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# 柬埔寨水稻生产技术效率及其决定因素研究

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# THE STUDY ON RICE PRODUCTION TECHNICAL EFFICIENCY AND ITS DETERMINANTS IN CAMBODIA

Major: **Economics and Management of Agriculture**

Research Field: **Economics and Management of Agriculture**

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# 柬埔寨水稻生产技术效率及其决定因素研究

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## 摘要

水稻是柬埔寨重要的粮食作物，因而研究水稻生产效率非常重要。本文主要目的是测量柬埔寨水稻生产技术效率(TE)，同时，识别柬埔寨水稻生产在国家和家庭层面的生产技术效率的核心影响因素。本研究运用随机前沿分析模型(SFA)，采用 2012 年至 2015 年来自柬埔寨皇家政府文件 “经济和社会上的形象” 国家层面的的数据，以及马德望省的三个地区 301 户水稻种植农户三年 (2013、2014 和 2015 年) 农户家庭层面微观调研数据，来测算和分析柬埔寨的水稻生产技术效率以及其影响因素，以期提出提高柬埔寨的水稻产量所应采用的技术政策。

研究结果表明，省级层面上，柬埔寨水稻产量取决于农业机械投资水平、水稻种植面积以及肥料的施用技术，而家庭水稻产量取决于生产技术、年度总水稻的实际播种面积、肥料和杀虫剂的使用量。水稻生产总体技术效率为 78.4%（国家层面）和 34%（家庭层面），表明在相同投入和技术条件下水稻产量潜在提高空间为 21.6%（国家生产）和 66%（家庭生产）。然而，在所研究的时期 由于严重受自然灾害和社会环境各种因素的影响，水稻技术效率减少了 −7%（国家层面）和 −14.3%（家庭层面）。

研究影响水稻产量的因素进一步表明，农业机械投资扩大、水稻实际播种面积的增加以及施肥、农药技术改进是柬埔寨水稻产量提高的主要因素。在柬埔寨水稻生产的所有投入因素里（国家和家庭层面），播种面积的产出弹性最高。因此，灌溉设施的发展和良好的水资源管理实践可能是扩大水稻种植面积的关键因素（通过耕地复种系统），更重要的是，灌溉系统对自然灾害有着重要的预防作用。此外，生产技术、员工数量及其技术技能也是柬埔寨水稻省级层面生产最重要的影响因素；导致家庭层面水稻生产技术效率降低的核心影响因素是自然灾害（如干旱、洪水和昆虫）的增加、较高的户主教育水平以及较大的家庭规模，而提升其生产效率的主要因素为灌溉面积的增加、大的块均面积和户主为女性。

**关键词：**农业生产效率，柬埔寨，水稻生产，随机前沿分析 (SFA)，技术效率

# THE STUDY ON RICE PRODUCTION TECHNICAL EFFICIENCY AND ITS DETERMINANTS IN CAMBODIA

Postgraduate: KEA SOKVIBOL Supervisor: Prof. LI HUA

## ABSTRACT

Rice is the most important food crop in Cambodia and its production is the most organized food production system in the country. Thus, it is of interest to examine the efficiency of rice production, the main objective of this dissertation is to measure the *technical efficiency* (TE) of rice production in Cambodia. Furthermore, the study was also trying to identify core influencing factors of the Cambodian rice production TE at both national and household level, in order to explain the possibilities of increasing productivity and profitability of rice by increasing efficiency gradually, and also identify what technical progress policy should be recommended to help decision-makers to increase the rice productivity in Cambodia, by using *translog production function* through *Stochastic Frontier Analysis* (SFA) model. Four-years dataset generated from the Royal Government of Cambodia's document "Profile on Economics and Social" of all 25 provinces between 2012 and 2015 was utilized for the national analysis, while in the analysis at household-level, the primary three-years data (2013, 2014, and 2015) collected from 301 rice farmers in three selected districts of Battambang province by structured questionnaires was applied. The results indicate that level of *rice output* in Cambodia varied according to the different level of capital investment in agricultural *machineries*, total rice actual *harvested area*, and technically *fertilizers* application within provinces, while level of *household rice output* varied according to the differences in efficiency of the production processes, production techniques, total annual rice actual *harvested land*, and technically application of *fertilizers* and *pesticides* of the farmers. The overall mean TE of rice production was estimated at 78.4% (at the national-level) and 34% (at household-level), indicates that *rice output* has the potential of being increased further by 21.6% (for national production) and 66% (for household) at the same level of inputs and technology if farmers had been technically efficient. However, the TE of rice production recorded a -7% decreasing rate at the national-level and -14.3% at the household-level due to highly affected of natural disasters and various environmental and social factors during the study periods.

Decomposing of SFA model reveals that enlarging capital investment at provincial level into agricultural *machineries*, expansion of rice actual *harvested area*, and technically improvement of *fertilizer* application are main input factors for rice production development in Cambodia at both national and household-level. Furthermore, *pesticide* is another important input factor for improving household's rice production.

*Harvested area* had the highest elasticity among all input factors of rice production in Cambodia (at both national and household-level). Thus, development of irrigation facilities, irrigation systems and good water management practices might be the key factors for enlarging rice cultivated area through multi-cropping systems. More importantly, irrigation systems are also playing the crucial role as the disasters prevention devices in most cases. Additionally, *production techniques*, technical skills and amount of *agricultural supporting staffs* are being as the most important influencing factors of national rice production in Cambodia. The core influencing factors lead to decreasing TE of household's rice production are frequently occurrence of natural *disaster* (i.e. droughts, floods, and insects), insufficient higher *education level of household's head*, *family size* and reduction of rice production area for *other crops' cultivated area*, while the main influencing factors that lead to increasing TE are enlargement of *irrigated area*, increasing in *number of plot area* and the *sex of household's head* (especially female head).

**Keywords:** Agricultural productivity, Cambodia, Rice production, Stochastic Frontier Analysis (SFA), Technical Efficiency

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# CHAPTER 1. INTRODUCTION

## 1.1. Background of Research

Food is the basic need of all lives on earth for survival, as well as an instrument of national power for maintaining independence, prestige, and honor of a nation. Food security is not only a key aspect of human development, but also the prime goal of any nations. Food security in the country is very essential for achieving primary goal of stability of a political government, since no any sensible nations would tolerate food insecurity particularly in the face of mounting population pressure which leads to further widening of already existing disparities (Ahmad 2009).

World population has been increasing energetically from 6.1 billion in 2000 to 7.2 billion in 2014, and expected to reach 9 billion by 2050 (FAOSTAT 2015). As a result of this rapid growth which is causing threat to food security, there is a need to understand agricultural growth and productivity for increasing agricultural outputs in order to meet the high demand for food. It is commonly believed that agriculture continues to support most of the growing population in the world in terms of nutrition, employment as well as income generation (Sawaneh et al. 2013). Agriculture remains fundamental in the 21st century for economic growth. It accounts for one-third of gross domestic product (GDP) and three-quarters of employment in Sub-Saharan Africa. Agriculture, however, is more vulnerable to climate change than any other sector. A warming climate could cut crop yields by more than 25%. Agriculture and land use change are also responsible for between 19–29% of global greenhouse gas emissions (World Bank 2014b).

The Cambodian economy is largely dependent on agricultural sector, which contributes 27% of national GDP, in which 65% of the labor force are engaged (CDRI 2012). Growth in agricultural sector has played a crucial role in the development of Cambodia (ADB 2014). Since 2004, garments, agriculture, construction, and tourism have driven Cambodia's growth. Between 2010 and 2013, GDP climbed more than 7% annually, and GDP per capita in purchasing power parity has increased from $2,462 (US Dollar) in 2010 to $3,056 in 2013 (CIA 2014; World Bank 2013). However, although Cambodian’s per capita income is rapidly increasing, it still remains low compared to other nations in the region. Most rural households depend on agriculture and its related sub-sectors; and rice, fish, timber, garments and rubber are Cambodia's major export products (CIA 2014).

Rice production is the central to Cambodian agricultural sector, not only do the majority of Khmer farmers depend both directly and indirectly on the success of the rice crop each year, and as it is the main food staple, rice production is a big factor in the national effort to promote food security. It occupies more than 80% of total cultivated land, and is the most important agricultural export commodity, as well as the main source of crop value added and the major driver of agricultural growth (Yu and Diao 2011). Being one of the most important staple crops for human consumption, rice plays an unprecedented role in combating food insecurity. Further, rice becomes a key economic crop dominated most agricultural economies in the world, particularly in developing countries like Cambodia.

Having similar characteristics to other agricultural crops, nowadays the growth of rice production yield seems to depend on three important aspects: (a) enlarging planting areas, (b) increasing input of material factors, and (c) raising productivity gradually (Liu and Li 2010). Due to the limitation of planting area and material input factors, along with the result of rapid population growth from 11.4 million in 1998 to 15.5 million in 2014 (NIS 1998; NIS 2008) and, thus, an increasing demand of land areas and material input factors for non-farm activities, raising productivity of rice production should be the most preferable factor among the three factors previously described.

Khmer farmers have been growing rain-fed rice for at least 2,000 years, possibly longer in the case of upland rice (Nesbitt 1997). Today, rice production still serves as the foundation of Cambodian economy. Between 1980 and 2010, rice production yield has been doubled from 1.21 tons/ha to 2.97 tons/ha (Sawaneh et al. 2013). However, productivity of Cambodian rice still has been relatively low compared to other Asian countries, such as Myanmar/Burma , Indonesia, Vietnam, Japan, South Korea, and China where rice productivity in 2010 was recorded 4.12 tons/ha, 5.01 tons/ha, 5.32 tons/ha, 6.51 tons/ha, 6.51 tons/ha, and 6.55 tons/ha respectively (FAO 2010). Therefore, in order to raise the productivity of rice production in Cambodia, it is important to identify the core factors influencing it.

## 1.2. Objectives and Significant of Research

### 1.2.1. Research objectives

The main objective of this dissertation was to measure the *technical efficiency* (hereafter, TE) of rice production in Cambodia. Additionally, the study was also trying to identify core influencing factors of the TE in order to explain the possibilities of increasing productivity and profitability of rice by increasing efficiency at household level as well as provincial level, and identify what technical progress policy should be recommended to help decision-makers to increase the rice productivity in Cambodia.

Specifically, this study aims to:

- Develop a broader understanding on characteristics of Cambodian rice production
- Measure the *technical efficiency* (TE) of rice production in Cambodia (for both national and household level)
- Compute the *technical efficiency changes* (hereafter, TEC) between 2013-2014, 2014-2015 and 2013-2015
- Identify the determinants of rice production TE and its influencing factors
- Try to come up with policy recommendation to help decision-makers increase rice productivity in Cambodia

Additionally, some of the research questions addressed in the present study are:

a. What is the level of TE of rice production in Cambodia?
b. How significant is the loss due to the inefficiencies?
c. What are the factors determining the inefficiency of rice production in Cambodia?

### 1.2.2. Significant of research

A pre-requisite for enhanced efficiency is to identify the core influencing factors at both the national-level and household-level that affect the efficiency of rice production in Cambodia. This study itself might help us to understand clearly what the factors influencing TE of rice production in Cambodia are. Likewise, insights into these factors will enable to come up with more effective policies and strategies for enhancing sustainable rice production, and obtain what technical progress policies should be chosen for improving rice sector in Cambodia. The implication is that there is a scope to increase output from existing farm areas if the efficiency of rice production is improved. Since increased output and productivity are directly related to production efficiency, the study becomes imperative, as it would identify factors that influence TE in the Cambodian rice production system. The identification of those factors, which influence the level of TE, is a valuable exercise because the factors are significant for policy formulation.

## 1.3. Literature Reviews

### 1.3.1. Rice in the world

Rice is one of the world's most important food crops. It is the fundamental staple food for more than half of humanity, supplying 20% of the calories consumed worldwide. World's rice production has risen continually from 397 million tons in 1980 to 672 million tons in 2010 (Sawaneh et al. 2013). After 2010, the world's farmers grow more than 715 million tons (approximately 480 million metric tons of milled rice) annually, and over 90% of the global rice is produced and consumed in the Asian Region, with China and India being the largest Asian producers, which collectively accounted for almost half of the world’s rice production and consumption in 2011 (Adjao and Staatz 2014; Muthayya et al. 2014). Moreover, China and India altogether with Indonesia, Bangladesh, Vietnam, Myanmar/Burma, Thailand, the Philippines, Japan, Pakistan, Cambodia, the Republic of Korea, Nepal, and Sri Lanka, Asian countries account for 90% of the world’s total rice production.

Rice is not only the grain that has shaped the history, culture, diet, and economy of billions people in Asia, rice production and consumption are also among the highest in Asian populations. It is a staple food for nearly 2.4 billion people in the region, and except for Pakistan and some parts of India and China, rice provides two thirds of the calories for most Asians with rice-based diets. World per-capita consumption of rice is about 57 kg per year. Most Asian countries consume more than 100 kg of rice per-capita per year on average, with Cambodia (292 kg), Laos PDR (289 kg), Bangladesh (218 kg), and Vietnam (217 kg) having among the highest per-capita consumption levels in the world (Adjao and Staatz 2014). Additionally, rice provides up to 50% of the dietary caloric supply and a substantial part of the protein intake for about 520 million people living in poverty in Asia and is, therefore, critically associated with food and nutrition security for a vast majority of populations, particularly those living in the developing world (Gomez 2001; Muthayya et al. 2014). More importantly, rice is also the primary source of income and employment for more than 200 million households across countries in the developing world. Most rice is grown in lowland regions but about one fifth of the world’s rice is upland rice, which grows in terraces in the mountains. However, Asian rice cultivated under rain-fed systems is highly dependent on climatic changes, resulting in uncertain rice yields and supplies (Muthayya et al. 2014)

With the global consumption reaching 444 million metric tons in 2011, rice is the world’s most consumed food grain after wheat. Although most of the rice is consumed in the countries where it is produced, Asian recently trend shows that production and trade has been growing while the consumption has been decreasing (Abdullah et al. 2005; Childs et al. 2016). Growing prosperity and social urbanization has been leading per capita rice consumption to decline in the middle and high-income Asian countries like Japan, Taiwan and the Republic of Korea. However, almost one-fourth of the Asian population is still poor and has significant unmet demand for rice, such as Afghanistan, North Korea, and Nepal. Thus, it is in these countries that rice consumption increases faster with the population growth (Abdullah et al. 2005; Kubo and Purevdorj 2004).

In 2010, approximately 154 million ha were harvested worldwide, of which 137 million ha (88% of the global rice harvested) were in Asia – of which 48 million ha (31% of the global rice harvested) were harvested in Southeast Asia alone. The greatest levels of productivity are found for irrigated rice, which is the most intensified production system, where more than one crop is grown per year and yields are high – 12.5 tons/ha/year compared with 2.5 tons/ha/year for rain-fed rice (Redfern et al. 2012).

Global rice production is projected at 475.5 million tons in 2014/15 crop year, i.e. down 1.5 million from the record 2013/14 crop. The increase in the 2014/15 crop is primarily due to an increase for Paraguay which is partially offset by a drop in Brazil. Global consumption for 2014/15 is increased 0.4 million tons to a record 483.3 million tons with small increases distributed among several countries. The export projection for 2014/15 is raised 0.7 million tons to a record 42.6 million due primarily to increases for Burma, Guyana, Paraguay, and Thailand. Imports are raised for Bolivia, Haiti, Syria, and the United States. Global rice ending stocks for 2014/15 are projected at 99.0 million tons, a decrease of 7.9 million from the prior year. Ending stocks projections are lowered for Brazil and Thailand, but increased for Bangladesh and the United States (Mekong Oryza Organization 2015).

### 1.3.2. Rice in the Southeast Asia

The world's largest source of rice exports is Southeast Asia. Rice is extensively cultivated throughout the region, with the most significant attentiveness of acreage in the mainland nations, broadening from Myanmar/Burma in the west to Vietnam in the east, where dominant river deltas that provide ample water and flat land existing in. Furthermore, rice is the life-line for millions people in the region particularly in eight agricultural nations (Cambodia, Indonesia, Laos PDR, Malaysia, Myanmar/Burma, the Philippines, Thailand, and Vietnam) of the Association of Southeast Asian Nations (ASEAN) as it is not only a dominant food crop, but also plays a significant role in their national economy, politic, and social development. It has been feeding the regional population for well over 4,000 years and is the staple food of about 557 million people. More than just food, rice is the fundamental subject of economic policy, a determinant of national objectives, and an essential anchor in the maintenance of political stability (Batello 2012; Canoy and Belangel 2004; Redfern et al. 2012).

Rice contributes about 30-76% to total daily calorie intake in the region, and accounts for a major share of cereal consumption ranging from 67% in the Philippines to 97% in Myanmar/Burma (Aldas Janaiah et al. 2002). The majority of both rice area and production in the region emanates from Indonesia, Thailand, and Vietnam. These major producers account for approximately 73% of total milled rice production. Myanmar/Burma and the Philippines are middle-level producers, with both countries' governments keen on increasing output over the coming decade. Myanmar/Burma hopes to become a major exporter while the Philippines want to achieve rice self-sufficiency. Cambodia, Laos PDR, and Malaysia are minor producers, though both Cambodia and Laos PDR have ambitious plans to increase crop yields and production to enable greater export potential. Rice yields vary enormously throughout the region. Vietnam (the highest) has rice yields more than double (134%) the yields in Cambodia (the lowest) (Shean 2015). The wide divergence is generally associated with differing levels of acreage under irrigation, varieties sown, and technology applied (fertilizer, pesticides, extension services).

Un-milled rice production in Southeast Asia rose from about 50 million tons during 1966 to about 140 million tons by 1999 with the annual growth rate of 3.2%, surpassing the population growth of 2.1% per annum. Yield improvements from the technological progress, largely in the favorable irrigated environments have contributed 78% of rice production growth between 1966 and 1986; and however the share of yield increases to total rice production has dropped to nearly 50% after 1986 (Aldas Janaiah et al. 2002). In 2002, Southeast Asia produced 150 million tons of paddies per year (25% of world production), of which 95% is consumed within the region. While per capita demand is expected to decrease in the future, total demand for rice in Southeast Asia is expected to increase to more than 160 million tons per year by 2020 due to population growth (Mutert and Fairhurst 2002).

