international assistance programs were (1) the Faay Namthane Scheme in Xayabouly province, the first large-scale irrigation scheme in Lao PDR constructed in the mid-1960s under the auspices of the United States Agency for International Development (USAID); (2) the Nam Houm Scheme in a suburb north of Vientiane Capital constructed in the late 1970s with technical assistance from the Vietnamese government--this scheme had played a very important role during the collectivization program; (3) the Nam Suang Scheme farther north of the Nam Houm Scheme constructed in the 1980s with financial assistance for water pump installation by the Mekong River Commission--this scheme also supplemented cropping under the collectivization program; and (4) irrigation systems in lowland areas along the Mekong River Valley in the central and southern regions during the 1990s and 2000s under supervision of the Department of Irrigation of the Ministry of Agriculture and Forestry.

Institutional development: Transfer of technology in terms of institutional development occurred during the "centrally planned" era between 1976 and 1985. International assistance from abroad during this period was dominated by the Union of Soviet Socialist Republics (thereafter referred to as Soviet Union) and the Socialist Republic of Vietnam. A model of large collective farming was introduced from the Soviet Union, and farmers were asked to form agricultural cooperatives in order to operate collective farming. Farmers worked in large collective farms together, and farm output belonged to each collective farm. The distribution of farm products was done by a collective management body through collective retail shops or state-owned shops. After the collapse of agricultural collectivization in the mid-1980s, farmers' perspective on agricultural cooperatives changed. At present, however, farmers realize the importance of farmer institutional development. Many farm institutional organizations such as farmer groups, water user groups, and agricultural cooperatives have been widely established.

Farm mechanization: Agricultural mechanization in Lao PDR emerged during the agricultural collectivization in the late 1970s and early 1980s to ease the shortfall of farm labor. A number of large-scale machinery, particularly large-sized tractors, were imported from the Soviet Union and distributed to farmers in the collective farms. It was reported that several factories that produce farm mechanical tools were established in Vientiane. It was the first time Lao farmers learned the use of machinery in farming. After liberalization, with easy access to regional agricultural markets, farmers returned to using machines in their farms, but they selected machinery suitable to their small farmland.

Extension service system: Extension service is an effective way to disseminate technology, know-how, and new management approaches learned from abroad to farmers. New technology and new management practices helped farmers improve farm productivity, thereby increasing their farm output. Milestones in the extension service system involved the following: (1) the establishment of the Extension Division in the Agriculture Department in 1957, with assistance from the United States Agency for International Development (USAID); (2) the establishment of the Lao national extension service system in 2001, with support from various international organizations and development partners in Lao PDR. The extension service system is under the Ministry of Agriculture and Forestry, providing extension service to farmers from the national to the village level. The National Agriculture and Forestry Extension Service (NAFES) serves as the national organization; the Provincial Agriculture and Forestry Extension Center (PAFES) in each province represents extension service at the provincial level; the District Agriculture and Forestry Extension Office (DAFEO) in each district represents extension service at the district level; and village extension workers (VEW) provide extension services to farmers in each village.

The National Agriculture and Forestry Extension Service (2005) reported on some of the most important assistance projects that helped develop the extension system in Lao PDR. These were the Pilot Extension Project – PEP (1996-1999) with technical support from the IRRI and funding by the Novartis Foundation; the Farmer Irrigated Agriculture Training (FIAT) Project (1994-1999) funded by the United Nations Development Programme (UNDP); the FAO Training in Integrated Pest Management (IPM) launched in 1996; the Lao-Swedish Forestry Programme (LSFP) (1996-2001); the Lao Extension for Agriculture Project (LEAP) (2001-2014) with support from various international organizations; and the Lao Upland Rural Advisory Services (LURAS) (2014-2017) with the assistance of the Swiss Development and Cooperation Agency (SDC), Helvetas, and the Netherland Agency for Cooperation and Development (NSV).

3.3. History of Release of Popular Rice Varieties in Lao PDR

The focus of seed-fertilizer technology transfer from abroad to Lao PDR is varietal improvement and distribution of improved varieties to farmers. This subsection reviews the history of popular rice varieties that national rice research institutions released to farmers for adoption over time. The types of varieties selected and released to farmers in different times were as follows: (1) Lao traditional varieties and modern varieties from abroad, before 1975; (2) second-generation modern varieties from abroad and elite Lao traditional varieties, 1975-1993; (3) release of modern varieties by the Lao national rice breeding program under the Lao-IRRI project, 1993-2005; and (4) locally bred modern varieties, from 2006 onward.

Release of Lao traditional varieties and modern varieties from abroad before 1975: This is the early period after a rice research institution (Salakham Station) was put in place. Its main task is seed multiplication and distribution to farmers in the mid-1960s. There was no major effort on adaptive research during this time. Most of the varieties released and distributed during that time were traditional varieties from within the country and from Thailand and modern varieties from IRRI, Thailand, and the Philippines. IR8 had also been released by the local institution in this period.

Do Nang Nuan, Do lay, and Keaw lay (early-maturing Lao glutinous traditional varieties) and Sanpatong (a photoperiod-sensitive Thai glutinous variety) were selected and released. These varieties became popular and were adopted by farmers in the mid-1960s. The glutinous endosperm type satisfied the high demand in the local markets. Another Thai improved variety from the RD series (RD6) was also very popular among Lao farmers. This variety was introduced to Lao farmers through farmer-to-farmer interaction across the Mekong River. As its grain quality was highly accepted by consumers, this variety was selected for multiplication and distribution to farmers in collective farms.

Some modern varieties from IRRI were selected and distributed to farmers by the national institution: IR2823-103, IR253-100, IR848-120, and IR8. Some of them with high yield potential (e.g., IR2823-103) were used as parent lines in the first cross-breeding venture during the 1980s. IR8 was likewise distributed to farmers, but its non-glutinous endosperm in spite of the high-yield characteristic made it less popular among farmers. Hatsadong (1986) reported that only approximately 5.3 metric tons of IR8 seeds were multiplied and distributed to farmers; no report of IR8 multiplication came after that. Compared with other IRRI varieties, higher adoption was seen in IR253-100 and IR848-120 because of their glutinous endosperm. About 157 metric tons of seed (121.4 metric tons for IR253-100, and 35.9 metric tons for IR848-120) had been multiplied and distributed to farmers by Salakham Station. Inthapanya et al. (2006) noted that the eating quality of these varieties was acceptable, but they were susceptible to multiple pests and diseases. Perhaps, because of this, farmers later stopped growing them.

It was reported that C4-63-1 (an intermediate non-glutinous type with good milling and eating quality and wide adaptability) was imported from the Philippines. More than 44 metric tons of C4-63-1 seeds had been multiplied and distributed to farmers. However, this variety has not been widely adopted by farmers because of limitations in the domestic non-glutinous rice market.

During the period before 1975, the most popular were traditional varieties with glutinous endosperm, including Do Nang Nuan, Do lay, and Keaw lay (Lao traditional variety) and the Thai traditional variety Sanpatong. Despite their low yield, they were classified by local consumers as aromatic and having good grain quality. Hatsadong (1986) stated that approximately more than 50 metric tons of their seeds were multiplied and distributed to farmers at the time. An improved Thai glutinous variety (RD6) was also reported to be popular among farmers presumably because of its aroma and good eating quality (Inthapanya et al., 2006). However, there is no accurate record on the total amount of seeds multiplied and distributed. This may be attributed to undocumented farmer-to-farmer exchange particularly across the Mekong River, where cross-border transactions are not restricted.

Overall, the main focus of rice improvement is varietal selection in the period before 1975. There was no major endeavour on adaptive research, rice improvement came through varietal selection of rice imported from abroad. The focus of varietal selection was the aromatic glutinous trait and good grain quality with less emphasis on yield. One possible reason is the fact that majority of rice farming at that time was subsistence and the money economy was not yet developed. Because of less focus on yield, rice yield in Lao PDR was dismally low, approximately 1 metric ton per hectare on average. There was little increase in rice yield in the late 1960s and early 1970s in spite of the introduction of modern rice varieties, including IR8.

Release of second-generation modern varieties from abroad and elite Lao traditional varieties, 1975-1993: Early attempt for adaptive research took place during this period with the cross-breeding of using high-yielding parental lines from IRRI and local traditional varieties. The national rice research institution released many modern varieties from abroad and some elite Lao traditional varieties. Most of these modern varieties were the second-generation type directly imported from abroad, which are high-yielding and resistant to pests and diseases. They came from IRRI, Thailand, the Philippines, Indonesia, and Vietnam. They were imported from abroad and were not developed locally. The elite Lao traditional varieties were selected for distribution to farmers as well as for use as resources for breeding. The first local cross-bred varieties were also released during this period.

Many modern varieties from IRRI were brought into Lao PDR: IR22, IR24, IR29, IR36, IR38, IR42, and IR789-98. Majority of these second generation modern varieties have short growth duration with good adaptability and good eating quality. Despite their non-glutinous endosperm, IR36, IR38, and IR42 were the three most adopted by farmers. Approximately 500 metric tons of their seeds had been multiplied and distributed to farmers. Since glutinous rice has the largest market share, the increase in non-glutinous rice area at that time might reflect the increase in rice commercialization and may relate to informal rice exportation to neighboring countries as claimed by Eliste and Santos (2012).

Most of the varieties coming from Thailand--RD8, RD10, and KDML105--are improved varieties. RD8 and RD10 were subsequently introduced to Lao farmers. Local consumers classified them as aromatic glutinous with good eating quality. RD10, a modern variety with high-yielding characteristic, had become popular among farmers. It was reported that more than 160 metric tons of RD10 seeds were multiplied and distributed to farmers during the 1980s (Hatsadong, 1986). KDML105 is an aromatic non-glutinous rice variety. Its rate of multiplication and distribution was not very high (approximately 2 metric tons), but its aroma makes it a good material for cooking popular traditional food such as fried rice. Farmers grew this rice variety to supply restaurants and to satisfy the growing demand for non-glutinous rice in urban areas.

Several improved varieties from Vietnam were also introduced: VN72, OM80, NN75-1, U9, and CR203. These varieties have non-glutinous endosperm and are high-yielding, but local consumers thought that eating quality was poor. They were not very popular and were not readily adopted by farmers. Altogether, only approximately 1.7 metric tons of their seeds were multiplied and distributed in the collective farms. No further distribution of these varieties happened. An exception was CR203, which is good for making noodles and beer. Commercial farmers still grow this variety to supply the Lao Brewery Company and noodle processors (Ingxay et al., 2016; Inthapanya et al., 2006; Schiller et al., 2006a).

One variety from Indonesia was brought in and introduced to Lao farmers. B1014-

bpN18-1-4 is a non-glutinous variety characterized by wide adaptability, resistance to some major diseases, but poor milling quality. According to Hatsadong (1986), almost 8 metric tons of this variety seeds were multiplied and distributed to farmers by a local rice research institution during the 1980s. But there was no further adoption after that.

During the late 1970s and 1980s, the local rice research institution selected and released many Lao traditional varieties, which had been identified as elite varieties: Deng home, Chao deng, Chao louk pa, Khao dork mai, Ee Khao ngan, Ee loup, Mak phai khao, Chao lep nok, Khao mae to, Khao nang dom, Khao khai, and Khao khai noi. Most of them were used as source of germplasm for breeding purposes. Only Deng home, an aromatic glutinous rice with good eating quality, was multiplied and distributed to farmers. Approximately 8.7 metric tons of its seeds were distributed to farmers during the 1980s. In 1984, the local rice research institution started releasing new, locally bred, high-yielding varieties from the SLK series to farmers, including SLK1-27, SLK1-11, SLK1-3-2, and SLK1-7-2. All of these varieties are glutinous, the progeny from the first attempt of cross-breeding using high-yielding parental lines from the IRRI and local traditional varieties. The main breeding objective was to produce high-yielding, glutinous, good-grain quality rice for local consumers. Approximately 6 metric tons of seeds of these varieties were distributed to farmers during that time, but they were not widely adopted by farmers. Eating quality as judged by local consumers was the main reason they were not widely adopted.

Rice yield had shown a substantial increase during the early and mid-1980s, which was the time when several high-yielding varieties were released. These were RD10, CR203, SLK1-27, SLK1-11, SLK1-3-2, SLK1-7-2 as well as IR42, which is resistant to major pests and diseases. Rice yield increased to 2.3 metric tons per hectare in 1986 from 1.4 in 1980. This substantial increase was attributed to the use of high-yielding and pest- and disease-resistant varieties and the adoption by farmers. Rice yield fluctuated over time until 1993; average yield was 2.3 metric tons per hectare.

Release of modern varieties of the Lao national rice breeding program under the Lao-IRRI project, 1993-2005: This is the period when major effort on adaptive research started to take place when locally bred varieties were developed and released to farmers. Since 1993, neither modern varieties nor traditional varieties from abroad have been released by local institutions. Most of the varieties coming from abroad had been used for breeding. 1993 was the year local-bred modern varieties (series of TDK, PNG, TSN, and NTN) were released. TDK is the acronym of the Tha Dork Kham rice experiment field under the Rice Research Center in Vientiane; PNG is Phone Ngam Rice Research Station in Champasak province; TSN is the Thasano Rice Research Station in Savannakhet province; and NTN refers to Namthane of the 30 Ha Rice Research Station in Xayabouly province. The TDK, PNG, and TSN varieties were very popular among farmers.

Between 1993 and 2000, four rice research institutions selected the most promising locally cross-bred varieties; altogether, nine varieties were released to farmers. They were TDK1, TDK2, TDK3, TDK4, TDK5, PNG1, PNG2, TSN1, and NTN1. All of them have glutinous endosperm, high yield, good grain quality, and relatively short growth duration, enabling farmers to adopt double cropping. They are suitable for rainfed and irrigated conditions, but most of them are susceptible to major pests and diseases. Except for upland rice (dominated by traditional varieties), rice grown in the rainfed and irrigated lowland ecosystems had been substantially replaced by these varieties (Schiller et al., 2006b). Rice yield increased and stabilized to 3.1 metric tons per hectare in 2000 from 2.3 metric tons per hectare in 1993.

Between 2001 and 2005, another eight promising varieties had been released by the local rice research institutions─TDK6, TDK7, TSN2, TSN3, TSN4, PNG3, PNG5, and PNG6. All of them are high-yielding glutinous rice with short growth duration and good grain quality. Some of them (TDK6, TDK7, and TSN2) have resistance to some major pests and diseases. Others such as TSN2, TSN4, PNG3, PNG5, and PNG6 have drought tolerance. Rice yield kept increasing during this period, reaching 3.5 metric tons per hectare in 2005.

Release of locally bred glutinous modern rices from 2006 onward: These are the subsequent varieties developed by Lao breeders under the Lao national rice breeding program. Because of the frequent occurrence of natural disasters in recent times, which resulted in huge crop losses, climate-resilient varieties became the main focus in the national varietal improvement program. In fact, an attempt to develop climate-resilient varieties started in 2003. Several drought-tolerant varieties had already been developed and released to farmers during the mid-2000s. The breeding program has successfully developed flood-tolerant varieties since 2006. These varieties have become popular among farmers in the drought-prone and flood-prone areas, especially in the central and southern regions. These varieties represent the first modern varieties developed by Lao breeders themselves after the Lao-IRRI project ended in 2005. This is a milestone in the rice history of Lao PDR that shows the improved scientific capacity of Lao rice breeders. From 2006 to 2014, Lao rice breeders had developed and released 12 promising varieties to farmers: TDK8, TDK11, TDK13, TDK1-sub-1, TSN5, TSN6, TSN7, VTE-450-1, VTE-450-2, Hom Savan, XBF2, and XBF3.

Since 2006 onward, not only the glutinous type of rice but also several non-glutinous modern rices have been developed (TDK13, VTE-450-1, Hom Savan, XBF2 and XBF3). This implies a structural change in rice market demand. All of them have high-yielding characteristic with short growth duration and resistance to major pests and diseases. Several varieties such as TDK11, TDK13, and VTE-450-2 also have resistance to toxins emerging from soil degradation. Subsequently developed were the flood-tolerant varieties such as TDK1-sub-1 and TDK13. After their release, wide adoption was seen in the flood-prone areas of the central and southern regions in particular.

In response to the recent change in rice demand structure (including rice export), the national rice breeding program further focused on developing varieties for commercial farmers. Since 2014, new modern varieties have been developed by local rice research institutions for release and distribution to farmers. Most of these varieties are aromatic and non-glutinous, which are in high demand in urban areas and foreign countries. The most popular varieties are XBF2, XBF3, and Hom Savan. These varieties were named after specific locations. XBF refers to the flood-prone area of Xebangfai plain, showing that the XBF series are characterized by flood-tolerance. Hom Savan is an aromatic variety (Hom means aromatic) and this type of rice is uniquely developed for the Savannakhet plain areas. With low amylose content (15-17%), these varieties are in very high demand among foreign markets. They have become very popular among farmers in specific areas, especially among those who grow rice on a commercial basis.

Rice yield during the early 2010s grew slowly, perhaps because of severe flooding in 2011/2012, which affected most rice-growing areas along the Mekong River (Mekong River Commission, 2012). After the release of flood-tolerant varieties in late 2012 and of subsequent rices with drought and flood tolerance, yield increased again and kept increasing after that. Rice yield reached 4.2 metric tons per hectare in 2016 from 3.5 metric tons per hectare in 2005. Figure 2.6 shows the yields of popular rice varieties released in Lao PDR from 1951 to 2016. The specific characteristics of each variety released by Lao rice research institutions are presented in Table A2.1 and A2.2 of the Appendix.

Although official statistics on rice area under modern varieties is not available, some studies have shown a gradual increase, particularly in major rice-growing areas of the country since 1976 (Table 2.2).

In this section, the history of technology transfer in the agriculture sector at the global level, the history of technology transfer from abroad to Lao PDR, and the release of popular varieties in Lao PDR were reviewed. It is obvious that rice yield and rice production have substantially and stably increased since the release of locally bred modern varieties. These varieties were developed by local rice breeders trained under the collaborative program with the international community. With the use of genetic materials from abroad and local germplasm resources, local research institutions have been able to continuously develop varieties and release these to farmers over time. Therefore, the most important element is the adaptive research capacity of local scientists.

IV. PATHWAYS OF TECHNOLOGY TRANSFER FROM ABROAD TO LAO PDR

As late as the 1940s and 1950s, Lao farmers still used primitive techniques in selecting the best seeds through simple seed selection (Appa Rao et al., 2002). Wieczorek and Wright (2012) considered this technique traditional, having been used by ancient societies a long time ago (10,000 years ago). A look at the history of agricultural development in Lao PDR shows that the science-based techniques of cross-breeding, mutation, and biotechnology (genetic engineering) have gradually been transferred from abroad through international assistance programs beginning in 1955 when the first rice research institution, the Salakham Station was established (Inthapanya et al., 2006; Thepphavong and Sipaseuth, 2007; Schiller et al., 2006a). There are three main pathways of technology transfer from abroad to Lao PDR. They involve 1) seeds and technical know-how, 2) genetic material, and 3) exchange of scientists and scientific work. This section reviews the chronological order of events in technology transfer from abroad.

4.1. Early Phase of the National Rice Breeding Program and Extension Work, 1955-75

Key events in this period are the following: (1) establishment of the very first rice research institution (Salakham Station) in 1955; (2) release of the findings on wild germplasm resources of Lao PDR by a Japanese scientist in 1957 and 1958; (3) establishment of the Extension Division of the Agriculture Department in 1957; (4) release of rice varieties from abroad such as those coming from IRRI, Thailand, and the Philippines in 1964; (5) development of the first large-scale irrigation system – the Faay Namthane Scheme in mid-1960s; and (6) the release of the very first modern rice variety (IR8), which is heralded as miracle rice in 1971.

The exchange of rice seed varieties among farmers in the border provinces of Lao PDR, Thailand, Vietnam, Cambodia, and China had been practiced for a long time (Appa Rao et al., 2002; Inthapanya et al. 2006; Schiller et al., 2006a). This was the only strategy then to improve the quality of rice seeds. It was only in the mid-1950s, through the establishment of the Salakham Station (with technical assistance from the European Economic Community [EEC] and the United Kingdom), that the varietal improvement program started in the country. Inthapanya et al. (2006) reported that breeding techniques and materials came largely from the EEC, the United States Agency for International Development (USAID), IRRI, France, Israel, Thailand, and Vietnam.

The Salakham Station had played a key role in varietal improvement in the early phase of the modern rice breeding program through varietal selection of good traditional varieties (TVs) and evaluation of modern varieties (MVs) coming from abroad for breeding purposes and also for seed multiplication and distribution to farmers. One important breakthrough is the scientific research on wild rice in Lao PDR conducted in 1957 and 1958 by a Japanese scientist (Hamada), as part of a regional study program on rice in the Mekong River countries (Kuroda et al., 2006). This study is considered until now as the most important reference on the existing rice germplasm resources of the country, which was particularly helpful to rice scientists in the early phase of the modern breeding program in the late 1950s.

In order to transfer modern rice varieties to farmers, the Extension Division of the Agriculture Department, with assistance from USAID, was established in 1957. The Extension Division played a key role in transferring know-how on modern rice varieties and related farm management practices to farmers (NAFES, 2005). To complement the work of the Extension Division, international experts who were dispatched to work in Lao PDR starting in the late 1950s focused their work on improving the capacity of local officers of the division.

Beginning in 1964, the Salakham Station started releasing key varieties from abroad to local farmers, including improved local traditional varieties such as Do Nang Nuan, Do lay, and Keaw lay (Lao traditional varieties); IR2823-103, IR253-100, IR848-120 from IRRI; Sanpatong from Thailand; and C4-63-1 from the Philippines (Inthapanya et al., 2006). RD6 from Thailand was also introduced to Lao farmers in the late 1960s; RD8 and RD10, in the late 1970s (Inthapanya et al., 2006; Hatsadong, 1986). In 1971, IR8 was distributed to Lao farmers (Schiller et al., 2006a). However, the improved traditional varieties and modern varieties released by the Salakham Station before 1975 were not popular among farmers because majority of these varieties were of the non-glutinous endosperm type, regarded by consumers as rices with low eating quality. With the exception of the RD series from Thailand, as recent as 2005, RD6, RD8, and RD10 are still being grown by some farmers in the rainfed and irrigated lowland environments (Inthapanya et al., 2006).

In addition to the modern rice breeding program, the first large-scale irrigation system (Faay Namthane Scheme) under the USAID program was constructed in the mid-1960s in Xayabouly province in the northwestern part of the country (Schiller at al., 2006a). It was also in the mid-1960s that several international experts on rice germplasm improvement, extension service, and irrigation management were dispatched to work with local officers and farmers (Chanthavong, 1996; NAFES, 2005).

In summary, 1955-75 was the early stage of the rice varietal improvement program, seed multiplication and dissemination, extension work, and development of large-scale irrigation system. The Salakham Station was the main platform in the modern rice breeding program and in the transfer of early modern rice varieties from abroad to

Lao farmers. The work of a Japanese scientist on wild rice served as an important resource in the selection of local varieties for the rice breeding program. Extension services, irrigation systems, and extension institutions were also initiated in 1955-75 in tandem with the rice varietal improvement program. This contributed significantly to the development of the rice sector in Lao PDR in the later periods.

4.2. Strengthening of the National Rice Breeding Program: 1976-1993

Key events in this period are the following: (1) first attempt on mechanization in the 1970s-1980s, (2) joint research with a Soviet Union scientist on soil mapping in the late 1970s, (3) joint research with Soviet Union scientists on yield response to fertilizer use in 1982-84, (4) Salakham Station releasing major varieties from abroad between 1977 and 1985, (5) first cross-breeding series in the 1980s in Salakham Station and the subsequent release of the SLK series developed in the Station, (6) signing of the Memorandum of Understanding between the Lao government and IRRI in 1987, (7) establishment of a consolidated national rice research network in the 1980s-90s, (8) establishment of the national rice breeding program under the Lao-IRRI project in 1991, and (9) release of the first cross-bred varieties undertaken by Lao breeders themselves (TDK series, PNG series, and TSN series described by local breeders as aromatic and glutinous modern varieties) since 1993.

After the Lao People Revolutionary Party (LPRP) came to power in late 1975, Lao PDR had been administrated under a centrally planned system for a decade from 1976 to 1985 (CPI, 2005; MICT, 2015). As in the other sectors, international collaboration in the agricultural sector was limited only to within the socialist-bloc countries, particularly Soviet Union and Vietnam (CPI, 2005; Inthapanya et al., 2006).

The major assistance programs focused on supporting "collectivization" or "cooperative movement," in line with reform on land ownership. Under the collectivization movement, farm land had been pooled together to effect large-scale farming, with the hope that this mechanism would enhance agricultural productivity and accelerate growth in agriculture and food production (Phomvihane, 1997; Stuart-Fox, 1980).

In fact, mechanization was the main priority to reduce labor shortage in large-scale farm management. Many agricultural machinery, particularly tractors from the Soviet Union, were brought in and introduced to Lao farmers in the collective farms (CPI, 2005). This mechanization in large-scale collective agriculture showed impressive results as rice production more than doubled and cash crop production more than tripled in 10 years. But post-assessment reports indicated inefficiency in production because of heavy subsidies with ineffective management in the cooperative movement (Oraboune, 2001). Growth in agriculture output was also attributed to the expansion of large-scale irrigation system during the period, allowing two crops per year.

Several international experts from the Soviet Union and Vietnam were dispatched to work in Lao PDR during the late 1970s and 1980s in order to support the cooperative movement (Arshad, 2005; Stuart-Fox, 1980). A remarkable scientific work was the comprehensive joint study between Lao and Soviet Union scientists on soils and soil-mapping conducted in the late 1970s and early 1980s; results of the study had later been used by the government for land-use planning in the late 1990s (Schiller et al., 2006a). Another scientific study was a joint Lao-Soviet Union experiment focusing on yield responsiveness of modern rices to fertilizer during 1982 and 1984 (CPI, 2005; Schiller et al., 2006a).

In terms of germplasm improvement, the Salakham Station had evaluated varieties from abroad and released several more lines and modern rices to farmers during the late 1970s and 1980s. These were IR29, IR36, and IR38 from IRRI and KDML105 from Thailand (released in 1977); IR22 and IR24 from IRRI (released in 1978) and IR789-98 (released in 1979); RD10 from Thailand (released in 1980); B1014bpN18-1-4 from Indonesia (released in 1981); RD8 from Thailand (released in 1984); VN72, OM80, NN75-1, U9, and CR203 from Vietnam (released in 1984); and IR42 from IRRI (released in 1986).

Some of these modern rices from abroad, particularly those from IRRI have resistance to multiple pests and diseases. These are called the second-generation modern rices, which are far more superior than the earlier modern rices (IR5 to IR34) in terms of yield capacity and pest and disease resistance. The first-generation modern rices are generally susceptible to attacks of pests (stem borers, brownhoppers and leafhoppers) and diseases (tungro and blight). An equally important trait of the second-generation modern rices is the shorter crop duration, enabling farmers to have two crops of rice per year under irrigated and favorably rainfed conditions.

Some promising traditional varieties were also selected and released to farmers during the 1980s: Deng home, Chao Deng, Chao Louk Pa, Khao Dork Mai, Ee Khao ngan, Ee loup, Mak phai khao, Chao lep nok, Khao mae to, Khao nang dom, Khao khai, and Khao kai noi (Hatsadong, 1986). These traditional varieties are generally resistant to pests and diseases, but their yield potential is lower compared with that of modern rices. Yet, these traditional rices are popular among farmers because of the good grain quality that commands a higher price in the market.

Following RD6, varieties RD8 and RD10 were later introduced to farmers in a village along the Mekong River in the late 1970s. They were grown by one of the agricultural cooperatives in the area afterward (Inthapanya et al., 2006). VN72, OM80, NN75-1, U9, and CR203 were brought in and introduced by a Vietnamese agricultural expert who was dispatched to work in Lao PDR (Hatsadong, 1986; Schiller et al., 2006a), but because of the non-glutinous endosperm and the low eating quality, they were not popular among farmers. CR203, a variety suitable for producing noodles and beer, is still grown by commercial farmers to supply the domestic noodle and brewery processing industries (Inthapanya et al., 2006; Hatsadong, 1986; Schiller et al, 2006a).

In the early 1980s, the Salakham Station began to undertake a series of rice crosses by using several elite local traditional varieties and high-yielding modern varieties from IRRI as parental lines to develop high-yielding glutinous modern rices. But these early crosses gave unsatisfactory results (Hatsadong, 1986; Inthapanya et al., 2006). Nevertheless, this was the very first attempt in the country to undertake cross breeding within the confines of a local scientific infrastructure with help from foreign experts. Early success in cross breeding at Salakham Station came when a few glutinous rices showed high-yield potential; these were SLK1-27, SLK1-11, SLK1-3-2, and SLK1-7-2 and they were released to farmers in 1984 (Hatsadong, 1986). In spite of their high-yield potential and moderate glutinous quality, cross breeding products from Salakham Station were not popular among farmers. Despite this, the Salakham Station produced approximately 1,000 metric tons of seeds and distributed them to farmers. Seeds of SLK1-27, SLK1-11, SLK1-3-2, and SLK1-7-2 altogether accounted for less than one per cent (0.6) of the total seeds distributed (Hatsadong, 1986; Inthapanya et al., 2006). Although these locally cross-bred modern varieties were not popular, they nevertheless represent the first successful cross-breeding endeavour undertaken within the Lao PDR and some of these locally bred rices were used as parent materials for the improvement of later locally bred modern varieties under the national rice breeding program.

After the liberalization in 1986, reform in agricultural sector was undertaken. International collaboration in agriculture has gradually been strengthened (Arshad, 2005; CPI, 2005). In 1987, the government of Lao PDR signed a collaborative Memorandum of Understanding (MOU) with IRRI, which has been, by far, the most important initiative in rice germplasm improvement and is believed to be the most important first step in the country's rice self-sufficiency program (Thepphavong and Sipaseuth, 2007; IRRI, 2016a).

After liberalization, the EEC and FAO extended support for the development of research infrastructure: rice research laboratories and seed-processing facilities at the Rice Research Center in Vientiane, the Phone Ngam Rice Research and Seed Multiplication Station (PNG) in Champasak, and the Thasano Rice Research and Seed Multiplication Station (TSN) in Savannakhet province (Inthapanya et al, 2006).

Most importantly, in the 1990s, with financial support from the government of Switzerland, a consolidated national rice research network was established by building and connecting all research infrastructure and institutional arrangements all around the rice-producing areas of the Lao PDR with technical help from IRRI (Lao-IRRI project). The national rice breeding program was officially launched in 1991 (Thepphavong and Sipaseuth, 2007) with the following the main objectives: (a) select and evaluate lines and varieties from different collaborative institutions such as IRRI, Thai-IRRI, Thai national breeding program, and other national breeding programs; (b) undertake cross-breeding to develop progeny that is suitable to the Lao agro-ecosystem, and (c) evaluate and select promising traditional varieties collected within Lao PDR (Inthapanya et al., 2006).

In the early phase of the national rice breeding program, several high-yielding and good-grain varietal lines to be used as parent materials were brought in from abroad. They included IR253-100, IR787-98, IR848-120, IR2070-423-2-5-6, IR1526-680-3, IR1561-228-3, IR2061-214-3-8-2, IR2070-414-3-9, IR9224-117-2-3-3-2, IR13240-108-2-2-3, and IR18348-36-3-3 from IRRI (Khush and Virk, 2005); SPT77149, RD1, RD6, RD23, RD10, UBN6721-B-5-6, KDML105, and Sanpatong from Thailand; PSBRC1 and PSBRC10 from the Philippine Seed Board; and CR203 and B1014 from Vietnam (Thepphavong and Sipaseuth, 2007; Xangsayasane et al., 2009). Elite traditional varieties such as the MakYom, Muang-Nga, Takhet, MakHing, Ikhao, DoYuan, and KhaoKham were also selected for cross-breeding (Thepphavong and Sipaseuth, 2007).

The Rice Research Center was upgraded to become the main institution to support research and development (R&D) in the rice sector at the national level; the Phone Ngam Rice Research and Seed Multiplication Station (PNG) was upgraded to become the regional center in charge of rice research in the southern provinces; and the Thasano Rice Research and Seed Multiplication (TSN) also to become a regional center in charge of rice research in the central provinces. Several research stations serving as regional research institutions in different parts of the country were also established, including the Namthane 30 Ha Station in Xayabouly province, the Louang Namtha Rice Research Station in Louang Namtha province, the Houay Khot Rice Research Station in Luang Prabang province, and several small agricultural research facilities established in other provinces (Inthapanya et al., 2006). With the improvement of the research infrastructure, the national rice breeding program had been strengthened and it played an important role in supporting the national rice self-sufficiency plan with technical support from IRRI (known as the Lao-IRRI project) (Thepphavong and Sipaseuth, 2007). With the birth of the Rice Research Center, the Salakham Station was downgraded to engage in seed multiplication and extension-related activities in collaboration with the Center. The two institutions are near each other, being both located in the main city of Vientiane.

Furthermore, as part of the bilateral cooperation between Lao PDR-Soviet Union and Lao PDR-Vietnam, many scholars from Lao PDR were sent to study in the Soviet Union and Vietnam during the 1980s and 1990s. While there are no accurate statistics on the number of Lao graduates from Soviet Union and Vietnam, today, many Lao officers who work in the Ministry of Agriculture and Forestry, the National Agriculture and Forestry Research Institute, the National Agriculture and Forestry Extension Service, as well as the agricultural system in Lao PDR hold degree diplomas from Vietnam and the Soviet Union. The current head of the Thasano Rice Research and Seed Multiplication Station in Savannakhet holds bachelor’s and master’s degrees in plant breeding from the Soviet Union (she studied in the Soviet Union between 1985 and 1989). After liberalization, under the Lao-IRRI project, scholarships for training and education, in particular, plant breeding and related subjects, have been provided to Lao scholars and researchers on an annual and periodic basis to enable them to study at IRRI in the Philippines (IRRI, 2016b; Thepphavong and Sipaseuth, 2007).