Rice production in Southeast Asia nations are meticulously linked to irrigation, utilization of modern varieties, application of fertilizer nutrients, use of mechanization and favorable support prices. Expansion in any of these production inputs rationalizes the increase in rice production (Canoy and Belangel 2004; Dawe 2013). Moreover, Dawe (2013) initiated that the main determining factor of (per capita) rice production is not rice yield per hectare, but rather the amount of per capita rice area harvested, which in turn is determined largely by the proportion of land that is well-suited for growing rice. Harvested area can be increased by cultivating more than one crop of rice per year on the same land. Double-cropping and triple-cropping areas are available in the tropical areas where water rather than temperature is the limiting factor. Irrigation plays an identical important role to facilitate availability of multi-cropping system and productivity improvement. Irrigated rice always provides greater level of productivity and yield compared to rain-fed rice. The largest irrigated rice area is found in Indonesia, followed by Vietnam, the Philippines and Thailand, while rain-fed rice systems, which have lower yield potentials, are dominant in Cambodia, Laos PDR and Myanmar/Burma (Canoy and Belangel 2004; Childs et al. 2016). Rain-fed rice typically makes up approximately 55% of total rice production in Southeast Asia, and is highly dependent on timely and consistent water availability in both upland and lowland paddy fields where it is cultivated (Shean 2015). Likewise, yields of Southeast Asian rice faithfully depend on climate, weather conditions, soil, and management choices. Greater use of fertilizer and chemical inputs can increase yields up to a point, and careful management including the planting and harvest timing, weeds and insects control, can also lead increasing in rice yields. Nevertheless, these management choices often involve higher costs, more time and expertise.

Production of rice in Southeast Asia has been increasing significantly in recent time; nevertheless, this occurred mostly in irrigated areas. The progress has been much leisurelier in the nations where the proportion of irrigated rice is small like Cambodia and Laos PDR. Although rice is an essential export commodity, farmers in rain-fed lowland areas however tend to cultivate rice for their home consumption with the limited inputs to grow rice. Moreover, infrastructure such as road and transport system is rather poor and undeveloped, causing further problems in marketing of rice and other commodities (Fukai 2006). Nevertheless, the growth rates of both rice production and consumption in Southeast Asia have been slowing down. Production growth is dependent on yield growth and growth in area harvested while the Southeast Asia has tiny potential for expanding rice fields. Most rice area is in paddies in which crops grow in standing water for part of a crop season. Paddy land needs to be flat and accessible to water sources. Most land of this type is already in use by rice farmers, and it will be difficult to find more in most countries in Southeast Asia (Childs et al. 2016). Irrigation, therefore, will be the core factor for enlarging cultivated land as well as harvested land.

In the Southeast Asia, rice production systems currently rely on an ample water supply and thus are more vulnerable to drought stress which is severely damaging during reproductive stages of the rice crop, particularly during flowering, although drought in other stages can also lead to significant yield reductions. Drought is the most significant limiting factor influencing annual production potential and is usually associated with an erratic or intermittent rainfall pattern which leaves crops dry for periods of weeks at a time, which becoming an increasingly severe problem (Redfern et al. 2012; Shean 2015). In 2010, the level of the Mekong River (that flows through Cambodia, Laos PDR, Myanmar/Burma, Thailand and Vietnam, covering some 4,350 km and affecting the livelihoods of more than 60 million people living along the riverside) reached its lowest water levels in 20 years (Redfern et al. 2012). More importantly, Post-harvest losses -- in the field, as well as in transporting, milling, processing, and storage -- remain high in most Southeast Asian rice economies, while Childs et al. (2016) also stressed that Cambodia is the nation suffers the most from inefficient milling.

### 1.3.3. Rice in Cambodia

Rice is the « White Gold » for all Cambodian population. The *Royal Government of Cambodia* (hereafter, RGC) has declared that supporting the development of the national rice value-chain is one of its first priorities. With the strongly support from the RGC, rice production has grown rapidly since 2003, which has firmly changed the country's position from rice deficit to surplus (Yu and Diao 2010). Nevertheless, growth of rice production in Cambodia has decelerated since 2012 and given the land area constraint, its recovery will depend from now on more on increases in rice productivity and quality than on area expansion (World Bank 2014a). Therefore, productivity and efficiency use of existing resources might be another source of rice development potential in Cambodia. Although significant productivity gains have been achieved in the country since the end of the conflict, the average rice yield remained below those reached by neighboring countries like Thailand and Vietnam. During crop year of 2015/16, the rains started to fall later than usual moderately casing the drought at the beginning of the cropping season leaded to delay in cultivated time, and conversely in the middle of the season, flood occurred and affect plenty of rice fields in most rice production provinces of the nation. In this period, rice was cultivated on 3,051,412 ha, but land area can be harvested was only 3,025,630 ha (0.11% decreased, compared to 2014/15 crop year) which totally produced 9,335,284 tons of un-milled rice (0.12% increased) with an average production yield of 3.085 tons/ha (increased 0.22%). Nonetheless, according to MAFF (2016) Cambodia still produced 2,975,809 tons of milled rice surplus which equivalence to 4,649,702 tons of un-milled rice (decreased by 1.26% compared to the prior crop year).

The studies of productivity and efficiency have taken the attention of most economists and policy makers in the recent years, since there is no meaningful welfare improvement and economic development can take place in the absence of productivity growth (Sawaneh et al. 2013). However, agricultural productivity and efficiency studies as well as rice production efficiency studies in Cambodia seem to be very poor. Most of research works were conducted only by the related government agencies, such as National Institute of Statistics (NIS), Ministry of Agriculture, Forestry and Fishery (MAFF), Cambodia Development Resource Institute (CDRI), Cambodia Agricultural Research and Development institute (CARDI), etc. Thus, only a few research works were conducted by the scholars. Given the scarcity of literature on efficiency in Cambodia, the present study therefore seeks to augment literature and contribute in many ways to bridge the gap and supplement the shortage.

## 1.4. Methodology and Research Frame

### 1.4.1. Methodology

Methods to estimate productivity and efficiency that commonly and frequently implement in most of today's empirical works are *Data Envelopment Analysis* (DEA) and *Stochastic Frontier Analysis* (SFA), which are non-parametric approach and parametric approach respectively.

Among DEA and SFA, which method should one use often depends on the application being considered. The SFA is recommended by Coelli (1995b) for use in most agricultural applications. This method has the added advantage of permitting the conduct of statistical tests of hypothesizes regarding the production structure and the degree of inefficiency. However, if an application is using farm level data where measurement error, missing variables (e.g. data on an input is not available or not suitably measured), weather, etc. are likely to play a significant role, then the assumption that all deviations from the frontier are due to inefficiency, which is made by DEA, may be a courageous assumption. Thus, only a small percentage of agricultural frontier applications have used the DEA approach to frontier estimation. However, DEA has a very large following in other professions, especially in the management science literature, and in applications to service industries where there are multiple outputs, such as banking, health, telecommunication and electricity distribution, include Yang et al. (2014), Svitalkova (2014), Detotto et al. (2013), Fu et al. (2013), Cullmann and von Hirschhausen (2007), etc. Another benefit of SFA approach is determinants of inefficiency which allowed external factors affecting efficiency of firms to be determined where unavailable in DEA approach. SFA, hence, was applied by a large number of papers in the recent years, particularly in agricultural researches. For instance, the studies implemented SFA approach include Mayston (2015), Lin and Long (2015), Manlagñit (2015), Manlagñit (2011), etc. Further detailed discussion of the differences between DEA and SFA has been given in Coelli (1995b). Therefore, SFA was also being applied to the present study.

Cogitate a firm that uses amounts of $N$ inputs (e.g. land, labor, capital) to produce a single output. The technological possibilities of such a firm can be summarized using the production function:

$$y = f(x) \tag{1}$$

where $y$ represents output (dependent variable) and $x = (x_1, x_2, \ldots, x_N)$ is an $N \times 1$ vector of inputs (i.e. explanatory variables). Function $f(.)$ is a mathematical function, reflect the relationship between output and input vector. Different algebraic forms of $f(.)$ give rise to different models of production function. $\gamma$, $\beta_n$, $\beta_m$ are unknown parameters to be estimated.

Many functional forms of production function (such as linear, quadratic, normalized quadratic, generalized Leontief, Constant Elasticity of Substitution CES, etc.) are linear in the parameters, making them amenable to estimate using the linear regression technique. The commonly and frequently uses functional form, i.e. Cobb-Douglas and *translog* functions, appear not to satisfy this property at the first glance. However, taking the logarithms of both side of these functions, resulted as:

Cobb-Douglas: $$ln\, y = A_0 + \sum_{n=1}^{N} \beta_n \, ln\, x_n \quad (2)$$

Translog: $$ln\, y = \beta_0 + \sum_{n=1}^{N} \beta_n \, ln\, x_n + \frac{1}{2} \sum_{n=1}^{N} \sum_{m=1}^{N} \beta_{nm} \, ln\, x_n \, ln\, x_m \quad (3)$$

which are both linear in the parameters. Thus, the parameters of Cobb-Douglas and *translog* functions can also be estimated in a linear regression framework. More discussion on functional forms is available in Chambers (1988) and Coelli et al. (2005).

Logarithmic form of *translog* production function was being applied to the present study due to its flexible algebra functional form and fitter with the dataset implemented in the present study than Cobb-Douglass function.

### 1.4.2. Research frame

The structure of this dissertation is organized as follows: Chapter Two briefly reviews the literatures on definitions, concepts, as well as measurement of productivity and efficiency analysis studies. Chapter Three outlines the overview and presenting several general statistics of Cambodian rice production. Technical efficiency of rice production in Cambodia at the national level is analyzed and discussed in Chapter Four, while the analysis and discussions of rice production’s technical efficiency of Cambodian households are given in Chapter Five. Finally, the conclusion remarks and recommendations are given in Chapter Six. Research frame of the current dissertation is given in Figure 1.

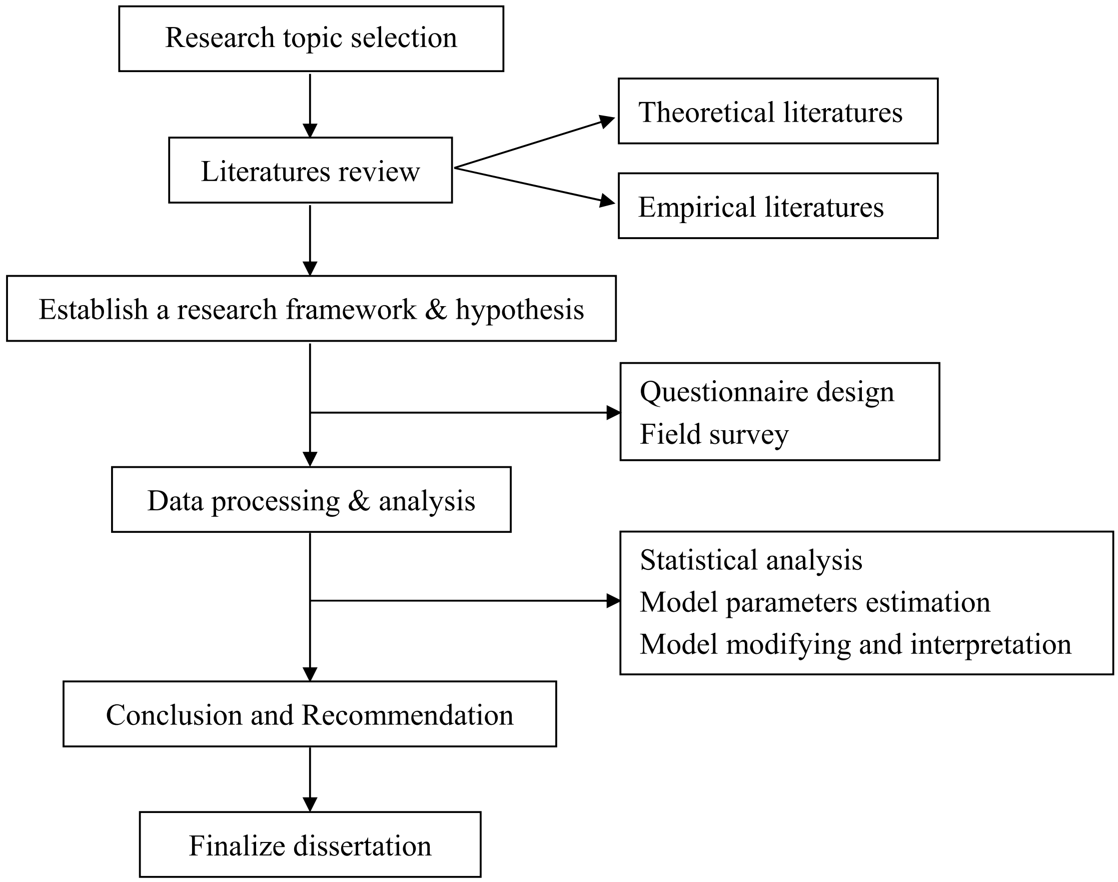


**Figure 1.** Research frame of dissertation

# CHAPTER 2. PRODUCTIVITY AND EFFICIENCY ANALYSIS

## 2.1. Definition of Terms

In the economics literature, *productivity* refers to the amount of output(s) obtained from given levels of input(s) in an economy or a sector. It is an important topic of study, since productivity is one of the two fundamental sources of larger income streams; the other being savings, which permit more inputs for employment (Fulginiti and Perrin 1998). Coelli et al. (2005) argued that productivity is the ratio of the output(s) that it produces to the input(s) that it uses [Productivity = Output(s) / Input(s)]. In other words, productivity is raised when growth in output(s) outpaces growth of input(s). Productivity growth without an increase in input(s) is the best kind of growth to aim for rather than attaining a certain level of output (Nin-Pratt et al. 2008). Productivity is a basic and intuitive measure of performance. Furthermore, *total factor productivity* (TFP) [1] is a method of measuring businesses performance. TFP is used both in competitive and regulated industries, such as electricity distribution companies (Ondrej and Jiri 2012) for instance. It is a method of measuring productivity and growth, which is a productivity measurement involving all factors of production. Other traditional measures of productivity, such as labor productivity in a factory, fuel productivity in power stations, and land productivity (yield) in farming, are often called partial measures of productivity. These partial productivity measures can provide a misleading indication of overall productivity when considered in isolation (Yao and Li 2010).

Theoretically, *efficiency* is defined as the level of operation that produces the greatest amount of output(s) with the lowest amounts of input(s). Efficiency relates to the use of all inputs, for instance labor, natural resources, money, time, etc. in producing any given output(s). It is the main factor to determine productivity. Efficiency score range from 0.00 to 1.00. The maximum score (1.00) represents the highest efficiency while the scores of 0.00-0.99 show a firm's inefficiency, indicating the relative displacement from the frontier [2] (Ueasin et al. 2015). Most references to the concept of efficiency are based directly or indirectly on Farrell (1957) which states that the efficiency can be measured in relative terms

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[1] Also called multi-factors productivity (MFP) in some lectures, like Zheng and Bloch (2013)

[2] According to (Coelli 1995b) "Frontier" refers to a bounding function, which provided benefits of heavily influencing of the best performing firms in a field (of economics), that always reflect the technology they are using. Additionally, the frontier function represents a best-practice technology against which the efficiency of firms within the industry can be measured.

as a deviation from best practices of producers compared with producer groups. The production process is technically efficient if and only if the maximum quantity of output(s) can be achieved for a given quantity of input(s) and technologies (Haryanto et al. 2015). More importantly, Farrell (1957) also suggested to measure technical efficiency by estimating frontier production function.

## 2.2. Components of productivity and efficiency

### 2.2.1. Technical efficiency (TE)

*Technical efficiency (TE)* is measured as the ratio between the observed output to the maximum output, under the assumption of fixed inputs (called *output-oriented* technical efficiency "OO"), or, alternatively, as the ratio between the minimum input to the observed input, under the assumption of fixed outputs, i.e. called *input-oriented* technical efficiency "IO" (Coelli et al. 2005; Farrell 1957). There are some basic differences between the OO and IO models as features of the technology are concerned, which further details in Hong and Yabe (2015) and Coelli et al. (2005). The model of TE in case of a single input and a single output is graphically defined in Figure 2.

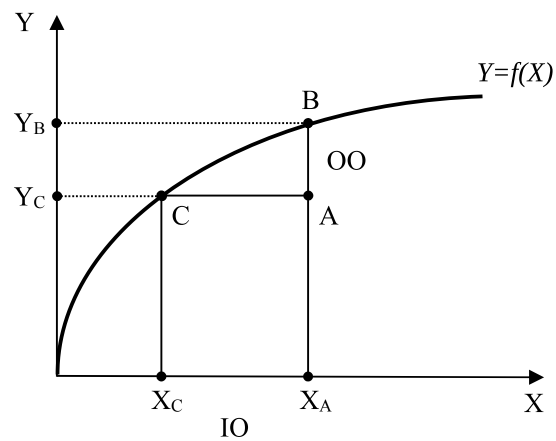


**Figure 2.** Technical efficiency concepts in the production frontier framework
*Source*: Coelli et al. (2005) and Hong and Yabe (2015)

The curve CB represents the frontier: any economy can lie either on the curve (i.e. points B and C) or below the curve (i.e. point A). Staying below the frontier point A is inefficient because it could either increase output from $Y_A$ to $Y_B$ without consuming any extra input or reduce input consumption from $X_A$ to $X_C$ without compromising output. A distance from point A to either point B or C represents its inefficiency levels. There are two general ways to achieve efficiency improvements: moving from point A to point B (i.e. output-oriented framework) or moving from point A to point C (i.e. input-oriented framework) (Hong and Yabe 2015). Further discussions on output-oriented and input-oriented framework of technical efficiency were given in Coelli et al. (2005).

*Technical efficiency in production* is defined as the ability of the producer (i.e. firm, factory, or farmer) to produce at the maximum output (frontier production), given the quantities of inputs and production technology (Aigner et al. 1977). *Production efficiency* is concerned with the relative performance of the process used in transforming input(s) into output(s). The analysis of efficiency is generally associated with the possibility of farms producing a certain optimal level of output from a given bundle of resources or certain level of output at least-cost. The greater the ratio of production output to the factor input, the greater the magnitude of technical efficiency and vice versa (Balde et al. 2014). This definition of technical efficiency implies that differences in technical efficiency between farms exist. Variation in technical efficiency of producers might arise from managerial decisions and specific-farm characteristics that affect the ability of the producer to adequately use the existing technology.

*Technical efficiency (TE)* of one measurement unit ($MU_i$) can be estimated by the ratio of observed output relative to the level of the potential output defined by SFA model, as follow:

$$TE_{it} = y_{it}/f(x_{it}, t) = exp(-u_{it}) \leq 1 \tag{4}$$

The values of the technical efficiency are always smaller or equal to one. When the efficiency scores equal to one, indicates $MU_i$ in the samples is fully technical efficiency. Therefore, the closer of the value of efficiency scores to one indicates the higher efficiency of $MU_i$.