Overall, between 1975 and 1993, the Salakham Station played the most significant role in the country’s rice breeding program by developing locallybred modern rice varieties for the first time using breeding techniques from abroad along with parental materials sourced locally and from abroad. Agricultural mechanization took place for the first time under the agricultural cooperative movement. After liberalization in 1986, the national rice research network system was developed and it expanded with the establishment of the Rice Research Center, which became the focal institution of national rice improvement in Lao PDR, while several regional and provincial rice research institutions were established all over the country. The establishment of the national rice research infrastructure made possible by the Lao-IRRI Project initiative in 1991 is by now widely believed as the springboard of success of the rice self-sufficiency program of Lao PDR.

4.3. The National Rice Breeding Program under the Lao-IRRI Project: 1993-2005

Key events in this period are the following: (1) release of modern varieties developed by Lao breeders in the national rice research network system between 1993 and the 2000s; (2) importation of massive amount of genetic materials from IRRI and Thai-IRRI; (3) conduct of comprehensive scientific joint studies between Lao scientists and international scientists on rice germplasm in Lao PDR between 1995 and 2000; (4) establishment of the Lao National Agriculture and Agriculture Extension Service (NAFES) in 2001 and its service network system at provincial, district, and village levels; (5) strengthening of the national rice breeding program through biotechnology (genetic engineering) in collaboration with the Thai Department of Agriculture and with financial support from the Rockefeller Foundation starting in 2003; and (6) the release of drought-tolerant modern varieties for central and southern drought-prone areas, the first climate-resilient varieties developed by Lao breeders since 2004.

During the 1990s and 2000s, several IRRI rice scientists worked with local scientists and farmers in Lao PDR. The international scientists provided on-the-job training in order to transfer know-how on breeding techniques to Lao scientists. In the early stage of the Lao national rice breeding program, between 1991 and 1994, all cross-breeding efforts were done in Salakham Station. Crosses developed at this facility used the prefix SLK from early cross breeding in the 1980s. In total, 12 glutinous rice varieties of SLK (SLK1 to SLK12) were crossed (Xangsayasane, 2009), but there were no reports of the release of these varieties after the first series of SLK1. Many crosses were done in Thailand in collaboration with Thai-IRRI to select promising lines (e.g., TDK1, TDK2 and PNG1) for the Lao national breeding program. TDK1 was crossed using parental lines from Thai-IRRI (SPT77149) and IRRI (IR13423-10-2-3); TDK2 was crossed using parental lines from IRRI (IR2061-214-14-8) and Thai-IRRI (RD1); and PNG1 was crossed using parental lines from Thai-IRRI (UBN6721-13-5-6) and IRRI (IR19660-73-4-2) (Xangsayasane, 2009).

Starting in 1994, all hybridization breeding was undertaken by Lao breeders in national rice research institutions with technical assistance from international experts from IRRI (Tepphavong and Sipaseuth, 2007; Xangsayasane, 2009). From 1995 to 2004, 14 Lao breeders have been trained under the Lao-IRRI program; they did cross-breeding activities at national research institutions in the country (Thepphavong and Sipaseuth, 2007). To develop and introduce better quality varieties to farmers, the national rice breeding program focused on identifying and selecting promising lines for crossing purposes. Between 1993 and 1998, more than 2,000 genetic materials from IRRI and Thai-IRRI were introduced and used in the Lao national rice breeding program. After selecting the materials, almost 300 crosses were made by Lao breeders. Eight clones were released under the name of TDK and TSN, and 34 promising lines were identified.

The Lao-IRRI exchange of scientists enabled local scientists themselves to do cross-breeding. Using materials from IRRI, Thai-IRRI, and Thai and Vietnamese national breeding programs as well as promising lines identified within Lao PDR, 17 of the most promising modern varieties had been released to farmers for adoption; of these, seven were developed at the Rice Research Center in Vientiane (TDK1, TDK2, TDK3, TDK4, TDK5, TDK6, and TDK7); five were developed at the Phone Ngam Rice Research and Seed Multiplication Station in Champasak province (PNG1, PNG2, PNG3, PNG5, and PNG6); four were developed at the Thasano Rice Research and Seed Multiplication Station in Savannakhet province (TSN1, TSN2, TSN3, and TSN4). NTN1 was developed at the Namthane 30 Ha Station in Xayabouly province (Schiller et al., 2006a; Thepphavong and Sipaseuth, 2007; Xangsayasane et al., 2009).

From 1995 to 2000, with Switzerland's funding, a joint study on rice germplasm collection in Lao PDR between IRRI and Lao researchers was carried out (Kuroda et al., 2006; Inthapanya et al., 2006). More than 13,400 samples of rice cultivars were collected─13,192 samples were cultivated rice and 237 were wild rice species (Appa Rao et al., 1996, 1997, 1998, 1999a and b; Kuroda et al., 2006). This project further expanded the germplasm resources available to local breeders, adding to the earlier collection by Hamada in 1957 and 1958. Rice germplasm collected under the Swiss-funded project have been stored at the Lao National Rice Genebank for conservation and used as well at the International Rice Genebank for accession under the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA).

Other collaborative research programs to support the rice improvement in Lao PDR were undertaken by international and Lao researchers, including studies on pests and diseases, weed ecology, soil fertility management, upland cropping and montane paddy rice conducted in 2000s with technical support and funding by the Australian Centre for International Agriculture Research (ACIAR) and the Rockefeller Foundation. The results of these scientific works were collected and published in a book entitled “Rice in Laos” (Schiller et al., 2006c).

In 2001, NAFES was established, building upon the extension work done by Salakham Station and extension pilot projects throughout the country. Through its Technical Division, direct links were forged with the R&D arm of the National Agriculture and Forestry Research Institute (NAFRI) and the Faculty of Agriculture and Forestry (FAF) of the National University of Laos (NUOL) (NAFES, 2005). Figure 2.7 outlines the collaboration scheme between the R&D of NAFRI and the extension service of the NAFES. In terms of technology in rice sector, the rice research and seed multiplication institutions in the respective provinces produced seeds for cultivation, while know-how on growing modern varieties was provided to farmers through the Central Extension Training and Development Unit of NAFES’ Technical Division. The Division disseminated technical information to farmers through its technical agencies at the provincial level (Provincial Agriculture and Forestry Extension Service–PAFES) and district level (District Agriculture and Forestry Extension Office – DAFEO). Some extension pilot projects have been conducted in the provinces and districts, where technical information was shared upon request. Village extension workers interacted with farmers on a regular basis under the Village Extension Service System (VES) (Figure

2.8). Rice farming manuals/booklets as well as visual instruction programs have also been developed and distributed to farmers through the NAFES system. In fact, a collaboration program on extension service began in the late 1980s. It played an important role in transferring knowledge on modern varieties and farm management extensively only after the release of modern varieties in the early 1990s. Since then, more assistance programs from abroad on extension service development have been continuously provided to support agricultural development.

Starting in the early 2000s, the national rice breeding program further extended its strategy in developing climate-resilient varieties with special focus on a) evaluation and selection of varieties and lines for drought-prone areas in central and southern parts of the country; b) selection of varieties that are suitable for direct seeding in lowland environments; c) selection of varieties adaptable to low temperature in the northern lowland area as well as for other location-specific environments; and d) development of a breeding data base in Lao PDR (Inthapanya et al., 2006).

In 2003, with technical support from ACIAR and the Rockefeller Foundation, the national breeding program extended its collaboration with the Thai Department of Agriculture in order to incorporate biotechnology into rice breeding. The aim is to speed up varietal improvement focusing on climate resilience while maintaining high-yield and good grain quality (Inthapanya et al., 2006; Thepphavong and Sipaseuth, 2007). Under this collaborative program, samples of genetic materials were sent for evaluation at the National Genetic Engineering and Biotechnology Center in Thailand before doing crosses in the dark room facility of the Rice Research Center in Lao PDR. Since 2004, modern drought-tolerant varieties with high-yield and short growth duration have been released and distributed to farmers: TSN2 and TSN4 developed at the Thasano Rice Research and Seed multiplication Station in Savannakhet province; PNG3, PNG5 and PNG6, developed at the Phone Ngam Rice Research and Seed Multiplication Station in Champasak province (Inthapanya, 2013; Schiller et al., 2006a; Xangsayasane et al., 2015).

From 1993 to 2005, the rice breeding program of the Lao-IRRI project played a key role in rice germplasm improvement. On one hand, capacity building programs through exchange of scientists and scientific work had a tremendous contribution to building the capacity of local scientists. On the other hand, imported materials from IRRI, Thai-IRRI/Thailand, and Vietnam had been key resources for making varietal improvement possible. Nevertheless, the local wild rice germplasm resources collected in an earlier period and those collected between 1995 and 2000 had contributed significantly and are still playing important roles in varietal improvement up to now. The establishment of NAFES proved crucial in diffusing new technology and know-how to farmers.

4.4. The National Rice Breeding Program After the Lao-IRRI Project Ended: 2006 onward

Key events in this period are the following: (1) collaboration study between the FAO-Netherlands Partnership Program (FNPP) and NAFRI on plant breeding in conjunction with biotechnology efforts in Lao PDR in 2007, (2) subsequent release of climate-resilient modern varieties in 2012, (3) release of new types of modern varieties for commercial farming in late 2014, (4) signing of an agreement on expanding collaboration between the Lao government and IRRI in 2017, and (5) signing of a Memorandum of Understanding between NAFRI and the Thai National Science and Technology Development Agency (NSTDA) on strengthening the rice breeding program of Lao PDR in 2017.

To support the 6th National Socio-Economic Development Plan (6th NSEDP), NAFRI, in collaboration with FNPP carried out a scientific survey on plant breeding in association with biotechnology in Lao PDR in 2007 (Thapphvong and Sipaseuth, 2007). Results of the study helped the Ministry of Agriculture and Forestry to develop short- and medium-term rice research plans with special focus on the use of available plant genetic resources to support rice germplasm improvement.

Lao breeders continued to produce varieties suitable to specific locations and with different characteristics that satisfy market demand. In 2012, climate-resilient varieties with tolerance for flooding (TDK1-sub-1 and TDK13) were developed and released. These modern varieties have survival rates ranging from 80 to 97 per cent in specific submergence scenarios, while the normal varieties and only a few varieties have a survival rate of only up to 20 per cent (Xangsayasane et al., 2012, 2015). In late 2014, new commercial modern varieties were released. These new types are aromatic non-glutinous with good grain quality and tolerance for drought and flooding: Hom Savan (developed at the Thasano Rice Research and Seed Multiplication Station in Savannakhet), XBF2 and XBF3 (developed at the Xebangfai Agriculture Development Center in Khammuane province by a breeder team from the Rice Research Center) (NAFRI, 2016; Xangsayasane et al., 2015). They were very popular among commercial growers who supply both domestic and export markets. This was the first time since 1993 that the national breeding program focused on the improvement of non-glutinous varieties, implying the growing commercialization in the rice sector.

Building on the success of the early collaboration on rice germplasm improvement, the Lao government and IRRI signed an agreement on strengthening research partnership and expanding the role of the IRRI in supporting food and nutrition security in Lao PDR in mid-2017. The agreement focused on collaboration to cope with challenges posed by climate change. This collaboration was included under the auspices of the Consortium for Unfavorable Rice Environment (CURE), which dealt with livelihood improvement of rural farmers who live in the most challenged areas through climate-ready technologies.

In the same year, the NAFRI signed a Memorandum of Understanding with the Thai NSTDA for a 5-year collaboration project (2017-2022). The project focuses on collaboration between Lao and Thai scientists in improving the capacity of the Lao national rice breeding program through adoption of more advanced techniques in biotechnology and giving access to facilities in Thailand to assist the rice breeding process in Lao PDR. Several Lao breeders worked with Thai scientists in biotechnology laboratories at Thailand's Kasetsart University, doing genetic analysis and transformation work for breeding purposes. Under this program, several scholarships in plant breeding and biotechnology were provided to Lao breeders to enable them to study at Kasetsart University.

Sending local scholars to study abroad is important to learn new technologies and know-how. This had been a priority area of technology transfer since the early phase of international collaboration in Lao PDR. With IRRI assistance, several Lao local scientists and officers attended training programs in foreign countries as early as in the mid-1960s. Statistics showed that more than 260 Lao rice scientists have been trained between 1964 and 2014; more than 220 local scientists including breeders were trained and educated under the Lao-IRRI project (IRRI, 2016a, b). Figure 2.9 shows number of Lao national researchers in the agriculture sector and the proportion of researchers per farmer in Lao PDR from 2000 to 2010. In 2000, total Lao researchers in the agriculture sector were 112 (six researchers per hundred thousand farmers). The number of researchers increased to 227 in 2010, the proportion increasing to 9.3 researchers per hundred thousand farmers. The scientists and researchers who were sent to study abroad have been working in the rice research network institutions under the NAFRI. Under the national agriculture and forestry research network, these local scientists and researchers also serve as resource persons in scientific courses at the Faculty of Agriculture and Forestry (FAF) in the National University of Laos. Aside from this, their scientific works have regularly been published in peer-reviewed publications of NAFRI. Since the mid-2000s, these scientific publications have been made available online.

From 2006 onward, the Lao breeder team in each local rice research institution has played a key role in varietal improvement, focusing on climate-resilient and commercial varieties. Lao breeders greatly benefited from the capacity building activities of previous international collaboration programs. The availability of rice germplasm resources, which had been collected in the early phase of the Lao-IRRI project, is one important factor that ensured the continuity of varietal improvement efforts.

In summary, in Section IV, pathways of the seed-fertilizer technology transfer from abroad to Lao PDR through exchange of seeds and know-how, genetic materials, and scientists and scientific works are discussed. During the early period, transfer of modern rice seeds, know-how on crop growing, as well as provision of a favorable environment for the adoption of modern rice seeds were emphasized. The early rice varieties imported from abroad did not satisfy domestic consumers' preference. Massive amounts of genetic materials were imported for breeding purposes. Capacity building of local scientists was achieved through exchange of scientists and scientific work. Through this exchange, local rice germplasm was enhanced, making possible the selection of promising lines for breeding varieties with the desired traits. Through the technology transfer pathways of the seed-fertilizer technology, adaptive capacity of local scientists was developed and Lao breeders were able to produce glutinous modern varieties which was in high demand among Lao consumers. This is the reason for their wide adoption and spread all over the country. A policy environment that ensures provision of relevant technology packages (irrigation system, expansion of favorable rainfed areas, extension services) is also crucial.

Figure 2.10 summarizes the interplay and interaction between three pathways of technology transfer from abroad in rice section in Lao PDR. In the early period between 1964 and mid-1980s, seeds of rice varieties from abroad were imported and directly disseminated to farmers for adoption. This strategy, however, did not increase rice production because majority of farmers did not adopt imported seeds so adoption rate remained low levels. Since the mid-1980s, adaptive research started taking place. Only genetic materials from abroad were brought in to be used as breeding lines in the national rice breeding program. In addition, Lao rice germplasm were collected under joint-research program between international scientists and Lao scientists. These local rice germplasm resources have been used in the national rice breeding program. Skill of Lao local scientists in rice breeding have been strengthened in various capacity building programs including job-training and studying abroad. The locally bred-modern rice varieties were released to farmers for adoption and it was successfully adopted by farmers because these seeds are glutinous modern rices that fit the domestic demand and the agro-ecological condition of rice farms in Lao PDR. In collaboration with extension service system, know-how on adoption of modern rice varieties have transferred directly to farmers.

Table 2.3 highlights important milestones of technology transfer from abroad to Lao PDR in rice sector in chronological events since the science-based technique in rice selection and breeding was initiated in Lao PDR.

V. SOURCES OF YIELD GROWTH

The essential element in the Lao Green Revolution of the1990s is the growth in rice yield, which was the outcome of varietal improvement efforts led by technology adaptation from abroad with proper policy support from the public sector. In order to identify strategies to support the new rice self-sufficiency target, it is necessary to identify the factors affecting rice yield growth. The section begins with an analysis of the sources of yield growth, followed by a review of trends in modern variety adoption, fertilizer use, and mechanization in rice farming.

5.1. Sources of Yield Growth

Following Hayami and Ruttan (1985) and Barker and Herdt (1985), there are two main sources of growth in rice production: (1) growth in yield and (2) growth in area[8]. Table

[8] In identifying the sources of growth, I used the equation: $ln\ Y_i = a + b\ ln\ X_i$ where Y_i refers to total production, area, and yield and X_i refers to year. The coefficient b is the growth rate. Total area planted to rice in a year includes dry and wet season so area with double cropping is already included.

2.4 shows the percentage growth in rice production, rice yield, and area expansion between 1951 and 2016. It is divided into chronological events: before liberalization (1951-1985) in column [1]; period of release of modern rices from abroad (1986-1992) in column [2]; period of release of locally bred modern rices (1993-2005) in column [3]; period of high inflow of foreign direct investment (FDI) in the agricultural sector (2006-2016) in column [4]; and average growth percentage of rice production, rice yield, and area expansion for the whole period (1951-2016) in column [5].

On average, the growth of rice production between 1951 and 1985 was approximately 2.8 per cent per year (Column 1). Growth in yield contributed 93 per cent of the growth in rice production, whereas area expansion contributed a mere 7 per cent. Column [2] shows the average growth percentage of rice production, rice yield and rice area expansion between 1986 and 1992. On average, growth of rice production was approximately 1.9 per cent per year, lower than the 2.8 growth of production in the previous period. Rice yield growth explains the entirety of rice production growth in this period. Growth of area planted was negative, indicating that large rice lands were left fallow because collective farmlands are being divided for distribution to individual farmers after the collapse of the agricultural collectivization era.

Column [3] reports the growth in rice production, rice yield, and area between 1993 and 2005. This is the period after modern rices developed under the Lao-IRRI project were released. On average, the growth of rice production was 6.2 per cent per year (highest growth rate over other periods). Yield growth and area growth contributed equally to the 6.2 production growth rate. The period 1993-2005 was also when area planted to rice started to expand, indicating the rising profitability of rice farming due to use of modern rices.

Column [4] shows the average growth of rice production, rice yield and area expansion between 2006 and 2016. This is when Agricultural Commercialization policy was being promoted by the Lao government, resulting in a considerable increase in FDI inflow into the agriculture sector. During this period, the value of FDI inflow into agriculture sector increased almost 10 times, from USD330 million (1988-2005) to USD2.7 billion (2006-2014) (IPD, 2015). On average, the growth percentage of rice production in this period was 4.6 per cent per year, 65 per cent of which was contributed by area expansion, indicating increased commercialization of rice farming.

Column [5] shows the average growth of rice production, rice yield and area expansion for the entire period when data are available between 1951 and 2016. On average, the percentage growth of rice production was 3.3 per cent per year. That of rice yield was 2.9 per cent per year (contributing 88 per cent of total rice production growth). Area expansion was 0.4 per cent per year (contributing the remaining 12 per cent). The high percentage contribution of yield growth to rice production points to the prime importance of yield growth in rice production growth. Therefore, to accelerate growth of rice production, it is important to understand the factors affecting yield growth.

Figure 2.11 shows rice production trends in three different ecosystems in Lao PDR from 1976 and 2016, when data are available. Rice production has steadily increased since 1993, which is when the first locally bred modern rices were developed and released by Lao breeders themselves. Figure 2.11 shows that wet-season rice is the most important contributor to total rice production. While upland rice production is declining, that of dry-season rice is increasing with its contribution to total rice production rising. This implies that in order to increase total rice production, efforts should be focused on increasing production of wet- and dry-season rice. The increased production of dry-season rice is attributed to the expansion of the irrigation system and the release of shorter duration modern rices, enabling farmers to have two croppings per year. Traditional rice varieties are commonly grown once a year for 180 days during the monsoon season. The advent of shorter duration modern rices, along with availability of irrigation, allowed farmers to plant a second crop during the late monsoon season. In brief, growth of total rice production is associated with growth of wet-season and dry-season rice.

Curvature details of total rice production divided into wet, dry, and upland rice production are as follows. Figure 2.11 shows that rice production has steadily increased since 1993, which is the year the first modern varieties were released. The total rice production curve is sloping upward, parallel to the curve of the wet-season rice production. This shows that both total rice production and wet-season rice production have an increasing trend. The slope of the curve became steeper between 1998 and 2001 in conjunction with the rising curve of dry-season rice. This implies that, because of increased production of irrigated rice, total rice production increased. Before 1998, there was very little production of dry-season rice, even less than that of upland rice. The curve of the dry-season rice traces below the curve of upland rice. Comparing the curves of rice production in the three ecosystems, upland rice production shows the most flat curve among others, but it declined slightly between 1994 and 1998. During the same period, from 1995 onward, the curve of the dry-season rice went up and traced the upper the curve of upland rice. This implies that, since 1995, dry-season rice production has increased dramatically, while production of upland rice remains stable over time. It is, therefore, important to know the reasons behind the increase in production of dry-season rice. Overall, the graph shows the rising trend of rice production in Lao PDR. Since 1993, rice production has increased steadily, as indicated by a stable sloping upward curve. The curve of wet-season rice is sloping upward parallel to the total rice production curve. The curve of dry-season rice has also sloped upward since 1995, while that of upland rice has gone down during the mid-1990s, tracing flatly after that. This implies that growth of total rice production is associated with the growth of wet-season and dry-season rice.

Figure 2.12 shows the rice area planted, by ecosystem, in Lao PDR between 1976 and 2016. The curve of total rice area planted slopes upward very steeply during 1976 and 1980, indicating a sharp increase in rice area planted during that time. This increase might be because of the sharp increase in mechanization in collective farms during the period. The curve continues to rise slowly until 1982 before slowing down steadily until 1988 (lowest level since 1976). The probable cause is the process of splitting the pooled land after the collapse of agricultural collectivization. The curve fluctuated between 1988 and 1994, the period of liberalization policy implementation when many reforms were undertaken. From 1995 onward, the curve went upward stably but slowly. For wet-season rice area planted, its curve has almost the same shape as the curve of total rice area planted. The curve of dry-season rice area planted traces very low and flat between 1976 and 1990, indicating that very few areas in Lao PDR engaged in double cropping during the period before 1990. Since the early 1990s, the curve of the dry-season rice area planted went upward slowly before it further went up substantially between 1997 and 2001, implying the expansion of irrigation system in the country. From 2010 onward, the curve of dry-season rice area traces at the same level of upland rice area planted. As to upland rice area, despite it tracing lower in the graph, its curve has a shape similar to the curves of wet-season and total rice area between 1976 and 1994. Since 1994, the curve of upland rice area has gone downward steadily until 2006 and then traced flatly after that. The slow-down of the upland rice area curve may imply the implementation of the government policy on curbing slash-and-burn practices associated with upland rice farming (Kenney-Lazar, 2012; Linquit et al., 2006b). Overall, the graph shows that rice area planted in Lao PDR is on a rising trend. The increase in total rice area planted is associated with the increase in wet-season rice area planted with some level of contribution from the dry-season rice area planted.

Figure 2.13 shows trends in rice yield, by ecosystem, between 1976 and 2016. The rice yield curve went up steadily over the period from 1976 to 2016, showing a rising trend in rice yield. The curve went upward substantially in 1983 and 1986, after which it fluctuated until 1993. Between 1993 and 2013, the curve went upward steadily before it further went up sharply in 2014 and went down a little in 2015. The curve then went upward again in 2016. Rice yield in Lao PDR reached 4.2 tons per hectare. Between 1976 and 1986, the curves of the wet-season and dry-season rice yield traced at similar levels, between 1.2 and 2.6 tons per hectare. Since then, the curve of dry-season rice yield went upward on a stable manner. During 1994 and 1997, the slope of the curve went up substantially before going up sharply in 2013. The curve went down slightly in recent times. In 2016, dry-season rice yield was 5.1 tons per hectare (the highest yield among all rices grown in the three different ecosystems). As to wet-season rice yield, the slope of its curve went up steadily between 1976 and 1986 before it went down sharply between

1986 and 1988. It fluctuated between 1988 and 1994 before it became stable between 1994 and 2013. The curve went up sharply in 2014, then went down slightly in 2015 and went up again a little in 2016. In 2016, yield of wet-season rice was 4.3 tons per hectare (slightly higher than the overall average rice yield). The curve of upland rice yield, overall, traced very low in the graph despite the slight sloping up between 1976 and 2016. Yield of upland rice in 2016 was 2.1 tons per hectare (half that of overall average rice yield). The yield graph implied that the growth of rice yield in Lao PDR is driven by the growth in yield of the dry-season and wet-season rice.

No modern varieties were grown in the upland ecosystem in Lao PDR (Roder et al., 1996). A study by Linquist et al. (2006a) shows that, before 1993, approximately 95 per cent of rice grown in the rainfed (wet-season) and irrigated (dry-season) lowland were traditional varieties, but, since 2002, almost 80 per cent of the varieties grown in these areas have been modern varieties. Appa Rao et al. (2000), Inthapanya et al. (2006), and Shrestha et al. (2002) confirmed that all varieties grown in the irrigated (dry-season) lowland are modern varieties. Therefore, growth in rice yield in the rainfed and irrigated lowland is strong associated with modern variety adoption.

Basnayake et al. (2006) reported that grain yield of TDK1 (a modern glutinous variety developed under the Lao-IRRI project) grown in Vientiane had increased by 63 per cent, and that of NTN1 (another modern glutinous variety from the Lao-IRRI project) grown in Xayabouly province had increased by 75 per cent when using fertilizer. Therefore, in technical terms, to achieve potential grain yield fully, fertilizer application has to be done. Latmany et al. (2008) confirmed the importance of mechanization in Lao PDR by conducting an empirical study; they found that, in 2007, tractor-owner farmers were able to produce rice about three times higher than the non-tractor-owner farmers because of the labor-saving effect of the machine. Goto and Douangngeune (2017) further supported this finding. Empirical studies and statistics show that modern variety adoption, fertilizer use, and mechanization have strong relationships with growth in rice production. In the following part of the Section, trends of modern variety adoption, fertilizer application, and mechanization are investigated.

5.2. Trends of Modern Variety Adoption, Fertilizer Application, and Mechanization

Modern Variety Adoption

As discussed in Section IV, modern varieties had been brought into Lao PDR from abroad and they have been released to Lao farmers for adoption since 1964. However, they have not been adopted widely by farmers at that time, making the proportion of modern rice grown low, only about 5 per cent of the rice area planted with modern rice until the mid-1990s. Since 1993, locally bred varieties have been released and distributed to farmers as they were adopted by farmers on a wider scale (Inthapanya et al., 2006; Xangsayasane et al., 2009). This was due to their high-yield and glutinous endosperm, which met the high domestic market demand. Shrestha et al. (2002) reported that the average yield of these modern varieties was 66 per cent higher than that of traditional varieties and about 24 per cent higher than that of modern varieties coming from abroad. The study also shows that, by adopting these modern varieties, farmers' net income increased by 24 per cent. However, because of the unavailability of fertilizer before the mid-1990s (Pandey and Sanamongkhoun 1998), there was no full utilization of yield potential and farmers' net income only increased marginally (Shrestha et al., 2002).

In 1999, the Lao Census of Agriculture showed that the percentage of modern variety adoption by farmers was 30 per cent. Of these adopters, 47 per cent were farmers residing in lowland areas along the Mekong River Valley[9] (MAF, 1999). In 2011, the percentage of modern variety adoption increased to 46 per cent (about 16 per cent increase in 12 years). The average percentage of modern-variety-adopting farmers in the lowland ecosystem increased to 62 per cent in 2011[10]. Champasak province reported the highest percentage of farmers who have adopted modern varieties (82 per cent), followed by Savannakhet province (74 per cent), and Vientiane Capital (63 per cent) (MAF, 2011).

Figure 2.14 shows the percentage of irrigated rice area to total rice area and the percentage of modern-variety-adopting farmers in Lao PDR between 1961 and 2015. On average, total irrigated area was less than 5 per cent of total rice area. Since 1975, the percentage of irrigated area has increased steadily, close to one-fifth of total rice area in the late 1990s. After that, it declined substantially until 2015; total irrigated area was only 10.3 per cent of total rice area. This decline was attributed to the increase in area planted since 2007, including rainfed farmland, the result increased FDI inflow to the agricultural sector and also by the decreased irrigation coverage caused by severe flooding (MPI/WB/UNDP/EU, 2014).

Overall, modern variety adoption had a rising trend, especially in the lowland ecosystem where the environment is favorable and the irrigation system has been

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[9]Average of farmers in Vientiane Capital, Vientiane province, Khammuane province, Savannakhet province, Saravane province, and Champasak province.
[10]Average of farmers in Vientiane Capital, Vientiane province, Khammuane province, Savannakhet province, Saravane province, and Champasak province.

developed. The statistics also imply the positive relationship between adoption of modern varieties and expansion of irrigation systems.

Fertilizer Application

Linquist et al. (2006a) claimed that one of the main factors contributing to the slow growth of rice yield was the fact that farmers do not use fertilizer in their farms even though they have adopted modern rice. Pandey and Sanamongkhoun (1998) reported that, in 1995, only farmers in the lowland area along the Mekong River Valley applied fertilizer. Most of the fertilizer used were 16-20-0 and 46-0-0 (urea) imported from Thailand.

The Ministry of Agriculture and Forestry (1999) reported that only 18 per cent of rice growers used fertilizer in 1999. Most of them reside in provinces along the Mekong River that share a border with Thailand. The 2010/11 agriculture census showed that this increased to 55 per cent in 2011 and that approximately 80 per cent of them live in the Mekong River provinces[11], particularly in Savannakhet province (84 per cent), Vientiane Capital (83 per cent), and Champasak province (81 per cent) (MAF, 2011).

Statistics showed an increasing trend in fertilizer use as farmers learned about the yield responsiveness to fertilizer application. Infrastructure development, particularly the construction of Mekong River bridges, has contributed to the increase in fertilizer use because farmers could now access the fertilizer market in Thailand. Linquist et al. (2006a)

[11]The lowland areas along the Mekong River provinces are Vientiane Capital, Vientiane province, Khammuane province, Savannakhet province, Saravane province, and Champasak province.

and the Ministry of Agriculture and Forestry (2011) reported that all rice growers along the Mekong River near the bridge have applied fertilizer.

Trends in Agricultural Mechanization

The main agricultural machinery in the country are tractors, threshers, and rice mills.

Tractor

Arshad (2005) and the Lao Statistics Bureau (2005) reported the intensive use of agricultural machinery under the agricultural collectivization program in the mid-1970s and 1980s. Most of them were imported from the Soviet Union. Approximately 159 units of tractor had been imported and distributed to agricultural cooperatives in Vientiane in 1976 (LSB 2005). Most of the tractors used during that time were the large and medium-sized four-wheel tractors that were suitable to large farmland. Because of the increase in demand for tractor imports to ease the shortage of labor in large-scale collective farms, tractors were imported every year during the late 1970s. In 1980, the number of tractors increased to 310 units. However, after the subdivision of land, many tractors were left unused because they cannot be used in small farms. There were only about 50 units of tractors used in some large state farms in 1990.

Hatsadong et al. (2006) and Latmany et al. (2008) reported that not until 1995 did Lao farmers return to the practice of using tractors. Most of these were hand-controlled two-wheel tractors that suit small farmland, are cheaper, and have more functional capacity than large tractors. The number of tractors increased sharply from 50 units in 1990 to 596 units in 1995, and more than 90 per cent of the tractors are two-wheel-type tractors imported from Thailand (LSB, 2005). The Committee for Planning and Investment (2005) reported that after the first Lao-Thai Friendship Bridge [12] was completed in late 1994, the number of tractor-owner farmers in Vientiane increased substantially. The construction of Mekong River bridges has played an important role in farm mechanization, bringing a dramatic increase in the number of units: nearly 30,000 in 2001 and more than 92,000 in 2004 (LSB, 2005).

According to the Lao Census of Agriculture in 1998/99, the percentage of tractor-using farmers was only approximately 21 per cent in 1999.Vientiane Capital and Vientiane province had the highest percentage of tractor-using farmers at 83 per cent and 61 per cent, respectively (MAF, 1999). In 2011, this percentage tripled; more than 80 per cent of farmers using tractors resided in Vientiane Capital, Vientiane province, Khammuane province, and Savannakhet province (MAF, 2011). This implies an increase in rice commercialization.

Thresher and Rice Mills

Under Lao traditional rice farming, paddy rice is harvested and dried in the field before threshing by hand using a traditional threshing tool made of wood. The dried seeds are kept in storage near the farmer’s house. Only some amount of paddy rice is milled manually using mortar and pestle for household consumption, enough for 2 weeks’ maximum (Hatsadong et al., 2006; Linquist et al., 2006a; Shrestha, 2012). Eliste and Santos (2012) and Linquist et al. (2006a) described more milling activities with improvement in market access and increased commercialization. When this happens,

[12] The First Lao-Thai Friendship Bridge is a Mekong River bridge connecting Vientiane Capital and Nong Khai province of Thailand. This bridge was completed and was officially opened in late 1994.

demand for postharvest activities such as milling also increases. Consequently, one or two small rice mills are set up in the villages to provide milling services; at the district and provincial levels, a few large rice mills serve the commercial farmers. These events imply an early stage of evolution of the capital market in the agricultural sector. As discussed in Section II, rice millers have played a critical role in rice commercialization. Several scholars pointed to the necessity to improve milling quality to improve the competitiveness of Lao rice in foreign markets (Eliste and Santos, 2012; Ingxay et al., 2016, World Bank, 2018).

In 1999, approximately 15 per cent of farmers in Lao PDR were using threshers and rice mills. Almost 90 per cent of these machines were available only in Vientiane Capital and Vientiane province (MAF, 1999). In 2011, the percentage of machine users had increased by more than four times (MAF, 2011). On average, more than 80 per cent of farmers in Vientiane Capital and Vientiane province were using threshers and rice mills; in Savannakhet, Saravane, and Champasak provinces, the corresponding figure was 70 per cent (MAF, 2011).