Furthermore, *technical efficiency changes (TEC)* of $MU_i$ between period $t$ and $t+1$ are measured as the ratio of one $MU_i$'s efficiency scores in period $t+1$ to its efficiency scores in period $t$, which can be expressed as the following formula:

$$TEC_i^{t,t+1} = TE_i^{t+1}/TE_i^{t} \tag{5}$$

### 2.2.2. Scale economies (SE)

In Figure 3, Coelli et al. (2005) use a ray through the origin to measure productivity at a particular data point. The slope of this ray is $y/x$ and hence provides a measure of productivity. If the firm operating at point $A$ were to move to the technically efficient point $B$, the slop of the ray would be greater, implying higher productivity at point $B$. However, by moving to the point $C$, the ray from origin is at a tangent to the production frontier and hence defines the point of maximum possible productivity. This latter movement is an example of exploring *scale economies* (or scale efficiency). The point $C$ is the (technically) optimal scale. Operation at any other point on the production frontier results in lower productivity. Thus, a firm may be technically efficient but may still be able to improve its productivity by exploiting scale economies. A unit is said to be scale efficient when its size of operations is optimal so that any modifications on its size will render the unit less efficient. The value for scale efficiency is obtained by dividing the aggregate efficiency by the technical efficiency. However, some researchers focus on measuring scale economies (SE) by summing the output elasticities. In particular, a positive value of $1 - SE$ indicates the presence of scale economies (Kumbhakar et al. 2014).

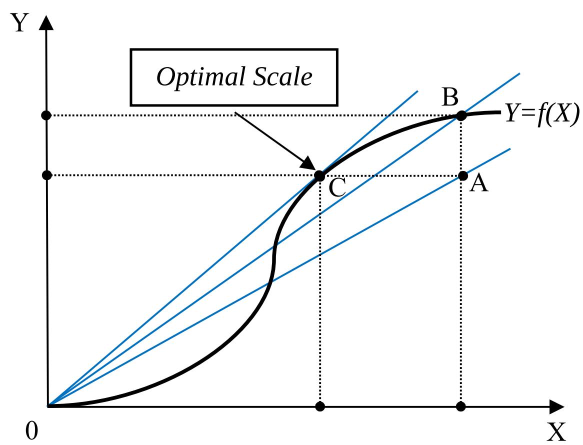


**Figure 3.** Productivity, Technical efficiency, and Scale economies

*Source*: Coelli et al. (2005)

### 2.2.3. Technical change (TC)

When one considers productivity comparisons through time, an additional source of productivity change, called *technical change* (TC)[3], is possible. This involves advances in technology that may be represented by an upward shift in the production frontier (Coelli et al. 2005). When we observe that a firm has increased its productivity from one year to the next, the improvement need not have been from efficiency improvements alone, but may have been due to *technical change* or the exploitation of *scale economies* or from some combination of these three factors (technical efficiency, technical change, and scale economies).

[3] Also called "Technological change".

*Technical change* can be defined by the following formula:

$$TC_{it} = \frac{\partial \, ln \, f(x_{it}, t)}{\partial_t} \quad (6)$$

where *technical change* is a derivation of production function $f(x_{it}, t)$ to time $t$. Some common algebraic forms of production function $f(x_{it}, t)$.

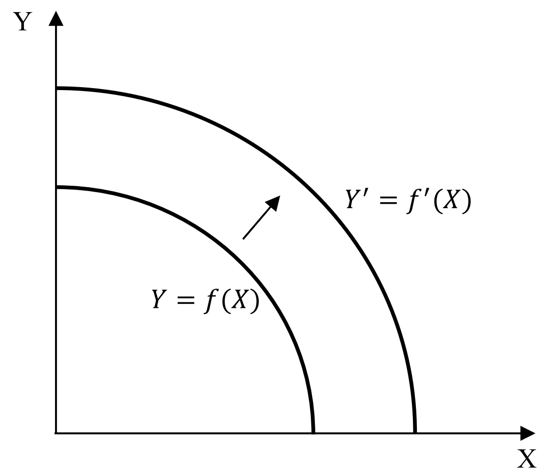


**Figure 4.** Concept of technical or technological change (TC)

The concept of *technical change* (TC) is illustrated in Figure 4. Moving to the right-side of production function curve from $Y$ to $Y'$ explained the technological development through time ($t$ to $t + 1$). Due to technical change is not neutral, values of TC can be different by the different values of input vector. Therefore, the geometric average of change in TC value within adjacent period $t$ and $t + 1$ should be adopted. Thus, TC change (TCC) i.e. *technological progress* can be expressed as:

$$TCC_i^{t,t+1} = \left[(1 + \partial f(x_{it}, t, \beta)/\partial_t) \times \left(1 + \partial f\left(x_{i(t+1)}, t + 1, \beta\right)/\partial(t + 1)\right)\right]^{1/2} \quad (7)$$

### 2.2.4. Allocative efficiency (AE)

In cases information on price is available and a behavioral assumption such as cost minimization or profit maximization is appropriate, it is possible to consider *allocative efficiency (AE)*, in addition to *technical efficiency (TE)*. It is a measure of the degree of success in achieving the best combination of different inputs in producing a specific level of output considering the relative prices of these inputs (Israel Ajibade 2015). According to Coelli et al. (2005), allocative efficiency in input selection involves selecting that mix of inputs (e.g., labor and capital) that produces a given quantity of output at minimum cost (given the input prices which prevail). Allocative and technical efficiency combine to provide an overall economic efficiency measure.

## 2.3. Productivity and Efficiency Measurements

*Data Envelopment Analysis* (DEA) and *Stochastic Frontier Analysis* (SFA), which respectively are non-parametric approach and parametric approach, are the two commonly and frequently implement methods to estimate productivity and efficiency in most today's empirical works.

### 2.3.1. Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) is defined as a non-parametric method that is exclusively applied to measure the firm's efficiency scores. The concept of the DEA model consists of two aspects, the constant return to scale (CRS-DEA) and variable return to scale (VRS-DEA). CRS-DEA implies a constant return to scale model which is usually used in a competitive market. In contrast, the VRS-DEA means a variable return to scale model which is best suited to an uncompetitive market (Ueasin et al. 2015).

In DEA, the efficiency scores as well as technical efficiency can be measured by using an input-based method or output-based method[4]. Input-based method identifies the *technical efficiency* as a proportional reduction in the quantity of input(s) use without causing a change in the quantity of output(s). In contrast, output-based method identifies the *technical efficiency* as an increase in the quantity of output(s) with a given quantity of input(s) use (Haryanto et al. 2015). Nevertheless, according Fare and Lovell in Coelli et al. (2005) both methods would generate the same technical efficiency if the production function has the characteristic of constant returns to scale (CRS).

### 2.3.2. Stochastic Frontier Analysis (SFA)

Stochastic Frontier Analysis (SFA) was originally and independently proposed by Aigner et al. (1977), and Meeusen and Van den Broeck (1977). It is a parametric method that requires a specific function to compute the efficiency scores. The stochastic frontier model (hereafter, *SFA model*) was also called *composed error model* (Heriqbaldi et al. 2014). The most commonly used package for estimation of *SFA model* is FRONTIER version 4.1c, see Coelli (1996). The general form of the *SFA model*:

$$Ln\, y_{it} = Ln\, f(x_{it}, t\, ;\, \beta) + v_{it} - u_{it} \tag{8}$$

[4] In most cases, terms "input-based" or "output-based" can be used interchangeably with the terms "input-oriented" or "output-oriented". Some studies like Haryanto et al. (2015) also used these terms interchangeably.

where $Ln$ indicates the natural logarithm function form; $y_{it}$ and $x_{it}$ denote rice production output(s) and input(s) within period $t$ respectively; $\beta$ represent estimated coefficients; $v_{it}$ is two-side random error term which represented statistical noise assumed to be normal distribution, $v_i \sim N(0, \sigma_v^2)$; $u_{it}$ denotes technical inefficiency, which is one-side error term that assumed to be independent to $v_{it}$ with half-normal distribution[5], $u_{it} \geq 0$, $u_i \sim |N(0, \sigma_u^2)|$; *i=1,2,…,N*; *N* is number of measurement unit ($MU_i$), i.e. total samples; and *t* is time variable measured as year, *t=1,2,…,T*.

The *technical inefficiency* effect ($u_{it}$) i.e. *TI model*, can be expressed in following general form:

$$u_{it} = \delta_0 + \sum_{k=1}^{n} \delta_k z_{kit} + \omega_{kit} \quad (9)$$

where $\omega_{kit}$ is the stochastic noises; $z_{kit}$ denotes exogenous variables that are factors affecting the efficiency scores; $\delta_0$ and $\delta_k$ are estimated coefficients; if $\delta_k$ is negative indicates positive relationship between affecting factor variables and the efficiency scores, conversely, if $\delta_k$ is positive shows negative relationship between the efficiency scores and affecting factors.

The parameters estimation of *SFA model* can be achieved by applying *Maximum-Likelihood* (ML) estimation method, which estimates the likelihood function in terms of two variance parameters, see Coelli (1995a):

$$\gamma = \sigma_u^2 / \sigma_s^2 \ ; \quad \sigma_s^2 = \sigma_v^2 + \sigma_u^2 \quad (10)$$

Gamma ($\gamma$) takes value between zero and one ($0 \leq \gamma \leq 1$), reflects validity of the random disturbances ($v_i$, $u_i$) proportion (shows the share of inefficiency in the overall residual variance). If $\gamma$ is equal to zero, it means that all variations of the production are due to noises. If $\gamma$ is closer to zero, it indicates that the gap between actual output and the maximum possible output mainly comes from other uncontrolled pure random factors, which makes the use of stochastic frontier model meaningless. In contrast, if $\gamma$ is closer to one, it shows that the gap comes mainly from the effects of one or more exogenous variables $z_{ki}$, indicates using stochastic frontier production function model is more appropriate. And if it is equal to one, then it means that all variations are due to technical inefficiency (Coelli and Battese 1996; Coelli et al. 2005).

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[5] The assumption can be replaced by other assumption as well, such as truncated-normal (Battese and Coelli 1992; Stevenson 1980)

## 2.4. Chapter summary

*Productivity* refers to the amount of output(s) obtained from given levels of input(s) in an economy or a sector. It is the ratio of output(s) that produces to input(s) that uses, while *efficiency* alternatively is defined as the level of operation that produces the greatest amount of output(s) with the lowest amounts of input(s). It is the main factor determining productivity. Efficiency score range between 0.00 and 1.00. The maximum score (1.00) represents the highest efficiency while the scores of 0.00-0.99 show a firm’s inefficiency. Furthermore, productivity and efficiency can be classified into four components, included technical efficiency (TE), scale economies (SE), technical change (TC), and allocative efficiency (AE). Additionally, *Data Envelopment Analysis* (DEA) and *Stochastic Frontier Analysis* (SFA), which respectively are non-parametric approach and parametric approach, are the two commonly and frequently implement methods to estimate productivity and efficiency in most today’s empirical works.

# CHAPTER 3. CAMBODIA AND RICE PRODUCTION

## 3.1. Cambodia: Overview

### 3.1.1. Geography

Officially called "The Kingdom of Cambodia", the country is situated on the southern portion of the Indochina peninsula in Southeast Asia, covering 181,035 square kilometers ($km^2$) of total area (land 97.5% and water 2.5%). Cambodia shares borders with Thailand 803 kilometers (km) to the north and west, Laos People's Democratic Republic (Laos PDR) 541 km to the north, Vietnam 1,228 km to the east and southeast, and 440 km of coastal border with the Gulf of Thailand to the southwest (see Figure 5). With the size of Missouri, the kingdom is about one-third the size of Thailand, or 293-times bigger than Singapore (UNESCO 1999). The country consists chiefly of a large alluvial plain ringed by mountains with the Mekong River to the east. The plain is centered around Tonle Sap Lake, which is a natural storage basin of the Mekong.

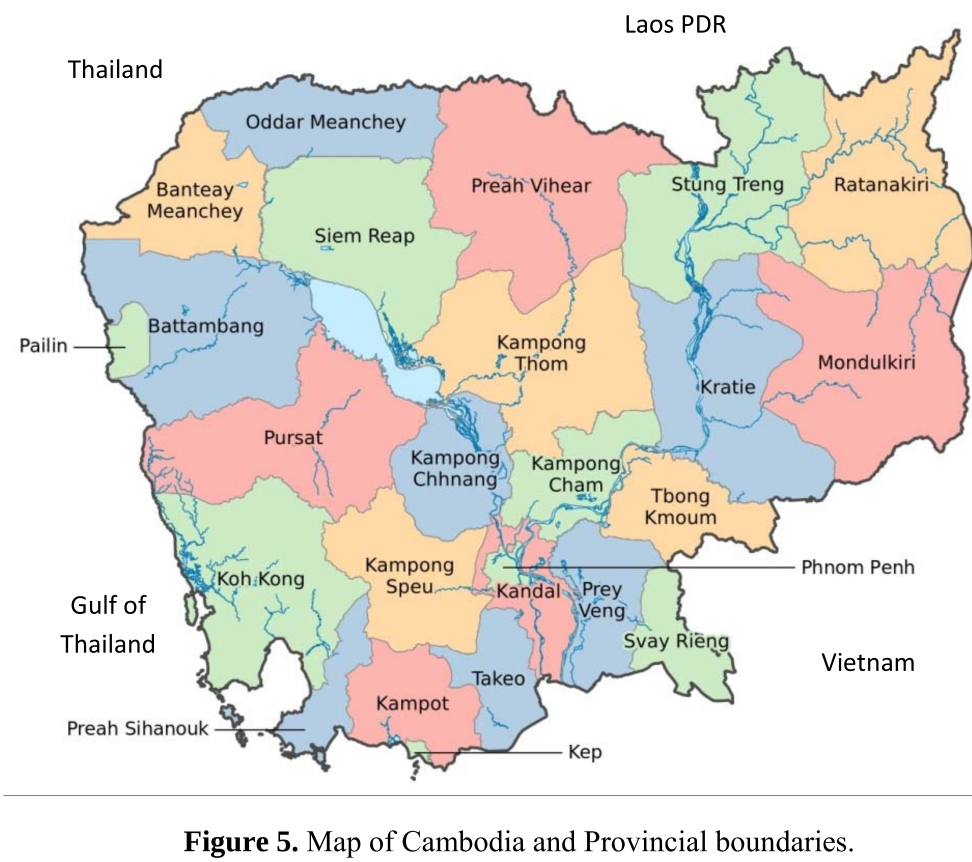


**Figure 5.** Map of Cambodia and Provincial boundaries.

*Source*: Map created by Wikipedia using QGIS (Wikipedia 2014)

Figure 5 illustrates the updated map of Cambodia and provincial boundaries created by Wikipedia using QGIS (Wikipedia 2014). In advance of the establishment of Tbong Kmom province in 2013, the kingdom was subdivided into 23 (twenty-three) provinces and one municipality of Phnom Penh. Tbong Kmom province was formed when Kampong Cham province was split in two by a royal decree signed on 31 December 2013 by King Norodom Sihamoni on the recommendation of Prime Minister Hun Sen. The province is located on the central lowlands of the Mekong River, bordering by the provinces of Kampong Cham to the west, Kratié to the north, Prey Veng to the south, and sharing an international border with Vietnam to the east. The request by Hun Sen's government to split the province, which was ostensibly for the purpose of improving administrative efficiency in the large province, was made after his ruling Cambodian People's Party (CPP) lost the province to the opposition in the July 2013 elections. The CPP won only eight of the available 18 National Assembly seats in Hun Sen's home province. The 10 districts that remain in Kampong Cham province overwhelmingly voted for the opposition Cambodia National Rescue Party (CNRP), led by Sam Rainsy, while five of the six districts cut out from Kampong Cham to form Tbong Kmom province were won solidly by the CPP.

Table 1 lists the information of all entire 24 provinces and a municipality in Cambodia in 2015. The most populous city of the country is Phnom Penh city, the capital city of Cambodia, where nearly 1.5 million populations are living in (2015) with the highest population density of more than 2,000 persons per $km^2$, but Phnom Penh is the second smallest in land area nationwide. Likewise, Kandal province which completely surrounds the capital Phnom Penh and a part of the greater Phnom Penh Metropolitan Area (PPMA) ranks as the second most populous province (after Phnom Penh). Kandal is also one of the wealthier provinces in the country as it serves as an economic belt of the capital. Many garment factories are located there, which hires more than 500,000 workers. Its capital and largest city is Ta Khmao located around 20 km south of Phnom Penh. Furthermore, Battambang province is the third largest province by population size and the fifth by area. With the moniker “*The rice bowl of Cambodia*”, Battambang is well-known as a leading rice production of the kingdom. The largest province by area is Mondulkiri and the smallest is Kep (which is also the least populated province). Mondulkiri was the second lowest population density in 2015 where the province that has lowest density was Koh Kong province.

**Table 1.** List of provinces and municipality in Cambodia

| № | Name | Capital | Population (2015) | Area (km²) | Density (2015) | ISO |
|---|---|---|---|---|---|---|
| 1 | Phnom Penh Municipality | Chamkarmon | 1,447,340 | 678.46 | 2,133 | KH-12 |
| 2 | Banteay Meanchey province | Serei Saophoan | 769,761 | 6,679 | 115 | KH-1 |
| 3 | Battambang province | Battambang | 1,205,050 | 11,702 | 103 | KH-2 |
| 4 | Kampong Cham province | Kampong Cham | 1,119,539 | 4,549 | 246 | KH-3 |
| 5 | Kampong Chhnang province | Kampong Chhnang | 538,945 | 5,521 | 98 | KH-4 |
| 6 | Kampong Speu province | Chbar Mon | 850,472 | 7,017 | 121 | KH-5 |
| 7 | Kampong Thom province | Kampong Thom | 763,943 | 13,814 | 55 | KH-6 |
| 8 | Kampot province | Kampot | 664,797 | 4,873 | 136 | KH-7 |
| 9 | Kandal province | Ta Khmao | 1,235,006 | 3,568 | 346 | KH-8 |
| 10 | Koh Kong province | KhemarakPhoumin | 40,006 | 11,160 | 4 | KH-9 |
| 11 | Kep province | Kep | 129,776 | 336 | 386 | KH-23 |
| 12 | Kratié province | Kratié | 372,589 | 11,094 | 34 | KH-10 |
| 13 | Mondulkiri province | Senmonorom | 79,502 | 14,288 | 6 | KH-11 |
| 14 | Otdar Meanchey province | Samraong | 243,802 | 6,158 | 40 | KH-22 |
| 15 | Pailin province | Pailin | 66,976 | 803 | 83 | KH-24 |
| 16 | Preah Sihanouk Province | Sihanouk ville | 211,526 | 868 | 244 | KH-18 |
| 17 | Preah Vihear province | Tbeng Meanchey | 229,390 | 13,788 | 17 | KH-13 |
| 18 | Pursat province | Pursat | 481,063 | 12,692 | 38 | KH-15 |
| 19 | Prey Veng province | Prey Veng | 1,203,570 | 4,883 | 246 | KH-14 |
| 20 | Ratanakiri province | Banlung | 188,402 | 10,782 | 17 | KH-16 |
| 21 | Siem Reap province | Siem Reap | 1,036,111 | 10,299 | 101 | KH-17 |
| 22 | Stung Treng province | Stung Treng | 138,936 | 11,092 | 13 | KH-19 |
| 23 | Svay Rieng province | Svay Rieng | 612,878 | 2,966 | 207 | KH-20 |
| 24 | Takéo province | Doun Kaev | 1,003,189 | 3,563 | 282 | KH-21 |
| 25 | Tbong Kmom province | Suong | 844,853 | 4,928 | 171 | KH-25 |

Source: Document sets "Profile on Economics and Social 2016" of 24 provinces and 1 municipality in Cambodia (RGC 2016).

**Table 2.** Geographical regions in Cambodia

| № | Region | Provinces | Area (km²) | %Area |
|---|---|---|---|---|
| 1 | Municipality | Phnom Penh | 678.46 | 0.38 |
| 2 | Tonle Sap plain | Banteay Meanchey, Battambang, Kampong Chhnang, Kampong Thom, Pailin, Pursat, and Siem Reap | 61,510 | 34.54 |
| 3 | Mekong plain | Kampong Speu, Kandal, Prey Veng, Svay Rieng, and Takéo | 21,997 | 12.35 |
| 4 | Mekong plateau | Kampong Cham, Kratié, Stung Treng, and Tbong Kmom | 31,663 | 17.78 |
| 5 | Mountain region | Mondulkiri, Ratanakiri, Preah Vihear, and Otdar Meanchey | 45,016 | 25.28 |
| 6 | Coastal region | Kampot, Koh Kong, Kep, and Preah Sihanouk | 17,237 | 9.68 |

Source: Document sets "Profile on Economics and Social 2016" of 24 provinces and 1 municipality in Cambodia (RGC 2016).

The geographical area of Cambodia can be categorized into six different regions as being showed in Table 2. *Phnom Penh Municipality* was classified into one region as it is a special zone, not a province but a superior administrative. The second region is *Tonle Sap river plain*, which is the biggest region covering all provinces around the Tonle Sap lake (or the Great Lake), accounted for almost 35% of total land area. This region is one of the two main agricultural lands of the kingdom. Various kinds of agricultural products, particularly wet season rice crop, are producing in this region. Another main agricultural land is being *Mekong river plain* region. It accounted for 12% of area covering all provinces in the lower Mekong plain from Phnom Penh to the border of Cambodia-Vietnam. Plenty water sources, rich availability of irrigation systems, and favorable land type in this region has been giving the worthy cropping environment which allowed the populations there crop multiple times per year (especially rice crop), causing this region to be a leading dry season rice production area of the kingdom. *Mekong plateau* region covering the provinces along the upper Mekong river from the border of Cambodia-Laos PDR to Phnom Penh, accounted for almost 18% area. Soil type in this region is very suitable for rubber trees. Thus, there are many rubber farms located in this region. *Mountain region* covered provinces along the borders, from Cambodia-Thailand border (Otdar Meanchey province) to Cambodia-Vietnam border (Mondulkiri province) where many mountain ranges existing in. These provinces are mostly the lowest population density provinces with the limited water resources. The last region is *Coastal region*, which covered all provinces along the coast of Cambodia. Beside salt and seafood products, one of the famous and special products from this region is Kampot Peppers i.e. the Geographical Indication (GI) product of Kampot province as well as Cambodia's coastal region.

### 3.1.2. Brief history

The Kingdom of Cambodia is one of the most ancient monarchies in the world. The Kingdom can trace its history back to Neolithic times, when it was first inhabited around 2000 BC. As one of the earliest known kingdoms to the region, the Funans rose to power in the 1st century AD, and flourished through the 6th century. Under the guidance of Fan Shih-man in the early 3rd century, the Funan Kingdom extended its boundary lines as far south as Malaysia and then west towards Burma, establishing a powerful organization of commercial monopolies, setting the way for future empires within the region. Following the death of ruler Jayavarman I in 681, the kingdom was broken up into several principalities dominated by the Malayans and Javanese. During the 12th century the Khmer Empire dominated the region, becoming Southeast Asia's largest empire. Conquests brought on by the Khmers were nearly unstoppable, and Angkor (the largest pre-industrial city in the world at the time) was built as the empire's center of power. The Khmer Empire began to gradually decline through the 13th century, and Angkor was completely abandoned in 1432 following an attack by the Ayutthaya Kingdom. Subsequently, the economy within the region faltered, and Cambodia reached an age of darkness that lasted until the 19th century. Cambodia was placed under French ruling by King Norodom in 1863, and remained a protectorate until 1953 when, with the help of successor King Norodom Sihanouk, Cambodia finally received their independence. As a new country, Cambodia established itself as a constitutional monarchy, and tried to uphold a policy of neutrality. However, as the eastern provinces of Cambodia served as bases for the North Vietnamese Army and Viet Cong (NVA/VC) forces operating against South Vietnam in the 1960s, the country found itself on the brink of war as the United States began target bombing sections of the NVA/VC. King Sihanouk unsuccessfully attempted to keep the communist North Vietnamese soldiers from entering the country, as well as the United States and its allies, but only managed to upset the US, who saw Sihanouk as a North Vietnamese sympathizer. In January of 1970, Sihanouk went abroad due to medical reasons, and in his absence General Lon Nol carried out a coup d’état against the king. Under the power of Lon Nol, Cambodia was immediately allied with the US, the monarchy abolished, and the country renamed the Khmer Republic. Cambodia became the forefront of worldwide news in 1975 as Communist Khmer Rouge forces captured the capital city of Phnom Penh, and ordered the evacuation of all cities and towns. Millions of Cambodians were subsequently executed, and many more died from horrible living conditions. In 1978, a Vietnamese invasion followed by two decades of fighting drove the Khmer Rouge out, and then in 1993, UN-sponsored elections helped restore some level of normalcy. A coalition government, formed after national elections in 1998, brought renewed political stability and the surrender of remaining Khmer Rouge forces in 1998. Still rebuilding from decades of war, Cambodia continues to see advancement in its economy, and maintains one of the best economic records in Asia in terms of growth. The capital city of Phnom Penh, located where the Tonle Bassac, Tonle Sab and Mekong rivers merge, is the main entry point into the country for travelers, and most tourists journey to this far-off land specifically to visit the ancient temples of Angkor Wat (Worldatlas 2016).

## 3.2. Agriculture in Cambodia

The Cambodian economy performed well in 2012 and the outlook continues to be positive in 2013. The economy grew 7.3% against a backdrop of low inflation (2.2%). The services sector is the biggest contributor to GDP, accounting for 41% of total GDP, followed by industry at 32%, and agriculture with 27%. However, agriculture is still the critical importance to Cambodian economy. This sector contributes the dominant quantity to the national GDP, and continues to make a rising contribution to the growth of the Cambodian economy. The sector grew 4.3% in 2012 and accounted for 4.75 million workers out of a labor force of 8 million in 2011 (OECD 2013b). Moreover, it employs more than half of the country's total labor force and is the chief source of income for the rural poor, who account for the poorest 10% of the population (OECD 2013a). More than 80% of the population earns their livings from the agriculture. Furthermore, agriculture plays the most important role in Cambodian society by ensuring food security at community and national level as well as in the provision of employment and income opportunity for a growing population. About 75% to 85% of the population is employed in the primary sector, 65% does simply rice farming and around 90% of Cambodia's poor citizen lives in rural areas (Mund 2010). Apparently, a process of agricultural development is considered to be an effective approach to promote the economic growth with a broadest possible base. Nonetheless, the development of this sector is mainly constrained due to the exceptionally low productivity if compared with the neighboring countries (Touch 2000).

Statistically, Cambodia covers a surface area of 18.1 million hectares, of which 2.7 million hectares are cultivated land and 1 million are taken up by urban areas, towns, infrastructure and waterways. Agricultural concessions cover 800,000 hectares, landmine-contaminated areas 100,000 hectares, and protected forestland 1.5 million (OECD 2013b). Temperature and rainfall patterns in Cambodia are governed by monsoons and characterized by two major wet and dry seasons. The average annual rainfall is 1,400 mm in the central low land regions and may reach 4,000 mm in certain coastal zones or in highland areas. The annual average temperature is 28°C, with an average maximum temperature of 38°C in April and an average minimum temperature of 17°C in January (Heng et al. 2015).

### 3.2.1. Production of Rice

Rice cultivation stands as the most essential segment of Cambodian agricultural sector and plays a major role in the national economic growth (contributing to 15% of the national GDP). The value-chain of rice is one of the four major mainstays of Cambodia's economy, along with textile, tourism and the construction industry. Unfortunately, the exportable surplus of Cambodian rice (3 to 4 million tons a year) are processed in Vietnam or Thailand today, which represents an important loss in terms of added-value for the sector (AFD 2011).

Rice production area of Cambodia has been improved greatly from year to year. As being showed in Figure 6, 35 years from the failed of Khmer Rouge regime in 1979 to current crop year of 2015/16, total cultivated area of Cambodian rice production has been enlarged from 1.4 million ha to 3 million ha. Before the war ended in 1993, enlargement of rice cultivated area was precisely unsteady as it was much contingent on the war situations, e.g. between 1985-1989 when the Cambodian Communist Party's army cooperated with Vietnamese army fight against Pol Pot's army (Khmer Rouge army) harder and harder, the total rice cultivated area of the nation also decreased greatly.

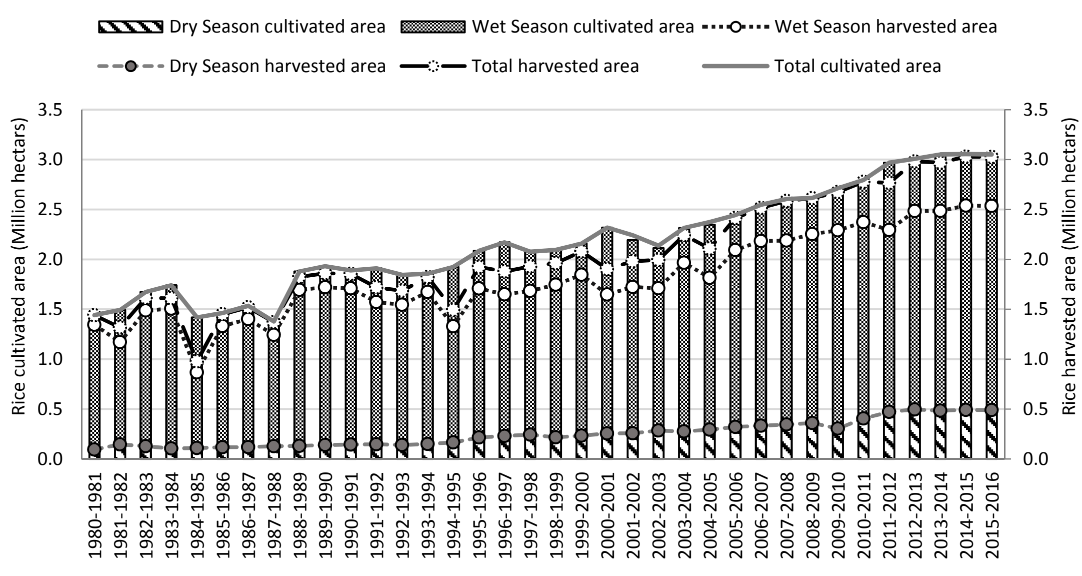


**Figure 6.** Cambodian's national rice cultivated area and harvested area from 1980 to 2015. *Source*: Combined statistics of Ministry of Agriculture, Forestry and Fisheries (MAFF) and Caminfo database (CamInfo 2015; MAFF 2016)

Peace returned to Cambodia in 1993 after the sign of the Paris Peace Agreement among all conflict actors in Cambodian civil war under the facilitation of the United Nations, and established the first national election in Cambodia (however, some parts of Cambodia still remained in war until 1998). Relax of war had been giving the chance to Cambodian farmers for enlarging rice cultivated area. Thus, rice production area has been increased gradually from that time (although in some crop years, natural disasters like floods and droughts destroyed rice production area e.g. 1994, 2000, 2002, 2004). However, although percentage of area harvested to area cultivated has been improved, particularly after crop year of 2005/06, the enlargement of rice cultivated area as well as harvested area in Cambodia had been slowing down after the fifth national election in 2013. Therefore, rice production in Cambodia is precisely sensitive to political stability and climate condition as most of Cambodian’s rice fields remains as rain-fed rice production. Cultivated area of dry season rice, on the other hand, has been also increasing but at a very slow speed, indicated limited ability of the RGC in the development of irrigation systems and good water management practices in order to develop the dry season rice production.

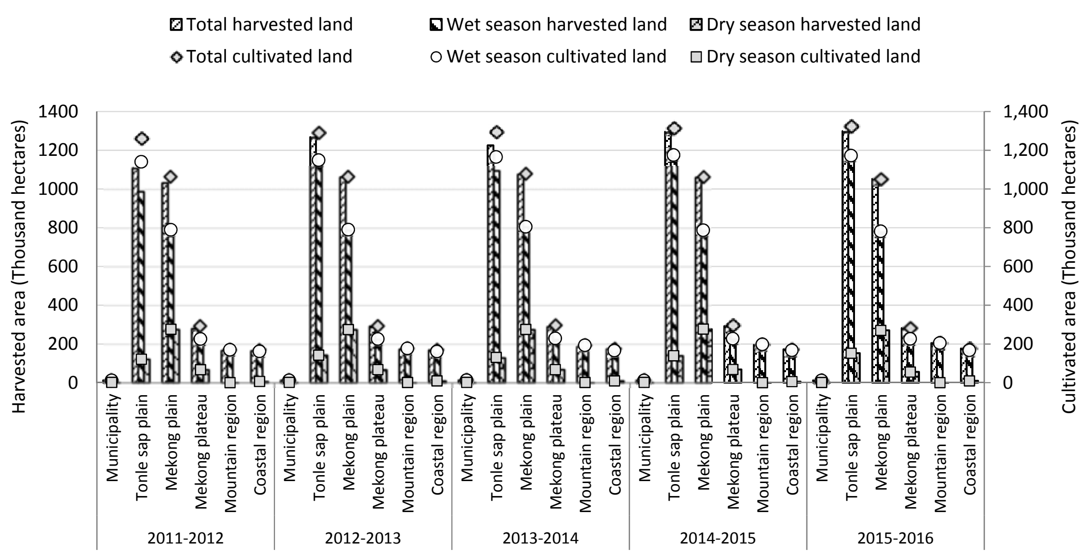


**Figure 7.** Regional rice cultivated area vs. harvested area in Cambodia, 2011-2015. *Source*: Ministry of Agriculture, Forestry and Fisheries (MAFF 2012; 2013; 2014; 2015; 2016)

Figure 7 illustrated cultivated area and harvested area of Cambodian rice production at regional level between 2011 and 2015. Rice was cultivated on the large amount of area in two regions for both wet and dry season rice production i.e. Tonle Sap plain and Mekong plain region where total cultivated area of rice was around 1.3 and 1.1 million ha respectively, accounted for almost 80% of the national total production area of rice. During 2015/16 crop year, total harvested area of rice production in Tonle Sap plain and Mekong plain region was

1,298,617 ha and 1,051,468 ha respectively. However, the ratio of harvested area to cultivated area in Mekong plain region was higher than in Tonle Sap plain region, indicated that rice fields in Tonle Sap plain region was more vulnerable to natural disasters (floods, droughts, as well as insects) than in Mekong plain region. During this crop year as well, wet season rice was cultivated mostly in Tonle Sap plain region on the area of 1,171,464 ha accounted for 46% of total wet season rice cultivated area (1,145,992 ha harvested) while in Mekong plain region wet season rice was cultivated on only 781,422 ha or 30% of total wet season rice cultivated area (781,112 ha harvested). Dry season rice alternatively was cultivated mostly in Mekong plain region rather than Tonle Sap plain region. Mekong plain region cultivated dry season rice on the total area of 270,356 ha (55% of total dry season rice cultivated area), while Tonle Sap plain region could be able to cultivate on only 152,625 ha (31%).

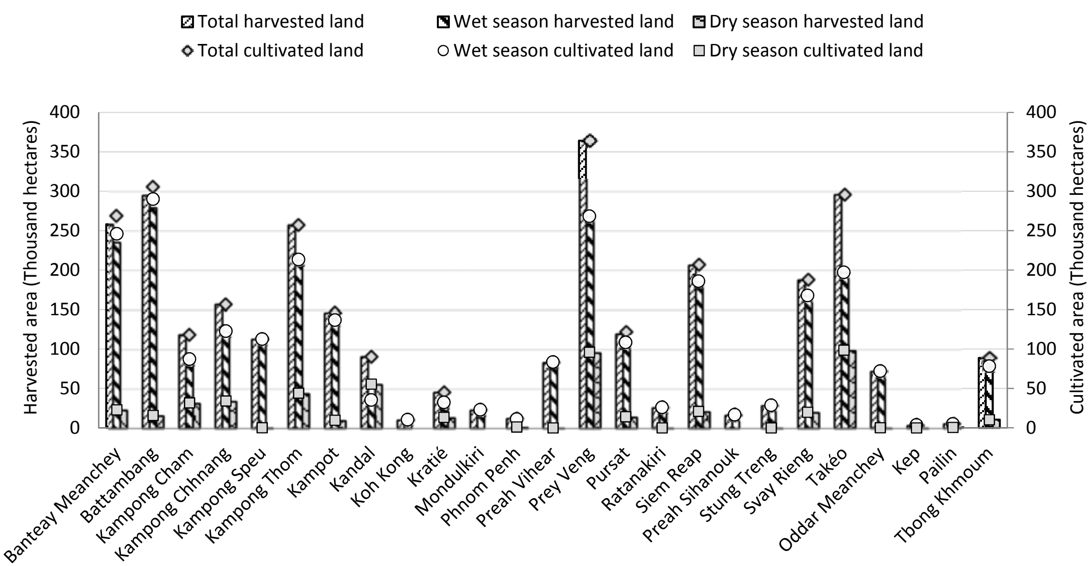


**Figure 8.** Provincial rice cultivated area vs. harvested area during 2015/16 crop year.

*Source*: Ministry of Agriculture, Forestry and Fisheries (MAFF 2016)

Cambodian rice cultivated area and harvested area at provincial level during 2015/16 crop year was illustrated in Figure 8. Rice was cultivated the most in Prey Veng province with the total cultivated area of 364,224 ha accounted for 12% of total rice cultivated area nationwide, while total cultivated area of Battambang and Takeo province accounted for around 10% and 9.7% respectively, followed by Banteay Meanchey 8.8% and Kampong Thom 8.4%. Thus, rice cultivated area of these five provinces altogether accounted for almost 50% of the national total rice cultivated area, being the top five leading provinces in rice production of the kingdom. Furthermore, Prey Veng and Takeo province are the top two leading rice production provinces in Mekong plain region especially dry season rice, which similarly cultivated around 20% (each) of the total dry season cultivated area. Battambang, Banteay Meanchey, Kampong Thom, alternatively are the top three leading rice production provinces in Tonle Sap plain region, particularly wet season rice production, which cultivated around 11.3%, 9.6%, and 8.3% of the total wet season rice cultivated area nationwide. Additionally, wet season rice cultivated area of Prey Veng province was about 10.5% which is comparable to Battambang and Banteay Meanchey province. More importantly, the ratio of harvested area to cultivated area in Prey Veng and Takeo province was quit higher than in Battambang and Banteay Meanchey (top rice production provinces in Tonle Sap plain region), indicated that rice fields in Battambang and Banteay Meanchey was considerably vulnerable to natural disasters than in Prey Veng and Takeo, where production of rice could be increased by increasing harvested area to cultivated ratio.