VI. FACTORS AFFECTING ADOPTION OF MODERN RICE, FERTILIZER USE, AND RICE YIELD

Inasmuch as yield growth is the main source of rice production growth and as adoption of modern rice affects yield, this section identifies the factors that constrain the adoption process and those that affect rice yield.

6.1. Dataset

Data from the Lao Census of Agriculture in 1998/999 and 2010/11 were used. The 1998/99 Census is available in hard copy only, while the 2010/11 Census is available as the only computerized dataset on agriculture in the country. The sample farm household component of the Census 2010/11, which covers 41,660 households in all districts of all provinces was used. Sample villages were selected using stratified systematic probability proportional to size (PPS) sampling. The data included farm size, land tenure, land fragmentation, land use, credit, and agricultural technology, including input use and fertilizer use.

6.2. Trends in Modern Variety Adoption, Fertilizer Use, and Rice Yield

In 1999, only 30 per cent of farmers nationwide were adopting modern rice, rising to 46 per cent in 2011. In both years, the six main rice-growing provinces exhibited the highest adoption rates. Champasak had the highest adoption rate (82 per cent of famers), followed by Savannakhet (74 per cent), Vientiane Capital (63 per cent), Saravane (62 per cent), Khammuane (56 per cent), and Vientiane province (37 per cent).

In 1999, only 18 per cent of the farmers were using chemical fertilizer; such proportion increased to 55 per cent in 2011. Again, the six major rice producers had the highest percentage of farmers using fertilizer. It indicates that adoption of modern rice is followed by fertilizer adoption as yield of modern rice responds positively to high fertilizer input. The southern and central provinces near Thailand had the highest adoption of fertilizer because there was easy access to the fertilizer market in Thailand. Interestingly, the northern provinces of Phongsaly and Louang Namtha had been experiencing increasing rates of adoption because these provinces share a border with China's Yunnan province. Each province has an international checkpoint with China so farmers in these northern provinces may have gained access to Chinese fertilizer markets.

6.3. Regression Model and Results

(Non-technical readers could proceed to the end of this section while skipping the results of the regression runs.)

A probit function on the probability of using modern rice has been used (Table 2.5). The explanatory variables were (1) proportion of farm area with irrigation, (2) farm size, (3) ownership of radio and television, and (4) provincial dummies using Houaphanh as control. This province is considered the most disadvantageous in terms of remoteness and poverty situation.

The results of the probit function shows that area irrigated, farm size, and television ownership have positive impacts on the probability of using modern rice (Table 2.5). Previous literature show that irrigation is one of the most important constraints to the adoption of modern rice (David and Otsuka, 1994; Barker and Herdt, 1985; Hayami and Ruttan, 1985). This is because a large number of rice varieties were developed to thrive in irrigated lowland ecosystem. Census 2010/11 shows that one out of two farmers were using modern rices, whereas the proportion of rice land with irrigation nationwide remained low at 22 per cent. The positive sign of farm size implies that large farmers have a higher probability of adopting modern rice than small farmers because the former have better access to the credit market enabling them to buy chemical inputs (i.e. fertilizer). Ownership of television (but not of radio) increased access to information, thereby increasing the probability of using modern rice. Famers in Phongsaly and Xiengkhuang had a significantly lower probability of using modern rice relative to farmers in Houaphanh (control). After running a probit function on the probability of using fertilizer (Table 2.5) using the same set of explanatory variables as those in modern rice, it was found that the same set of variables (irrigation, farm size, television) had a positive impact on the probability of using fertilizer. Proportion of area irrigated and ownership of radio and television are endogenous variables (variable that cause reverse causality with adoption of modern rice varieties). In this case, results are merely association and not necessary causality. Nevertheless, literature on the factor affecting adoption shows that irrigation and farm size are significant factors in the uptake of modern rice (David and Otsuka, 1994).

The yield function using ordinary least squares (OLS) and two-stage least squares (2SLS) was estimated (Table 2.5). In the 2SLS, predicted the first stage was the adoption of modern rice. The results of OLS and 2SLS were fairly similar. The explanatory variables are (1) use of modern rice (1=yes), (2) use of fertilizer (1=yes), (3) percentage of area with irrigation, and (4) farm size. Fertilizer was not used in the 2SLS because the use of fertilizer and that of modern rice were highly correlated. Importantly, instrumental variables for fertilizer use such as education of farmer, tenure of farmland, and value of assets are not in the dataset. The main result is that the use of modern rice and fertilizer increased rice yield significantly. Rice yield tended to increase with irrigation. Small farms have a significantly higher yield because family farms tend to use family labor, who exerts more conscientious effort than the hired labor that is largely used in big farms. There were significant variations in rice yield across provinces after controlling for the adoption of modern rice, fertilizer use, and farm size.

Overall, what are the constraints in the adoption of modern rice? It was found that availability of irrigation is by far the most important impediment to the adoption of modern rice. Thus, it appears that the Lao government’s investment in irrigation is a step in the right direction. The most important factor affecting rice yield is use of modern rice and fertilizer. Thus, an effective extension program and a well-developed fertilizer market are necessary conditions to increase rice yield and rice production.

VII. SUMMARY AND CONCLUSION

Food security is critically important for Lao PDR as it means self-sufficiency in rice. The Lao government proclaimed that it has achieved its rice self-sufficiency target in 1999, after the country experienced rapid growth in rice production in the 1990s. Many believe that this was the outcome of successful technology transfer from abroad and adaptive research. This chapter aims to explore how technologies that were transferred from abroad have affected the growth in rice production. The focus was on modern rice varieties because it is the core component of technology transfer from abroad.

The most important finding is that adaptive research played the most significant role in increasing rice production and achieving rice self-sufficiency. It successfully tailored modern rices from abroad to suit local market preferences for glutinous rice, resulting in higher farmer adoption rates and higher production. Large-scale adoption of modern rices and rapid rice production growth took place starting in 1993 with the release of modern Lao glutinous varieties, a product of joint adaptive research efforts between IRRI and local scientists. The improved research capacity of local rice scientists, increased availability of local rice germplasm resources, and good policy undertakings such as development of irrigation system and provision of extension services are equally important pillars in launching the Lao Green Revolution in 1993.

To continue the country's Green Revolution, it is important to invest in irrigation further as its contribution to total production in the lowland irrigated ecosystem is becoming large. Also, irrigation is an important precondition to the adoption of modern rice. Improvement of extension service is critically important in order to disseminate the necessary information and know-how on modern varieties, farm management practices, and related technologies to farmers. It is also important to support commercialization in the rice sector by improving the rice supply chain and strengthening the connection between farmers and rice markets. The rice sector has been moving in the right direction since 1993 and the government has been exerting effort in implementing good policies that support smallholder farmers. It is with optimism that Lao PDR is viewed as a country that will never experience food insufficiency as far as rice is concerned.

CHAPTER III

Technology Transfer from Abroad, Commercialization and the Evolution of Maize Economy in Lao PDR

I. INTRODUCTION

Food security is critically important for a developing country in achieving the United Nations' sustainability development goals of eradicating poverty (SDG1) and ending hunger (SDG2) (UN, 2015). The World Bank (2008) defines food security as having enough food to eat (i.e., producing enough food); ability to have enough food to eat (i.e., improving capacity to gain access to food); and enough dietary food to eat (i.e., having enough nutrients from food). Together with rice, maize is one important crop grown in Asian countries. Maize is the world's number one source of feed grain, providing the required calories to both humans and animals (CGIAR[13]). Maize is a good source of calories and maize farming is a good source of income for farmers in developing countries worldwide.

Maize has the second largest area planted to cereal crops in Lao PDR. It occupies approximately 6.2 per cent of total agricultural area (254,000 ha) in 2015 (LSB, 2016). Maize is a staple crop and is used to substitute for rice when rice production is not enough, particularly in rural areas. Traditionally, maize is grown in small garden plots along the river bank. After the economic liberalization in 1986 and the subsequent introduction of the Agricultural Commercialization policy in 2002, area planted to maize, yield, and production have increased substantially. Maize production has increased from a mere 17,000 metric tons in 1961 to 41,000 metric tons in 1986 to 372,000 metric tons in 2005

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[13] https://maize.org/why-maize/

and to 1,550,000 metric tons in 2016 (FAOSTAT[14]). Maize has shifted from a traditionally subsistence crop to a commercial crop.

The increase in maize production is believed to have been driven by the increase in foreign direct investment (FDI) largely in the form of contract farming (CF), which has been emerging along the areas in the Mekong River Floodplain of Lao PDR. These areas are maize suppliers to the livestock industry in the regional and global food value chains.

The main purpose of this chapter is to identify the driving forces of the evolution of maize economy in Lao PDR. I explore three drivers: (1) government policies, more importantly the economic liberalization in 1986, Lao PDR's ascension to ASEAN in 1997, and the Agricultural Commercialization policy in 2002; (2) the transfer of new technology from abroad brought in by CF in maize, and (3) commercialization in the maize farming sector, as seen in the evolution of local maize traders and various marketing channels.

This chapter has the following main findings: First, transfer of technology from abroad through CF came through new seeds, fertilizer, herbicide, pesticide, machinery, and farm management know-how. Second, CF appeared to be an important factor stimulating the evolution of hired farm labor market because of high labor demand in land preparation and crop care. CF appeared to play fostering role in interregional labor migration to maize CF areas. Third, CF also appeared to stimulate the development of the rural nonfarm economy through the development of rural transport and trade as well as postharvest processing of maize. Interestingly, small local maize traders selling to

[14] http://www.fao.org/faostat/en/#data

domestic livestock industry have emerged. Fourth, and lastly, CF also appeared to stimulate social and economic mobility. Some farmers became traders, owners/operators of transport services, and small CF providers, shifting the mode of their livelihood away from farming to nonfarm endeavours. Obviously, CF has appeared to play a transformative role on the rural economy of Lao PDR.

This chapter has five remaining sections. Section II presents the conceptual framework. Section III deals with a literature review of CF. Section IV explores the evolution of the maize economy in the country. Section V discusses the methodology and describes the study areas. Section VI shows the results and discussion. Finally, Section VII gives the summary and conclusion.

II. CONCEPTUAL FRAMEWORK

Evolutionary forces in the maize economy

Figure 3.1 frames the evolution of maize economy in Lao PDR. There are three driving forces in the evolution of the maize economy: (1) government policies, (2) new agricultural technology brought in by CF, and (3) commercialization. The three government policies that drive the development of the maize sector are (1) economic liberalization in 1986, (2) Lao PDR's full membership in the Association of South-East Asian Nations (ASEAN) in 1997, and (3) the Agricultural Commercialization policy in relevant to FDI promotion in 2002.

With economic liberalization, FDI started coming into the local economy. Subsidiary companies of agribusiness transnational corporations (ATCs) from foreign countries have played an important role in bringing in new technologies and management practices from abroad to Lao PDR under CF agribusiness. Two main models of CF were promoted in Lao PDR, the ‘1+4’ and the ‘2+3’. The 2+3 is common in maize. The emergence and evolution of CF have accelerated maize area expansion, and new technology such as use of new seeds, fertilizer, herbicide, pesticide, and management practices have improved farm efficiency and increased yield. Consequently, growth in maize production increased, and maize emerged as a new commercial crop.

Growth in maize production has further strengthened commercialization, leading to the emergence of local traders and to the improvement of local livelihood opportunities. Both farm and non-farm employment have developed and created income opportunities to local people. The growth in maize production has boosted rural income-earning activities. Besides maize export through CF, where subsidiary companies export maize to their headquarters abroad, many local enterprises engaged in post-production processing and marketing, directly linking local maize producers to the global maize value chain.

Technology transfer from abroad and maize production growth

Figure 3.2 frames the pathways in the growth of maize production through CF. There was a boom in CF because of FDI coming from the agribusiness transnational corporations. 2+3 is the common model of maize CF in Lao PDR. Under this model, farmers are usually responsible for two key production factors: land and labor. Contractors, who often are foreign subsidiary companies, are responsible for three production factors: capital (usually refers to key inputs such as seed, fertilizer, herbicide, pesticide, and production cost [e.g., for land preparation, etc.]); technical know-how and management practices; and product markets (i.e., contractor buys all farm products from farmers). Maize area expanded, and maize yield also increased, leading to growth in maize production. CF is believed to be one major driving force in technology transfer from abroad to Lao PDR in the maize sector.

III. LITERATURE REVIEW ON CONTRACT FARMING

3.1. Definition and Types of CF

Contract farming (CF) has long been practiced in developed countries, dating back in the late 19th century (Little and Watts, 1994; Otsuka et al., 2016). Many international organizations have promoted CF especially in developing countries, believing that CF could serve as an important vehicle for agricultural modernization and poverty reduction (WB, 2008). The Food and Agriculture Organization (FAO) (2012) defines CF as an agribusiness firm, where a contractor and farmers have developed an agreement with conditions for the production and marketing of a farm product. Glover (1987), Kirsten and Sartorius (2002), and Wang et al., (2014) pointed out that CF agreements are usually made on volume, quality, timing of delivery of product, use of inputs, and price or pricing formula, which accounts for future market prices. It is strongly believed that the emergence of CF is an important means to overcome market failures in agriculture such as information asymmetry and difficulty in accessing markets (inputs, credit, products, etc.) (Glover and Kusterer, 1990; Grosh, 1994; Key and Runsten, 1999).

Generally, two types of CF have been practiced in both developed and developing countries: production contract (PC) and marketing contract (MC) (MacDonald and Korb, 2011). Quality control is not strictly followed under MC and most of the production processes are shouldered by the farmers, with majority of the products being sold domestically. PC is often used in developing countries for high-value crops with high-quality restrictions in the export markets (Key, 2005). Under PC, farmers are mainly responsible for land, labor, and equipment while the contractor provides key inputs such as credit and technical assistance. Under this system, contractor is guaranteed to receive farm quality products after harvest. As the contractor usually provides the key inputs and teaches management practices to farmers, it can be presumed that technology transfer from abroad to local farmers is often in place under PC than under MC.

The government of Lao PDR has promoted CF using two models (1+4 and 2+3). Under the 1+4 system, farmers provide only labor, whereas land[15]; key inputs such as seed, fertilizer, herbicide, pesticide; technology/management; and market access are the contractor's responsibility. Under the 2+3 system, farmers provide land[16] and labor and the contractor provides key inputs, technology/management, and the markets (NERI/PEI, 2014). In both models, key inputs and management practices are provided by contractors, commonly foreign ones. In maize, 2+3 system is common, while 1+4 is practiced in rubber. Technology transfer from abroad is ongoing under CF in Lao PDR.

3.2. Benefits of CF to Farmers and Contractors

Contract farming benefits both farmers and contractors. Farmers are benefiting from receiving key inputs, credit, technology/management skills, and institutional development. Setboonsarng et al. (2008) show that rice CF in rural Lao PDR has significantly improved small farmers' income and helped reduced poverty. Huddleston (2011) shows that by participating in CF, oil palm small farmers in the Philippines are able to gain access to agronomic advice, new technologies, and economic or other forms of assistance from foreign processing companies, which helped improve farm efficiency and household income. Miyata et al. (2009) reported contracted apple farmers having higher yield than non-contracted farmers due to technical assistance from packers. Bellemare and Novak (2015) show that engaging in CF enabled farm households in

[15] Commonly contractors were granted land concession from Lao government in operating 1+4 CF business.
[16] Under 2+3 CF system, land is under farmers' ownership, farmers use their own land in operating 2+3 CF business.

Madagascar to earn a more stable income and this helped reduce the average time of food shortage by 10 days. Here, 20 per cent of participating households were able to end their food shortage. AgriProFocus, GrowAsia, and Man (2018) confirmed that CF helped increase small farmers' income in Myanmar by linking them with production market, technology, and world standard. Overall, farmers benefit from CF participation in terms of accessing new technology, farm management practices, and credit, which helped improve farm efficiency and thereby led to increased income and reduced poverty (Minot and Ronchi, 2014; Simmons, 2002).

Several studies have also shown that contractors are benefiting from CF as it helped reduce transaction cost in agribusiness. Ramsundar and Shubhabrata (2014), for example, show that CF helped improve the competitiveness of producers of many crops in India in the era of globalization. Eaton and Shepherd (2001) show that, overall, contractors benefit in terms of gaining political acceptability, overcoming land constraints, achieving production reliability and sharing risk; quality consistency; and promotion of farm inputs.

However, some studies reported that the contribution of CF to poverty reduction is not very clear (Otsuka et al., 2016). An important reason is that CF seems to favor large farmers than poor and small farmers. The National Economic Research Institute (NERI) and Poverty and Environment Initiative (PEI) (2014) reported that CF practices in banana, cassava, and maize production in Lao PDR only had moderate contribution to poverty reduction. AgriProFocus, GrowAsia, and Man (2018) also suggested that CF can only support and facilitate some specific groups of farmers, which may not necessarily contribute to overall poverty reduction as a whole. Cahyadi and Waibel (2013) reported that the oil palm industry in Indonesia has contributed significantly to overall smallholder income, but that poorer households are often excluded from CF.

3.3. Factors Affecting Farmers' Participation in CF

Many studies have shown the reasons why small farmers are excluded from CF and what determined farmers' participation in CF. The Asian Development Bank (2015b) identifies that trust between farmers and the enterprise is very important in the potato industry in China. Barrett et al. (2012) show that the incentive for farmers in Ghana, India, Madagascar, Mozambique, and Nicaragua to participate in CF is the welfare gain associated with participation, but the reasons for nonparticipation are highly related to the extent of contract noncompliance and the considerable dynamism of the production value chains. Miyata et al. (2009) suggest that farmers in Shandong province of China decided to participate in CF because they realized income benefit from such participation.

Key and Runsten (1999) show that small farmers are often excluded from CF because of the higher transaction costs associated with providing inputs, credit, extension services, product collection, and grading. Factors to ensure that farmers would benefit from CF participation are associated with the size of land they own and their level of education. Simmons and Paul (2005) also report that farm size, farmer's age, education, and participation in farmers' group are important factors motivating farmers in East Java, Bali, and Lombok, Indonesia to participate in CF. Similarly, Chaovanapoonphol and Somyana (2018) show that age and education level of farmers have a positive association with efficiency in CF, while farm size has negative effects on maize production efficiency in Lao PDR. Arumugam and Fatimah (2010) report that the three main positive factors that influence farmers' decision to participate in CF are land ownership, land size, and education of farmers; the three main negative factors are complicated contract, lack of opportunities, and price risks.

3.4. Role of Government in CF Promotion

Several studies have identified the role of government in CF performance. Rehber (1998), for example, suggests that the key success of CF in developing countries is attributed to the consciousness of collaboration and coordination between farmers and contractors, and to effective support from the government. The National Agriculture and Forestry Research Institute (NAFRI) (2016) also suggests that the government should have comprehensive policy packages to ensure the success of rice, pig, and green bean CF in Lao PDR. However, Sukhpal (2005) argues that, although the Thai government has intervened intensively in the promotion of CF across crops and regions, the good relationship between farmers and the company through active coordination of middlemen still played a predominant role in CF operation in Thailand.

Ragasa et al. (2018) suggest that both government and donors should support maize CF in Ghana in order to ensure that local farmers adopt new technology effectively. Ha et al. (2015) also confirm that multi-stakeholder partnership and government support program are required to guarantee the success of smallholder agribusiness in rural Vietnam. Freguin-Gresh et al. (2013) show the need for pro-poor public policy support to ensure the benefits of CF to smallholders in Brazil and Latin American countries. Robert et al. (2018) suggest that, while the private sector has intensively invested in the global food value chain, there is still a critical need for public resources to finance essential public goods and services such as human capital, agricultural research, and complementary public infrastructure to ensure effectiveness in food value chain operation.

IV. THE EVOLUTION OF MAIZE ECONOMY

4.1. Where Maize is Grown

Similar to rice, maize is grown in all provinces in Lao PDR. However, statistics show that the majority of the area grown to maize is in the northern provinces[17]. Six provinces in the north accounted for almost 80 per cent of total maize area planted in the country. These are the provinces of Xayabouly, Oudomxay, Houaphan, Xiengkhouang, Louang Prabang, and Phongsaly. Table 3.1 shows that Xayabouly province has the largest area grown to maize in 2015, accounting for about one-fifth of total maize area and more than one-fourth of total maize production in Lao PDR. Oudomxay province occupies 23 per cent of total maize area and produced more than 21 per cent of total maize production in 2015. Altogether, maize area in these two provinces accounted for almost half of the total maize area and contributed almost 45 per cent of total maize production in Lao PDR.

Interestingly, with the exception of Xayabouly province, rice production in these major maize-producing provinces reportedly fell short of their rice consumption, indicating the shortage of supply of this crop (Eliste and Santos, 2012). It is reasonable therefore to presume that maize is grown to make up for the rice shortage. With liberalization, majority of the maize produced went to the animal feed industry rather than used as food. This shows that maize farming has shifted from subsistence to commercial farming.

In 1976, total maize production in Lao PDR was only 30,000 metric tons. It

[17] The eight provinces in the northern region are Phongsaly, Loaungnamtha, Oudomxay, Bokeo, Luang Prabang, Houaphanh, Sayabouly, and Xiengkhoung

increased to 66,000 metric tons in 1990 and then sharply increasing to 1.5 million metric tons in 2015. Altogether, the six provinces produced approximately 1.1 million metric tons of maize, accounting for more than 75 per cent of total maize production in Lao PDR. Because maize is marketed, even at the lowest world maize price, total maize production in Lao PDR had foreign exchange earnings of approximately US$ 130–150 million, a big income to local maize growers.

Saravane province is a special case because its maize area was only 700 ha, with total maize production of approximately 1,800 metric tons in 1990. In 2015, the area planted to maize increased to more than 4,000 ha (an almost sixfold increase) and total maize production increased to 29,000 metric tons. Also, CF in maize has become common in Saravane as it is located along the Mekong River Floodplain.

In addition to the increase in total area, maize yield has also substantially increased from 1 metric ton/ha in 1976 to 6 metric tons/ha in 2015. An interesting observation, especially since the Agricultural Commercialization policy in 2002, was the sharp increase in maize yield in the southern provinces: average maize yield ranged from 8 to 10 metric tons/ha, approximately 2 to 3 metric tons higher than the country's average maize yield. On the other hand, the average maize yield of the six major maize-producing provinces in the north was lower than the national average yield, probably because of lower fertilizer application in these provinces.

4.2. Trends in Maize Production, Area, and Yield

Trends in Maize Production

Figure 3.3 shows the trend in maize production, the area planted, and yield of maize in Lao PDR between 1961 and 2016. They occurred in three epochal periods─before liberalization (1961-1985), after liberalization (1986-2005), and the high FDI period (2006-2016). In 1961, total maize production was only approximately 17,000 metric tons. It increased to 41,000 metric tons in 1986 to 117,000 metric tons in 2000, and to 1.5 million metric tons in 2016. Between 1961 and 1975, average growth rate of maize production was approximately 4 per cent per year. During the agricultural collectivization program (1976-1985), it was 5 per cent per year. After liberalization, average growth was more than 12 per cent per year between 1986 and 2000. Since 2000, this figure has jumped to more than 80 per cent per year. Overall, a rising trend in maize production was seen in Lao PDR, which has been driven by economic liberalization beginning in 1986.

The growth in maize production is particularly the outcome of the 2002 Agricultural Commercialization policy, which has led to a sharp increase in FDI inflow into the agriculture sector. Importantly, the CF under the 2+3 system became a major platform in bringing in investment, technology, and management practices from abroad, thus accelerating growth in maize production.

Trends in Maize Area Planted

The most important contributor to total maize production growth is the expansion of area planted to maize. Between 1961 and 1985, a very small area was used to grow maize (Figure 3.3). The area planted to maize was growing very slowly during that period. Then, between 1986 and 2005, the area planted to maize started to grow dramatically; it has grown sharply since 2006 with the implementation of the Agricultural Commercialization policy.

The average growth in area planted to maize between 1961 and 1985 was approximately 7.8 per cent per year; it was 12.4 per cent per year between 1986 and 2005. Since 2006, area planted to maize has grown by more than 20 per cent per year. This is because of the high FDI inflow into the agriculture sector driven by CF.

Trends in Maize Yield

Yield is also an important contributor to the growth in maize production in Lao PDR. The graph in the right panel of Figure 3.3 shows that maize yield in Lao PDR was very low between 1961 and 1995, averaging only 1.5 metric tons/ha. Maize yield reached 2.1 metric tons/ha in 1996. It has a dramatically increased after that, reaching 3 metric tons/ha in 2004. It jumped sharply to 4.3 metric tons/ha in 2005, to 5.5 metric tons/ha in 2009, and to 6 metric tons/ha in 2015. This remarkable increase in maize yield since 2005 is believed to be driven by the adoption of new seeds, increased fertilizer application, and good farm management brought in from abroad by foreign investors in the form of CF. Overall, maize yield in Lao PDR has been sharply increasing since the mid-2000s.

4.3. Sources of Maize Production Growth

Two main contributors to maize yield growth are area planted and yield[18]. Table 3.2 shows the growth in maize production, area planted, and yield in chronological period between 1961 and 2016, when data are available. Column [1] is the period before the liberalization policy (1961-1985); column [2] is the period after liberalization (1986-2005); column [3] is the period of high FDI (2006-2016); and column [4] is the average percentage of the whole period (1961-2016).

[18] Similar to rice, I follow Hayami and Ruttan (1985) and Barker and Herdt (1985) in calculating the relative contribution of area and yield growth to output growth for estimating the output and contributors of maize production, using equation $ln\ Y_i = a + b\ ln\ X_i$. Where Y_i is total production, area, and yield, and X_i is year, and b is the annual growth rate.

Between 1961 and 1985, average growth of maize production was 2.9 per cent; that of area planted was 4.9 per cent, and that of yield was negative. This implies that area expansion explained all the production growth (column [1]). In column [2], average growth of maize production was 7.8 per cent, that of area expansion was 3.6 per cent per year, and that of yield was 4.2 per cent. Maize yield had improved and contributed to maize production growth at 54 per cent (slightly higher than area expansion's). In Column [3], average growth of maize production was 11.2 per cent per year (the highest among the other periods), that of area expansion was 7.6 per cent (contributing 68 per cent to production growth), and that of yield was 3.6 per cent (contributing 32 per cent to production growth). The lower contribution of maize yield indicated slow technical improvement in the maize sector. Column [4] shows the average figures for the whole period between 1961 and 2016. The average growth of maize production was 8.1 per cent per year, that of area expansion was 5.5 per cent (contributing 68 per cent to production growth), and that of maize yield was 2.6 per cent (contributing 32 per cent to production growth). Overall, the growth of maize production in Lao PDR is driven largely by area expansion, with modest contribution from yield improvement.

The expansion of area planted to maize is driven by the increase in FDI, which is commonly in the form of CF. The growth in maize yield is the outcome of technical improvement after new technology and farm management practices have been introduced from abroad through CF. Since 2006, CF has contributed to area expansion and yield. Looking at the data in Table 3.1, one may conclude that further improvement in yield is necessary to support the Green Revolution in maize in Lao PDR as the country's land frontier is nearly closing.

4.4. The Emergence of CF

The government of Lao PDR opened up the country in 1986 with the introduction of the "Chintanakarnmay[19]" or New Economic Mechanism (NEM) aiming at transforming the traditional way of subsistence mode of production to a market-oriented one (LPRP, 2001). In the 5th Party Congress in 1991, eight national priority programs[20] were introduced, and under the second priority program of Commodity Production Promotion, commercialization in agricultural production has been emphasized (CPI, 2005). In supporting commodity production in agriculture sector, series of decrees and legal documents were developed and released including the Contract Law in 1990, the Decree on Privatization (1990), Foreign Investment Law (1994), the 8-Year Public Investment Programs (1993-2000), the Agricultural Law (1998), Agricultural Sector Strategic Vision (1999), and Decentralization for FDI Approval Decree in 2002 and the Integrated Agricultural Development and Marketing (IADM) in 2006, which served as important vehicle in agricultural commercialization process in Lao PDR by inducing more FDI inflow into agriculture sector in two main forms of 1+4 and 2+3 CF in the Lao context. All these decrees and legal documents are commonly known as Agricultural Commercialization policy. The sharp increase in FDI in agriculture sector since the mid-2000s under the 1+4 and 2+3 have driven the emergence of CF in Lao PDR. Some important legal framework relating to Agricultural Commercialization policy are listed in Table A3.1 of the Appendix.

There was no report on CF in the Lao Census of Agriculture in 1998/99 (MAF,

[19] Chintanakarnmay means new vision.
[20] Eight National Priority Programs are 1) Food Production; 2) Commodity Production Promotion; 3) Stabilization of Shifting Cultivation; 4) Rural Development; 5) Infrastructure Development; 6) Service Sector Development; 7) Human Resource Development; and 8) Regional Economic Integration.

1999). In the 2010/11 census, CF was reported to be operated in 14 per cent of the total villages in Lao PDR (MAF, 2011). This indicates the emergence of CF in Lao PDR in very recent times. Some queries may be raised: where and which crops is CF concentrated in? What is the main reason for CF emergence in Lao PDR? What are the driving forces behind CF in Lao PDR?

The Lao Census of Agriculture 2010/11 reported that, in 14 per cent of the villages (where CF is operating), more than 76 per cent are located in the north, approximately 17 per cent are located in the central part, and the remaining 7 per cent are located in the south. CF is more concentrated in the northern provinces. Fifty-two per cent of the total villages in Houapanh province were engaged in CF (highest CF concentration in Lao PDR). Other provinces in the north also reported having a high percentage of villages engaged in CF: Luang Namtha (29 per cent), Xayabouly (25 per cent), Oudomxay (21 per cent), Bokeo (19 per cent), and Phongsaly (16 per cent). Eliste and Santos (2012) reported that some of these provinces were having a rice shortage at that time.

A crop diversification trend was observed in Lao PDR. The Lao Census of Agriculture 2010/11 reported that almost 60,000 farm households (approximately 8 per cent of rice-growing households) had shifted from rice to other crops in 2011 (MAF, 2011). Interestingly, the number of households in Phongsaly province (a province in the north sharing border with China) that made the shift increased from 700 in 1999 to 3,200 in 2011 (an almost fivefold increase in 12 years). It is reasonable to assume that the source of these non-traditional crops is China, which also serves as a major market. Some major non-rice crops that had been increasingly farmed were maize, cassava, vegetables, sugarcane, sesame, and rubber. Rubber has emerged as a permanent crop under CF very recently. The Lao Census of Agriculture 1998/99 reported zero area planted to rubber in 1999, but the 2010/11 Census reported that approximately 10 per cent of total agricultural area in Lao PDR was planted to rubber, with about 50,000 farm households being engaged in rubber plantation in 2011 (MAF, 1999, 2011). Most of rubber farming in Lao PDR was conducted under the CF 1+4 system (NERI/PEI, 2014).

There has been an increasing trend in commercialization in agriculture since the introduction of the Agricultural Commercialization policy in 2002. Only 6 per cent of farm households in Lao PDR grew commercial crops in 1999. This increased to 24 per cent in 2011 (MAF, 1999, 2011). With the Agricultural Commercialization policy, CF (1+4 and 2+3) became an important marketing approach. As indicated by farm households, several methods of commercializing their agricultural products have been used: (1) direct selling of products to processing companies; (2) selling products through brokers in their villages; (3) selling products through brokers coming from other villages; (4) selling products in the village market; and (5) contract farming (MAF, 2011). CF is an important commercialization method that is widely practiced in the northern provinces, where rice production is insufficient. The emergence of CF in rural Lao PDR, therefore, appeared to be an important avenue for rural farmers to earn income.

V. METHODOLOGY AND STUDY AREAS

5.1. Survey Area and Characteristics of Sample Households

Location

Xayabouly province in the northern part and Saravane province in the southern part were selected for assessment (Figure 3.4). Xayabouly is the top maize producer in Lao PDR. It was here that CF first emerged through the establishment of a Thai food processing company in the late 1990s. There has, since then, emerged Chinese maize CF in Xayabouly province. Two districts were selected for the surveys in Xayabouly: Parklai district, where Thai CF reportedly dominates; and Nguen district, where there was an emerging Chinese CF. Saravane district of Saravane province shares a border with Thailand and there has also been a Thai CF operating in this area since the mid-2000s. Saravane district of Saravane province was also selected for the survey.

The surveys

Data from three surveys were used for this chapter assessment: (1) NERI's household data survey in 2013; (2) the National Graduate Institute for Policy Studies (GRIPS) Emerging State Project Survey in 2017 (as panel data of 2013); and (3) National Institute for Economic Research (NIER)'s maize CF survey in 2018.

NERI's household survey in 2013 was used as benchmark, covering 121 households in three villages in Saravane province. All sample households were engaged in maize CF with a Thai subsidiary company. The GRIPS–Emerging State Project's Survey (GRIPS-ESP) in 2017 aimed to interview the same households covered by the NERI survey in 2013. The survey was able to reach 95 households out of the 121 original households in 2013. The 95 households consisted of 61 households continuing under CF and 34 households that dropped out of CF (Table A3.2 of the Appendix). The remaining 26 households migrated outside the village and could not be reached.

In Table 3.3, I show the characteristics of sample farmers. For 2013, I show the characteristics of all farmers (N=121, column A) and those farmers who continue participating in CF in 2017 (N=61, column B). The characteristics of the two sets of sample farmers (N=121, and N=61) are fairly the same.

About 70 per cent of household heads in 2013 obtained some or completed primary schooling (5 years); the corresponding percentage was 63 per cent in 2017. Average year of schooling of heads of dropped-out households was lower (3.2 years) compared to those who continued under CF (4.4 years) (Table 3.3). Those who dropped out of CF were either engaged in cassava production (which was increasingly replacing maize), involved in village nonfarm employment, or seasonally migrated to Thailand. The questionnaires used in 2013 and 2017 were the same. There were seven parts: (1) household head personal information; (2) household characteristics; (3) contract arrangement; (4) maize CF participation and gain from CF; (5) maize CF arrangement and practices; (6) maize CF and technology transfer; and (7) price, cost, and income from maize farming. Importantly, the questionnaires contained information on how CF contributed to transfer of new technology and on the sources of new technology, know-how, and management practices.