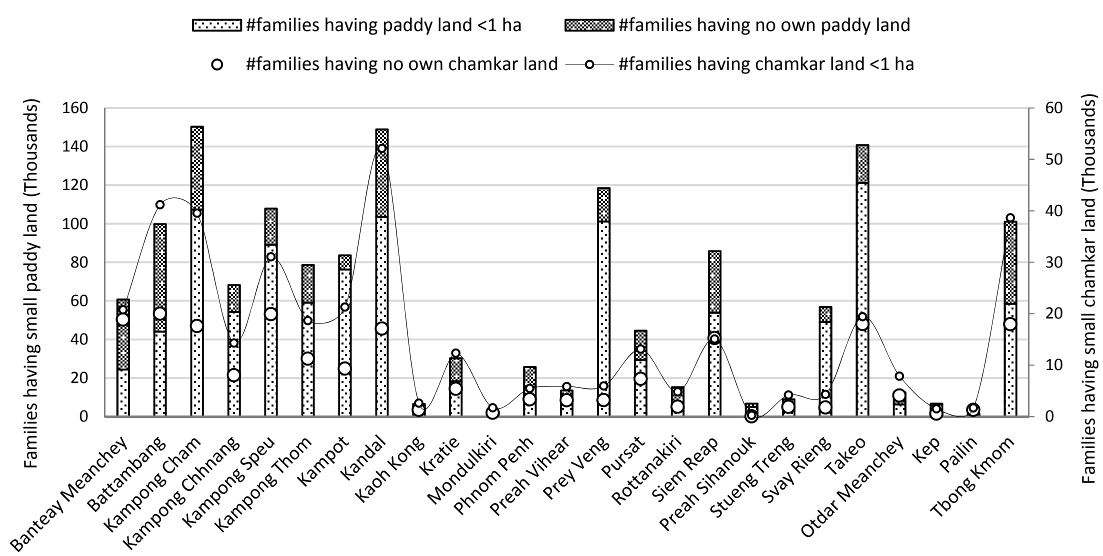


**Figure 9.** Number of families having no owned and owning small (smaller than 1 ha) of paddy land and *chamkar* land during 2015/16 crop year.

*Source*: Ministry of Agriculture, Forestry and Fisheries (MAFF 2016)

Figure 9 illustrated the number of families having no owned, and owning small of paddy land and *chamkar* [6] land (less than 1 ha) during 2015/16 crop year. The statistics reveal that families having small paddy land (i.e. families having no paddy land altogether with families owning paddy land less than 1 ha) are living mostly in Kampong Cham province (more than 150 thousand households), following by Kandal and Takeo province. Prey Veng province, on the other hand, ranks as the forth, while Kampong Speu, Battambang and Tbong

[6] *Chamkar* land: refer to agricultural land under other crops beside rice, such as short and long-term crops, etc.

Kmom province stand on the fifth, the sixth and the seventh (of number of families having small paddy land). These seven provinces are top rice production provinces of the country. Thus, these statistics indicated that most rice farmers, particularly in the high potential provinces of rice production, are the small land farmers who having paddy land less than 1 ha. More importantly, Figure 9 also shows that number of families having no owned paddy land in Battambang province was the top in the country during 2015/16 crop year. Furthermore, number of families having no *chamkar* land in Battambang was also the top in the nation, while number of families having *chamkar* land less than 1 ha (in Battambang) ranked as the second top after Kandal province. As being mentioned previously, Battambang province is *the rice bowl of Cambodia*, and *land* resource might be the core input factor for rice production. Thus, owning small rice production land by rural farmers in Battambang might be constraints for household's rice production development.

Figure 10 illustrates the quantity and yield of rice production in Cambodia between the crop year of 1980/81 and 2015/16. After the Khmer Rouge regime[7] was defeated in 1979, Cambodian people could see the bright to be re-born from the darkness of the civil war. However, Cambodia still has to re-build the nation from the zero stage again while dealing with hunger remained as the first priority for entire nations. Rice production played a very imperative role for combating food insecurity, and being self-sufficient was the top priority goal for the RGC at that time.

Rice production in the kingdom has been improved greatly from year to year, particularly between 2005/06 and 2012/13 crop year after Cambodia be able to fill self-sufficiency in 2003. Moreover, Cambodia correspondingly started to export rice to the world market after the successful of 2005/06 cropping. Between this period, rice production output increased rapidly from 4 million tons (un-milled rice) in 2004/05 to almost 9.3 million tons in 2012/13 (132.5% increased within 9 years) as the result of production yield improvement in both wet season and dry season rice production, as well as harvested area enlargement. However, after the fifth election year of July 2013 rice production of Cambodia remained steady, fluctuated around 9.3 million tons of un-milled rice output. This might be caused by political instability after the 2013 election in some reasons, as well as unfavorable weather condition, and slowing down (or remain steady) of total area harvested. Rice production yield

[7] Cambodia's demography has been largely shaped by its history over the last four decades. The civil war and Khmer Rouge regime left millions dead, but the fall of the regime in the early 1980s and the lasting peace which took shape in the 1990s were marked by baby booms. The result today is a so-called "youth bulge" in Cambodia's population, which has led to an expanding workforce and a shortage of skilled labor due to the country's inefficient education system (OECD 2013a).

was also remaining fluctuated around 2.8 tons/ha for wet season rice and 4.4 tons/ha for dry season rice (annual production yield fluctuated around 3 tons/ha, closer to wet season rice production yield, meanwhile quantity of dry season rice in average just accounted for 20% of total production within the last 10 years).

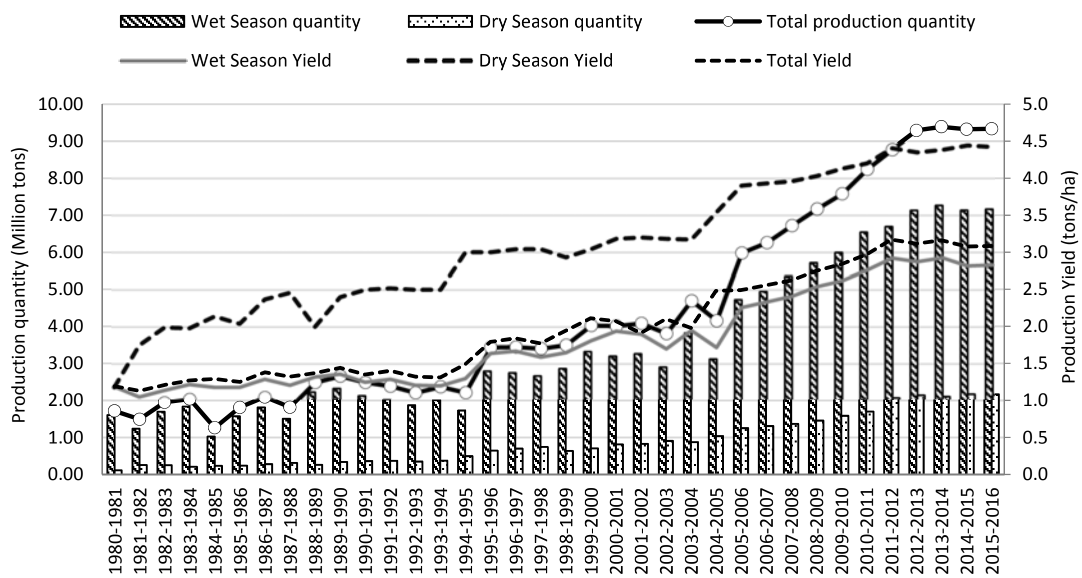


**Figure 10.** Production quantity and yield of Cambodian rice, 1980-2015.

*Source*: Combined statistics of Ministry of Agriculture, Forestry and Fisheries (MAFF), and Caminfo online statistical system (CamInfo 2015; MAFF 2016)

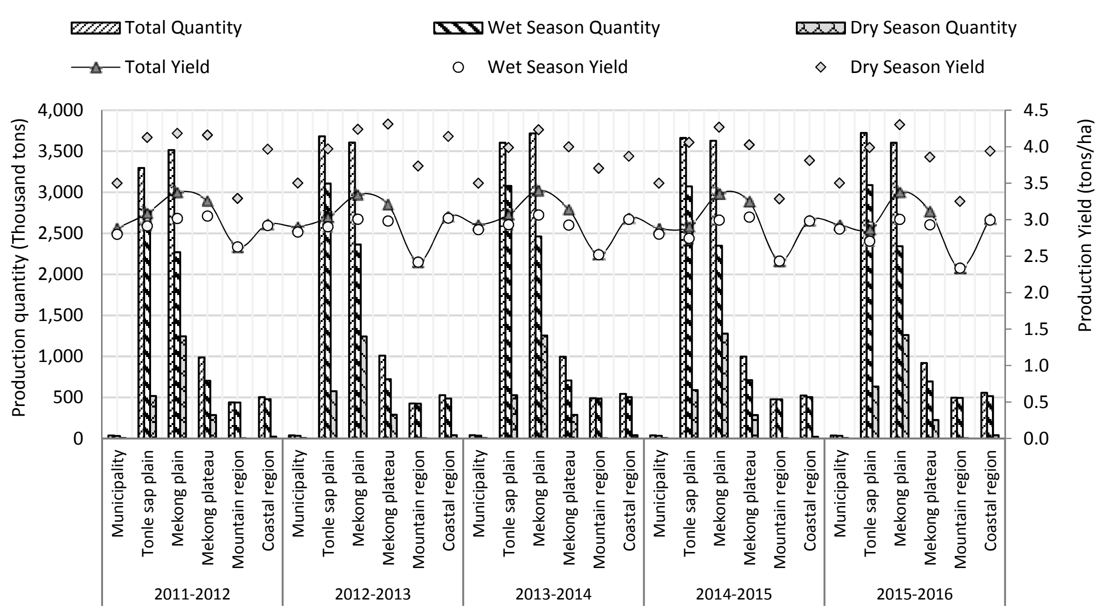


**Figure 11.** Regional production quantity and yield of Cambodia rice, 2011-2015.

*Source*: Ministry of Agriculture, Forestry and Fisheries (MAFF 2012; 2013; 2014; 2015; 2016)

Figure 11 presents the regional-level of rice production quantity and yield in Cambodia between 2011/12 and 2015/16 crop year. The Tonle Sap plain and Mekong plain are the top-two leading rice production regions. The total quantity produced in these two regions altogether accounted for almost 80% of total quantity produced within the entire nation. Tonle Sap plain is the leading region for wet season rice production which produces more than 3 million tons of wet season rice annually while Mekong plain, on the other hand, can produce just 2.3 million tons per year. Conversely, Mekong pain is the leading region for dry season rice production. This region produces 1.2 million tons of dry season rice annually, while Tonle Sap plain can produce only around 0.5 million tons of dry season rice per year. However, there is no greatly different in total production quantity of these two regions.

Average total yield was highest in Mekong plain region between this 5 crop years (2011-2015), fluctuated around 3.5 tons/ha. Moreover, production yield of dry season rice in this region is also reached the greatest level nationwide where average dry season yield was 4.303 tons/ha during 2015/16 crop year. Tonle Sap plain region, on the other hand, although it is the leading wet season rice production region of the kingdom, its wet season production yield has not been reached the greatest level yet. Its yield still remained relatively low compared to other regions, particularly within the crop year of 2015/16 where wet season rice production yield of Tonle Sap plain region was only 2.7 tons/ha in average. Although dry season rice yield of this region could reached up to almost 4 tons/ha (similar to dry season rice yield of Mekong plateau and Coastal region), due to farmers in Tonle Sap plain cultivated just a small amount of dry season rice, thus, lower yield of wet season rice production has been leaded the average total yield to be low at only 2.87 tons/ha. The region with the lowest rice production yield in both wet and dry season rice production remain as Mountain region where the vast area of this region covered by mountains, and irrigation system remain identically lack. Wet and dry season rice yield of this region during crop year of 2015/16 was 2.3 tons/ha and 3.2 tons/ha respectively, which leaded the average total yield reached to only 2.3 tons/ha (due to very tiny area of dry season rice cultivated).

Figure 12 demonstrates the provincial level of rice production quantity and yield during 2015/16 crop year. The top two leading rice production provinces in quantity was Prey Veng and Takeo (located in Mekong plain region) where the production quantity during this period reached 1,266,426 tons and 1,126,470 tons respectively, ranked as the first and the second leading rice production provinces nationwide. These two provinces cultivated enormous area of dry season rice which provided the highest level of yield of over 4.8 tons/ha (highest within entire nation). Additionally, Battambang, Kampong Thom, and Banteay Meanchey province, which located in Tonle Sap plain region, ranked as the third, the forth, and the fifth leading rice production provinces in 2015/16, where the total production quantity reached 861,506 tons, 723,228 tons, and 710,720 tons respectively. These three provinces cultivated greater amount of wet season rice rather than dry season rice. However, production yield of these three provinces still remain relatively low (just fluctuated around average yield nationwide). Moreover, before the division of Kampong Cham province into two provinces (Kampong Cham and Tbong Kmom province) in 2013, total rice production of Kampong Cham province can be ranked at the sixth. After the foundation of Tbong Kmom province, land area as well as rice cultivated area of Kampong Cham province comes to be greatly smaller which caused the total production low compared to other large provinces. Anyway, total production yield of these two provinces still remained at the higher level than those reached by production of Battambang, Kampong Thom, and Banteay Meanchey province.

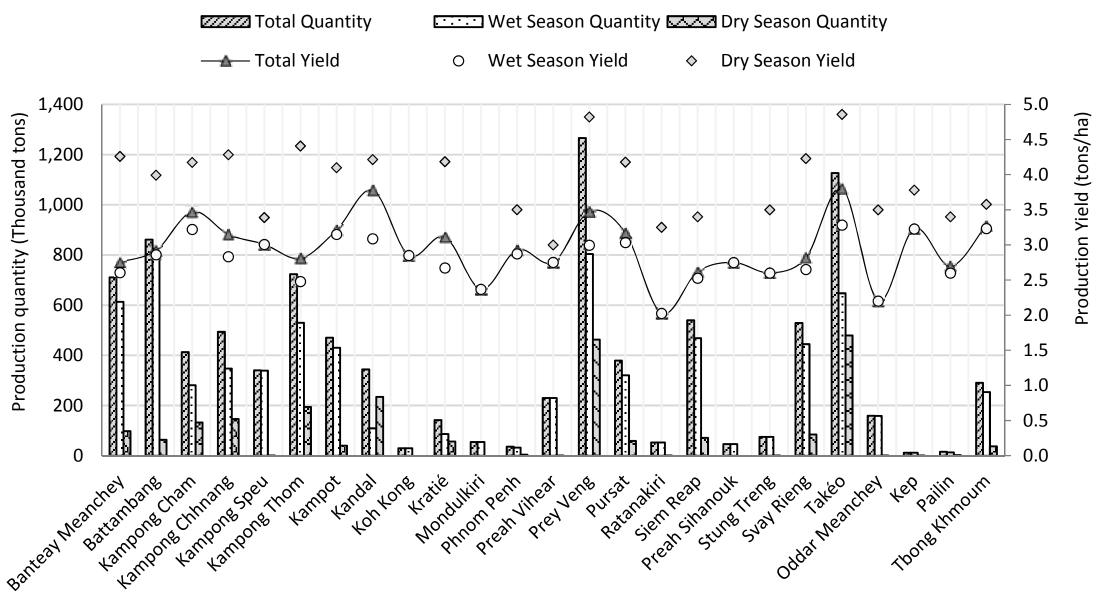


**Figure 12.** Provincial rice production quantity and yield during crop year 2015-2016.

*Source*: Ministry of Agriculture, Forestry and Fisheries (MAFF 2016)

The statistics of Cambodian total milled rice and milled rice surplus from the second national election year of 1998 to 2015/16 crop year were illustrated Figure 13. Entire nation of Cambodia reached national self-sufficiency level after the successful of 2003/04 rice production. However, Cambodia unfortunately faced a huge flooded again in 2004 (after occurred in 2000, and 2002) and destroy almost half of the production. Thus, Cambodia started to export rice products to the world market after 2006, and rice production was improved rapidly generated milled rice surplus from 2 million tons in 2003/04 to over 3 million tons in 2013/14. Nevertheless, after the fifth national election year of 2013, rice production of Cambodia started to be slowing down, as the results of conflicts and political instability, unfavorable weather condition, and more frequency occurrence of floods and drought, etc.

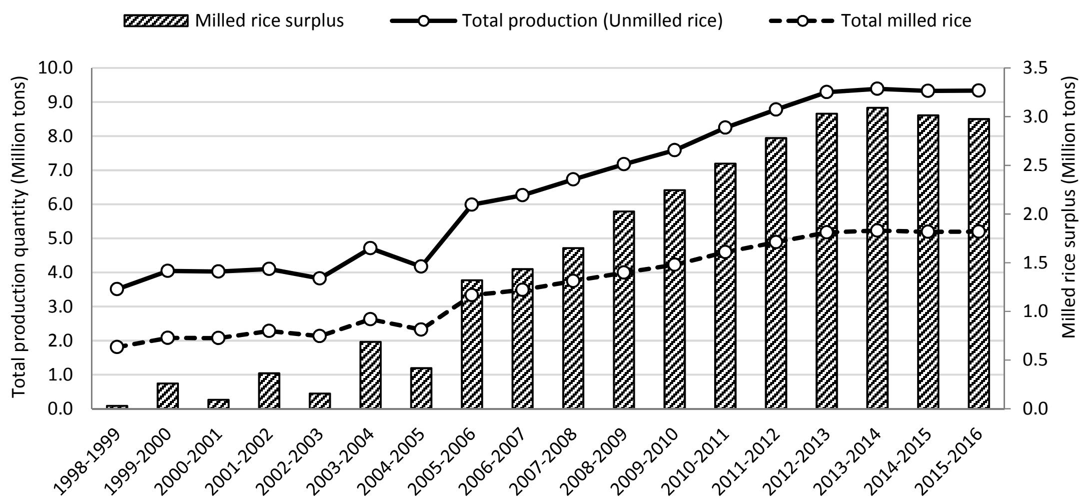


**Figure 13.** National production, milled rice and milled rice surplus (1998-2015).
*Source*: Combined statistics of Ministry of Agriculture, Forestry and Fisheries (MAFF) and Caminfo online database (CamInfo 2015; MAFF 2016)

Figure 14 clarifies regional rice production, total milled rice and milled rice surplus of Cambodia between 2011/12 and 2015/16 crop year, while Figure 15 alternatively illustrates the food security status at provincial level of Cambodia during the crop year of 2015/16. Tonle Sap plain and Mekong plain region are the two leading regions which respectively produced un-milled rice over 3.7 million tons and 3.6 million tons per year (totally equivalent to around 4 million tons of milled rice) accounted for almost 80% of total production nationwide. At the end of 2015/16 crop year, Tonle Sap plain and Mekong plain region has total rice surplus in excess of 1.4 million tons and 1.3 million tons respectively, which generated a huge percentage (84%) of total rice surplus. Other regions like Mekong plateau, Mountain region, and Coastal region are able to be self-sufficient and similarly produced rice surplus around 0.15-0.18 million tons annually. Municipality of Phnom Penh was the only one region that has rice deficit, since Phnom Penh is the capital city of the nation, where a huge percentage of population and land area did not involve in rice production. Rice consumption in Phnom Penh, therefore, exceeds regional rice production.