NIER's maize CF survey in 2018 employed several survey methods: key informant interviews; focus group discussions; household case studies; foreign and local contractor and trader interviews.

Key informants included eight provincial officers (two officers from the Department of Planning and Investment, two from the Department of Agriculture and Forestry, two from the Department of Industry and Commerce, and two from the Provincial Chamber of Commerce and Industry) in Saravane and Xayabouly provinces; nine district officers (one each from the District Office of Planning and Investment, Office of Agriculture and Forestry, and Office of Industry and Commerce) in Saravane district of Saravane province, and Parklai and Ngeun districts in Xayabouly province; and 15 village chiefs and 15 village commune solidarity staff from 15 villages. In total, there were 47 key informants (see details in Table A3.3 of the Appendix).

Important guideline questions asked of provincial and district officers included the following: (1) Please share with us the provincial/district policy on maize farming and maize CF in specific terms, if any. What is the main obstacle to maize CF that the province/district is facing? What is the trend in the maize sector and in maize CF in particular in the province/district? Which area in the province/district is maize CF predominant? What impact on socio-economic development of the province/district does maize CF have? What should be done to improve maize CF in the province/district and to ensure its contribution to the development of your province/district? Please share with us any other opinion related to maize farming, maize CF or CF in general in your province/district, if any.

Structured questionnaires were used to interview the 15 village chiefs and 15 village commune solidarity authorities. The questionnaire had four main parts: (1) village chief/authority information (age, education, etc.); (2) village information (population, agricultural area, maize area, etc.); (3) information on maize CF; and (4) information on public extension service. Importantly, the questionnaire gathered information on area planted under maize CF, proportion of villagers engaged in maize CF, maize CF contractors, time of maize CF emergence, and socio-economic infrastructure in the villages.

Focus group discussion: Two focus group discussions were employed in each surveyed village: one involving a general group (consisting of villagers with different professions, occupations, education levels, sex, age, seniority, etc.) and a female group (consisting of female villagers from different professions, occupations, education levels, seniority, etc.). There were 10 persons per group (details in Table A3.4 of the Appendix).

Guideline questions were used for group discussion. The important discussion topics tackled were the following: (1) situation on maize CF before and after 2010[21]; (2) how maize farming in the village is operated and who is doing what under maize CF (land preparation, plowing, weeding, fertilizing, sowing/planting, watering, harvesting, husking, drying, shelling, packaging, transporting, etc.); (3) land use for maize CF, starting year of maize CF; (4) who are maize CF providers/contractors in the village and where they are from; (5) whether villagers know where/who are the final buyers of maize products from the village; (6) whether villagers know what the maize products from their village are used for; (7) whether villagers have received any instruction/training on maize farming from any agency; (8) income from maize CF and its contribution to village development; (9) negative impact of maize CF; (10) and opinion on the future of maize CF and how to improve it in order to ensure a positive impact on the socio-economic development of the village.

Household case study: aiming to assess the reason for participating in and dropping out of CF, household case study interviews were done. The study planned to interview three categories of households in each village: (1) continuing households (those that had participated in maize CF in the last 5 years and still continue to participate in CF); (2) households that dropped out; and (3) new CF participants. In the actual surveys, out of 15 villages, only one village has all three categories of households (continuing, dropped out, and new entry households). One village has only one continuing household and 13 villages have households in only two categories (continuing and dropped-out households). In total, there were 30 household case studies 15 of which were continuing households, 14 dropped out, and one was a new participant. (Details on the household

[21] This survey is part of a study that assessed the implementation of the Lao National Agricultural Development Strategy 2001-2010; the survey focused on the period before and after 2010.

case studies are given in Table A3.5 of the Appendix).

A structured questionnaire was used to do the household case studies. The questionnaire consisted of three main parts: (1) household head information (age, education, occupation, etc.); (2) information on maize farming; and (3) other information. Importantly, the questionnaire got information on the household's commercialization purpose, participation in maize CF, new inputs (seeds, fertilizer, pesticide, herbicide, machine, etc.), management/know-how, postharvest activities, and opinion on the future of maize CF.

Foreign and local contractors and traders: the survey staff interviewed foreign and local contractors who have made contracts with local maize farmers in the areas. Three foreign contractors were interviewed (two in Saravane province and one in Xayabouly province). In Saravane, one foreign contractor came from Thailand, who reported having engaged in maize CF in the area since 2005. A Lao-American contractor from the United States reported investing in the area since 1999. In Xayabouly, there was one Chinese contractor married to a local woman who recently started providing maize CF. Additionally, also interviewed was one local maize CF contractor in Parklai district, Xayabouly province, who took over CF activities from a former Thai contractor (CP) in 2014. Furthermore, five local registered traders/collectors in the areas were also interviewed. In total, three foreign contractors, one local contractor, and five local traders were interviewed (see details in Table A3.6 of the Appendix).

Structured questionnaires were used to interview foreign contractors. The questionnaire consisted of three main parts that gathered the following data (1) foreign contractor information (age, sex, education, nationality, family, year of investment in Lao PDR, etc.); (2) information on maize CF; and (3) other information. Importantly, the questionnaire got information on CF agribusiness experience, when and why contractors invest in Lao PDR, on hiring local people, on providing new technology (seeds, fertilizer, herbicide, pesticide, machine, etc.) and management practices to farmers, on number of local farmers engaged in contractors' CF, business competition and competitors, problem solving, and other opinions.

Similarly, structured questionnaires were used to interview local contractors and local maize traders. The questionnaire gathered (1) contractors/traders' information (age, sex, education, nationality, etc.); (2) business information; and (3) other information. Importantly, the questionnaire obtained data about business startup, the motivation to run this type of business, the main buyers of the product, hiring of local labor, operating other post-harvest activities other than collecting and trading, business competition and competitors, future plan, and other opinions.

VI. RESULTS AND DISCUSSION

6.1. The Emergence of Contract Farming in Maize in Lao PDR

(1) Overview of Contract Farming

The 2013 and 2017 surveys show that CF emerged in Lao PDR during the high FDI period in the mid-2000s. In 2013, the survey covered 121 contracted farm households. Approximately 80 per cent of them had participated in CF between 2005 and 2010, and about 20 per cent had participated after 2010. The 2017 survey aimed to assess the performance of the same household participants in CF in 2013. The 2017 survey, however, was able to reach only 95 households (approximately 78.5 per cent that of 2013). The reason is the outmigration of 26 households (approximately 21.5 per cent that of 2013) at the time of the survey. Furthermore, out of the 95 households surveyed in

2017, 34 (or approximately 28 per cent that of 2013) reportedly dropped out from CF. Altogether, the dropped-out and out-migrated households made up 60 households or almost half of the 2013 households have dropped out from CF (Table 3.3).

Of 95 households in 2017, only 61 households continued to participate in CF. More than 85 per cent of CF-participating household heads of 2013 completed some years or completed entirely their primary schooling (5 years), compared with 82 per cent in 2017. The 2013 statistics of the households that continue participating in CF in 2017 are fairly similar (column 2013 (B) of Table 3.3). The average years in schooling of heads of households that continued participation in CF was 4.4 years; it was only 3.2 years for dropped-out households, implying that household heads with lower education tend to drop out from CF. Table 3.3 shows that more than 75 per cent of CF participating household heads in 2018 completed primary schooling or higher and that average years of schooling of CF continuing households was 6.2 years, higher than the average of dropped out households (5.7 years). This confirms the finding that less educated farmers are reluctant to participate in CF possibly because they have better option such as cross-border migration. Most of the jobs in Thailand for cross-border migration are low level jobs that only the less educated people are willing to take. Moreover, my finding is consistence with what other studies have found: Arumugam and Fatimah (2010), Chaovanapoonphol and Somyana (2018), Key and Runsten (1999), and Simmons and Paul (2005) concluded that education is an important determinant of smallholder participation in CF.

(2) Division of Inputs

The 2+3 system is common in maize CF in Lao PDR. It refers to the division of input responsibility between farmers and the contractor. Land and labor inputs are the farmers' responsibility under maize CF, and the remaining three inputs─ key production inputs (such as seeds, fertilizer, herbicide, pesticide, machine, etc.); investment capital (cost of land preparation, crop care, etc.); and marketing are the contractor's responsibility. In Table 3.4, I show division of input for 4 sets of farmers. In 2013, farmers included two columns (column A for the entire sample N=121, and column B, N=61 for the sample set that participated in CF in both 2013 and 2017). Results in column A and B show that division of input are the same in the entire sample and those who continued participating in CF in 2017.

In terms of land, farmers commonly provide their own land for farming under CF. The 2013 and 2018 surveys show that 100 per cent of land under maize CF was owned by farmers. The 2017 survey shows that approximately 92 per cent of land under CF was provided by farmers. Approximately 8 per cent of the farmland was provided by the contractor, and similarly to the labor cost (Table 3.4). This implies that there has been a little change in the maize CF contract arrangement on land. This change may related to the land concession that the foreign contractor received from Saravanh provincial authority. Approximately a hundred hectares of land concession were granted to a foreign contractor by Saravanh provincial authority for growing maize in response to the decline in maize areas in the province because some farmers have shifted their partial or whole of their land to cassava farming. Further investigation on the change in CF structure and its impact is needed to be carried out in the future.

For key inputs, seeds were generally provided by contractors (more than 75 per cent of farmers in the 2013 survey reported that seeds were provided by the contractor, approximately 92 per cent of farmers in the 2017 survey said so, and more than 73 per cent of farmers in the 2018 survey mentioned the same thing). Some farmers bought seeds from their own sources. In 2013, the contractor did not provide any fertilizer to the farmers at all, and less than 3 per cent of the farmers used fertilizer. The 2017 and 2018 surveys showed that contractors started to provide fertilizer to farmers, indicating that fertilizer has become increasingly important to increase production. The contractor provided more in terms of herbicide, more than 35 per cent in 2013 and almost 50 per cent in 2017. Pesticide use has an increasing trend. There was no report on pesticide use in 2013, but approximately 33 per cent of pesticides used in 2017 were provided by the contractor; it was 40 per cent in 2018. All contracted farmers in 2018 reported using pesticide, with 60 per cent of them buying pesticide on their own. The persistent use of pesticide might indicate incidence of maize infestation. Very few pieces of machinery and/or production tools were provided by the contractor. Only about 8 per cent of farmers reported receiving machines from the contractor in 2017. There was none in 2018. It was reported that, despite the introduction of some machines/tools to farmers by the contractor, farmers bought the machinery and production tools by themselves (commonly on cash basis).

Information on investment capital (such as spending on land preparation, crop care, etc.) was not available for 2013 and 2018. But the 2017 survey shows that almost 92 per cent of the farmers had to pay for these types of services by themselves. Only a mere 8.2 per cent was put under the contractor’s expense. Finally, the contractor is responsible for production marketing. In summary, land and labor were provided by the farmers, while key inputs such as seeds, fertilizer and herbicide were provided by the contractor. It is important to mention that contractors started to provide fertilizer to farmers only in 2017.

(3) Contract Stipulation

The contract is formulated according to the division of key inputs and responsibility of each contracting party. Generally, the contract specifies which contracting party would contribute to each input and in what form. Five key inputs were specified in the contract: (1) land, (2) labor, (3); capital, (4) techniques, and (5) market.

In 2013 and 2018, 100 per cent of land use under CF was set as the farmers' contribution to CF. In 2017, almost 92 per cent was set as farmers' contribution with the remaining 8 per cent regarded as concession land that contractor received from provincial authority in operating the CF business. Labor inputs were also commonly identified as farmers' contribution. In 2013 and 2018, 100 per cent of labor contribution came under farmers' responsibility. In 2017, approximately 92 per cent was under farmers' contribution and the other 8 per cent was paid by the contractor (Table 3.4). This change may also relate to change in land contribution. The arrangement of input contribution for the entire sample (N=121, column A) and the sample who participated in CF in both 2013 and 2017 (N=61, column B) is fairly similar.

There was increasing capital contribution in terms of key inputs (seeds, fertilizer, herbicide, pesticide, and production tools) by the contractor. Seed provision by the contractor in Saravane province increased from 75 per cent in 2013 to 92 per cent in 2017; fertilizer provision by the contractor increased from nil in 2013 to 41 per cent in 2017; herbicide, from 36 per cent in 2013 to 49 per cent in 2017; and pesticide, from 33 per cent in 2017 to 40 per cent in 2018. This indicates that CF tends to promote the use of modern chemical inputs, leading to increases in yield and total production growth. But, in terms of production tools, very few (8 per cent) reported having been provided by the contractor in 2017; there were none in 2013 and 2018. Production tools usually fall under farmers' responsibility. In 2013, approximately 90 per cent of the farmers bought production tools by themselves. In 2017, about 48 per cent of farmers did so, while about 8 per cent had been provided by the contractor. The use of machine tools tends to share on labor, which has become increasingly scarce with the spread of CF in rural villages.

As to production training, the contractor is supposed to provide training to farmers, but not all farmers reported receiving any training from the contractor. In 2013, approximately 36 per cent of farmers received training from the contractor, while almost half of them learned from other sources by themselves. In 2017, approximately 20 per cent had received training from the contractor and 64 per cent of them learned from other sources by themselves. In the case study of households in 2018, none of the farm households reported receiving training from any agency. Training was provided to village chiefs and heads of farmers' groups instead.

One important contribution of CF is marketing. Based on the 2+3 system, the contractor buys all the farm products from contracted farmers based on the existing market price. In 2013, more than 93 per cent of the contractors promised to buy the products from farmers (more than 90 per cent promised to buy all products from farmers, some 4 per cent promised to buy a certain volume, and less than 1 per cent would buy on the basis of specific quality standards). In 2017, more than 98 per cent of the products under CF were to be purchased by the contractor, but about 54 per cent would be based on certain quality standards. In many cases, under CF, farmers were assured of a ready market for their maize.

(4) Credit Arrangement

Glover and Kusterer (1990), Grosh, (1994), and Key and Runsten (1999) explained that

CF is a mechanism to help overcome market failure, particularly easing access to inputs, products, as well as credit markets. Under the 2+3 system, some credit arrangement was made between the contractor and the farmers.

Table 3.5 shows the credit arrangement set up with farmers by the contractor under maize CF in Lao PDR. Most of the key inputs under CF were given to farmers on credit. Most farmers received seeds in advance from the contractor on credit terms (about 75 per cent of farmers under CF received seeds on credit in 2013; it was 92 per cent in 2017 and 73 per cent in 2018). For fertilizer and pesticide, no farmer in 2013 received any of these inputs under credit. Farmers received herbicide on credit as early as 2013; credit on fertilizer started in 2017. In short, under CF, farmers were able to use modern chemical inputs through advance credit. A system of tied-in credit (Stiglitz, 1974) for key inputs fairly similar to the landlord-tenant arrangement under share tenancy in Asia appears to have emerged in CF.

(5) Farm Production Training

Farmers benefit from participation in CF because they learn new management practices and know-how from capacity building/training activities provided by the contractor. This is a major feature of CF for technology transfer from abroad.

Table 3.6 reports technical benefits that farmers received in terms of capacity building. In 2013, approximately 36.4 per cent of the farmers received training on production techniques from the contractor─53.7 per cent reported learning by themselves and almost 10 per cent received training from other sources. In 2017, approximately 52.5 per cent of farmers under CF reported being trained on farm management. Aside from being provided new key inputs, farmers were also trained on how to apply such inputs.

Approximately 40.9 per cent of them reported receiving instructions on how to apply fertilizer; 49.2 per cent, on pesticide use; 32.8 per cent, on herbicide use; and another 8.2 per cent, on machinery use. Obviously, CF provided both modern inputs and know-how from abroad. But not all farmers under CF benefited from capacity training programs provided by the contractor.

In a 2018 case study, despite some training given by foreign contractors, not all households surveyed received any training from any agency. This was because training was provided only to the village chiefs and/or heads of farmers' groups, in the hope that they would later transfer the knowledge to other farmers in the village and/or groups. This did not happen, however.

(6) Market Price

In terms of pricing, the current market price is commonly used as price determinant. Based on market price, the value of the farm product is calculated, after which the cost of inputs provided by the contractor in advance on credit is deducted. The farmer gets the remaining price value. This arrangement is fairly similar to that operating under share tenancy.

In 2013, a minimum price was set in the contract: from 700 kip (US$0.08) to 1,000 kip (US$0.12) per kilogram, while approximately 32 per cent of the contracts followed certain quality standards in determining the price. Majority of the farmers received money from the contractor the day after price calculation, but approximately 12 per cent of farmers reported getting money between 120 and 150 days after the delivery of maize products to the contractor. In a way, farmers have advanced credit to the CF contractor by way of delayed payment.

In 2017, 54 per cent of the contracts determined the price based on certain quality standards; approximately 84 per cent reported that a minimum price was set. Majority of the farmers received money on the same day price was calculated, but some 4 per cent reported receiving money afterward, usually between 90 and 125 days. In 2018, market price was applied but a minimum price was set at the beginning of the season. This minimum price was based on guidelines set by the provincial authority. Maize pricing based on quality standard is a new phenomenon, brought in only by CF. This indicates that markets exist for maize with different quality traits.

(7) Farm Labor Usage and Postharvest Activities

Family labor constitutes the main source of labor in maize farming. Table 3.7 shows the labor use trend among sample households in the study villages. In 2013, on average, time used for land preparation (such as land clearing, plowing, etc.) took about 10.3 days for a farm household where, approximately 7.4 family labor was used in handling the activity and only 0.6 hired labor added. In 2017, average use of family labor decreased to 5.4, while use of hired labor increased to 1.4 per household. This more-than-double increase in hired labor use per household from 2013 and 2017 indicates an increase in farm laborers to meet the high demand for labor. The increase in demand for hired labor indicates the large evolution of the labor market in rural Lao PDR. This phenomenon was also observed during the early phase of the Green Revolution in Asia, where hired labor was used for crop care, harvesting, and threshing.

As to planting and crop care, a farm household used 7.5 family labor and 1.5 hired labor in 2013; in 2017, the figures were 7.7 family labor and 0.7 hired labor. For harvesting, a farm household used 3.8 family labor and 0.8 hired labor on average in 2013.

In 2017, a farm household used 2.7 family labor and 0.4 hired labor. For postharvest activity, there was no report on husking and shelling activities undertaken by farm households in 2013. But, in 2017, farm household use averaged about 3.3 family labor and 0.7 hired labor on husking and shelling. For transportation, about 6.9 family labor and 0.3 hired labor were used per household on average in 2013, but the figures decreased to 1.7 labor and no hired labor, indicating that some farm families might have given up handling transportation activity by themselves and have availed of transportation services from providers.

Maize CF has contributed to farm and nonfarm employment. Land preparation, planting, and crop care are the most labor-intensive segments that need hired labor. The 2018 survey reported the emergence of some transportation services. Better-off farm households have shifted to providing transportation services to other farmers. Overall, a CF-participating household had, on average, 24 farm labor-days during the whole harvest season. This was a quite substantial increase as the hired labor market did not exist before the advent of CF.

It is important to note that, however, labor shortages appear to be increasingly manifested in rural areas as regional migration started to take place in areas with high labor demand. The Lao Expenditure and Consumption Surveys show an increase in wages between 2003 and 2013 by about threefold increased from approximately LAK 11,440 in 2003 to LAK 34,000 kip in 2013[22]. The government has also increased the minimum wage from LAK 900,000 to 1,100,000 per person per month starting from May,

[22] The 3rd Lao Expenditure and Consumption Survey (LECS3) in 2002/03 reported on labor wage of rice farming, was LAK 11,441 per labor per day for planting in 401 villages, and LAK 11,380 per labor per day for harvesting. LECS5 in 2012/13 reported that average wage for planting in 429 village was LAK 33,900 per labor per day, and for harvesting was LAK 34,000 per labor per day in 437 villages.

2018.

(8) Competition in CF

In terms of competition in CF, most foreign and local contractors reported that the emergence of informal maize traders created a major pressure on contractors. These informal traders usually offered higher prices to farmers, which led to side-selling and breaking of contract agreements in many cases. The 2017 survey reported more than 100 cases of side-selling in the maize CF of the Thai Company in Saravane district of Saravane province. The problem remains unsolved. The presence of informal maize traders who sell maize to the local livestock industry indicates the development of this industry and competitive market pressure in the maize market.

Aside from side-selling, another problem for the CF contractor was the shift to other crops such as cassava and rubber, which are also under CF but under a different company. Majority of cassava CF are local CF providers, who are sub-contractors of foreign cassava-flour processing factories. Rubber CF in the northern region is dominated by Chinese investors, while rubber CF in central and southern regions is dominated by Vietnamese investors (Schonweger, Heinimann, Epprecht, Lu, and Thalongsengchanh, 2012). To stabilize the maize farming business, contractors have reshaped their business into other more secure forms. The Thai Company in Saravane, for example, has gotten a land concession from Saravane provincial authority (approximately 100 ha) for growing maize to replace the decline in maize area under CF. Some maize CF companies also buy cassava from their contracted farmers, and sell to cassava-flour processing factories in the country. From this point of view, contractors reported that competition in recruiting farmers in CF was not seriously contested. However, there is a need to improve CF legal framework in order to solve the problems and ensuring that CF could bring benefits to smallholder farmers and rural development as a whole.

6.2. Contract Farming and Its Contribution to the Evolution of the Maize Economy

(1) Case Study of a Thai Company in Saravane Province[23]

The Chanasay Import-Export Company (a Thai-subsidiary company – hereafter referred to as the Thai company) came to invest in Saravane district of Saravane province in 2005. This company has operated agribusiness ventures under CF in Thailand for more than 60 years. The Thai company supplies all agricultural products to the Charoen Pokphand Group (a leading food industry corporation in Thailand – hereafter referred to as CP). Under the CF's food value chain, maize products are used to produce animal feeds. The Thai company was motivated to cross borders and operate maize CF in Saravane province for two reasons: (1) area planted to maize in Thailand is declining as many maize growers in Thailand had shifted to other crops, particularly rubber; (2) the CP has expanded its animal feed and livestock section in Lao PDR (three CP feed factories and several chicken farms are operating in Lao PDR). About 90 per cent of the maize products that the Thai company collected from local contracted farmers were supplied to the CP feed factory in Vientiane, with the remaining 10 per cent exported to the CP headquarters in Thailand.

The Thai company set up a small drying field equipped with small machines in Saravane district to do simple shelling, drying, and packaging activities before delivering the product to the CP factory in Vientiane. Thirty employees work in the Thai company's

[23] Information provided in the case study is based on an interview of the 41-year-old Thai manager of the company.

office and drying field, 20 of whom are local villagers. At present, the Thai company has contracts with more than 2,000 farm households in nearby villages. Under the Thai company's CF, key inputs particularly seeds, fertilizer and herbicide were provided to farmers in advance on credit. This arrangement is fairly similar to the arrangement between a landlord and a share tenant in which the former advances credit to the latter for key inputs and then deduct the cost of these inputs from the share of the tenant. After harvesting, contracted farmers sell maize products to the company based on market price. Expenses on key inputs that the company provided in advance were deducted before paying the farmers. In CF, a minimum price guarantee was set based on general instructions from the provincial authority. In the case when market price was lower than the minimum price, the government-guaranteed minimum price was used for the transaction.

The contract was developed by the Thai company with individual farm households, witnessed by the village chief and/or head of farmers' group in the maize growers' village. There is no report of other public agencies participating in contract formation. Optionally, the Thai company sells maize-sowing machines to farmers on demand. However, only a few better-off farmers bought the machine for use in maize farming. Furthermore, the Thai company also provides farm management training to contracted farmers but only through the village chiefs and/or head of farmers' groups of the contracted maize growers' villages. The farmers were not directly trained. According to the Thai company, the low education level of farmers necessitated only face-to-face instruction in this area. This type of instruction, however, is costly and time-consuming when compared with other methods (paper manuals, visualization, video, etc.). This is the main reason why the Thai company only offered training through village chiefs and/or heads of farmers' group. The aim is to convey technical information to other contracted farmers through them. The household case studies, however, revealed that no such training on maize farming occurred.

One important issue is whether CF has been an important factor stimulating the development of the rural labor market. Under maize CF, it is common to use hired labor due to the higher labor demand in intensive farming. Due to the increase in demand for hired labor since the start of CF, hired farm laborers (some local; others migrants) have emerged in the villages.

CF also appeared in stimulating the development of the rural transport sector. It was reported that demand for transportation to transport maize from the farm to the company's field collection site after harvest increased, leading to the emergence of transportation services in the villages. Better-off farmers and normally those who own at least a tractor have provided transportation services to other farmers in the villages. It was also reported that some tractor-owner farmers, who used to grow maize under CF, have shifted to giving full-time transportation services. It was reported that land preparation and transportation services emerged in the villages several years ago, initiated by a villager who migrated from Xayabouly province and has experience in maize CF. Some of those who provided transportation service turned to be seed and input providers as well and later operated small-scale maize CF with other farmers in the villages. Furthermore, after the harvest season, several informal maize traders came to the villages. Some were from Vietnam and others came from other areas. This indicates the early evolution of the trade and transport sector in the villages stimulated by CF.

The maize economy evolution is illustrated in Figure 3.5. Maize products from rural villages have been used as input for animal feed processing (CP Vientiane factory[24]). After processing, some parts of the animal feed products are exported to the headquarters of the CP Group in Thailand. Other parts of the animal feed products went to the domestic livestock industry. Local traders in the villages also sold maize from farmers to the domestic livestock industry. Meat products were supplied to domestic wholesalers and retailers before they reach final meat consumers in Lao PDR.

Overall, Figure 3.5 demonstrates the evolution of the maize economy along the global and domestic food value chains. CF has apparently played an evolutionary role in diversifying the rural livelihood system in Saravane province. Under CF, new technology in the form of seeds, fertilizer, herbicide, and pesticide, and management practices from abroad were brought in. The new technology and management practices helped improve maize farming efficiency, leading to growth in maize production. On the other hand, adoption of new technology and management practices led to intensive farming system demanding labor-intensive farming. Consequently, the hired farm labor market has emerged to meet the increasing labor demand in maize production. Additionally, the maize economy has stimulated the evolution of the rural nonfarm economy by creating nonfarm livelihood opportunities to the local people. They engaged in transportation service, local maize trading, small-scale maize CF, and postharvest processing. Furthermore, maize CF has directly linked local smallholder producers to the global food value chains through integration into animal feed processing and livestock industries.

Some drop-out cases under the Thai company's CF have been reported. Side-selling and contract violations have likewise been observed.

[24] The CP Vientiane animal feed processing factory is a subsidiary company of the CP Group in Thailand.

(2) Case Study of a Lao-American Company in Saravane Province[25]

The Southern Livestock Farm, owned by a Lao-American businessman (hereafter referred to as Lao-American company), started investing in pig and poultry farms in Saravane province in 1999. The Lao-American company, on its first decade in business, purchased animal feed products from Thailand. Because of the growing domestic demand for pig and poultry, which accelerated the demand for animal feed, the Lao-American company decided to set up a small-scale animal feed processing facility in its farm in 2008. The aim was to cut the cost of acquiring animal feed from Thailand. Since then, the Lao-American company has operated maize CF in Saravane province.

In total, only 44 farmer households in 14 villages were involved in the Lao-American company's CF. The contract terms and conditions were similar to those established by the Thai company in Saravane province. Despite its small size, the maize CF contribution to the rural economy came in the form of local farm and nonfarm employment opportunities and services along its supply chain (Figure 3.6). The difference is that, unlike the CP of Thailand, the Lao-American company did not engage in the export of maize or livestock. However, it was reported that local maize traders in the villages also supplied maize products bought from farmers to an import-export company who might have exported maize products abroad.

There is no report on farm households dropping out under the Lao-American CF. No side-selling and/or breaking of contracts were seen. Some farmers sold additional maize products that they produced to other maize traders.

[25] Information provided in this case study is based on an interview of 26 year-old Lao manager of the company.

(3) Case Study of a Lao Contractor in Parklai District, Xayabouly Province[26]

Parklai district of Xayabouly province is said to be the first area in Lao PDR where maize CF emerged. CP, a Thai Company, was also reported as the first maize CF provider in this district. The CP has operated CF in Parklai for a decade, between the early 2000s and 2014. Since then the Lao Maize Producing Enterprise (hereafter referred to as Parklai Company) has taken over the maize CF business from CP in Parklai district). The Parklai Company began its business in 2006 as a maize trading company that deals with maize collection for CP. It took over the maize CF business after the CP left. The Parklai Company still sells maize products to the CP branch located in Vientiane.

The Parklai Company has contract arrangements with 132 farm households in 12 villages of Parklai district. There were 50 local employees operating the Parklai Company's business activities. The CF system being followed was similar to those implemented by the Thai and Lao-American companies in Saravane province. However, the main difference was that the Parklai Company did not provide management practices and training directly. It was the CP branch in Vientiane that gave farm management training to the Parklai Company. The seeds, fertilizer, herbicide, pesticide, and other key inputs that the Parklai Company distributed to farmers also came from the CP. This implies that the Parklai Company has overtaken only the financial operation while the other business processes are still under CP. This is fairly comparable to a production CF where quality control is strictly observed. Side-selling and violation of contracts were experienced by the company. No drop-out was reported, however.

Figure 3.7 shows the evolution of the maize economy along the domestic and

[26]Information provided in this case study is based on an interview with a 53-year-old Lao entrepreneur.

global value chains as it relates to maize CF in Parklai district. The flow of maize products along the food value chains and the pattern of livelihood development were similar to those seen in the Thai company's case in Saravane province. There were differences though: (1) the contract terms were implemented by a local company (Parklai Company); (2) some contracting farmers who practiced maize CF during the CP period have developed trade networks with Thai middlemen and sold their maize products directly to Thailand through these Thai middlemen; and (3) some local traders in Parklai district reported selling their maize products to China, indicating local trade integration with this country.

(4) Case Study of a Chinese Contractor in Ngeun District, Xayabouly Province[27]

Maize CF in Ngeun district in Xayabouly province has emerged in recent years with the rising demand for maize from China. CF in Ngeun district was operated by a Chinese investor (hereafter referred to as Chinese Company) who married a local Lao woman in Ngeun district. There is no accurate number of local maize farmers engaged in maize CF under the Chinese Company. It was reported that the Chinese CF is based on verbal contract. The Chinese provided key inputs to farmers in advance on credit without any formal written contract, only a small memo noting the details of key inputs with cost value. After harvest, farmers sold the maize products to the Chinese Company using current market prices. The cost of key inputs was deducted based on the memo and the farmers were paid the remaining amount.

Figure 3.8 shows the evolution of the maize economy through maize CF in Ngeun district along the domestic and global food value chains. Generally, the maize product

[27]Information provided in this case study is based on an interview with a 26-year-old woman, the wife of the Chinese company's owner.

flow along the value chains was the same as those seen in the three previous companies. The differences are as follows: (1) the Chinese Company sold maize products from Ngeun district directly to China; (2) there emerged more maize traders (including Lao, Vietnamese, and Chinese) who came to buy maize products from farmers during harvest season; and (3) the Chinese Company as well as local traders have to get export permission from the Agricultural Products Export-Import Enterprise in Oudomxay province (hereafter referred to as Oudomxay Company). The Oudomxay Company regulates the export of agricultural products to China, including maize. Side-selling and contract breakups often occurred in the area.

Based on mix-methods of data analysis, the evolution of maize economy in rural villages of Lao PDR can be displayed in Figure 3.9, showing how smallholder farmers in rural village have been linked with larger domestic and global markets, and the contribution of maize CF on rural development in Lao PDR. Figure 3.9 shows that the Agribusiness Transnational Corporations (ATCs) in linking maize farmers in rural Lao PDR with global food industry by opening their subsidiary companies in rural village to operate CF business in line with the Lao government policy of 1+4 and 2+3 system. The subsidiary companies export maize to their headquarters in abroad to supply in global markets. Based on the surveys, however, majority of maize products from the CF business appeared to supply to domestic animal feed processing industry in Lao PDR. Interestingly, the animal feed processing factories appeared to be subsidiary companies of the global food industry. The animal feed processing factories export their product to their headquarters in abroad and supply large parts to domestic livestock industry. Similarly for the livestock industry, large livestock farms appeared to be under foreign direct investment. The livestock industry supply meat products mainly to domestic consumers in Lao PDR.

Figure 3.9 also shows how maize CF has contributed to rural village development. Due to the increase in investment in maize farming, the adoption of new technology and good management practices with more intensive works requirement under CF, maize production has increased substantially. Because of this, it appeared that the intensive work under CF has stimulated the emergence of hired farm laborers in rural livelihood. With increasing demand for transportation in transporting maize products from farm to the contractor's collecting field, this services also appeared to emerge in the villages. Furthermore, due to the expansion in maize markets, local traders appeared to emerge across the country. Similarly for farmers who have developed trading network have shifted to become CF providers to other farmers. Both local traders and CF providers have further induced maize production in rural village in order to supply domestic demand of the food industry and export to foreign countries through the agricultural import-export enterprises. Finally, the survey found that some farmers have exported maize products to foreign countries directly through the foreign middlemen who have been their trade partners for a long time.

VII. SUMMARY AND CONCLUSION

In Lao PDR, maize used to be grown as a subsistence crop, mainly for home consumption. But, recently, maize has emerged as a commercial crop. The emergence of CF is the main contributing factor to this development. Maize CF is believed to have contributed to the improvement of farmers' income, food security, and poverty reduction in Lao PDR (Douangsavanh and Bouahom, 2006; Thanichanon et al., 2018). The evolutionary forces that pushed the emergence of maize CF are government policies, new technology transfer from abroad, and commercialization. The promulgation of economic liberalization, integration with ASEAN, and Agricultural Commercialization policy led to the inflow of FDI into the agriculture sector, commonly in the form of CF. Under maize CF, modern technologies from abroad such as seeds, fertilizer, herbicide, pesticide and machine as well as management know-how have been transferred to local farmers. In addition, under CF, maize farmers were assured of a market for their produce at favorable prices (following either the government-guaranteed price or the current market price, whichever is higher).

The objective of this chapter is to illustrate the evolution of the maize economy in Lao PDR by analyzing the emergence of maize CF and its effects on the rural livelihood system. These are the main findings: First, transfer of new technology from abroad through CF came through the introduction of new seeds, fertilizer, herbicide, pesticide, machine, and farm management know-how. Second, CF appeared to be an important factor stimulating the evolution of hired farm labor market because of the high labor demand in land preparation and crop care. CF appeared to play fostering role in inter-regional labor migration to CF areas. Third, CF also appeared to stimulate the rural nonfarm economy through the development of rural transport and trade as well as postharvest processing of maize. Interestingly, small local maize traders selling to domestic livestock industry have emerged. Fourth, CF has shown a stimulating role in social and economic mobility. Some farmers became traders, owners/operators of transport services, and small CF providers shifted their means of livelihood away from farming to nonfarm endeavours.

Apparently, CF has been an important venue in transferring new technology from abroad to farmers, transforming maize production away from subsistence mode to commercial mode. This transformation is facilitated by farmers' access to credit from contractors, which are tied to the purchase of modern inputs as new seeds, fertilizer, herbicide, and machinery. The speed by which CF evolved is accompanied by the development of the rural labor market, the rural trade and transport sector, post-harvest processing, and the rural nonfarm economy at large. Surprisingly, these evolutionary changes are the same as those found in rural Asian economies that embraced the Green Revolution technology in the mid-1960s. To what extent CF parallels the Green Revolution in terms of its transformative impacts on the rural economies of developing countries in Asia needs further exploration.

CHAPTER IV
Conclusion and Policy Implication

I. CONCLUSION

In Lao PDR, currently one out of five people still live in poverty, two out of three live in the rural area, and approximately 70 per cent of the labor force rely on agriculture for their livelihood. Agricultural development is thus critically important for food security and poverty eradication in the country. It is well known that Lao PDR has achieved rice self-sufficiency in 1999 largely because of growth in domestic rice production. This dissertation aims to explore how technologies that were transferred from abroad and commercialization have contributed to production growth in the rice and maize sectors. Rice is a major crop, whereas maize is newly emerging commercial crop.

Technology imported from abroad in the rice sector was facilitated by the public sector through research collaboration with the International Rice Research Institute (IRRI) and foreign countries, particularly Thailand, Vietnam, and China. This study shows that such collaboration has positive impacts on the growth of rice production in Lao PDR. This growth is mainly driven by the growth in rice yield, made possible by the increase in adoption rate of modern rice varieties by farmers. Expansion of area devoted to rice has moderately contributed to rice production growth. The adoption of modern rices, which is the main driver of yield growth, has risen only when locally bred modern glutinous rices were released beginning in 1993, which is the outcome of joint adaptive research efforts between international scientists from IRRI and local scientists, along with the expansion of the irrigation system. Furthermore, the acceleration of commercialized rice farming, driven by rising urbanization and rice export, has further enhanced rice production growth through increased farm mechanization and application of modern inputs such as fertilizer.

In the case of maize, the private sector has played a facilitating role in bringing in new technology from abroad such as new seeds, fertilizer, herbicide, pesticide, and machinery, as well as management practices through the contract farming (CF) channel. The emergence of CF was stimulated by the Agricultural Commercialization policy in the form of 1+4 and 2+3 FDI promotion in 2002. Growth in maize production began in the mid-2000s, with expansion of area planted to maize a large contributor. Area under maize cultivation expanded sharply with the inflow of FDI in agriculture largely in the form of CF. Yield growth in maize contributed moderately to maize production growth. Maize commercialization under CF has linked rural smallholder farmers with the larger domestic and global markets, stimulating the development of a more diversified rural livelihood economy and the development of the hired labor market, credit market, and capital market and the rural nonfarm economy at large.

In summary, growth in rice and maize production in Lao PDR can be traced to technology transfer from abroad and commercialization. The two main channels of technology transfer from aboard to Lao agriculture are 1) through public collaboration programs with international organizations and foreign countries and 2) through the private sector under CF. Commercialization, made possible by the Agricultural Commercialization policy, has effectively linked smallholder farmers with the urban and global economies and has transformed the rural livelihood system from a subsistence-oriented mode to a market-oriented mode accelerating rural development.

So, what are the lessons learned from the Lao PDR experience?

Good government policies on research collaboration, extension service, irrigation development, and importantly, economic liberalization and linking with internationally recognized organizations such as the ASEAN have served as important catalysts of agricultural development in Lao PDR. These government policies have enhanced the positive role of new technology from abroad and commercialization in bringing forth production growth in rice and maize that strengthens domestic food security. This study has shown that sound government policies, new technology from abroad, and commercialization have worked harmoniously for the benefit of the agricultural sector in general and for the benefit of smallholder farmers in particular.

II. TRANSFER OF TECHNOLOGY: PUBLIC VERSUS PRIVATE

There are similarities and differences between technology transfer in rice and maize sector in Lao PDR. The main similarity is new technology transferred to rice and maize sectors both come from abroad. The main difference is in the purpose and actors. In the rice sector, the international organizations have served as the main source of knowledge in transferring new technology and management practices under public collaboration scheme, which represents as “open” technology transfer system aiming at international collaboration to support national food security. While technology transfer in the maize sector has been operated within the business system of private organization which is rather “close” system under the multinational corporation with business profit-oriented objective.

Based on the success in rice sector, open innovation system could be extended to other crops including maize. Strengthening the capacity of public R & D institutions under the NAFRI as well as the extension services of NAFES to cover all agricultural activities in Lao PDR including under private business activities would bring benefit to all stakeholders including farmers, consumers, and the country's economy as a whole. Similarly, for the maize sector, it is important to change from the current close innovation system focusing only transferring technologies that were developed within the corporation system. Open innovation system, which relies on interplay of actors would bring more benefits to the corporation as well to farmers to develop a better business model rather than focusing on improving technology within the close system of corporation (Chesbrough, 2003, 2006, and Chesbrough and Boger, 2014).

From the policy point of view, in order to enhance the development of maize sector in Lao PDR in particular, it is necessary for the government to formulate a concrete policy on maize sector development by extending a comprehensive collaboration with relevant maize research organizations abroad to strengthen domestic maize research system in Lao PDR, which is still in its infancy. Furthermore, it is important to extend public extension services to cover agricultural activities under private business. Strengthening the public R & D and extension service systems in maize sector, and extending collaboration with the maize CF business organizations domestically and abroad would help improve maize farming efficiency. Extending the open system in the public sector in supporting the move toward open business model under the so-called "Public-Private-Partnership" would bring better outcomes to the maize CF business and the possibility for the Green Revolution in maize in Lao PDR.

III. POLICY IMPLICATIONS

This dissertation has confirmed the importance of agricultural development in enhancing the growth of production of rice and maize in Lao PDR. Agricultural development is made possible by the adoption of new technology and management know-how from abroad and commercialization in agriculture. The following are some policy implications drawn from the study.

(1) To further enhance production growth in both the rice and maize sectors, strategies should focus on enhancing yield growth as virgin forests are becoming scarce. This could be done by increasing the adoption of modern varieties through expansion of irrigated areas. Importantly, together with modern variety adoption, fertilizer application is needed.

(2) To enhance productivity growth in the rice and maize sectors as well as in agriculture as a whole, priority should be given to strengthening adaptive research capacity of local scientists through both channels of technology transfer from abroad (public research collaboration and private sector under FDI scheme).

(3) Lastly, providing sound policy support such as on expansion of irrigation, germplasm improvement, enhancement of coverage and quality of extension service, and strengthening access to quality inputs such as chemical fertilizer and mechanical technology must be continued.

IV. DIRECTION FOR FUTURE RESEARCH

Since the implementation of the Agricultural Commercialization policy in 2002, there has been an increasing incidence of CF in maize, cassava, and rubber. These three crops are emerging commercial crops in Lao PDR. This dissertation has shown in Chapter III that CF in maize has downstream effects on the development of markets that had not existed before in Lao PDR but are quite well developed in other developing countries. These markets are the hired labor market, capital market, and credit market. CF also appeared to stimulate the development of agriculture-based nonfarm activities in postharvest operations.

Of particular interest is the evolution of different contractual arrangements in the hired labor market. During the Green Revolution in Asia, this market has developed from daily rate to piece rate contracts (i.e., per hectare of land) and this has triggered the expansion of irrigation, which created a sharp demand on labor in transplanting, where timely completion of the task is crucial. To what extent CF stimulates the evolution of hired labor arrangements in different activities in maize, cassava, and rubber remains to be explored.

As to the credit market, it is interesting to explore how CF could stimulate the emergence of local moneylenders, thus softening the cash constraints associated with the purchase of modern inputs, most importantly, fertilizer. In Chapter III, I have discussed the case of Lao farmers themselves becoming local contractors and replacing foreign contractors. If CF is profitable, local moneylenders will emerge and assist local Lao contractors with their cash constraint in advancing modern inputs to farmers. The emergence of local moneylenders alongside the spread of CF remains unexplored. The Chapter on maize sector has provided some insights on the contribution in the literature of maize CF on rural livelihood development in Lao PDR mainly based on extensive case studies. Quantitative analysis cannot be carried out to confirm the impacts of maize CF on poverty reduction mainly due to lack of suitable dataset. Improvement of data availability on CF and maize as well as other crops in the next Lao Census of Agriculture is necessary in order to make possible quantitative analysis particularly for those emerging important crops in Lao agriculture. Nevertheless, it appears that a few structural change in the standard 2+3 maize CF has been emerging based on my case studies indicating that CF is dynamically evolving.

Regarding capital market, the main issue is mechanization (i.e., importantly the use of tractors) as demand for labor for new commercial crops increases and cross-border migration to Thailand becomes common, leading to scarcity of labor in agriculture and to subsequent increase in rural wages. The main task is to explore the factors affecting the uptake of farm machinery as some farmers mechanize (i.e., use tractors) while others continue to use animals and traditional tools. Nevertheless, cross-border out-migration is an important issue on rural development and a critical contributor to labor shortage for the country's industrialization as a whole. A comprehensive study to address cross-border migration with clear policy implication has to be carried on.

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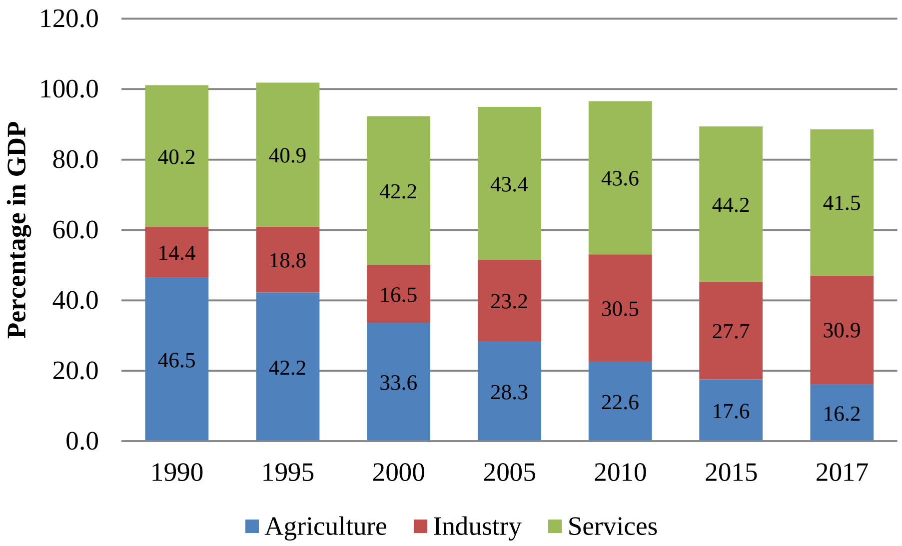
Figures

Figure 2.1: Gross domestic product (GDP) share, by sector, in Lao PDR, 1990-2017



Note: Figure drawn using data from World Development Indicators

Figure 2.2: Gross domestic product (GDP) of Lao PDR at constant price of 2010 (billion USD), 1984-2017

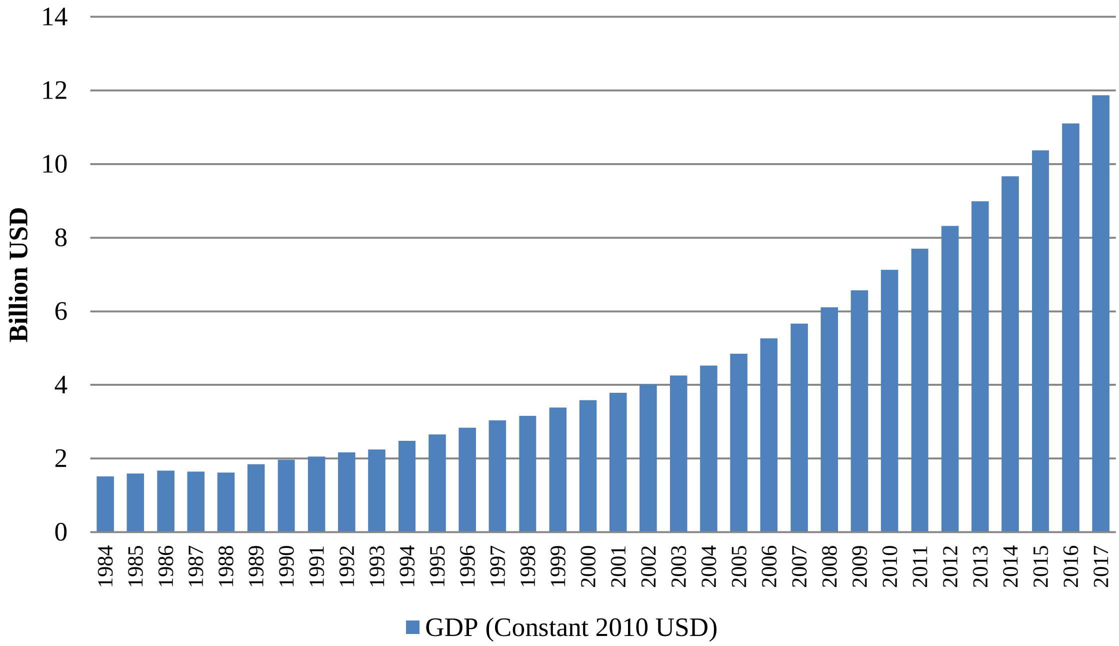


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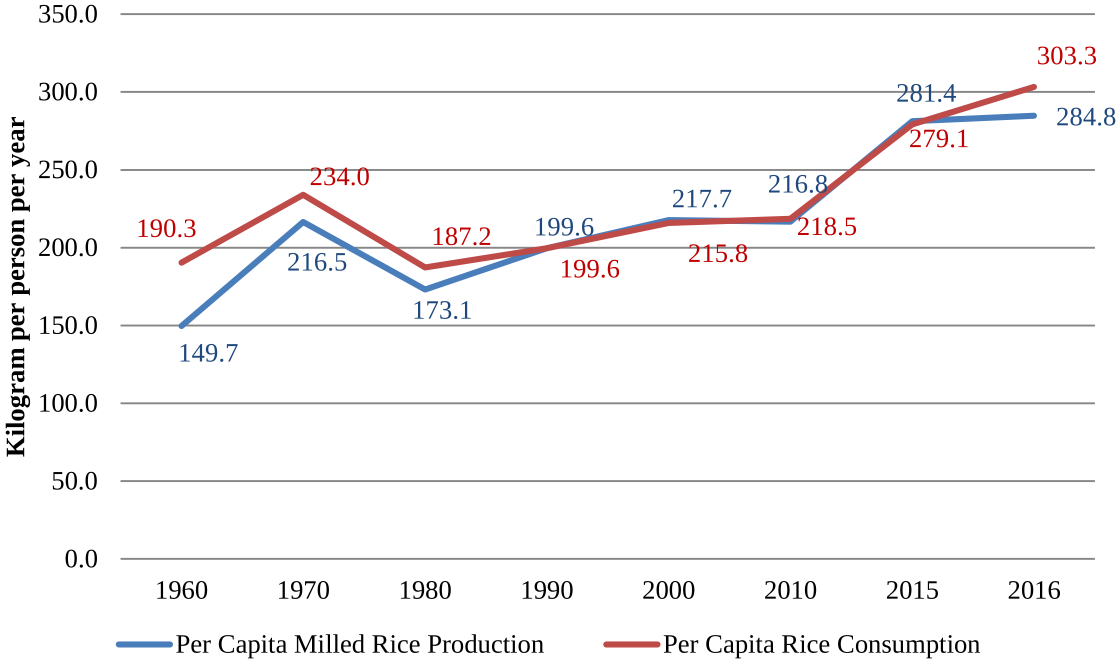
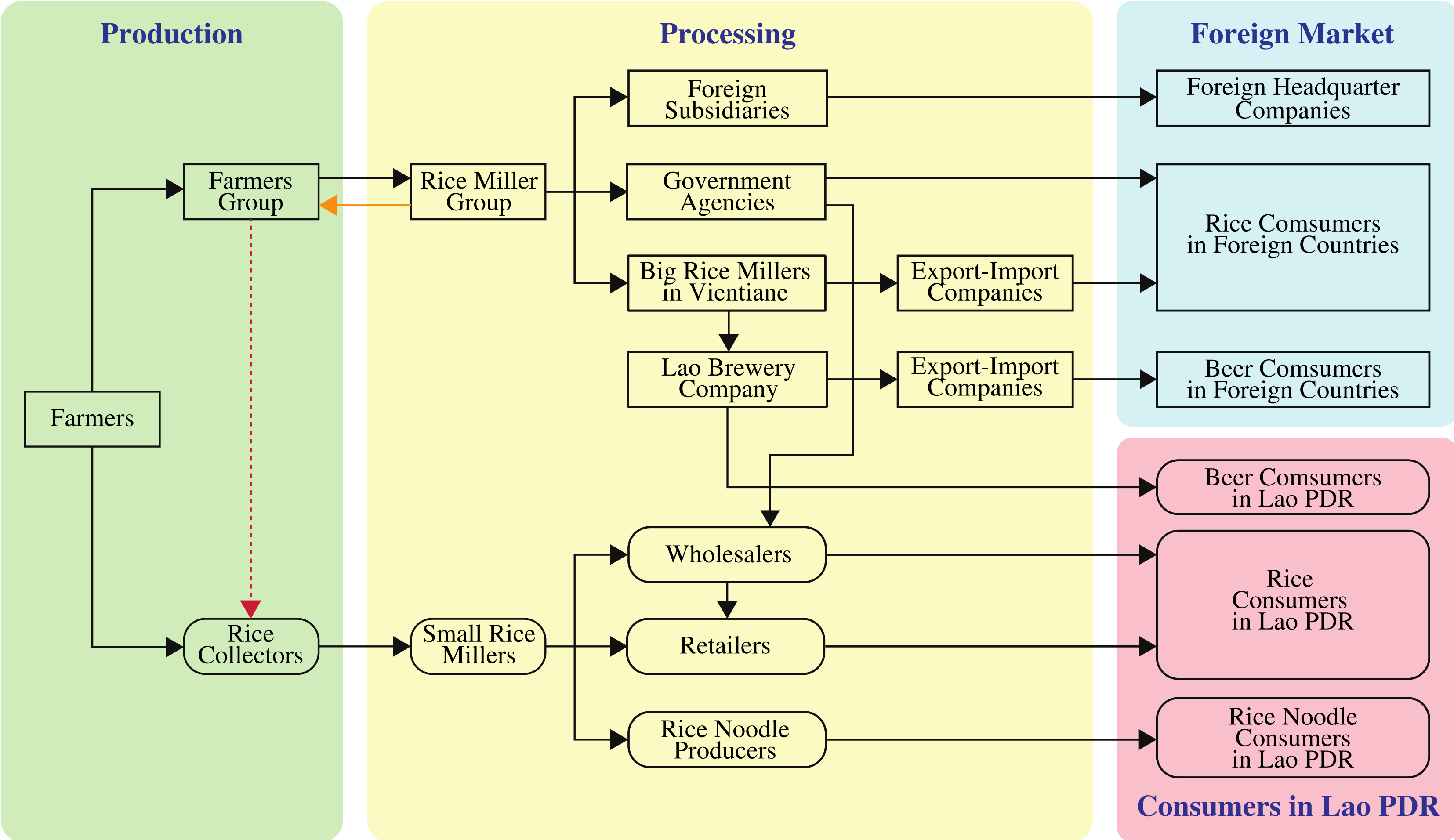
Figure 2.3: Per capita rice production and per capita rice consumption in Lao PDR, 1960-2016



Note: Figure drawn using data from FAOSTAT, World Rice Statistics, and World Development Indicators

Figure 2.4: Rice production in Lao PDR and its supply chain



Source: Author's modification based on Eliste and Santos (2012); Ingxay et al. (2016); and World Bank (2018)

Figure 2.5: A model of technology transfer in the rice sector of Lao PDR

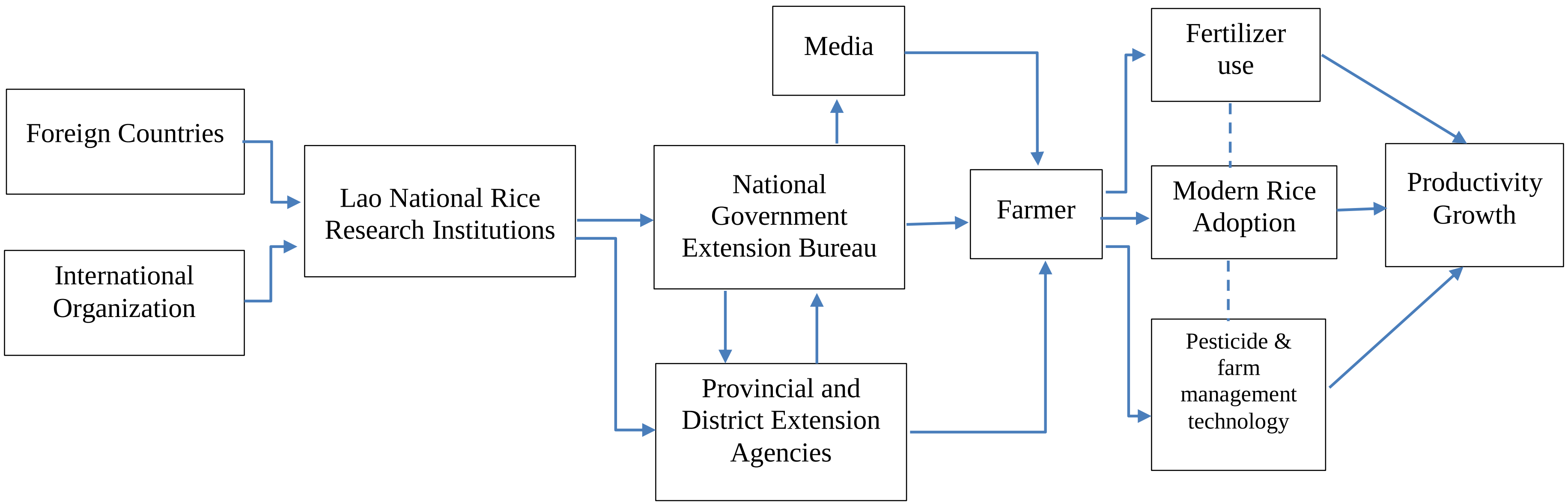
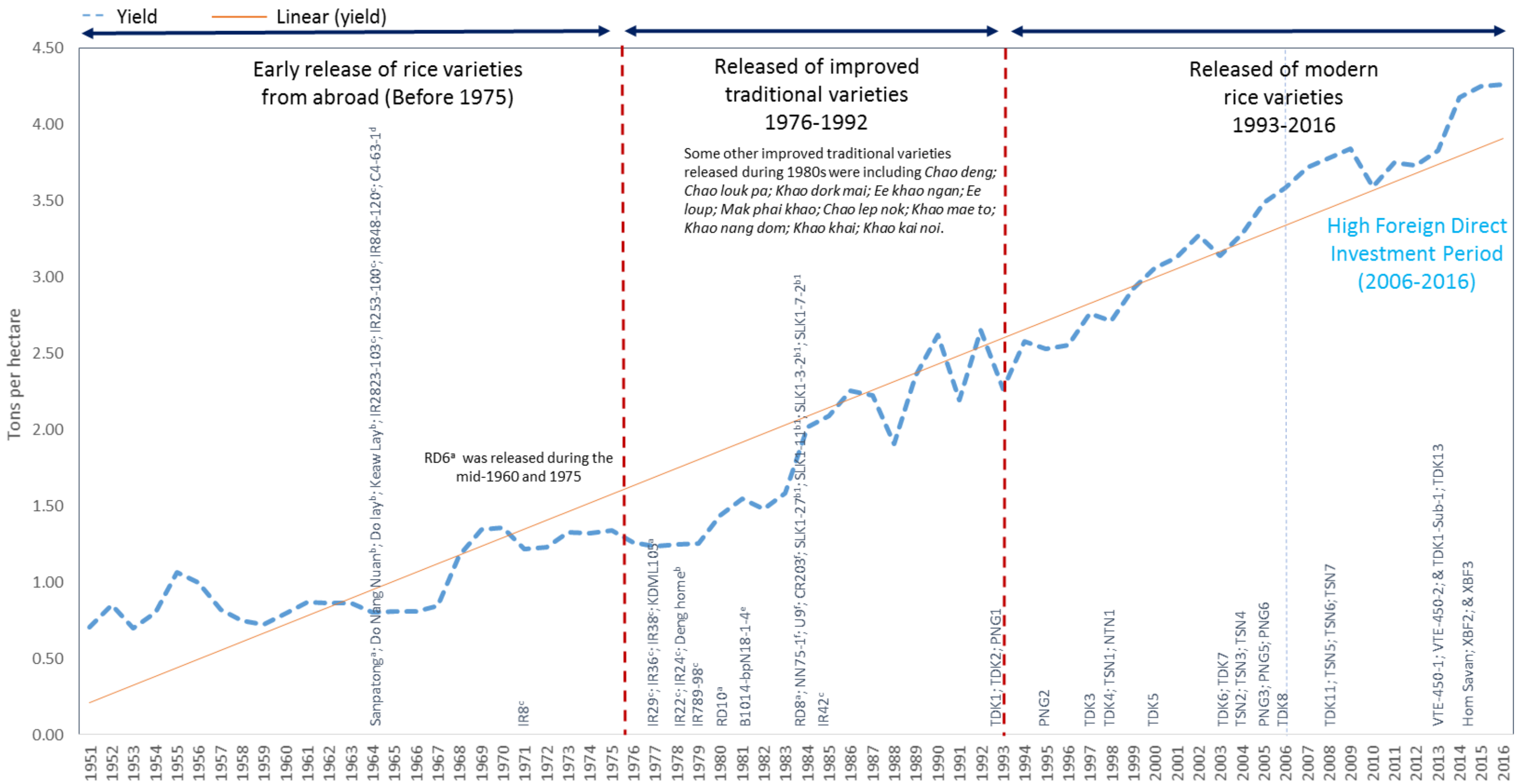


Figure 2.6: Popular rice varieties and rice yield in Lao PDR, 1951-2016

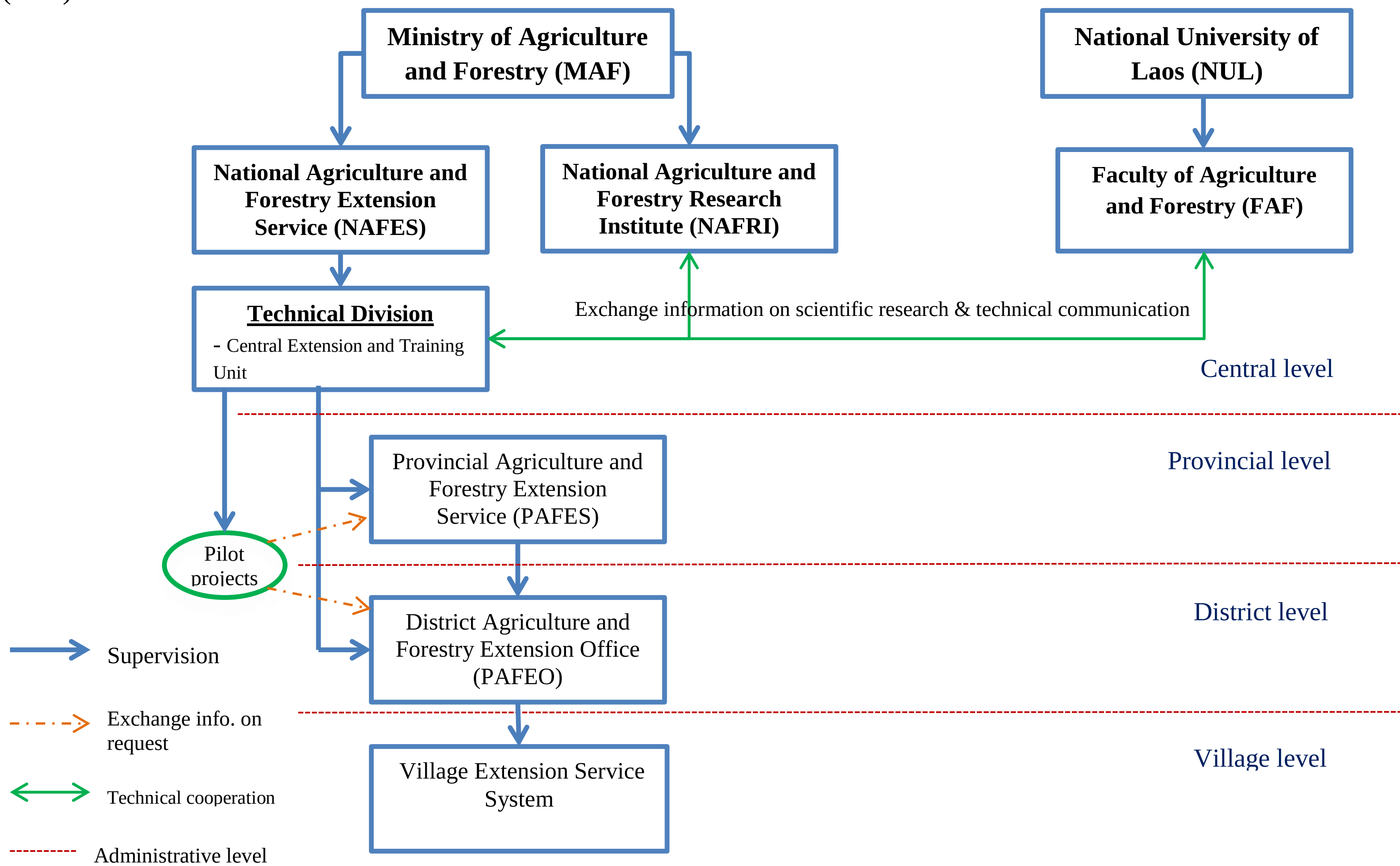


Note: Figure drawn using data from IRRI, World Rice Statistics, FAOSTAT, Hatsadong, 1986, Inthapanya et al., 2006 & 2013; and Xangsayasane et al., 2009 & 2013

a = variety from Thailand; b = from Lao PDR; b1 = First crossed variety in Lao PDR; c = from IRRI; d = from Philippines; e = from Indonesia; f = from Vietnam

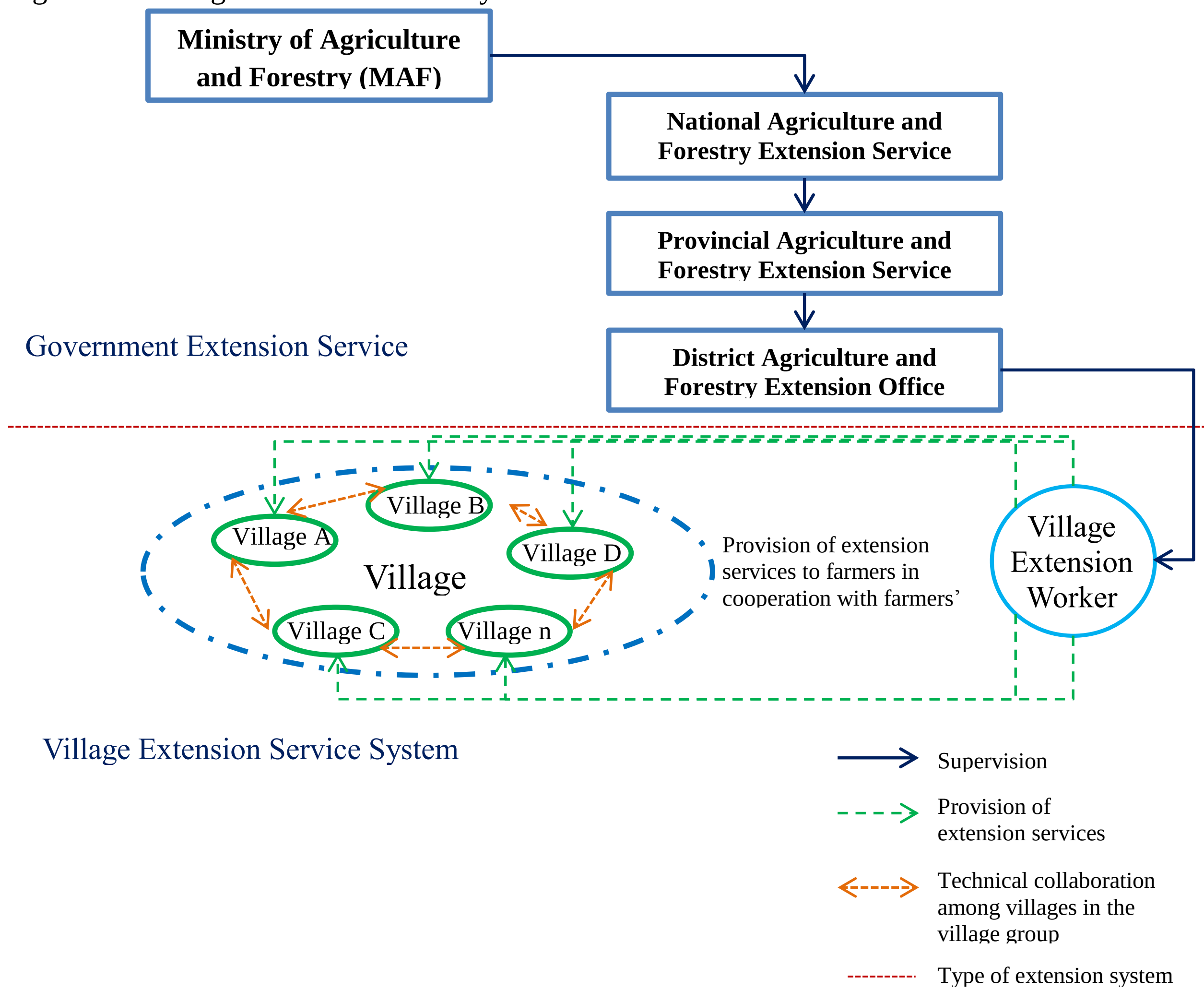
The varieties released from 1993 on ward are MVs developed by local rice research institutions in Lao PDR