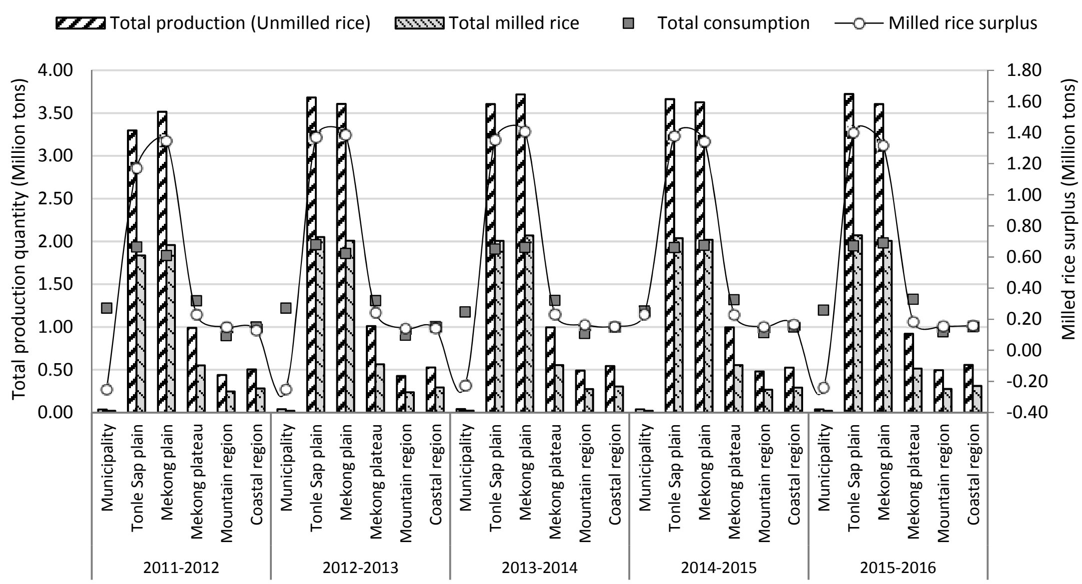


**Figure 14.** Regional production, milled rice and milled rice surplus, 2011-2015. *Source*: Ministry of Agriculture, Forestry and Fisheries (MAFF 2012; 2013; 2014; 2015; 2016)

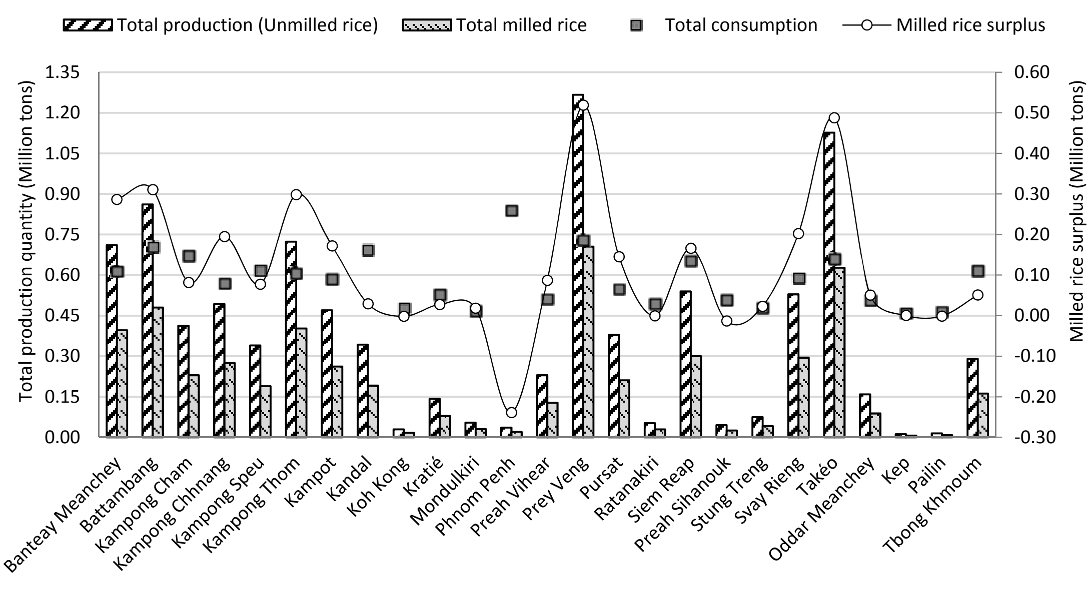


**Figure 15.** Provincial production, milled rice and milled rice surplus during 2015/16 crop year. *Source*: Ministry of Agriculture, Forestry and Fisheries (MAFF 2016)

At the provincial level, there are five out of 25 provinces faced rice deficit, included Ratanakiri, Pailin, Koh Kong, Preah Sihanouk, and Phnom Penh, ranking from 301 tons (lowest) to 238,811 tons (highest) of milled rice. As the most populated city and the capital of the country, Phnom Penh had the highest rice demand around 258,836 tons per year while rice production of Phnom Penh itself was just 20,025 tons (of milled rice) at the end of 2015/16 crop year. Nevertheless, other four provinces had milled rice deficit just from 301 tons (Ratanakiri) to 13,121 tons (Preah Sihanouk), which was much lower than rice deficit rate in Phnom Penh. More importantly, Prey Veng and Takeo province still ranked as the first and the second province with the highest milled rice surplus quantity. Prey Veng province had milled rice surplus of 519,031 tons at the end of 2015/16, while Takeo's rice surplus was around 487,899 tons. Additionally, Battambang, Kampong Thom, and Banteay Meanchey province, were also ranked from the third to the fifth in total milled rice surplus with the surplus value of 310,516 tons, 298,466 tons, and 286,631 tons in 2015/16 respectively.

### 3.2.2. Labor Forces

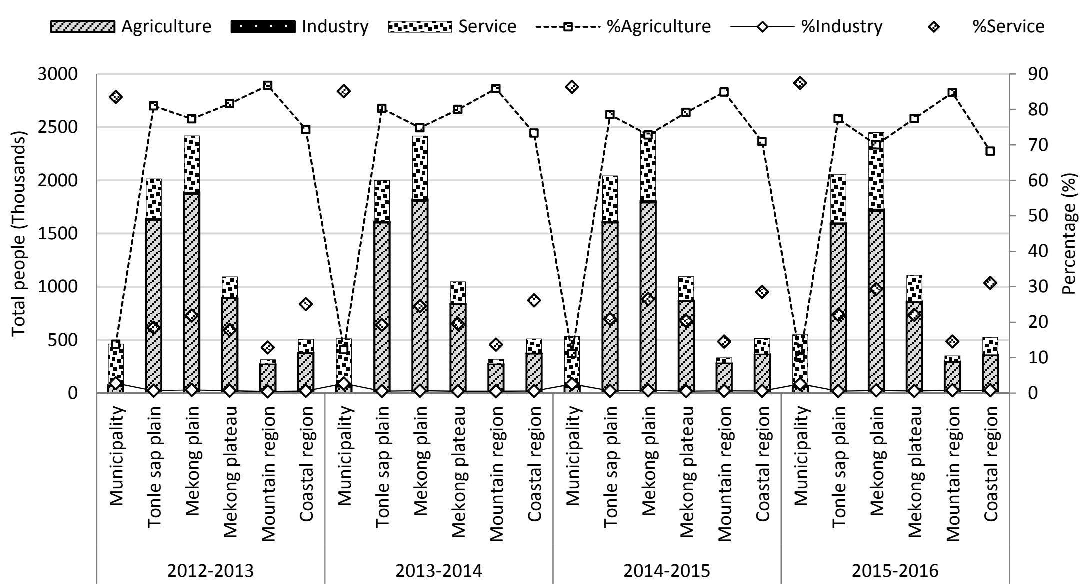


**Figure 16.** Number and percentage of regional labor forces by sectors, 2012-2015
*Source*: Ministry of Agriculture, Forestry and Fisheries (MAFF 2012; 2013; 2014; 2015; 2016)

Figure 16 illustrates the number and percentage of regional labor forces by sectors between 2012 and 2015, while Figure 17 alternatively illuminates the number and percentage of provincial labor forces by sectors during crop year of 2015/16. Most Cambodian labor forces are working in agricultural sector as their primary occupation, particularly for the rural people. As being showed in these two figures, labor forces working in agriculture in all regions (except municipality of Phnom Penh) accounted for 70-87% of regional total labor forces. The provinces in the mountain region has the highest rate of labors working in agriculture, following by Mekong plateau region, since services sector in these two regions are not developed well. Moreover, percentage of people working in services sector in these regions are also extremely low (compared to other regions in the country). Furthermore, this figure also reveals that rate of labors working in industrial sector still remains very low (less than 3%) in entire regions of Cambodia, indicating under-development of this sector.

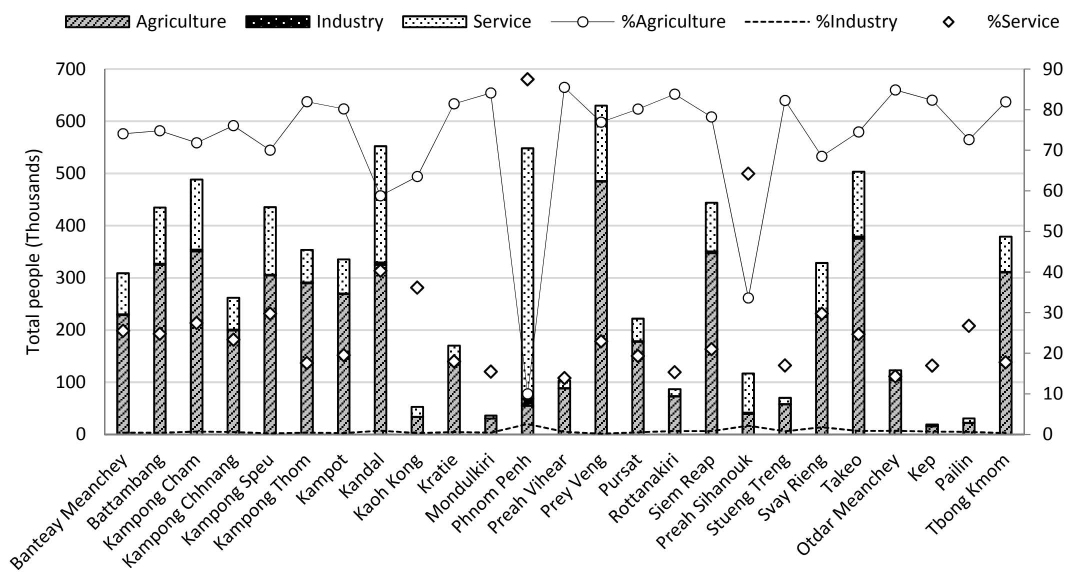


**Figure 17.** Number and percentage of provincial labor forces by sectors, during crop year of 2015/16. *Source*: Ministry of Agriculture, Forestry and Fisheries (MAFF 2016)

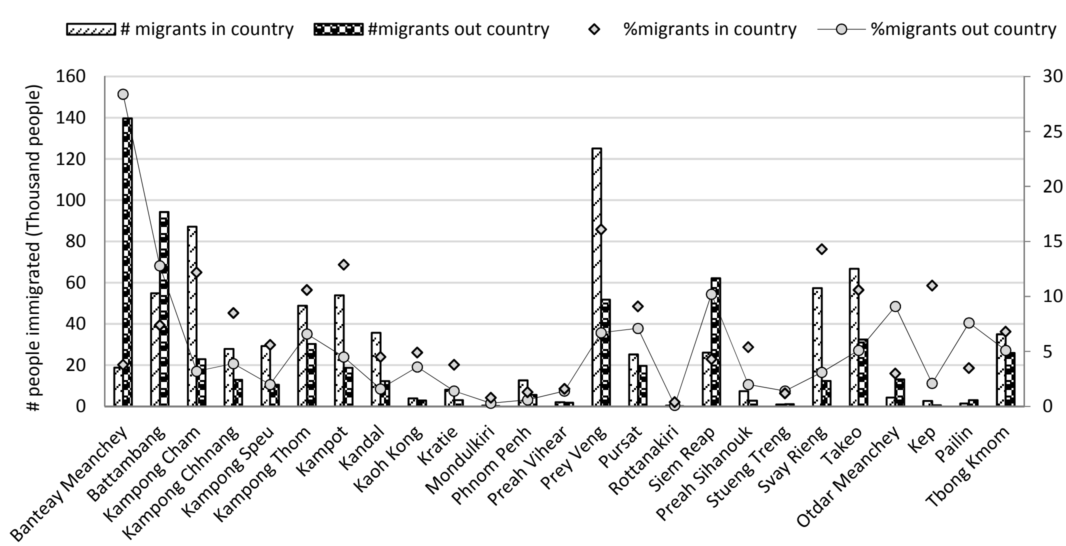


**Figure 18.** Number and percentage of migrants inside and outside country by province, in 2015/16 crop year. *Source*: Ministry of Agriculture, Forestry and Fisheries (MAFF 2016)

As being showed in Figure 18, which presents the number and percentage of migrants inside and outside country by province during crop year of 2015/16, Banteay Meanchey and Prey Veng are the two provinces with the highest rate of migrants nationwide. The figure discloses that Banteay Meanchey province which sharing the border with Thailand has had the highest rate (28.4%) of migrants outside country (international immigration to Thailand), while Prey Veng province has had the highest rate (16.1%) of migrants inside country (immigration to other provinces in Cambodia). These statistics indicate the high rate of the transferring process of labor forces out of agriculture to other higher paying sectors by rural farmers within these two provinces.

### 3.2.3. Agricultural Machineries

Agricultural mechanization in Cambodia still facing numerous challenges include: 1) national policy on agricultural mechanization is not yet prepared; 2) structure of the Provincial Office of agricultural engineering is still weak; 3) inadequate skilled workforce at both national and provincial level; 4) credit scheme for buying farm machinery and equipment is not existent; 5) most of workshops for repairing and maintenance of farm machinery and equipment are not available at the rural areas; 6) annual budget allocated for the implementation of agricultural mechanization activities fails the nationwide coverage; 7) less activities on research and development on agricultural machinery and equipment and it exists mainly at the national level; 8) external support and cooperation with development partners is still missing; and 9) gap in cooperation with private sector dealing with farm machinery (Chan 2013). Local manufacturers of farm machineries and equipment, usually, produce thresher, water pump, local-made truck for transportation, trailer, implements and spare parts such as cage wheel. Nonetheless, they can manufacture only simple machines which do not required sophisticated production process or tools. Normally, they are still small scale and family owned with a few workers and operate seasonally and to supply to local market (Chan 2014). Thus, large-scale machineries, such as tractors, walking tractors (*koryons*), etc., still being imported from some major countries, included Belorussia, China, Japan, India, US and Thailand. This revealed the lack of ability as well as local technical experts for Cambodia to be able to manufacture large heavy-scale agricultural machineries by itself.

Figure 19 presents the ratio of number of agricultural machineries to provincial total cultivated area, during crop year of 2015/16. The statistics reveal that farmers in Cambodia use walking tractors or *koryons* rather than large-scale tractors for plowing (rice). Likewise, ratio of agricultural machineries to provincial cultivated area of high potential provinces for rice production like Battambang, Banteay Meanchey, Prey Veng and Takeo, still remain tremendously low compare to the lower potential provinces (like Otdar Meanchey, Preah Vihear, Pailin, for instance).

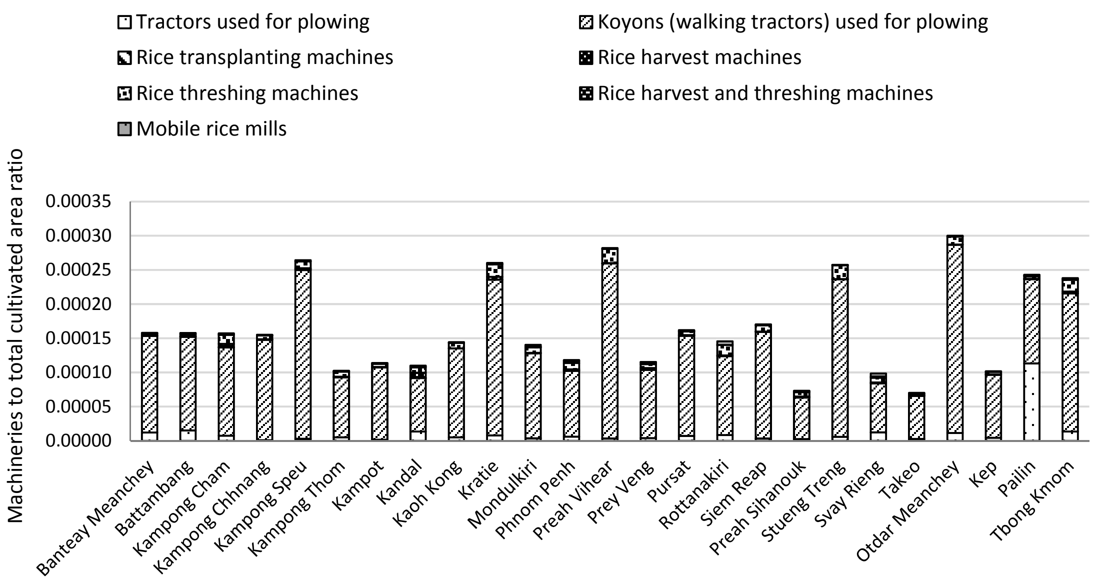


**Figure 19.** Ratio of number of agricultural machineries to provincial total cultivated area, in 2015/16 crop year. *Source*: Ministry of Agriculture, Forestry and Fisheries (MAFF 2016)

## 3.3. Chapter summary

Rice production is the most important segment of Cambodian agricultural sector and plays a major role in the national economic growth. Production of rice has been improved greatly from year to year. Cambodia started to export rice to the world market after the successful of 2005/06 cropping. The Tonle Sap plain and Mekong plain are the top-two leading rice production regions, altogether accounted for almost 80% of total quantity produced within the entire nation. Tonle Sap plain is leading for wet season rice while Mekong plain is leading for dry season rice production. The top five leading rice production provinces are Prey Veng, Takeo, Battambang, Kampong Thom, and Banteay Meanchey.