Figure 2.7: Organizational structure of the National Agriculture and Forestry Extension Service (NAFES) and its Technical Coordination with the National Agriculture and Forestry Research Institute (NAFRI) and the Faculty of Agriculture and Forestry (FAF)



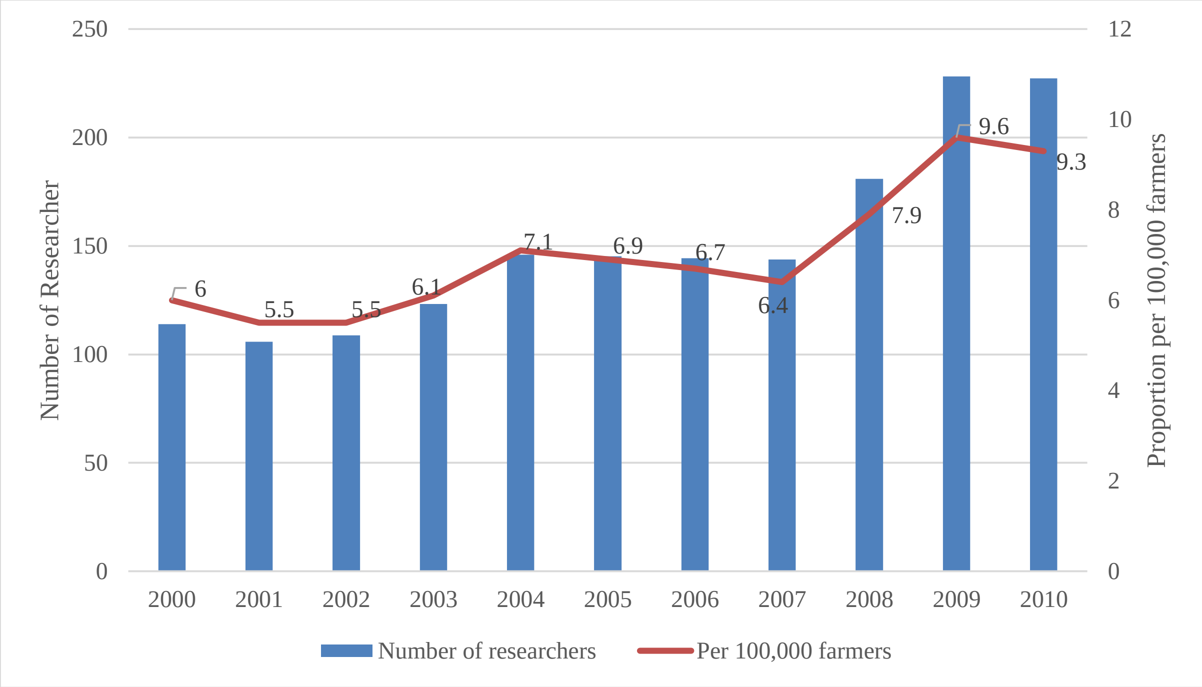
Source: Author's modification based on information from Chanthavong, 1996 and NAFES, 2005

Figure 2.8: Village extension service system in Lao PDR



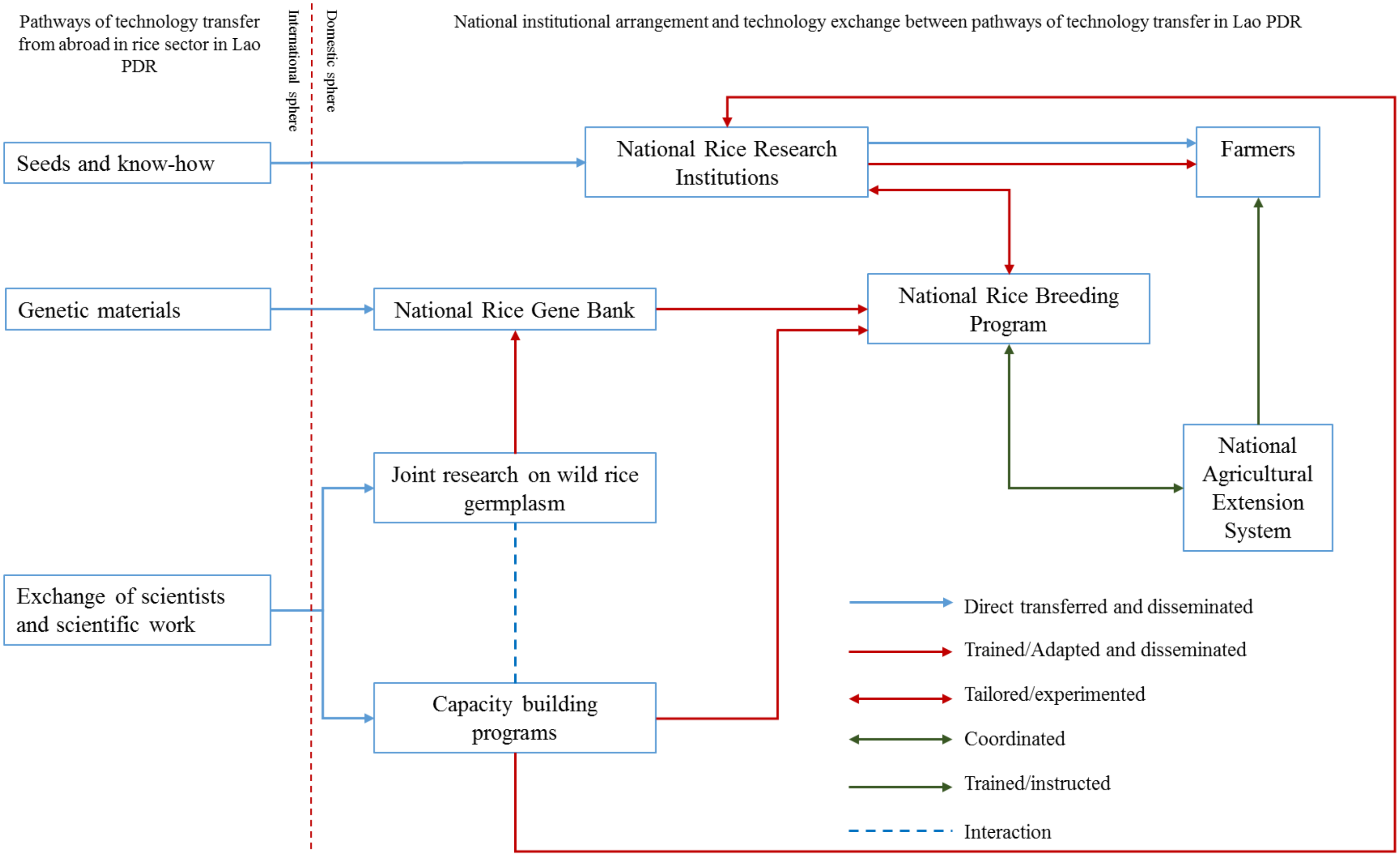
Source: Author's modification based on information from NAFES, 2005 and Vannaso, 2006

Figure 2.9: Number of Lao national researchers in the rice sector and proportion of researcher per farmer in Lao PDR, 2000-2010.



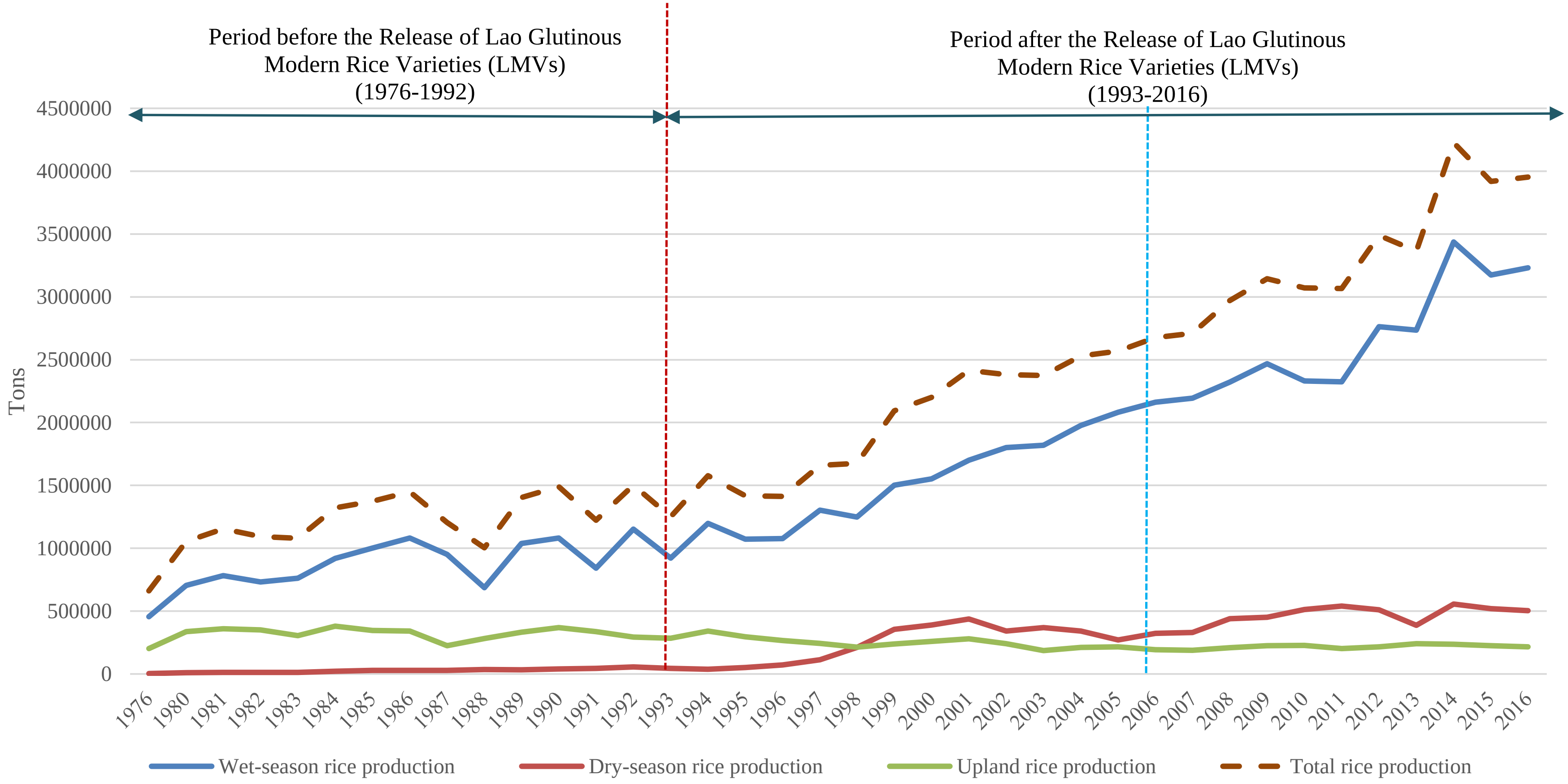
Note: Figure drawn using data from IRRI

Figure 2.10: Interplay and interaction between the three pathways of technology transfer from abroad in rice sector in Lao PDR



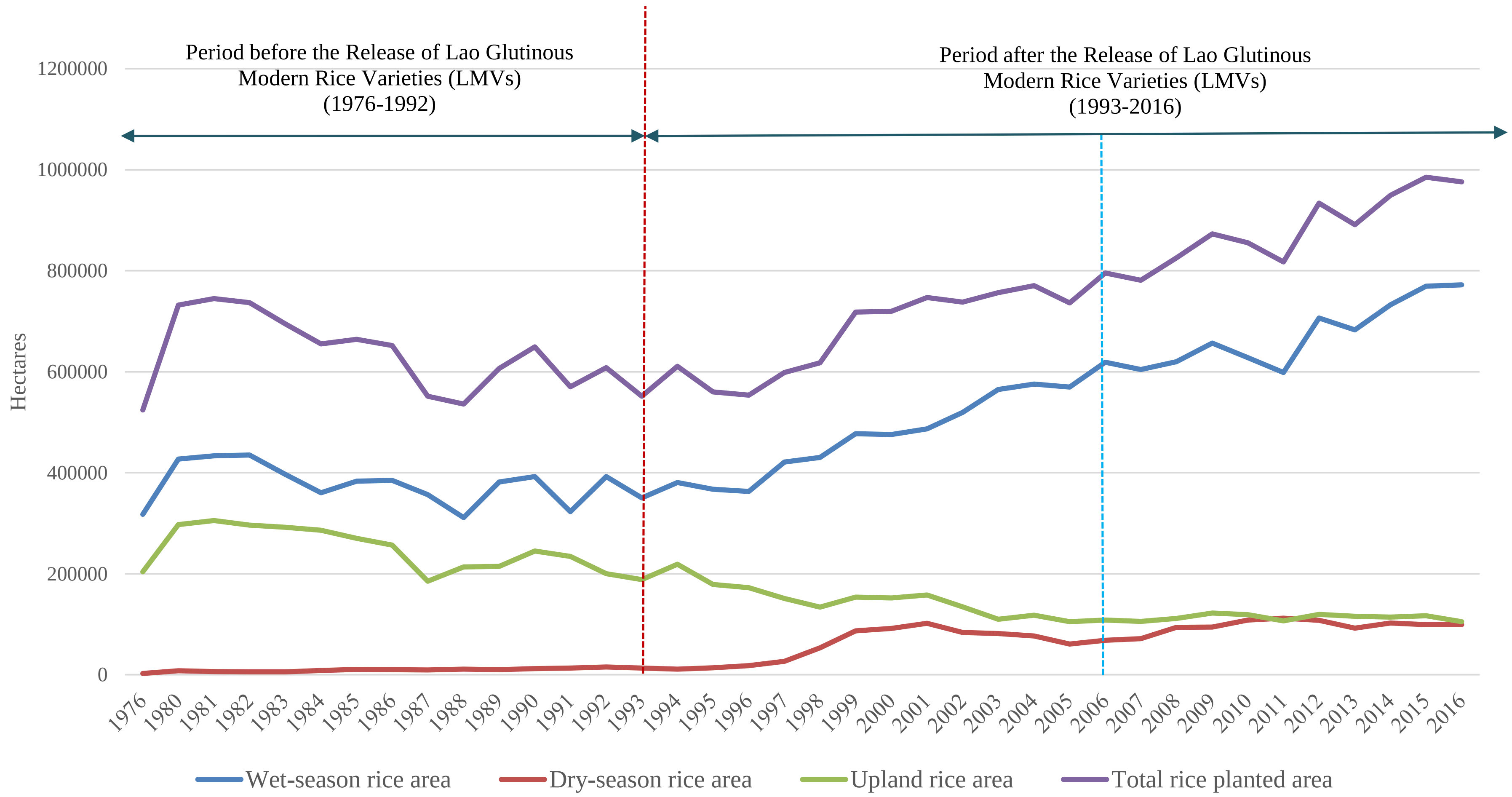
Source: Author's schematic diagram based on reviews and interviews

Figure 2.11: Trends in rice production (tons), by ecosystem, in Lao PDR, 1976-2016



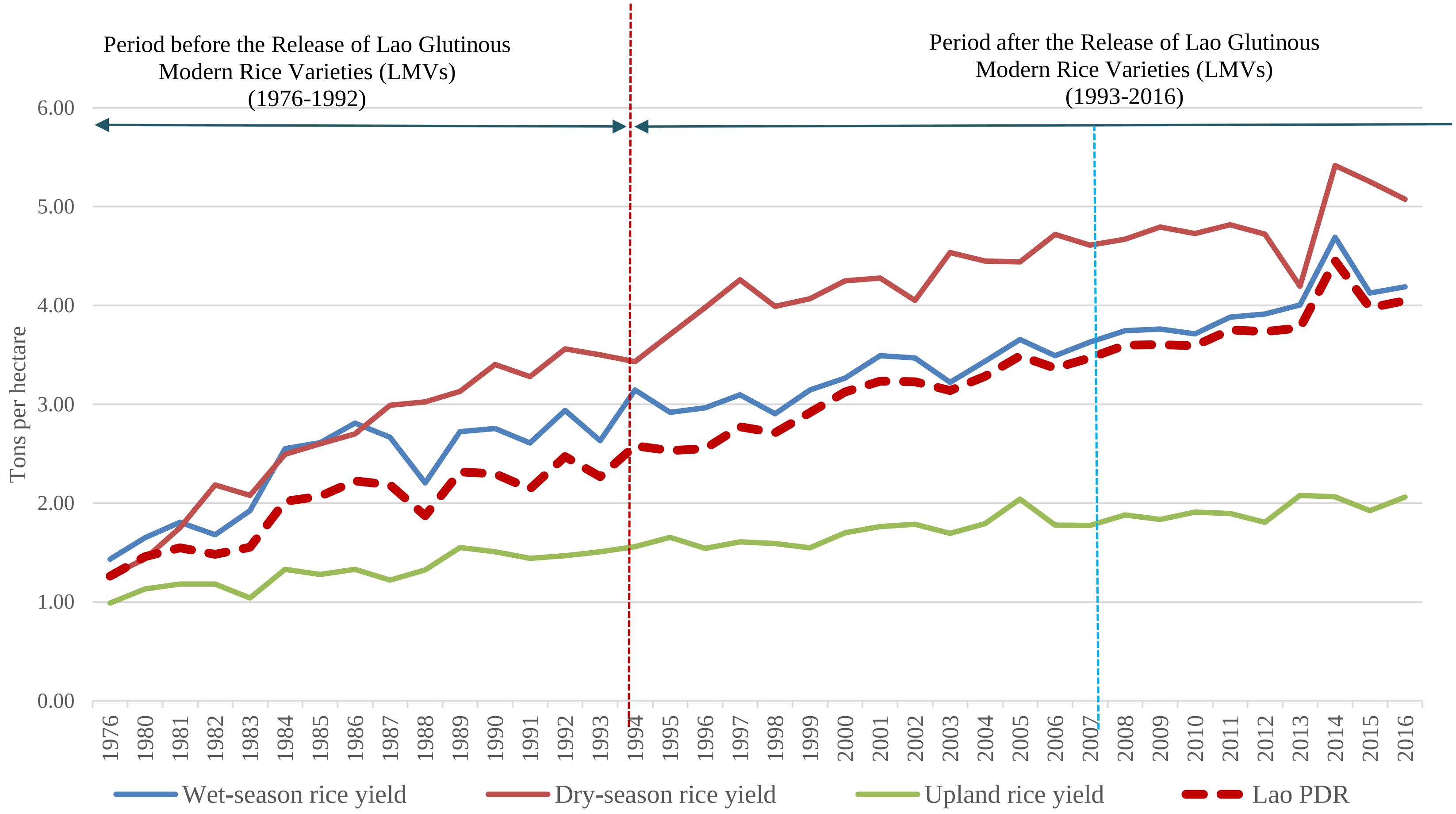
Note: Figure drawn using data from Lao Statistic Bureau, 1976-2016

Figure 2.12: Trends in rice area planted (ha), by ecosystem, in Lao PDR, 1976-2016



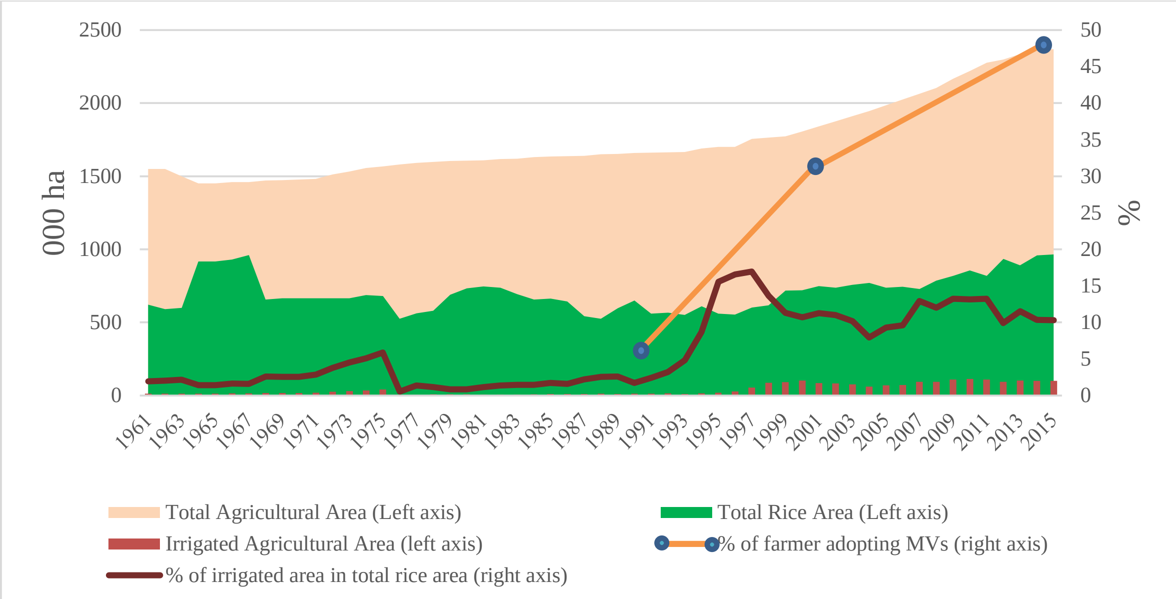
Note: Figure drawn using data from Lao Statistical Bureau, 1976-2016

Figure 2.13: Trends in rice yield (tons per hectare), by ecosystem, in Lao PDR, 1976-2016



Note: Figure drawn using data from Lao Statistical Bureau, 1976-2016

Figure 2.14: Irrigated area as part of total agricultural area and MV adoption in Lao PDR, 1961-2015



Note: Figure drawn using data from FAOSTAT, Lao Census of Agriculture 2010/11, and Schiller et al., 2006a.

Figure 3.1: A model of driving forces and the evolution of the maize economy in Lao PDR

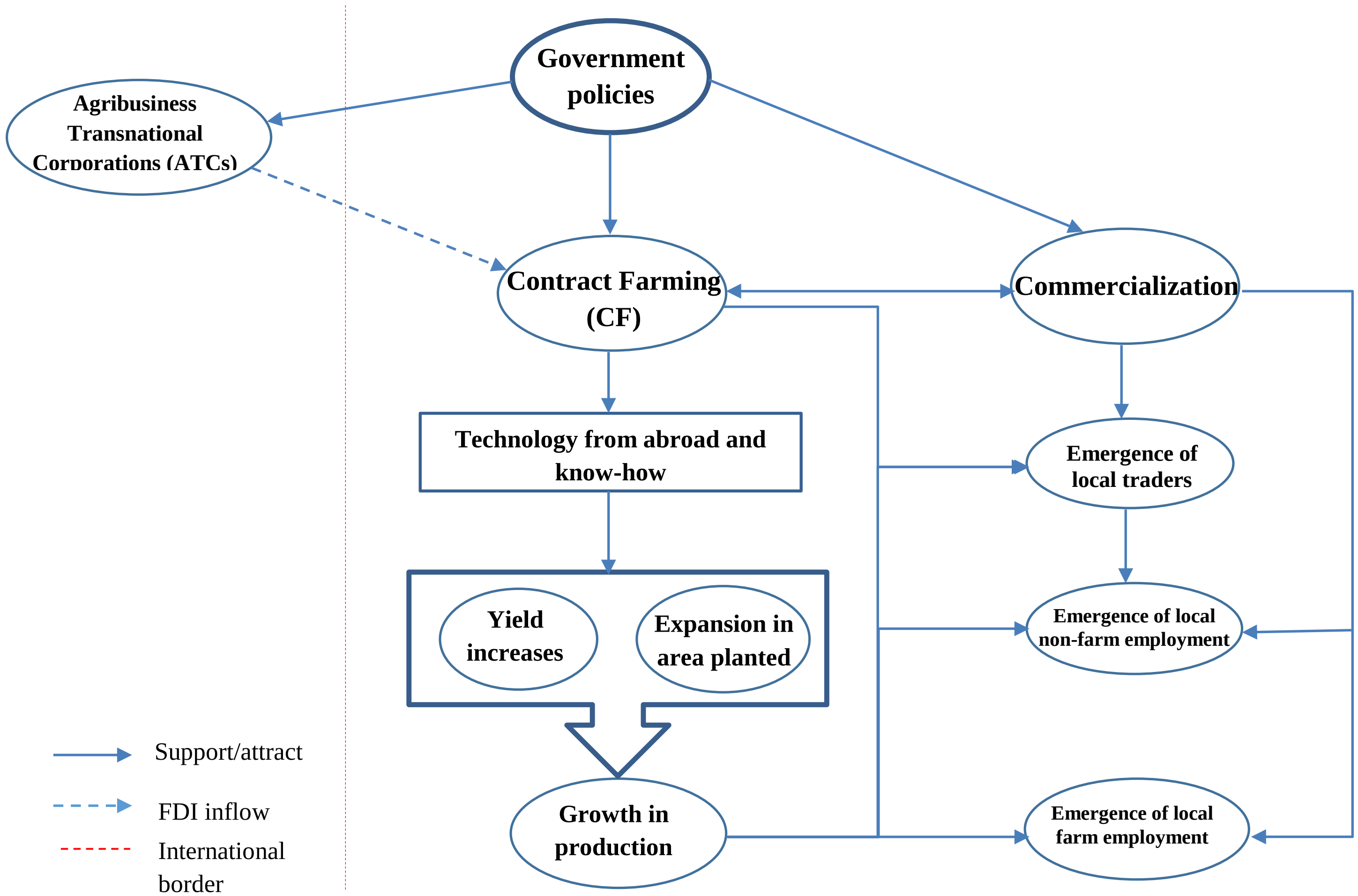
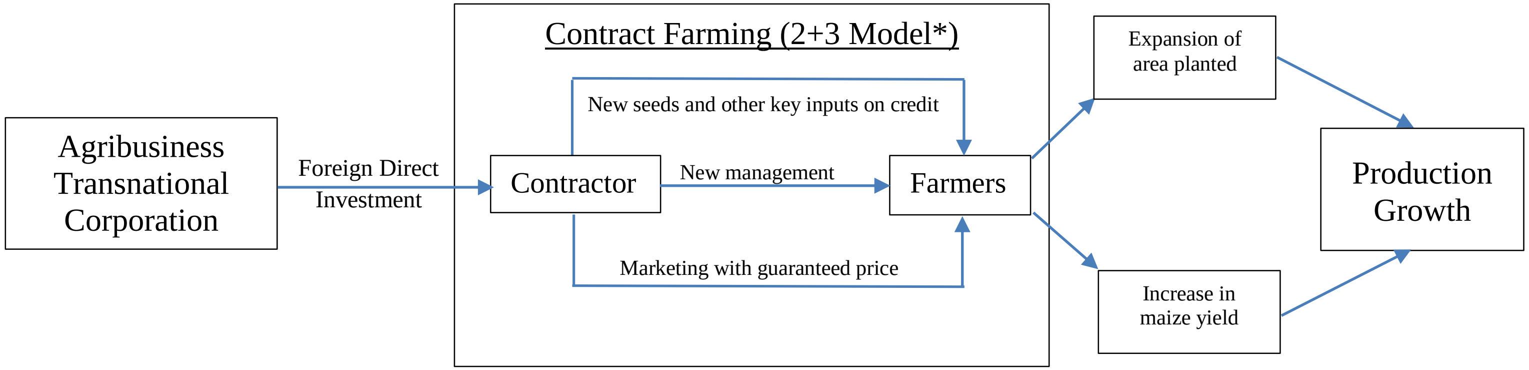


Figure 3.2: A model of technology transfer in the maize sector of Lao PDR

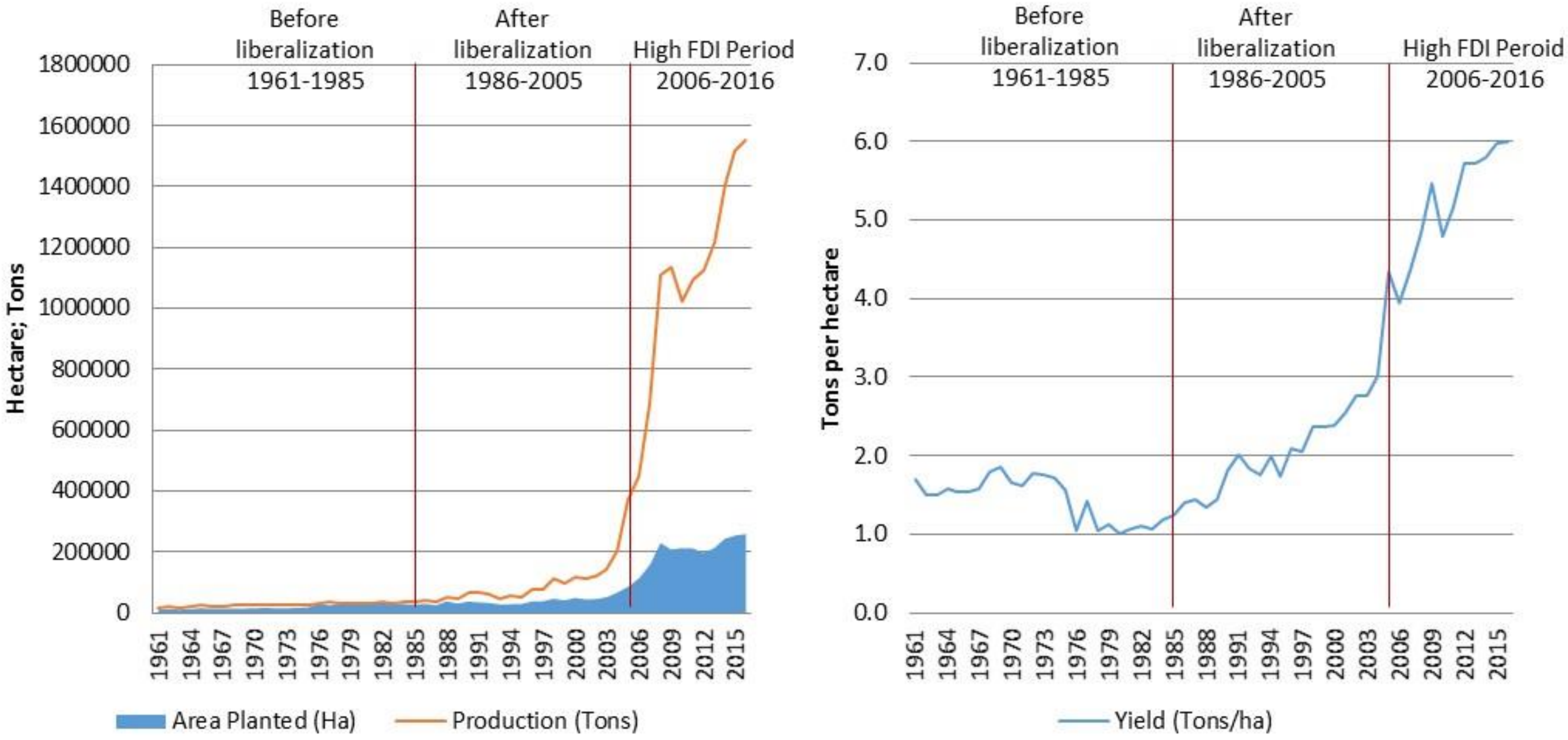


*The 2+3 model of contract farming in Lao PDR refers to production cost sharing between farmers and contractor as follows:

- Farmers are usually responsible for two key production factors: (1) land and (2) labor.

- Contractor is usually responsible for three production factors: (1) capital (usually refers to key inputs such as seed, fertilizer, etc.; and production cost in some cases [e.g., land preparation, etc.]); (2) technical know-how/management; and (3) product markets (i.e., the contractor buys all farm products from the farmers).