Most Cambodian labor forces are working in agricultural sector as their primary occupation, particularly for the rural people (accounted for 70-87% of labor forces). However, Banteay Meanchey and Prey Veng are the top two provinces with the highest rate of migrants nationwide, indicating the high rate of transferring process of labor forces out of agriculture to other higher paying sectors by rural farmers within these two provinces. Furthermore, ratio of agricultural machineries to cultivated area of high potential provinces for rice production like Battambang, Banteay Meanchey, Prey Veng and Takeo, still remain low compared to the lower potential provinces like Otdar Meanchey, Preah Vihear, Pailin, etc.

# CHAPTER 4. "TECHNICAL EFFICIENCY OF CAMBODIAN NATIONAL RICE PRODUCTION"

## 4.1. Data and Descriptive Statistics

The data used for the case study of technical efficiency analysis of rice production in Cambodia at the national level were drawn from 4-years dataset (2012-2015) generated in document sets of the Royal Government of Cambodia (RGC), namely "*Profile on Economics and Social*" of entire 25 provinces in Cambodia i.e. 24 provinces and 1 municipality of Phnom Penh (RGC 2015; RGC 2016). These document sets were prepared by Provincial Department of Planning of every province based on computer program namely Commune Database (CDB) that provided derived-data from village and commune data books which are annually documented and kept at commune/sangkat and village chief or village representative who is member of Planning and Budgeting Committee.

The stochastic production frontier function (hereafter, SFA model), which is originally and independently proposed by Aigner et al. (1977), and Meeusen and Van den Broeck (1977) were conducted for estimate the technical efficiency. The most commonly used package for estimation of SFA model, FRONTIER version 4.1c (Coelli 1996), was applied. Furthermore, the present study utilized the logarithmic form of translog production function of SFA model, which can be written as:

$$Ln\, y_{it} = \beta_0 + \sum_j \beta_j Lnx_{jit} + \beta_t t + \frac{1}{2}\sum_j \sum_k \beta_{jk} Lnx_{jit} Lnx_{kit} + \frac{1}{2}\beta_{it} t^2 + \sum_j \beta_{jt} Lnx_{jit} t + v_{it} - u_{it} \quad (11)$$

At the national level, the SFA model was constructed by one output variable (i.e. *quantity*) and five input variables, included *land*, *labor*, *fertilizer*, *pesticide*, and *machinery*. Output was the total provincial un-milled rice production *quantity* (hereafter, *rice output*), which measured in tons. *Land* input was the total area of rice actually harvested within the year (included both wet season and dry season), measured in hectares (ha). In many agricultural nations, *land* always plays as an important input in production of agricultural crops like rice. Countries harvested larger land of rice tend to be able to produce higher amount of rice output, for example, Thailand and Indonesia where about 10-12 million hectares of rice was harvested annually compared to Cambodia that could harvested only 2-3 million hectares per year. Thus, production of rice in this two countries were respectively recorded around 20 and 36 million tons (of milled rice) annually, compared to only around 4 million tons per year produced in Cambodia (Baldwin et al. 2012). Additionally, provinces of

Cambodia that harvested more land of rice were also able to produce more rice output compare to provinces with lower rate of rice harvested land. For instance, the province of Battambang and Prey Veng where around 279 and 268 thousand hectares of rice area were respectively harvested in 2015 and produced more than 798 and 803 thousand tons of rice output (respectively), which was much higher compared to Phnom Penh suburbs that harvested on only 11 thousand hectares and produced about 2 thousand tons within this year (RGC 2016). Harvested area (i.e. *land* input), hence, was expected to have positive effect on provincial as well as total *rice output*. *Labor* input, on the other hand, measured as total farmers with rice farming as primary occupation (hereafter, rice farmers), unit in persons. According to dataset of the Royal Government of Cambodia (RGC 2015; RGC 2016), provinces with higher rate of rice farmers tended to produce higher amount of *rice output* since rice remains as their provincial dominant crop as well as the dominant commodity. Thus, *labor* input was also expected to have positive effect on *rice output*. Furthermore, *fertilizer* input measured as total amount of chemical and organic fertilizers' quantity using by total families cultivating rice (hereafter, rice families) in the province (unit in tons), while *pesticide* input also measured as total amount of poisons for insects and grass's quantity (for both chemical and organic poisons) using by total rice families in the province, unit in tons. Followed by the concept of green revolution (Wikipedia 2016), these two input variables were also expected to be positively related to *rice output*. Additionally, another important input variable was determined as the variable of capital investment on agricultural *machineries* which measured as total amount of tractors, walking tractors ("*koryons*" in Khmer language), and rice transplanting machines existing in the provincial territory. This input variable was also expected to have positive effect on *rice output* as well. Along with the global technological expansion, the development of agricultural sector was inevitably linked to the mechanization improvement as many works/tasks in agricultural production, particularly rice production in Cambodia (which normally is labor-intensive), could be completed faster and greater with the performances of these machineries. Table 3 provides summary statistics of the output and inputs of rice production within entire 25 provinces in Cambodia from 2012 to 2015.

Output *quantity* of rice production in Cambodia was higher in 2015 than in 2012 which increased 8.4% in average from 290 thousand tons (2012) to 315 thousand tons (2015). Total area of rice actually harvested in average also increased around 8% from 134 thousand hectares in 2012 to 145 thousand hectares in 2015. Total rice families using quantity of chemical and organic fertilizers (i.e. *fertilizer* input), on the other hand, increased in average by 7%, while *pesticide* and *machinery* input (definition same as above) increased greatly between this period. Total rice families using quantity of poison for insects and grass increased by nearly 25% (3-times larger than *land* and *fertilizer* input), while the total capital investment on agricultural *machineries* between this period increased by a huge percentage of 64.4%, indicated a huge improvement of mechanization in Cambodian agriculture, particularly in rice production sector. Nevertheless, along with the improvement of agricultural mechanization, *labor* input which measured as total people with rice farming as primary occupation tended to slightly decrease by 8%, presented the progression of transformation of labor forces out of agriculture to other higher productivity and profitability sectors, such as industries and services.

**Table 3.** Input and output summary statistics for 25 provinces in Cambodia, 2012-2015

| **Variable** | **2012** | | **2013** | | **2014** | | **2015** | |
|---|---|---|---|---|---|---|---|---|
| | Mean | S.E. | Mean | S.E. | Mean | S.E. | Mean | S.E. |
| Output | | | | | | | | |
| *Quantity* [1] *(tons)* | 290,808 | 52,994 | 329,872 | 60,296 | 391,150 | 80,437 | 315,270 | 57,785 |
| Inputs | | | | | | | | |
| *Land* [2] *(hectares)* | 134,629 | 23,192 | 144,944 | 25,893 | 212,785 | 56,497 | 145,685 | 26,699 |
| *Labor* [3] *(persons)* | 168,703 | 27,044 | 163,805 | 26,208 | 160,163 | 25,683 | 155,159 | 24,486 |
| *Fertilizer* [4] *(tons)* | 74,061 | 13,236 | 75,027 | 13,300 | 160,043 | 13,436 | 79,038 | 13,618 |
| *Pesticide* [5] *(tons)* | 45,116 | 9,610 | 47,926 | 10,021 | 52,205 | 10,596 | 56,117 | 11,047 |
| *Machinery* [6] *(units)* | 10,196 | 1,937 | 12,213 | 2,135 | 14,569 | 2,394 | 16,762 | 2,675 |

Source: Measured by Ms. Excel 2016 using combined datasets of the Royal Government of Cambodia (RGC 2015; RGC 2016). "S.E." = Standard Error. [1] Rice *quantity* was the total provincial un-milled rice production output quantity, measured in tons. [2] *Land* input was the total area of rice actually harvested within the year (included both in wet and dry season), measured in hectares. [3] *Labor* input measured as total farmers in the province with rice farming as primary occupation, unit in persons. [4] *Fertilizer* input was total amount of chemical and organic fertilizers' quantity using by total rice families in the province, unit in tons. [5] *Pesticide* input measured as total amount of chemical and organic poisons for insects and grass's quantity using by total rice families in the province, unit in tons. [6] *Machinery* measured the capital investment on agricultural machineries was the total amount of tractors, walking tractors (*koryons*), and rice transplanting machines existing in the provincial territory, unit in units.

Figure 20 illustrates the percentage changes of input and output statistics of Cambodian rice production between the study period 2012-2015. A closer look to percentage changes within output and input variables from year to year indicated that from 2012 to 2013, there were not significantly changed within both output and input variables. However, there were a massive change in inputs, particularly in *land* and *fertilizer* between 2013-2014 which caused *rice output* to increased greatly. Unfortunately, the natural disasters (drought, flood, and insects) at the end of 2014 and in 2015 had destroyed a huge percentage of rice cultivated land in most leading rice production provinces (totally reduced around 30% of 2014 production) and *fertilizer* input was also decreased greatly (by more than 50%). *Rice output*, therefore, also decreased by a great percentage of 20%. Conversely, development of capital investment in agricultural *machineries* still continued to increase by 15-20% per year, while implementation of *pesticide* by farmers tended to increased 6-9% annually as well. *Labor* input, on the other hand, had the decreasing trend from year to year in the percentage of 2-3%.

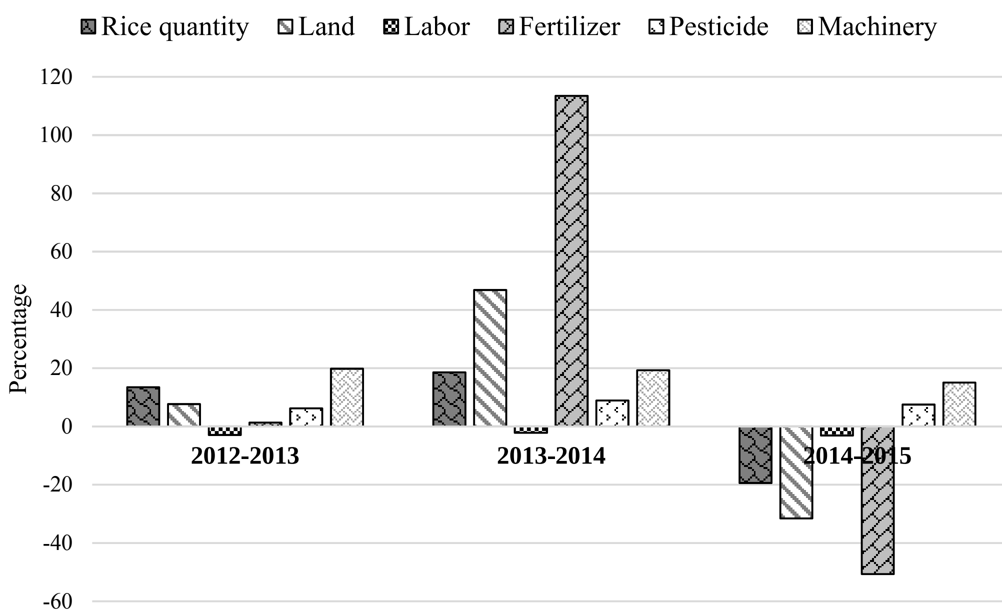


**Figure 20.** Percentage changes in input and output statistics for 25 rice producing provinces in Cambodia for the periods 2012-2013, 2013-2014, and 2014-2015

In the *technical inefficiency model* (*TI model*), there were seven influencing factors of rice production TE to be considered in the present study. *Disaster* measured as percentage of rice production land damaged by floods, droughts, and insects to total rice production land actually harvested within the year. Apparently, *disaster* always caused the lower of harvested land to cultivated land ratio. Thus, *disaster* was expected to have negative effect on rice production TE. *Irrigation*, on the other hand, measured as percentage of provincial paddy land having or benefit from irrigation systems (as well as paddy land located near water sources, such as rivers, lakes, ponds, etc.) to total provincial cultivated land within the year. Irrigation systems could cause the availability of rice cultivated land expansion by improving multi-cropping[8], hence, *irrigation* was stalwartly expected to have positive relationship with rice production TE. Additionally, *production technique* measured as percentage of families cultivating rice under the system of rice intensification (SRI) to total families cultivating rice. Under SRI which introduced by MAFF with the supporting of CEDAC[9], various rice cultivation techniques with less utilization of modern inputs and inexpensive method of planting in relatively dry area could result in an average yield of 3.6 ton/ha, while under a similar situation the yield with traditional farming practice is only 2.4 ton/ha (CEDAC 2008). Farmers cultivated rice under SRI were expected to have higher productivity than farmers using traditional techniques for cultivating rice. However, the percentage of families cultivating rice under this system still seem to be very low in Cambodia. Furthermore, farmers living in villages located closer to the center of district/khan might be able to get further and faster market information about rice, hence, this factor of *distant to information sources* was measured as average distance from village center to the center of district/khan (in kilometers). Agricultural staffs, on the other hand, might have played some crucial roles for providing technical supports as well as technical knowledge of rice production to the rural farmers. Thus, number of agricultural supporting staffs existing in province was expected to have positive effects on TE of rice production. The variable of *agricultural supporting staffs* was included in technical inefficiency model, measured as percentage of agricultural staffs included both government officers and NGOs staffs (working on agricultural plans or projects) to total rice farmers existing in the province. Likewise, there are two main seasons in Cambodia, i.e. wet season and dry season. Greater availability of water resource during wet season have caused rice crop to be able to grow in every provinces of Cambodia. However, during dry season only some provinces (as well as some parts of a province) where rice fields benefit from irrigation systems or located near water sources could be able to cultivated rice crop. Dry season rice crop always provides higher yield of production, nonetheless it requires plenty of water and utilization of fertilizers, as well as higher commitments to watch over. However, rice production during dry season of Cambodia was still highly depends on availability of water resources during this season. Available land for cultivating rice during dry season sometimes was abundance due to the lack of water. Thus, the improvement of dry season rice was expected to have positive effect on TE of rice production in Cambodia. The factor of *dry-*

[8] Multi-cropping: cropping/cultivating several times of crop on the same plot land

[9] CEDAC: Cambodian Center for Study and Development in Agriculture (Centre d'Etude et de Dévelopment Agricole Cambodgien)

*season production* measured as percentage of dry-season paddy land actually harvested to total available land for rice cultivation in dry-season was correspondingly included in the model. Size of farm land owned by farmers was also expected to have positive effect on rice production TE. The great percentage of rice farmers owning farm land less than one hectare, which might cause limited ability for them to improve their rice production. This factor (*small-land farmers*) measured as percentage of families having paddy land smaller than one hectare altogether with families having no paddy land to total rice families. Conversely, some external factors, such as social, economic, demographic, as well as geographic perspectives of each province were omitted from the technical inefficiency model, due to un-sufficient availability of appropriated datasets during the study period. Furthermore, the present study utilized only four-years dataset of entire 25 provinces of Cambodia, which limited availability to included too many influencing factors into the model as it might cause unexpected conflicts or correlations among factor variables. Likewise, provinces of Cambodia were quiet tiny in area and normally the local governance as well as economy are still under directly controlled by the central government in Phnom Penh (i.e. provincial local government in Cambodia are not much independence from each other as the situation in other countries like China for instance). Therefore, the present study assumed these external factors to be neutral to rice production TE. Thus, *TI model* for national-level analysis can be written as:

$$u_{it} = \delta_0 + \delta_1 Disaster_{it} + \delta_2 Irri_{it} + \delta_3 Tech_{it} + \delta_4 Distant_{it} + \delta_5 Staff_{it} + \delta_6 Dry_{it} + \delta_7 SmallF_{it} \quad (12)$$

Table 4 presents descriptive statistics of Cambodian rice production efficiency’s influencing factors between 2012-2015. Percentage of rice land damaged by floods, droughts, and insects was lower in 2015 compared to 2012. Rice land damaged by *disasters* in 2012 was 18.8% in average, while in 2015 *disasters* destroyed only 5.2% of rice production land in average (decreased by 72.4%). However, flooded in wet season of 2014 have still destroyed almost 30% of total rice cultivated land within the year. These percentages still remain huge, which ought to be considered by RGC and the related agencies. Furthermore, from 2012 to 2015, there were also large percentage changes in rural farmers’ *production technique* and amount of *agricultural supporting staffs* existing in the province. *Production technique* which measured as percentage of families cultivating rice under SRI decreased greatly by 20% within 3 years, while percentage of *agricultural supporting staffs* (to total rice families) also decreased by around 17% during this period, indicated lack of technical supporting techniques as well as technical improvement training for farmers in the purpose of improving the national rice production, particularly for small-land rural farmers which most of them are rice farmers. Although percentage of *small-land farmers* (farmers owned no rice cultivated land or having rice land smaller than one hectare) have been slightly reduced during the study period (less than 5%), in 2015 small-land farmers in Cambodia still accounted for 39.8% in average which was still the vast percentage. Moreover, during the dry season, available land for cultivating rice still not fully cultivated yet. In the study period 2012-2015, in average more than 30% of available dry season rice land was abundant annually. During 2012, in average only 68.5% of the total available dry-season rice production land had been actually cultivated and this percentage became worse in 2013 (58.8%). Although situation had been faintly improved in 2014 while this percentage slightly increased to 65.1%, water shortage during the dry season of 2015 had reduced the percentage of dry-season actually cultivated again to around 64.9%. Therefore, there is still a huge gap for Cambodian famers to improve their rice production during dry season as well as total production of rice.