Figure 3.3: Trends in maize production, area planted, and yield in Lao PDR, 1961-2016



Note: Figure drawn using data from FAOSTAT

Figure 3.4: Map of Study Areas

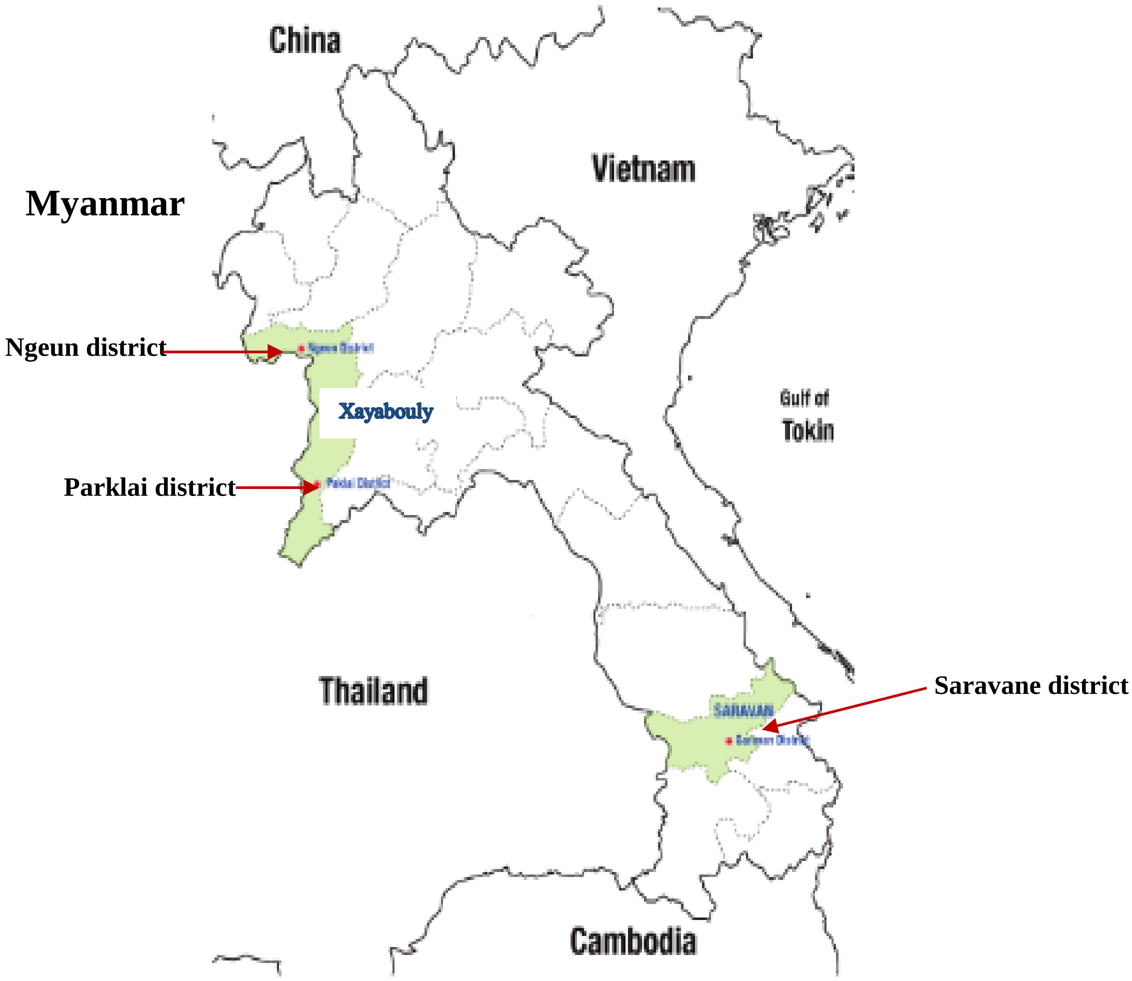
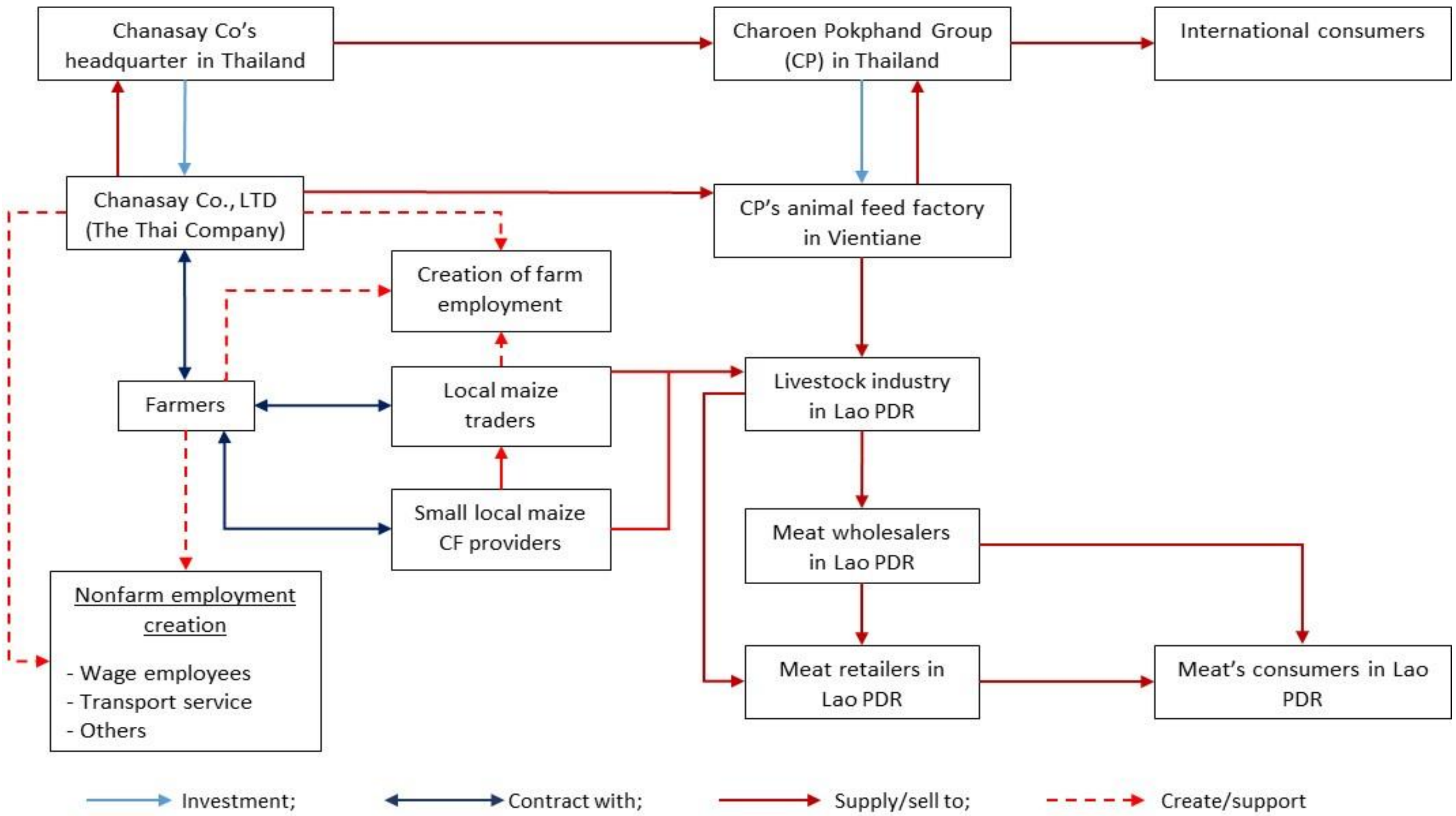
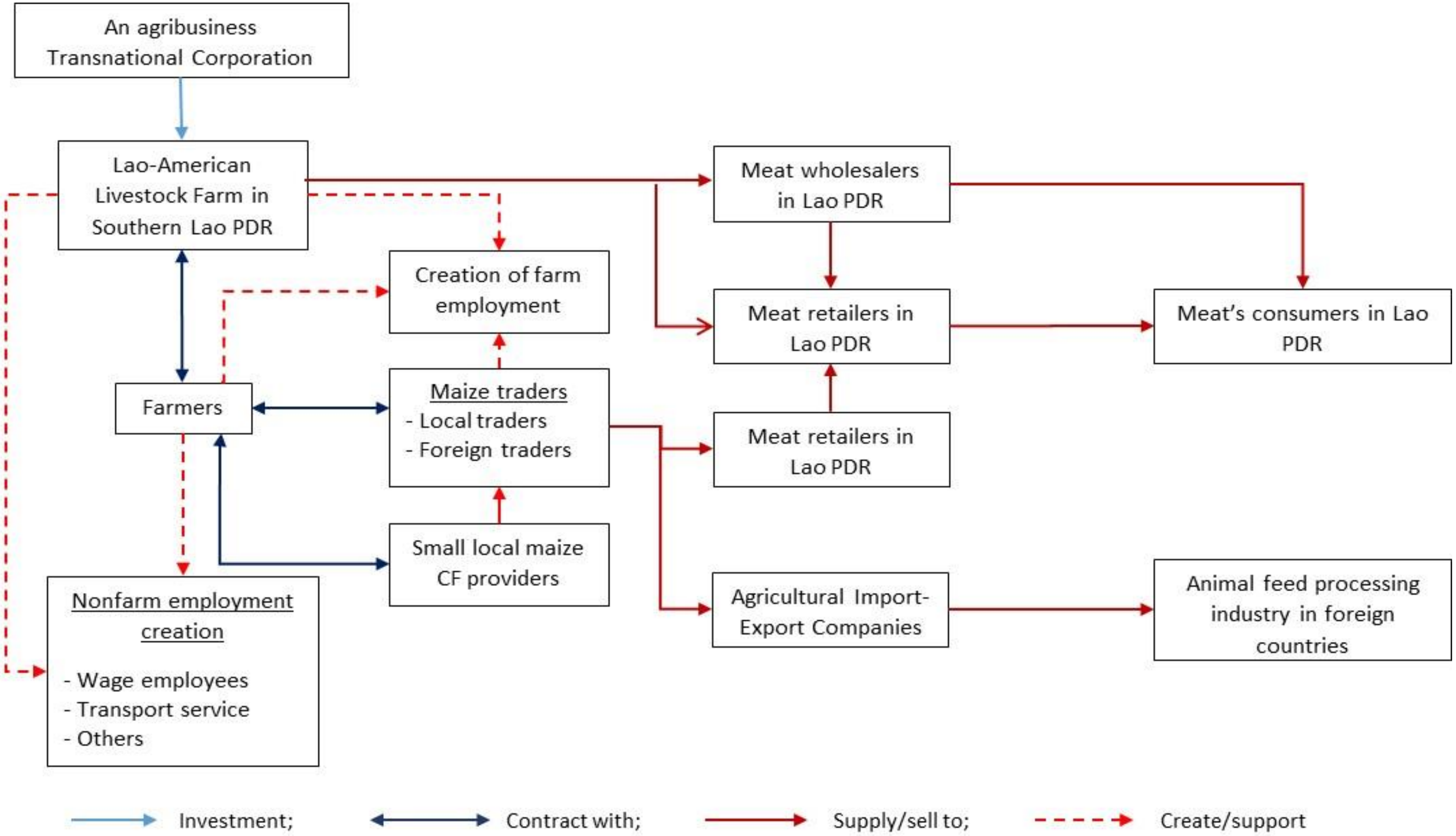


Figure 3.5: A value chain analysis of the evolution of the maize economy in Saravane province: The case of the Thai Company



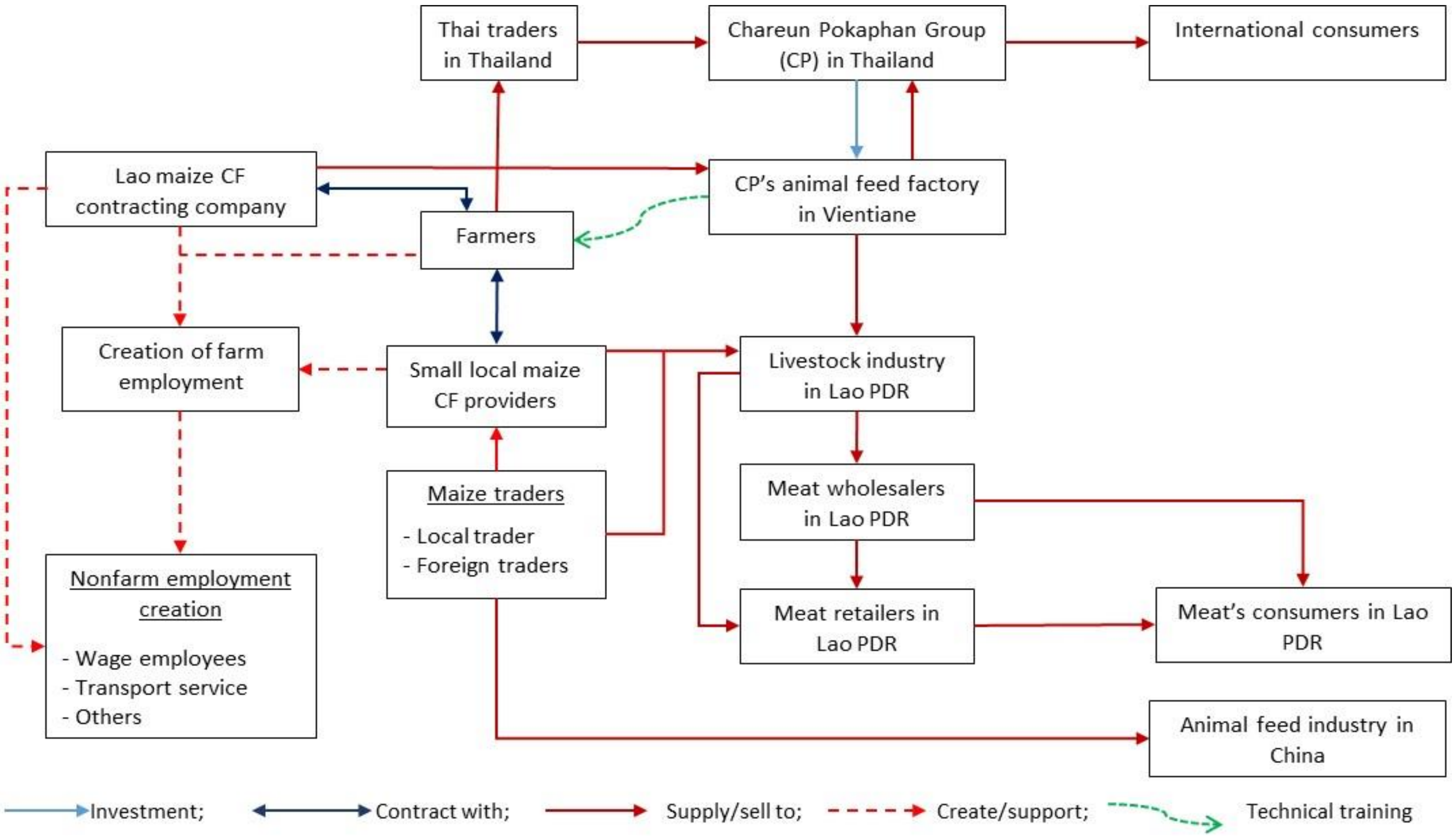
Note: Figure drawn based on field survey interviews in sample villages

Figure 3.6: A value chain analysis of the evolution of the maize economy in Saravane province: The case of the Lao-American Company



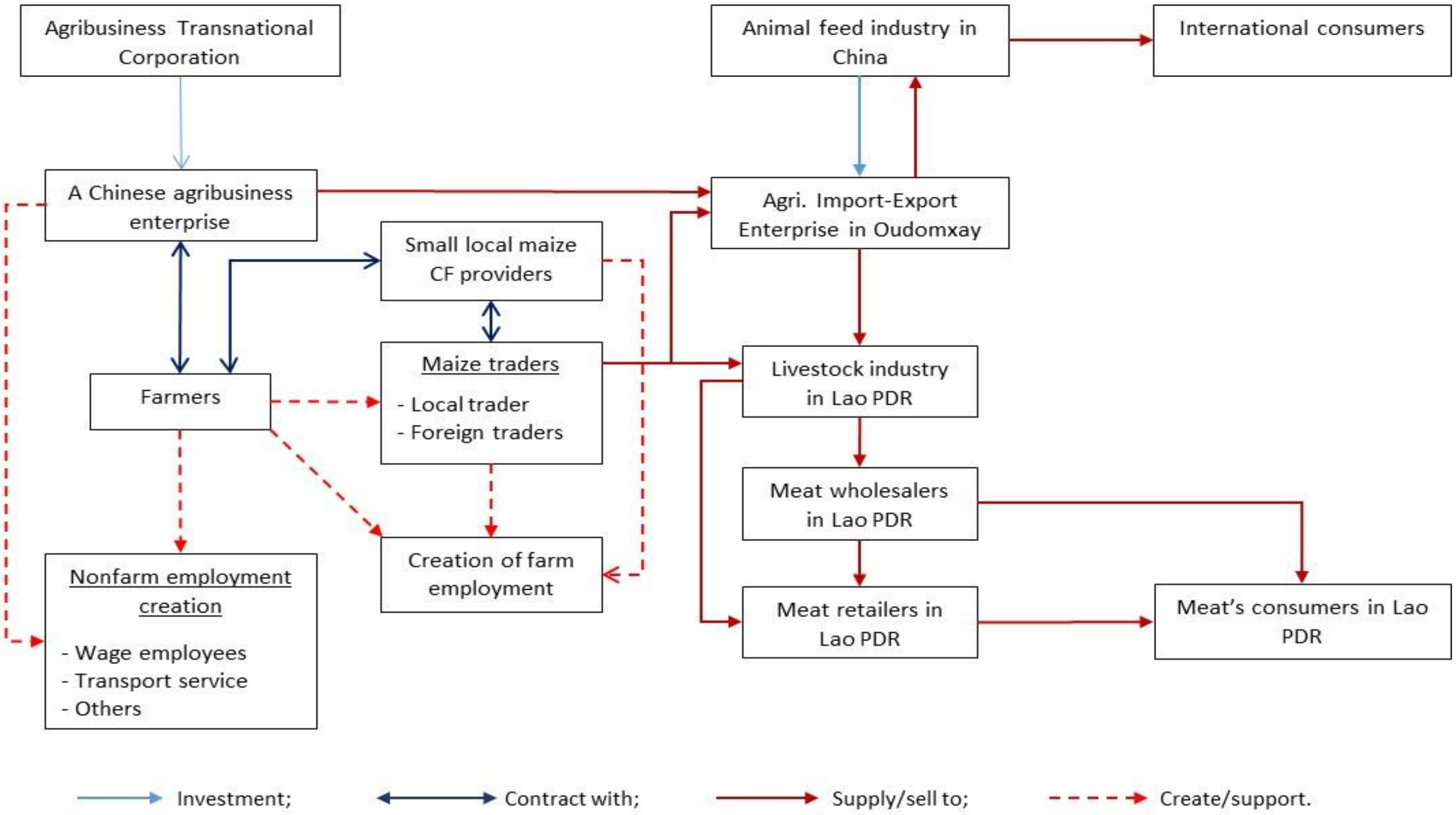
Note: Figure drawn based on field survey interviews in sample villages

Figure 3.7: A value chain analysis of the evolution of the maize economy in Parklai district of Xayabouly province: The case of a Lao Company



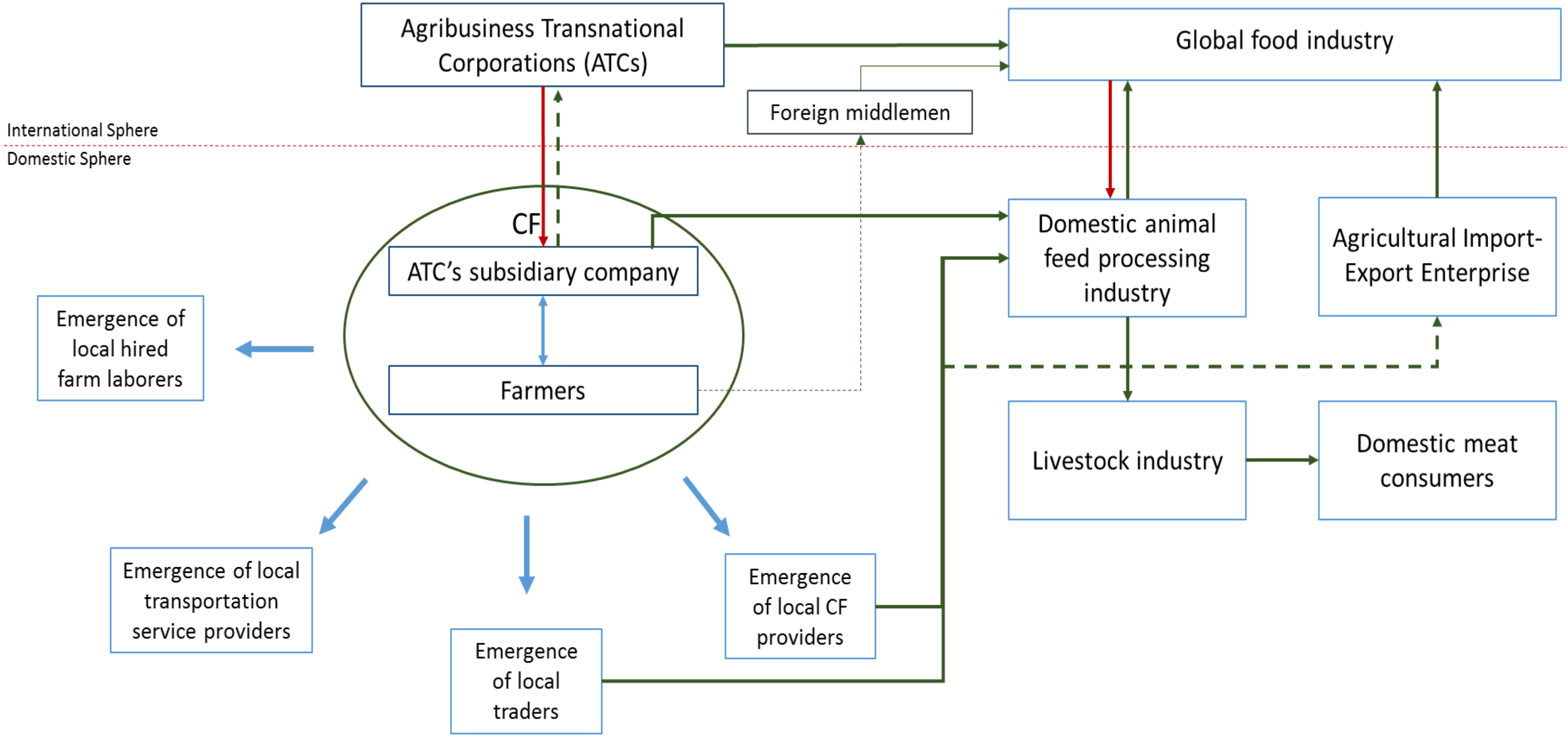
Note: Figure drawn based on field survey interviews in sample villages

Figure 3.8: A value chain analysis of the evolution of maize economy in Ngeun district of Xayabouly province: The case of a Chinese Company



Note: Figure drawn based on field survey interviews in sample villages

Figure 3.9: The evolution of maize economy in rural villages in Lao PDR



Source: Author's modification based on the surveys in 2018

Tables

Table 2.1: Rice area planted and rice production in Lao PDR, by province, 2016

Province	Area		Total rice production	
	Hectares	Percentage	Tons	Percentage
Lao PDR	976,231	100%	3,952,599	100%
Vientiane Capital	71,968	7%	335,300	8%
Phongsaly	16,475	2%	52,422	1%
Luang Namtha	16,625	2%	56,670	1%
Oudomxay	24,395	2%	84,860	2%
Bokeo	23,385	2%	91,740	2%
Luang Prabang	40,135	4%	121,930	3%
Houaphanh	27,970	3%	107,268	3%
Xayaboury	45,901	5%	192,200	5%
Xiengkhouang	30,358	3%	108,286	3%
Vientiane province	69,064	7%	308,337	8%
Bolikhamxay	45,640	5%	178,236	5%
Khammuane	90,658	9%	394,300	10%
Savannakhet	221,910	23%	983,700	25%
Saravane	92,485	9%	432,400	11%
Sekong	11,680	1%	46,900	1%
Champasak	125,410	13%	415,200	11%
Attapeu	22,172	2%	42,850	1%

Source: Lao Statistics Bureau, 2016

Table 2.2: Rice area under modern varieties in Lao PDR, 1976-2011

Time period	Area under modern varieties (%)	Sources
1976 - 1990s	5% of rice area	Barclay and Shrestha (2006); Schiller et al. (2006)
Mid-1990s - 2002	80% of lowland area in the Mekong River Valley and 100% of irrigated area	Appa Rao et al. (2000 & 2006), Inthapanya et al. (2006), Linquist et al. (2006), Shrestha et al. (2002)
2004	Approximately 70% of rice area	Inthapanya et al. (2006), IRRI (2016)
2011	96% of rice area and 100% of irrigated area in the southern provinces	Soulinphouthone (2012)

Table 2.3: Highlight of chronological events of technology transfer from abroad to Lao PDR in rice sector

Year	Event
1955	Establishment of the first rice research institution in Lao PDR (Salakham Station)
1957	Establishment of Extension Division (marked as the primary extension service development in Lao PDR)
1957-58	Released of the findings on wild germplasm resources of Lao PDR by a Japanese scientist (Hamada)
1964	First release of rice varieties from abroad by Salakham Station
Mid-1960s	First large-scale irrigation system construction in Lao PDR – Faay Namthane Scheme
1971	Released of the very first high-yielding modern variety (IR8) from IRRI
Mid-1970s	Early introduction of farm mechanization in Lao PDR under collectivization program
Adaptive Research began	
Mid-1980s	First cross-breeding efforts in Lao PDR leading to the release of SKL series
Mid-1980s-1990s	Establishment of rice research institutions in main rice growing areas including Tha Dokkham (TDK) rice experiment station of the RRC in Vientiane, Phone Gnam Rice Research Station (PNG) in Champasak province, and Tasano Rice Research Station (TSN) in Savannakhet province.
1991	Establishment of the Lao national rice breeding program in collaboration with IRRI – Lao-IRRI project
1993	Release of the first locally bred Lao glutinous modern rice by Lao breeders themselves including TDK, PNG, and TSN series of varieties, which were popularly adopted by Lao farmers
1994-1998	Importation of massive amount of genetic materials from IRRI and Thai-IRRI (more than 2,000 rice genes were imported for breeding purpose)
1995-2000	A comprehensive collection of rice germplasm in Lao PDR was carried out
1999	Establishment of the Lao National Agriculture and Forestry Research Institute (NAFRI)
2001	Establishment of Lao National Agriculture and Forestry Extension Service (NAFES)
Since 2006	Lao breeders undertake varietal improvement by themselves to meet the changes in rice market demand and pay special attention to development of climate-resilient and commercial rice varieties

Source: Author’s collection from Arshad (2005), Inthapanya et al. (2006), NAFES (2005), NAFRI (2016), Schiller et al. (2006), and Xangsayasane et al. (2015).

Table 2.4: Average percentage growth of rice production, rice yield, and rice area planted in Lao PDR, 1951-2016.

	Before liberalization (1951-1985) [1]	**Release of modern varieties from abroad (1986-1992) [2]**	**Release of locally bred modern varieties (1993-2005) [3]**	**High FDI* period (2006-2016) [4]**	**Average Growth in Rice Production in Lao PDR (1951-2016) [5]**
Area growth (A)[1]	0.2 (7%)	-0.3 (-16%)	3.0 (48%)	3.0 (65%)	0.4% (12%)
Yield growth (B)[1]	2.6 (93%)	2.2 (116%)	3.2 (52%)	1.6 (35%)	2.9% (88%)
Production growth (C = A+B)[1]	2.8 (100%)	1.9 (100%)	6.2% (100%)	4.6 (100%)	3.3% (100%)

*FDI = Foreign direct Investment

[1] The equation used in the estimation is $ln\ Y_i = a + b\ ln\ X_i$, *where* Y_i *is area, yield, and production, and* X_i *is year, and b is annual growth rate.*

Note: Numbers in parentheses are percentages of contribution

Source: Author's calculation using data from FAOSTAT

Table 2.5: Factors affecting adoption of modern rice, fertilizer use, and rice yield

	Probit Function		OLS[a]	2SLS[a]
	Modern rice	**Fertilizer use**	**Yield**	**Yield**
Area irrigated (%)	0.005***	0.006***	0.006***	
	(25.24)	(25.01)	(31.30)	
Farm size (ha)	0.192***	0.151***	-0.254***	-0.421***
	(23.55)	(21.35)	-(41.12)	-(32.80)
Radio (1 = yes)	-0.006	-0.060***		
	-(0.38)	-(3.39)		
Television (1 = yes)	0.181***	0.384***		
	(12.30)	(22.03)		
Modern rice			0.051***	4.096***
			(3.35)	(21.97)
Fertilizer use			0.282***	
			(16.24)	
Vientiane Capital (1 = yes)	1.300***	1.779***	-0.188***	-2.000***
	(30.54)	(35.23)	-(4.55)	-(18.35)
Phongsaly (1 = yes)	-0.695***	-0.059	0.016	0.716***
	-(15.27)	-(0.97)	(0.40)	(10.37)
Louang Namtha (1 = yes)	0.344***	0.417***	-0.173***	-0.648***
	(8.66)	(7.43)	-(4.25)	-(9.52)
Oudomxay (1 = yes)	0.285***	-0.603***	-0.351***	-0.790***
	(8.00)	-(7.82)	-(9.53)	-(13.55)
Bokeo (1 = yes)	0.684***	0.264***	0.015	-1.072***
	(17.59)	(4.81)	(0.39)	-(13.43)
Luang Prabang (1 = yes)	0.245***	-0.449***	-0.333***	-0.672***
	(7.24)	-(6.84)	-(9.75)	-(12.48)
Xayabouly (1 = yes)	0.543***	-0.091	0.217***	-0.634***
	(16.27)	-(1.69)	(6.30)	-(9.84)
Xiengkhuang (1 = yes)	-0.551***	0.556***	0.238***	0.812***
	-(13.61)	(10.89)	(6.32)	(12.63)
Vientiane province (1 = yes)	0.466***	0.922***	0.238***	-0.447***
	(14.34)	(20.68)	(7.17)	-(7.21)
Bolikhamxay (1 = yes)	0.499***	0.528***	-0.466***	-1.207***
	(13.31)	(10.07)	-(12.08)	-(17.78)
Khammuane (1 = yes)	1.319***	1.171***	-0.812***	-2.701***
	(35.23)	(24.16)	-(21.54)	-(27.09)

Continued

Table 2.5 (Continued)

Savannakhet (1 = yes)	1.797***	1.804***	-0.697***	-2.994***
	(49.88)	(39.93)	-(20.09)	-(26.04)
Saravane (1 = yes)	1.329***	1.259***	-0.784***	-2.683***
	(35.63)	(26.39)	-(21.14)	-(26.48)
Sekong (1 = yes)	1.037***	-0.091	-1.083***	-2.547***
	(23.42)	-(1.14)	-(23.33)	-(26.86)
Champasak (1 = yes)	1.900***	1.902***	-0.791***	-3.175***
	(43.57)	(39.46)	-(20.42)	-(25.70)
Attapeu (1 = yes)	0.873***	0.624***	-0.959***	-2.224***
	(20.31)	(10.45)	-(21.40)	-(25.90)
Log likelihood	-23,353.80	-16,108.38		
R^2	0.216	0.269	0.195	
N	43,061	38,361	38,361	43,061

a OLS = ordinary least square; 2SLS = two-stage least square

*Significant at 10% level. **Significant at 5% level. ***Significant at 1% level.

Note: Numbers in parentheses are *t*-statistics

Table 3.1: Maize area planted (ha) and production (t) in Lao PDR, by province, 1976-2015

Province	Area						Production					
	1976		1990		2015		1976		1990		2015	
	Ha	%	Ha	%	Ha	%	Tons	%	Tons	%	Tons	%
Lao PDR	29,422	100.0	36,670	100.0	254,025	100.0	30,387	100.0	66,559	100.0	1,516,250	100.0
Vientiane capital	-	-	300	0.8	2,380	0.9	-	-	600	0.9	16,640	1.1
Phongsaly	2,896	9.8	1,650	4.5	8,815	3.5	2,710	8.9	4,210	6.3	52,825	3.5
Luang Namtha	3,963	13.5	1,000	2.7	5,490	2.2	2,734	9.0	2,500	3.8	33,735	2.2
Oudomxay	3,488	11.9	4,150	11.3	58,930	23.2	2,934	9.7	14,525	21.8	323,235	21.3
Bokeo	-		450	1.2	4,285	1.7	-	-	1,440	2.2	22,160	1.5
Luang Prabang	5,199	17.7	3,998	10.9	13,240	5.2	4,142	13.6	3,486	5.2	80,185	5.3
Houaphanh	5,167	17.6	7,563	20.6	31,550	12.4	7,128	23.5	6,655	10.0	173,690	11.5
Xayabouly	1,836	6.2	1,794	4.9	61,530	24.2	2,895	9.5	4,851	7.3	335,465	22.1
Xiengkhouang	1,676	5.7	3,937	10.7	26,790	10.5	1,843	6.1	6,139	9.2	155,578	10.3
Vientiane	610	2.1	2,800	7.6	8,180	3.2	651	2.1	6,430	9.7	56,276	3.7
Bolikhamxay	-		1,750	4.8	4,650	1.8	-		2,765	4.2	32,166	2.1
Khammuane	405	1.4	900	2.5	1,800	0.7	476	1.6	2,025	3.0	16,990	1.1
Savannakhet	2,867	9.7	3,435	9.4	5,030	2.0	3,403	11.2	5,840	8.8	48,770	3.2
Saravane	753	2.6	700	1.9	4,015	1.6	855	2.8	1,820	2.7	29,010	1.9
Sekong	-		900	2.5	4,640	1.8	-		1,080	1.6	39,150	2.6
Champasak	512	1.7	845	2.3	7,130	2.8	568	1.9	1,603	2.4	42,120	2.8
Attapeu	50	0.2	498	1.4	5,570	2.2	48	0.2	590	0.9	58,255	3.8

Source: Author's calculation using data from the Lao Statistical Yearbooks, 1976-2015

Table 3.2: Growth in maize production, area planted, and yield in Lao PDR, 1961-2016

Period	1961-1985 [1]	1986-2005 [2]	2006-2016 [3]	1961-2016 [4]
Production growth (A = B+C)[1]	2.9% (100%)	7.8% (100%)	11.2% (100%)	8.1% (100%)
- Growth in area expansion (B)[1]	4.9% (169%)	3.6% (46%)	7.6% (68%)	5.5% (68%)
- Growth in maize yield (C)[1]	(-2.0%)	4.2% (54%)	3.6% (32%)	2.6% (32%)

Note: Author's calculation using data from FAOSTAT, 2018.

[1]The equation used in the estimation is *ln* $Y_i = a + b \ln X_i$*, where* Y_i *is area, yield and production and* X_i *is year, and b is the annual growth rate.*

- Numbers in parentheses are percentage of contribution

Table 3.3: Characteristics of sample households in the 2013, 2017 and 2018 surveys

	2013		2017	2018
	(A)*	(B)**		
Total sample households	121	121	95	30
Under CF	121 (100%)	61 (50.4%)	61 (50.4%)	16 (53.3%)
Drop-out of CF	0	0	34 (28.1%)	14 (46.7%)
Migrated outside the village	0	0	26 (27.4%)	NA
Average education of household head	121 (100%)	61 (100%)	95 (100%)	30 (100%)
Under CF	121 (100%)	61 (100%)	61 (100%)	16 (53.3%)
Kindergarten	2 (1.7%)	0	0	0
Illiterate (0 year)	18 (14.9%)	8 (13.1%)	9 (14.8%)	1 (6.3%)
Not completed primary (1 - 5 years)	47 (38.8%)	21 (34.4%)	24 (39.3%)	3 (18.8%)
Completed primary (5 years)	38 (31.4%)	20 (32.8%)	17 (27.9%)	4 (25%)
Lower secondary (6 - 9 years)	14 (11.6%)	10 (16.4%)	10 (16.4%)	6 (37.5%)
Upper secondary (10 - 12 years)	2 (1.7%)	2 (3.3%)	0	2 (12.5%)
Middle diploma (More than 13 years)	0	0	1 (1.6%)	0
Drop-out of CF	NA	NA	34 (100%)	14 (46.7%)
Illiterate (0 year)	NA	NA	7 (20.6%)	1 (7.1%)
Not completed primary (1 - 5 years)	NA	NA	17 (50%)	1 (7.1%)
Completed primary (5 years)	NA	NA	6 (17.7%)	8 (57.1%)
Lower secondary (6 - 9 years)	NA	NA	4 (11.7%)	2 (14.3%)
Upper secondary (10 - 12 years)	NA	NA	0	1 (7.1%)
Middle diploma (More than 13 years)	NA	NA	0	1 (7.1%)
Average year in schooling of household head	NA	NA	3.9	6.1
Under CF	NA	NA	4.4	6.2
Drop-out of CF	NA	NA	3.2	5.7
Migration outside the village	NA	NA	NA	NA

*Total sample households

**Households that continue participating in CF in 2017

Sources: Author's calculation based on NERI's survey of 2013, GRIPS-ESP's survey of 2017, and NIER's survey of 2018.

Table 3.4: Arrangement of input contribution between farmers and contractors

	2013		2017	2018
	(A)*	(B)**		
Number of respondents	121	61	61	30
Land contribution				
Farmer	121 (100%)	61 (100%)	56 (91.8%)	30 (100%)
Contractor	0	0	5 (8.2%)	0
Labor cost contribution				
Farmer	121 (100%)	61 (100%)	56 (91.8%)	30 (100%)
Contractor	0	0	5 (8.2%)	0
Seeds contribution				
Farmer	21 (17.4%)	8 (13.1%)	5 (8.2%)	8 (26.7%)
Contractor	91 (75.2%)	53 (86.8%)	56 (91.8%)	22 (73.3%)
Fertilizer contribution				
Farmer	3 (2.5%)	3 (2.5%)	4 (6.6%)	20 (66.7%)
Contractor	0	0	25 (40.9%)	10 (33.3%)
Herbicide contribution				
Farmer	31 (25.6%)	7 (11.5%)	7 (11.5%)	NA
Contractor	43 (35.5%)	34 (55.7%)	30 (49.2%)	NA
Pesticide contribution				
Farmer	0	6 (9.8%)	4 (6.6%)	18 (60%)
Contractor	0	0	20 (32.8%)	12 (40%)
Machine/production tool contribution				
Farmer	NA	NA	29 (47.5%)	30 (100%)***
Contractor	NA	NA	5 (8.2%)	0
Contribution on the cost of land preparation and crop care				
Farmer	NA	NA	56 (91.8%)	NA
Contractor	NA	NA	5 (8.2%)	NA
Party in production marketing				
Farmer	8 (6.6%)	2 (3.3%)	1 (1.6%)	0
Contractor	113 (93.4%)	56 (91.8%)	60 (98.4%)	30 (100%)

*Total sample households

**Households that continue participating in CF in 2017

*** The Thai contractor in Saravane province recommended the use of sowing machine to farmers, but farmers have to purchase the machine on their own. Only one farmer bought the machine from the contractor.

Sources: Author’s calculation based on NERI’s survey of 2013, GRIPS-ESP’s survey of 2017, and NIER’s survey of 2018.

Table 3.5: Provision of credit to farmer from contractor by key inputs under maize CF in Lao PDR

	2013		2017	2018
	(A)*	(B)**		
No. of respondents	121	61	61	30
Seeds	91 (75.2%)	53 (86.8%)	56 (91.8%)	22 (73.3%)
Fertilizer	0	0	25 (40.9%)	10 (33.3%)
Pesticide	0	0	20 (32.8%)	12 (40%)
Herbicide	43 (35.5%)	34 (55.7%)	30 (49.2%)	NA
Machine	0	0	0	0

*Total sample households

**Households that continue participating in CF in 2017

Sources: Author's calculation based on NERI's survey of 2013, GRIPS-ESP's survey of 2017, and NIER's survey of 2018.

Table 3.6: Sources of farm management training provided to farmers under CF in Lao PDR

	2013		2017	2018
	(A)*	(B)**		
No. of respondents	121	61	61	30
Provider of farm training				
Contractor	44 (36.4%)	25 (40.9%)	32 (52.5%)	0
Goverment agency	0	0	0	0
Other sources	12 (9.9%)	0	1 (1.6%)	0
Farmers	59 (48.8%)	28 (45.9%)	28 (45.9%)	30 (100%)
Not specified	6 (4.9%)	5 (0.8%)	0	0
Type of training received				
Fertilizer use	NA	NA	25 (40.9%)	NA
Herbicide use	NA	NA	20 (32.8%)	NA
Pesticide use	NA	NA	30 (49.2%)	NA
Machine use	NA	NA	5 (8.2%)	NA

*Total sample households

**Households that continue participating in CF in 2017

Sources: Author's calculation based on NERI's survey of 2013, GRIPS-ESP's survey of 2017, and NIER's survey of 2018.

Table 3.7: Trends in family and hired labor use in sample CF participating households in the study villages (average number of persons per household)

	2013		2017	2018
	(A)*	(B)**		
No. of respondents	121	61	61	16
Cultivation				
Land preparation, ploughing, etc.				
Family labor	7.4	7.05	5.4	NA
Hired labor	0.6	0.6	1.4	NA
Plantation and crop care				
Family labor	7.5	4.05	7.7	NA
Hired labor	1.5	2.4	0.7	NA
Harvesting				
Family labor	3.8	3.8	2.7	NA
Hired labor	0.8	1.05	0.4	NA
Postharvest activity				
Husking and shelling				
Family labor	NA	NA	3.3	NA
Hired labor	NA	NA	0.7	NA
Transportation				
Family labor	6.9	2.5	1.7	NA
Hired labor	0.3	0.4	0	NA
Hired labors use for an entire harvest season	NA	NA	NA	24 farm labors-day

*Total sample households
**Households that continue participating in CF in 2017

Sources: Author's calculation based on NERI's survey of 2013, GRIPS-ESP's survey of 2017, and NIER's survey of 2018.

Appendix

Table A2.1: Rice varieties released by the Lao Rice Research Center/Station, 1960s–1980s

Year of release	Name of lines/varieties	Origin of varieties	Center that developed/released the varieties	Characteristics
1964	Niew Sanpatong	Thai-IRRI	Salakham Rice Research and Seed Multiplication Station (Salakham Station)	Glutinous; grain quality with relative low yield between 3 and 4 tons per hectare; growth duration between 140 and145 days
1964	IR2823-103	IRRI	Salakham Station	Non-glutinous rice with sturdy culms; relative high yield potential between 3 and 5 tons per hectare; short growth duration between 125 and130 days; erect leaves; wide adaptability; resistance to BPH; susceptibility to adverse soil conditions, BLB, and STB
1964	IR253-100	IRRI	Salakham Station	Glutinous rice with sturdy culms; big grain with relative high yield potential between 3 and 6 tons per hectare; moderate growth duration between 130 and150 days; drought tolerance; wide adaptability; acceptable eating quality; low threshing ability; susceptibility to BLB, NBLS, FS, STB, and BPH
1964	Nang Nuan	Laos	Salakham Station	Traditional glutinous rice; moderate grain and yield between 2 and 3 tons per hectare; moderate growth duration between 135 and 140 days
1964	C4-63-1	Philippines	Salakham Station	Non-glutinous rice with high yield potential between 3.5 and 7 tons per hectare; growth duration between 130 and 135 days; intermediate plant type; good milling and eating quality; susceptibility to low temperature; wide adaptability; susceptibility to NBLS
1964	IR848-120	IRRI	Salakham Station	Glutinous rice with sturdy culms; relative high yield between 3 and 7 tons per hectare; relative short growth duration between 130 and 140 days; soft; wide adaptability; high threshing ability; low milling quality; susceptibility to low temperature, BLB, NBLS, STB, and BPH
1971	IR8	IRRI	Salakham Station	Non-glutinous rice with relative high yield potential between 3 and 5 tons per hectare; growth duration between 135 and 145 days; highly responsive to fertilizer; wide adaptability; susceptibility to drought and BPH; but relatively poor eating quality

Table A2.1 (Continued)

Year of release	Name of lines/varieties	Origin of varieties	Center that developed/released the varieties	Characteristics
1977	IR36	IRRI	Salakham Station	Non-glutinous rice with relative high yield potential between 3 and 5 tons per hectare; short growth duration between 120 and 125 days; wide adaptability; good milling quality; resistance to BPH; and susceptibility to drought
1977	KDML105	Thailand	Salakham Station	Non-glutinous with high yield potential between 4 and 6 tons per hectare; relative short growth duration between 125 and 135 days; photoperiod sensitive; tall plant type; aromatic with good eating and milling quality; tolerance for saline and acid soils; resistance to root-knot nematode; suitable for growing in the central and southern agricultural regions; suitabilty for direct seedling; susceptibility to leaf Bl, neck Bl, BLB, orange leaf virus, grassy stunt virus, BPH, GLH, and STB
1978	IR22	IRRI	Salakham Station	Non-glutinous rice with relative high yield potential between 3 and 6 tons per hectare; growth duration between 130 and 140 days; uniform plant; good eating quality; wide adaptability; susceptibility to BLB, BPH, STB, BLS, GLS, GM, and drought
1978	Deng home	Laos	Salakham Station	Glutinous traditional rice with good quality; moderate yield potential between 3 and 4 tons per hectare; growth duration between 130 and 140 days
1979	IR789-98	IRRI	Salakham Station	Glutinous rice with long and slender grains; relative high yield potential between 3 and 6 tons per hectare; growth duration between 130 and 140 days; good milling quality; narrow adaptability; delayed flowering; susceptibility to NBLS, bakanae, yellow-orange leaf disease, BPH, and STB
1980	RD10	Thailand	Salakham Station	Glutinous rice; relatively high yield between 4 and 5 tons per hectare; growth duration between 130 and 135 days; long and slender grains; good milling and easting qualities; broad adaptability; can be grown in both wet and dry seasons; intermediate response to fertilizer, susceptibility to flooding, to BLB, LBl, BPH, STB, and GM
1981	B1014-bpN18-1-4	Indonesia	Salakham Station	Non-glutinous rice with yield potential between 3 and 5 tons per hectare; growth duration between 130 and 135 days; wide adaptability; resistance to BPH and STB; poor milling quality.

Table A2.1 (Continud)

Year of release	Name of lines/varieties	Origin of varieties	Center that developed/released the varieties	Characteristics
1984	CR203	Vietnam	Salakham Station	Non-glutinous rice with relative high yield potential between 3 and 5 tons per hectare; relative short growth duration between 125 and 130 days; photoperiod insensitivity; suitability as raw material for producing noodles and for brewery; broad adaptability; can be grown in wet and dry seasons; poor eating and milling quality; suitability for direct seedling; resistance to BPH, leaf Bl, BLB
1984	SLK1-7-2	Laos	Salakham Station	Glutinous rice with relative high yield potential between 3 and 6 tons per hectare; growth duration between 135 and 140 days; good milling and eating quality; wide adaptability; resistance to BLB; susceptibility to drought and BPH
1984	RD8	Thai-IRRI	Salakham Station	Glutinous rice with yield between 3 and 4 tons per hectare; growth duration between 130 and 140 days; photoperiod sensitivity; tall plant type; large seeded; good eating and milling qualities; moderate resistance to Bl and BLS; suitability for direct seedling; suitability to middle terraces of central and southern agricultural regions of Laos; susceptibility to BLB, BPH, GLH, GM; tendency to lodge
1985	IR42	IRRI	Salakham Station	Non-glutinous rice with yield potential between 3 and 5 tons per hectare; growth duration between 135 and 145 days; wide adaptability; resistance to major pests and diseases; high response to fertilizer; poor milling quality

Note: BPH=brown planthopper; NBLS=narrow brown leafspot; STB=stem borer; Bl=blast; GLH=green leafthopper; GM=gall midge; FS=false smut
Source: Hatsadong, 1986

Table A2.2: Modern rice varieties released by the Lao Rice Research Center/Station since 1993

Year of release	Name of lines/varieties	Origin of varieties	Center that developed/released the varieties	Characteristics
1993	TDK1	Lao-IRRI	Rice Research Center in Tha Dorkkham, Vientiane under NAFRI (RRC-Vientiane)*	Glutinous rice with high yield potential, growth duration between 135 and 140 days; photoperiod non-sensitivity; suitability for wet- and dry-season planting; resistance to BPH, moderate resistance to Bl and BLB, highly responsive to nitrogen, wide adaptability; susceptibility to neck blast, bakanae disease, and GLH; poor milling quality in dry season
1993	TDK2	Lao-IRRI	RRC-Vientiane	Glutinous rice with high yield potential; growth duration between 135 and140 days; photoperiod non-sensitivity; suitability for wet and dry seasons; good eating quality; moderate resistance to Bl and BLB; susceptibility to BPH and GLH
1993	PNG1	Lao-IRRI	Phone Ngam Rice Research and Seed Multiplication Center in Pakse of Chamnpasak province, a regional network center under NAFRI (PNG-Pakse)	Glutinous rice with high yield potential; relatively short growth duration between 125 and 130 days; photoperiod non-sensitivity; suitability for wet and dry seasons; good eating and milling quality; good adaptability to drought-prone areas of central region; resistance to GLH and Bl; moderate resistance to BLB; susceptibility to neck blast and BLB
1995	PNG2	Lao-IRRI	PNG-Pakse	Glutinous rice with moderate growth duration; photoperiod sensitivity; tall plant type; good milling and eating quality; good adaptability to drought-prone areas of central and southern regions of Laos; susceptibility to neck blast, leaf blast, BPH, and GLH
1997	TDK3	Lao-IRRI	RRC-Vientiane	Glutinous rice with high yield potential; growth duration between 130 and135 days; photoperiod non-sensitivity; suitability for wet and dry seasons; good eating quality; moderate resistance to Bl, good resistance to BLB, good milling quality in dry season, susceptibility to BPH, GM, and bakanae disease.
1998	TDK4	Lao-IRRI	RRC-Vientiane	Glutinous rice with moderate growth duration; photoperiod sensitivity; intermediate plant type; good eating and milling quality; resistance to Bl and BLB, moderate resistance to BPH; suitability to fertile soils; susceptibility to acidic soils, GLH, and GM

Table A2.2 (Continued)

Year of release	Name of lines/varieties	Origin of varieties	Center that developed/released the varieties	Characteristics
1998	TSN1	Lao-IRRI	Thasano Rice Research and Seed Multiplication Center in Savannakhet province, a regional network center under NAFRI (TSN-Savannakhet)	Glutinous rice with high yield potential; growth duration between 140 and 145 days; photoperiod non-sensitivity; suitability for wet season; good eating and milling quality; moderate resistance to Bl, BLB; tolerance for acidic soils; moderate susceptibility to BPH, GLH, and GM; not suitable for dry season
1998	NTN1	Lao-IRRI	Nathane Rice Research Center in Sayabouly province, a regional network center under the Ministry of Agriculture and Forestry (NTN-Sayabouly)	Glutinous rice with high yield potential; relative short growth duration between 130 and 135 days; photoperiod non-sensitivity; suitability for wet and dry seasons; good eating quality in dry season; moderate resistance to Bl, good adaptability in drought-prone areas of central and southern regions; moderate susceptibility to BLB, BPH, and GLH
2000	TDK5	Lao-IRRI	RRC-Vientiane	Glutinous rice with high yield potential; short growth duration between 125 and 130 days; photoperiod non-sensitivity; suitability for wet and dry seasons, good eating; good milling quality in dry season; moderate resistance to Bl and BLB; good adaptability to high elevation in northern region of Laos; moderate susceptibility to BPH and GLH; easy to shatter
2003	TDK6	Lao-IRRI	RRC-Vientiane	Glutinous rice with high yield potential; growth duration between 135 and 140 days; photoperiod non-sensitivity; suitable for wet and dry seasons; moderate resistance to Bl and BLB; good adaptability to high elevation in northern region of Laos; moderate susceptible to neck blast, BPH, GLH, and GM
2003	TDK7	Lao-IRRI	RRC-Vientiane	Glutinous rice with high yielding potential; growth duration between 135-140 days; photoperiod non-sensitivity; suitability for wet and dry seasons; good eating quality; good milling quality in dry season; moderate resistance to Bl and BLB; tolerance for acidic soils; high susceptibility to neck blast; moderate susceptibility to BPH, GLH and GM
2004	TSN2	Lao-IRRI	TSN-Savannakhet	Glutinous rice with high yield potential; growth duration between 130 and 135 days; photoperiod non-sensitivity; suitability for wet season; good eating and milling quality; moderate resistance to Bl and BLB; tolerance for drought; susceptibility to BPH, GLH, and GM

Table A2.2 (Continued)

Year of release	Name of lines/varieties	Origin of varieties	Center that developed/released the varieties	Characteristics
2004	TSN3	Lao-IRRI	TSN-Savannakhet	Glutinous rice with high yield potential; growth duration between 135 and 140 days; photoperiod non-sensitivity; suitability for wet and dry seasons; good eating and milling quality; resistance to BLB; susceptibility to Bl, BPH, GLH, and GM
2004	TSN4	Lao-IRRI	TSN-Savannakhet	Glutinous rice with high yield potential; growth duration between 125 and 130 days; photoperiod non-sensitivity; suitability for wet and dry seasons; good eating and milling quality; resistance to BLB; susceptibility to Bl, BPH, GLH, and GM
2005	PNG3	Lao-IRRI	PNG-Pakse	Glutinous rice with high yield potential; growth duration between 130 and 135 days; photoperiod non-sensitivity; suitability for wet season; good eating and milling quality; moderate resistance to Bl; tolerance for acidic soils; suitability to drought-prone areas of central and southern regions of Laos; susceptibility to BLB, BPH, GLH, and GM; susceptiblility to low temperature; not suitable for dry season
2005	PNG5	Lao-IRRI	PNG-Pakse	Glutinous rice with high yield potential; growth duration between 125 and 130 days; photoperiod non-sensitivity; suitability for wet and dry seasons; good eating and milling quality; moderate resistance to BLB; tolerance for acidic soils; suitability to drought-prone areas of central and southern region of Laos; suitability for direct seeding; susceptibility to Bl, BPH, GLH, and GM
2005	PNG6	Lao-IRRI	PNG-Pakse	Glutinous rice with high yield potential; growth duration between 130 and 135 days; suitability for wet season; good eating and milling quality; moderate resistance to BLB; suitability for drought-prone areas of central and southern regions of Laos; susceptibility to Bl, BPH, GLH, and GM; susceptibility to low temperature; not suitable for dry season

Table A2.2 (Continued)

Year of release	Name of lines/varieties	Origin of varieties	Center that developed/released the varieties	Characteristics
2006	TDK8	Tha Dork Kham in Lao PDR	RRC-Vientiane	New type of high-yielding glutinous rice variety; growth duration between 130 and 135 days; photoperiod non-sensitivity; wide adaptability; suitability for wet and dry seasons; suitability for central and southern regions of Laos; moderate resistance to BLB and leaf blast diseases; resistance to bakanae disease; good response to nitrogen fertilizer; long grain with brown color, high milling and good eating quality; moderate susceptibility to neck blast, BPH, GLH; moderate susceptibility to Fe toxicity
2008	TDK11	Tha Dork Kham in Lao PDR	RRC-Vientiane	New type of high-yielding glutinous rice variety with grain yield over 5 tons per hectare; medium growth duration between 130 and 135 days; intermediate plant type; wide adaptability; suitability for wet and dry seasons; long grain; good milling and acceptable eating quality; tolerance for F+2 toxin; resistance to Bl and BLB
2008	TSN5	TSN-Savannakhet	TSN-Savannakhet	Glutinous with relative high yield potential; growth duration between 135 and 140 days; medium susceptibility to BPH; medium resistance to BI, resistance to BLB, NB, BD; susceptibility to GLH, GM; and medium resistance to Fe toxicity
2008	TSN6	TSN-Savannakhet	TSN-Savannakhet	Glutinous with relative high yield potential; relative short growth duration between 120 and 130 days; resistance to BD; and susceptibility to GLH and GM
2008	TSN7	TSN-Savannakhet	TSN-Savannakhet	Glutinous with relative high yield potential; relative short growth duration between 120 and 130 days; medium resistance to BI and BLB; resistance to BD; susceptibility to GLH and GM
2012	VTE-450-1	Tha Dork Kham in Lao PDR	RRC-Vientiane	Non-glutinous semi-dwarf plant type rice with relatively high yield; growth duration between 135 and 140 days; good resistance to lodging; slight photoperiod sensitivity; resistance to damage by bakanae disease, has moderate resistance to leaf blast diseases, moderate susceptibility to neck blast disease, susceptibility to BPH, GLH, and GM; moderate tolerance for Fe toxicity; high milling quality

Table A2.2 (Continued)

Year of release	Name of lines/varieties	Origin of varieties	Center that developed/released the varieties	Characteristics
2012	VTE-450-2	Tha Dork Kham in Lao PDR	RRC-Vientiane	Glutinous intermediate plant type with large panicles; moderate duration between 140 and 150 days; slight photoperiod sensitivity, suitability for wet-season cultivation, but can also be grown under irrigated conditions in the dry season if sown from mid-November to early December; resistance to damage from bakanae disease, moderate resistance to leaf blast and bacterial leaf blight; moderate susceptibility to neck blast disease; susceptibility to BPH, GLH, and GM; moderate tolerance for Fe toxicity
2012	TDK1-Sub1	Tha Dork Kham in Lao PDR	RRC-Vientiane	Glutinous rice with growth duration between 139 and 145 days; photoperiod non-sensitivity; semi-dwarf plant type (106-125 cm); wide adaptability; suitability for flooded areas in central and southern agricultural region of Laos; good milling quality and high milling percentage for dry season; good eating quality but non-aromatic; susceptibility to BLB, GLH, neck blast, and Fe toxicity
2012	TDK13	Tha Dork Kham in Lao PDR	RRC-Vientiane	Non-glutinous intermediate plant type with growth duration between 125 and 130 days; photoperiod non-sensitivity; suitability for wet and dry seasons; resistance to bacterial leaf blight, bakanae disease, and BPH; moderate resistance to leaf blast and neck blast diseases and moderate tolerance for Fe toxicity; susceptibility to GLH and GM
2014	Hom Savan	TSN-Savannakhet	TSN-Savannakhet	Aromatic non-glutinous with good grain quality, growth duration of approximately 140 days; low amylose content; suitability in flooded and droughty plains of Savannakhet province
2014	XBF2	Xe Bang Fai in Khammuan province in Lao PDR	Xebangfai Agriculture and Development Center in Khammuane province under the Ministry of Agriculture and Forestry (XBF-Khammuane)	New aromatic non-glutinous rice with growth duration approximately 140 days; good eating quality, low amylose content (15-17%); flood and drought tolerance
2014	XBF3	Xe Bang Fai in Khammuane province in Lao PDR	XBF-Khammuane	Aromatic non-glutinous rice with good eating quality, low amylose content (15-17%), flood and drought tolerance; photoperiod sensitivity

Note: BPH=brown planthopper; NBLS=narrow brown leaf spot; STB= stem borer; Bl=blast; GLH=green leafhopper; GM=gall midge; FS=false smut
Sources: Hatsadong, 1986; Inthapanya et al., 2013; Inthapanya et al., 2014; IRRI 2016; NAFRI, 2016

Table A3.1: Policies, instruments and milestones affecting the Agricultural Commercialization policy in Lao PDR

Year	Policies, Instruments and Milestones
1986	4th Congress of Lao People Revolutionary Party institutes the "Chintanakarnmay" or New Economic Mechanism (NEM) enabling economic liberalization of the country.
1990	Contract Law that specified basic contract types, participants, and enforcement.
1991	New Constitution formalizes the market-oriented economy, rights to private property and "Open Door Policy" toward foreign investment.
1991	5th LPRP's Congress emphasizing the important of agriculture sector and confirms that farm household as the main unit of agricultural production.
1992	Introduction of the eight national priority programs: 1) Food Production; 2) Commodity Production Promotion; 3) Stabilization of Shifting Cultivation; 4) Rural Development; 5) Infrastructure Development; 6) Service Sector Development; 7) Human Resource Development; 8) Strengthening Regional and International Economic Integration
1993-2000	8-Year Public Investment Programs focusing on agricultural production development
1994	Foreign Investment Law provides detail incentives aiming at attracting FDI.
1994	Prime Minister Decree No. 187 reducing import taxes on agricultural inputs such as fertilizer, pesticides, agricultural tools, and equipment.
1995	Tax Law that provides incentive tax rates on FDI.
1997	Becoming full membership of ASEAN.
1998	Agricultural Law.
1999	Agricultural Sector Strategic Vision.

Continued

Table A3.1 (Continued)

Year	Policies, Instruments and Milestones
2001	7th LPRP's Congress emphasizing the need to move forward regional and international economic integration with concrete strategy toward graduation from least developed country status by 2020.
2002	Prime Minister Decree No. 46/PM on decentralization of small FDI projects to provinces, enabling the expansion of 1+4 and 2+3 CF projects at provincial levels.
2002	Decision No. 013/1/CPC of the Chairperson of the Committee for Planning and Cooperation in setting detail on the implementation of the Law on the Promotion and Management of Foreign Direct Investment project in Lao PDR. The Decree includes detail on FDI in agriculture sector.
2003	Prime Minister Decree No.125/PM on the Lao Chamber of Commerce & Industry setting equal rights of all business entities in the country.
2004	Prime Minister Decree No. 42/PM on SME Development and Promotion.
2004	Prime Minister Decree No. 119/PM on Domestic and Foreign Investment enhancing business environment to attract foreign and domestic investment.
2005	6th Five-Year Plan (2006-2010) emphasizing market development for local products particularly for export.
2006	Strengthening the commodity production in agriculture sector by introducing the "Integrated Agriculture Development and Marketing Program - IADM" identifying 14 measures: 1) agricultural land development and allocation; 2) improvement of rice yield through intensive agriculture approach in 7 main flat areas; 3) water resource development and management; 4) sustainable irrigation system development; 5) commercialization in cash crop and other plantations; 6) organic agriculture; 7) export-oriented livestock and poultry farming; 8) cattle and goats raising in upland for poverty reduction; 9) Fishery and expansion of natural fishery sources; 10) building livestock and fish seed/baby and animal feeding center; 11) plantation and animal disease prevention and protection; 12) development of household economy and agricultural cooperative; 13) agriculture extension for farmers; and 14) market development to support agricultural commercialization.

Remarks: the reforms on FDI, business environment, and agricultural development starting in 2002 has served as important forces in inducing FDI inflows into agriculture sector in the form of 1+4 and 2+3 systems enabling the commodity production promotion program in agriculture (Agricultural Commercialization) to be materialized since the mid-2000s.

Source: CPI, 2005, CPI & JICA, 2002, Konishi, 2005, Mallon, 2005, MAF, 1999, LPRP, 1987, Oraboune, 2008, and UNDP, 2001

Table A3.2: Some basic information about the CF participating households in the 2013 and 2017 study villages

	2013	2017	2018
Respondents	121	95	30
Under CF	121 (100%)	61 (50.4%)	16 (53.3%)
Drop-out od CF	0	34 (28.1%)	14 (46.7%)
Migrated outside the village	0	26 (27.4%)	0
Adopting modern variety	121 (100%)	61 (100%)	30 (100%)
Who gave seeds			
Contractor	121 (100%)	59 (96.7%)	NA
Bought	0	3 (4.9%)	NA
Other	0	1 (1.6%)	NA
Beginning to participate in CF			
2005-2010	95 (78.5%)	41 (67.2%)	13 (43.3%)
After 2010	24 (19.8%)	21 (34.4%)	17 (56.7%)
Maize area irrigated	NA	6 (9.8%)	NA
Incentive reason for participation in CF			
Receive production factors	56 (46.3%)	28 (45.9%)	NA
Guaranteed market	94 (77.7%)	46 (75.4%)	NA
Guaranteed price	88 (72.7%)	35 (59%)	NA
Receive traning on production technique from contractor or public sector	8 (6.6%)	5 (8.2%)	NA
Receive cash for initial investment from contractor	1 (0.8%)	3 (4.9%)	NA
Have spare pieces of land	14 (11.6%)	2 (3.3%)	NA
Have spare labors	0	5 (8.2%)	NA
Lack support on capital	2 (1.7%)	2 (3.3%)	NA
Receive assistance or welfare from contractor	0	1 (1.6%)	NA
Made a loss from growing other crops before	2 (1.7%)	1 (1.6%)	NA
Receive higher income (profit) than growing other crops	50 (41.3%)	31 (50.8%)	NA
Was convinced to join by others	14 (11.6%)	11 (18%)	NA
Others	12 (9.9%)	4 (6.6%)	NA
Nationality and type of contractor			
Thai contractor	108 (89.3%)	61 (100%)	10 (33.3%)
Chinese trader	10 (8.3%)	0	9 (30%)
Lao contractor	0	0	11 (36.7%)
Others	2 (1.7%)	0	0
Sources of CF information/introducer			
Maize farmers' group	2 (1.7%)	6 (9.8%)	NA
Relatives/friend	35 (28.9%)	7 (11.5%)	NA
Village/district authority	65 (53.7%)	34 (57.3%)	NA
Thai trader	25 (20.7%)	4 (6.6%)	NA
Representative from domestic company	17 (14%)	3 (4.9%)	NA
Others	4 (3.3%)	0	NA

Sources: Author's calculation based on NERI's survey of 2013 and GRIPS-ESP's survey of 2017 and NIER's survey of 2018

Table A3.3: Details on key informant interviews, 2018 NIER survey

Level	Name of Agency	Total number	Type of Interview
Province	1. Department of Planning and Investment 2. Department of Agriculrture and Forestry 3. Department of Industry and Commerce 4. Provincial Council of Commerce and Industry	8 (4 Depts in 2 provinces)	Guideline questions
District	1. Office of Planning and Investment 2. Office of Agriculture and Forestry 3. Office of Industry and Commerce	9 (3 offices in 3 district)	Guideline questions
Village	1. Village chief 2. Other village authority body	30 (15 vill. chiefs+ 15 vill. Auth)	Questionnaire
Total number of key informant agency		47	

Source: NIER's survey of 2018

Table A3.4: Details on focus group discussion, 2018 NIER survey

Village	Type of Group	Number of Group Discussion Participants in each village	Total Group
Sapone	G and F	13	2
Senvangyai	G and F	40	2
Senvangnoy	G and F	30	2
Khiengkhong	G and F	24	2
Bengoudom	G and F	26	2
Houyngery	G and F	29	2
Bimy	G and F	10	2
Kang	G and F	18	2
Thong	G and F	19	2
Nathon	G and F	25	2
Boumlao	G and F	15	2
Muongva	G and F	12	2
Nakang	G and F	18	2
Namyang	G and F	13	2
Takdath	G and F	15	2
Total		**307**	**30**

Note: G=general group discussion; F=female group discussion.
Source: NIER's survey of 2018

Table A3.5: Details on household case studies, 2018 NIER survey

Province	District	Village	Type of Case
Saravane	Saravane	Sapone	C1, C2
		Senvangyai	C1, C2
		Senvangnoy	C1, C2
		Khiengkhong	C1, C2
		Bengoudom	C1, C2
Xayabouly	Ngeun	Houyngery	C1
		Bimy	C1, C2
		Kang	C1, C2
		Thong	C1, C2
		Nathon	C1, C2
	Parklai	Boumlao	C1, C2
		Muongva	C1, C2
		Nakang	C1, C2
		Namyang	C1, C2, C3
		Takdath	C1, C2
2	**3**	**15**	**30**

Note: C1=case study of category 1 (a case study of maize farm household that has been practicing maize CF and still operating maize CF; C2=case study of category 2 (a case study of maize household that has practiced maize CF but has stopped maize CF at present; and C3=case study of category 3 (a case study of new maize CF-entering household).
Source: NIER's survey of 2018

Table A3.6: Details on foreign and domestic contractor and trader interviews, 2018 NIER survey

Category	Province	District	Unit	Nationality
ATC-subsidiary	Saravane	Saravane	1	Thai
	Saravane	Saravane	1	Lao-American
	Xayabouly	Ngeun	1	Chinese*
Lao company	Xayabouly	Parklai	1	Lao
Local traders	Xayabouly	Parklai	4	Lao
	Xayabouly	Ngeun	1	Lao
Total			9	

Note: * A Chinese married to a Lao woman.
MNC-Subsidiary is a subsidiary of a foreign multi-national corporation (MNC).
Source: NIER's survey of 2018