**Table 4.** Descriptive statistics of factors affecting the efficiency of rice production in Cambodia between 2012 and 2015

| **Variable** | **2012** | | **2013** | | **2014** | | **2015** | |
|---|---|---|---|---|---|---|---|---|
| | Mean | S.E. | Mean | S.E. | Mean | S.E. | Mean | S.E. |
| *Disaster* [1] | 18.86 | 12.34 | 5.16 | 1.12 | 30.98 | 26.37 | 5.20 | 1.16 |
| *Irrigation* [2] | 21.70 | 3.49 | 22.75 | 3.52 | 19.94 | 3.58 | 22.64 | 3.54 |
| *Production technique* [3] | 3.04 | 0.48 | 2.79 | 0.47 | 2.74 | 0.42 | 2.44 | 0.37 |
| *Distant info-source* [4] | 14.92 | 1.53 | 14.86 | 1.22 | 14.67 | 1.14 | 15.01 | 1.20 |
| *Supporting staffs* [5] | 0.11 | 0.03 | 0.10 | 0.02 | 0.09 | 0.02 | 0.09 | 0.02 |
| *Dry-season prod.* [6] | 68.47 | 5.72 | 58.76 | 6.33 | 65.12 | 5.89 | 64.91 | 6.43 |
| *Small-land farmers* [7] | 41.80 | 3.17 | 40.99 | 3.43 | 40.35 | 3.45 | 39.76 | 3.67 |

Source: Measured by Ms. Excel 2016 using combined datasets of the Royal Government of Cambodia (RGC 2015; RGC 2016). "S.E." = Standard Error. [1] *Disaster* measured as percentage of rice land damaged by floods, droughts, and insects to total rice actual harvested land within the year. [2] *Irrigation* measured as percentage of provincial paddy land having or benefit from irrigation systems as well as paddy land located near water sources to total provincial cultivated land within the year. [3] *Production technique* measured as percentage of families cultivating rice under the SRI system to total rice cultivated families.[4] *Distant to information sources* measured as average distance from village center to the center of district/khan (in kilometers). [5] *Agricultural supporting staffs* measured as percentage of agricultural staffs included both government officers and NGOs staffs (working on agricultural plans or projects) to total rice farmers existing in the province. [6] *Dry-season production* measured as percentage of paddy land actually harvested during dry season to the total available cultivated land for rice cultivation during dry season. [7] *Small-land farmers* measured as percentage of families having paddy land smaller than one hectare altogether with families having no paddy land to total rice families (i.e. families cultivating rice).

*Irrigation* plays as a very important role for rice production in Cambodia, particularly in dry-season. Between 2012-2015, irrigation systems were improved gradually by increased the percentage of paddy land having irrigation system from 21.7% in 2012 to 22.6% in 2015 (3.5% increased within 3 years). However, this irrigation rate still seems to be very low compared to other agricultural nations, especially its neighboring countries like Thailand, and Vietnam, since another nearly 80% of total cultivated land still being performance as the rain-fed agricultural land. These statistics reveled that irrigation systems in Cambodia still remain lack, shortage far behind its potential to improve the national rice production. In many developed countries, irrigation systems were not only used for agriculture, but also being used as natural disasters prevention devices. Global climate change had been affecting Cambodia in the latest decade. Natural disasters like floods and droughts occurred more frequently than previous times. Sometimes, within a year, Cambodian people suffered from flood in wet-season, and then suffered again from droughts in dry-season. These could be the results of irrigation systems shortage, which caused Cambodia to had no ability to deal with such frequently-occurred disasters. What if Cambodia could build irrigation and water storage systems in order to store an over-needed water resources during the wet-season keeping for utilization in agriculture during the dry-season?

## 4.2. Results and Discussion

### 4.2.1. SFA Model Estimation

Table 5 lists the parameters estimation results by implementing the maximum likelihood estimation method in FRONTIER version 4.1c econometrics software of Coelli (1996). The variance ratio parameter of gamma ($\gamma$) had a value of 1.00 and significant at 1%, shows that the variation of the composite error term was mainly from the technical efficiency ($u_i$) almost 100%, and the variation of random error ($v_i$) less than 1%, indicated the efficiency source of Cambodian rice production within the study period came mainly from the production's technical efficiency.

Almost all estimated coefficients have the expected signs. Total actual harvested *land* and agricultural *machineries* involved in rice production were both positively related to *rice output* and significant at 1%, while the total amount of chemical and organic *fertilizers*' quantity using by total families in the province for the production of rice was also positively related but significant at 5%. These results indicated that enlarging in total actual harvested *land*, more capital investment in agricultural *machineries* and technically improvement of *fertilizers* application by smallholder rice producers (farmers) could cause the result in increasing output (quantity) of rice within the province. Moreover, with the estimated coefficient of 1.86, capital investment in agricultural *machineries* was the main input factor driven more output for Cambodia's provincial rice production compared to *land* and *fertilizer* input factor during the study period. This means that the provinces with higher capital investment (in agricultural *machineries*) tended to produce higher level of *rice output* than the provinces with lower capital investment.

**Table 5.** Parameter estimates of SFA model

| Variables | Coefficient | Standard Error | t-ratio |
|---|---|---|---|
| *Constant* | -1.1869 * | 0.6189 | -1.9178 |
| *Ln(land)* | 0.6796 *** | 0.2475 | 2.7458 |
| *Ln(labor)* | 0.0775 | 0.3279 | 0.2364 |
| *Ln(fertilizer)* | 0.9245 ** | 0.4664 | 1.9820 |
| *Ln(pesticide)* | -1.8588 *** | 0.3565 | -5.2139 |
| *Ln(machinery)* | 1.8642 *** | 0.2629 | 7.0914 |
| *t* | 0.0573 | 0.0369 | 1.5529 |
| *Land × Labor* | 0.0420 ** | 0.0197 | 2.1339 |
| *Land × Fertilizer* | -0.0771 * | 0.0429 | -1.7966 |
| *Land × Pesticide* | 0.1680 *** | 0.0309 | 5.4381 |
| *Land × Machinery* | -0.1210 *** | 0.0241 | -5.0263 |
| *Labor × Machinery* | -0.0585 ** | 0.0271 | -2.1577 |
| $t^2$ | 0.0013 | 0.0068 | 0.1888 |
| *Gamma* ($\gamma$) | 1.0000 *** | 0.0001 | 13,538.2280 |
| *Sigma-squared* ($\sigma^2$) | 0.0336 *** | 0.0062 | 5.3882 |
| Log likelihood function | | | 75.7787 |

Source: Estimated by FRONTIER 4.1c. * indicates significant at 10%, ** significant at 5%, and *** at 1%.

In addition to capital investment in agricultural *machineries* and *fertilizer* application, total actual harvested *land* was the another core input factor for increasing output of rice. The provinces which cultivate more additional lands of rice have the ability to maintain reasonable levels of other necessary inputs in order to cause the rice output to increase faster than the provinces with low rate of rice cultivated land. This result confirmed the results of several previous studies, such as Yu and Diao (2011), Smith and Hornbuckle (2013) and some studies of Asian Development Bank (ADB 2012; ADB 2014). Furthermore, total families using quantity of poison for insects and grass (included both chemical and organic poison) existing in the province, i.e. *pesticides* input factor, was negatively related to rice output and significant at 1%, indicated that provinces with more amount of poison (*pesticides*) application tended to produced lower *rice output* than the provinces with smaller amount of poison application. This could be the result of inefficiency used of poison in rice production by farmers. Be noted that most of smallholder rice producers are the farmers with low education. Furthermore, the instruction of product usage for most imported agricultural poison products have not been totally translated into Khmer language yet before imported (to Cambodia), which might cause numerous misunderstanding and leaded to incorrected technical used as well as inefficiency used in field practices by farmers. However, the study established that there was no significant relationship between *rice output* and the *labor* force involved in rice production.

Table 6 illustrates the input elasticities of rice production in Cambodia between 2012-2015. From this table, all input factors, except *machinery*, have had increasing return to scale to *rice output*, and elasticity of *land* input was the highest among all input factors, followed by *fertilizer* and *labor* input. Between the study period of 2012-2015, harvested land elasticity was 0.976 in average, indicated that 1 hectare increasing in harvested land could cause *rice output* to increase by 0.976 tons, while the other input factors just had minor of elasticity value (less than 0.10). Input elasticities of *machinery*, on the other hands, were unexpectedly negative related to *rice output* during the study period of 2012-2015. As being shown in the previous table (Table 5), *machinery* input had the highest positive coefficient of 1.86 (compared to other inputs) and significant toward *rice output* at confidence level 99%, indicated the expansion of amount used of *machinery* in rice farming could increase *rice output* level. However, a closer look at the relationship between *machinery* and another inputs, such as *land* and *labor*, indicated that *machinery* has had negative (substitution) relationship with *labor* input, which was not surprising for most agricultural researches that unskilled-workers could be replaced by the utilization of *machinery* for gaining more output as well as saving more times. Likewise, *machinery* has also had negative relationship with *land* input and strongly significant at confidence level 99%, which was quite surprised. Conversely, the ratio of investment level on agricultural machineries to total rice cultivated land in most high-potential provinces in the production of rice, such as Battambang, Banteay Meanchey, Kampong Thom, Kampong Cham, Prey Veng, Takeo, Svay Rieng, etc., seemed to be relatively low compared to some other provinces with lower-potential in rice production like Phnom Penh suburb and Pailin for instance. This could be explained the insufficient investment of *machinery* in the territory of high-potential provinces in rice production. Moreover, negative relationship between *land* and *machinery* input (showed in Table 5) also indicated inefficiency performances of existing agricultural machineries for rice farming in high-potential provinces, which leaded input elasticities of *machinery* input to be negative between the study period of 2012-2015. Thus, in addition to enlargement of investment on machineries, for improving rice production in Cambodia (particularly in high-potential provinces) the techniques or solutions for increasing the performance efficiency of existing machineries as well as labor skills also needed to be considered (by related agencies).

**Table 6.** Input elasticities of rice production in Cambodia, 2012-2015

| Year | Ln(land) | Ln(labor) | Ln(fertilizer) | Ln(pesticide) | Ln(machinery) |
|---|---|---|---|---|---|
| 2012 | 0.9898 | 0.0465 | 0.0569 | 0.0317 | -0.1701 |
| 2013 | 0.9816 | 0.0340 | 0.0559 | 0.0339 | -0.1709 |
| 2014 | 0.9694 | 0.0248 | 0.0537 | 0.0386 | -0.1729 |
| 2015 | 0.9632 | 0.0156 | 0.0551 | 0.0356 | -0.1687 |

Source: Calculated by Ms. Excel 2016

### 4.2.2. Technical Efficiency Analysis

The study indicated that individual provincial-level TE ranged from a low of 49.8% to a high of 99.7% with a mean technical efficiency of 79.5% in 2012. Rice production TE in 2015, on the other hand, ranged from a low of 36.8% to a high of 99.9% with a lower mean technical efficiency of 74% (7% decreased). However, the findings revealed that the overall mean of rice production TE is estimated as 0.784 which indicated that Cambodian produce 78.4% of rice at best practice at the current level of production inputs and technology. It means that *rice output* could have been increased further by 21.6% at same levels of inputs if farmers had been full technically efficient. There were only 10 out of 25 provinces have had TE above the TE overall mean, while TE of another 60% of provinces still ranged below the average mean efficiency.

Figure 21 illustrates distribution of Cambodian rice production's TE from 2012 to 2015. Rice production in Cambodia performed very well during 2013, which 40% of provinces had technical efficiency score between 0.91-1.00, and another 28% had technical efficiency score between 0.81-0.90. Thus, in 2013 nearly 70% of provinces produce more than 80% of rice at best practice at the current level of their production inputs and technology. However, natural disasters in 2014 and 2015 caused the decreased in technical efficiency score in most Cambodian provinces.

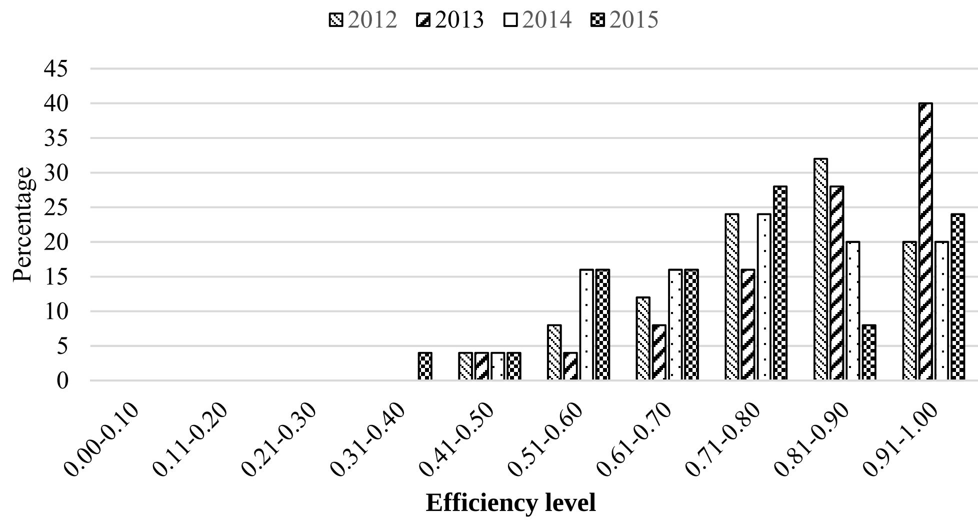


**Figure 21.** Technical efficiency distribution of rice production in Cambodia, 2012-2015

**Table 7.** Regional technical efficiency of rice production in Cambodia, 2012-2015

| Regions | 2012 | | 2013 | | 2014 | | 2015 | | TE Change (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *M* | *S.E.* | *M* | *S.E.* | *M* | *S.E.* | *M* | *S.E.* | 12-13 | 12-14 | 12-15 |
| *Phnom Penh* | 0.83 | 0.00 | 0.84 | 0.00 | 0.81 | 0.00 | 0.61 | 0.00 | 1.2 | -3.4 | -26.5 |
| *Tonle Sap plain* [1] | 0.81 | 0.05 | 0.87 | 0.04 | 0.71 | 0.05 | 0.77 | 0.04 | 6.8 | -12.4 | -5.4 |
| *Mekong plain* [2] | 0.86 | 0.07 | 0.89 | 0.10 | 0.88 | 0.07 | 0.88 | 0.07 | 3.2 | 2.6 | 2.2 |
| *Mekong plateau* [3] | 0.79 | 0.04 | 0.79 | 0.04 | 0.74 | 0.06 | 0.70 | 0.06 | 0.0 | -6.7 | -11.3 |
| *Mountain* [4] | 0.66 | 0.09 | 0.76 | 0.08 | 0.63 | 0.09 | 0.53 | 0.09 | 14.6 | -5.7 | -19.7 |
| *Coastal* [5] | 0.81 | 0.07 | 0.84 | 0.06 | 0.86 | 0.09 | 0.79 | 0.08 | 4.7 | 6.3 | -2.0 |
| Cambodia | 0.80 | 0.03 | 0.84 | 0.03 | 0.76 | 0.03 | 0.74 | 0.03 | 5.4 | -3.9 | -6.9 |

Source: Estimated by FRONTIER 4.1c; "M" = Mean; "S.E." = Standard Error; "12-13" = TE change between 2012 and 2013; "12-14" = TE change between 2012 and 2014; "12-15" = TE change between 2012 and 2015. [1] *Tonle Sap plain region* included the province of Banteay Meanchey, Battambang, Kampong Chhnang, Kampong Thom, Pailin, Pursat, and Siem Reap. Total area: 61,510 km² (accounted for 34.54% of the country's total area). [2] *Mekong plain* included the province of Kampong Speu, Kandal, Prey Veng, Svay Rieng, and Takéo. Total area: 21,997 km² (12.35%). [3] *Mekong plateau* included the province of Kampong Cham, Kratié, Stung Treng, and Tbong Kmom. Total area: 31,663 km² (17.78%). [4] *Mountain region* included the province of Mondulkiri, Ratanakiri, Preah Vihear, and Otdar Meanchey. Total area: 45,016 km² (25.28%). [5] *Coastal region* included the province of Kampot, Koh Kong, Kep, and Preah Sihanouk. Total area: 17,237 km² (9.68%).

Table 7 shows the rice production TE in different regions of Cambodia from 2012 to 2015. The results revealed that in the study period, *Mekong plain* which is the second-largest rice production region of Cambodia had highest TE score in almost all years from 2012 (0.860) to 2015 (0.878) among all regions, and the only one region have had increasing TE score during the study period 2012-2015 (by 2.2%). In 2015, all provinces in this region, except Svay Rieng province, had rice production TE more than 91%. Takeo province was the most effective province in this region with the highest TE score of 0.999, while Svay Rieng province's TE score in 2015 was just 0.599. However, *Tonle Sap plain* which is the largest rice production region of Cambodia in production area had TE score of 0.814 in 2012, but decreased by 5.4% to 0.770 in 2015 as the results of natural disasters at the end of 2014 (flooded) and in 2015 (drought) that affected most provinces in this regions. The province with highest TE score in this region in 2015 was Kampong Chhnang province (0.914), while Banteay Meanchey was the province that had lowest TE score within the region.

### 4.2.3. Technical Inefficiency Model and Affecting Factors

Table 8 presents the parameters of the rice production's technical inefficiency model estimated by FRONTIER version 4.1c. In the model specification, it is obvious that *irrigation* and *production technique* both had negative coefficient signs and significant at 1%, while *agricultural supporting staffs* had also negative coefficient signs but significant at 5%, indicated positively related of these three factors to TE of rice production in Cambodia. These results revealed that development of *irrigation* systems and good water management practices, development of rice *production technique* to the rural farmers, and increasing the number of *agricultural supporting staffs* in the provincial territory are the three core factors to cause rice production TE to increase. With the highest coefficient of 0.95 and 0.08, the factor of *agricultural supporting staffs* and *production technique* played as the first and second core affecting factors respectively. Provinces with more *agricultural supporting staffs* existing and higher rate of families using SRI tended to have higher TE score than provinces with less amount to *supporting staffs* and lower rate of families using SRI, which indicated the important of technical supporting services from agricultural staffs (both government officers and NGOs staffs) and new production techniques implementation in rice production. These coefficient values (0.95 and 0.08 for *agricultural supporting staffs* and *production technique* respectively) indicated that 1% increasing of the percentage of *agricultural supporting staffs* (to total farmers cultivating rice) within the provincial territory and the percentage of families cultivating rice under the SRI system to total rice cultivated families, could cause the increasing of rice production TE by 0.95% and 0.08% respectively.

*Irrigation*, on the other hand, served as the third core affecting factor of Cambodian rice production TE. With the coefficient of 0.01, revealed 1% increasing of the percentage of provincial paddy land having or benefit from irrigation systems (to total provincial cultivated land) within the year could push TE of provincial rice production to increase by 0.01%. In Cambodia, *irrigation* is mainly used for dry-season rice and to complete wet season rice if necessary. It is also an essential component to ensure that farmers can crop during the dry season. ADB (2014) argued rice production's efficiency in Cambodia is always constrained by low-rates of *irrigation*, while Smith and Hornbuckle (2013) suggested that rice yields could be improved by helping to better regulate water inputs. Khmer farmers are mostly able to cultivate rice only once per year because of inadequate irrigation systems and good water management practices.

**Table 8.** Rice production technical inefficiency model parameters estimation

| Variables | Coefficient | Std. Error | t-ratio |
|---|---:|---:|---:|
| *Constant* | 0.9241 *** | 0.1484 | 6.2261 |
| *Disaster* | 0.0003 | 0.0005 | 0.5641 |
| *Irrigation* | -0.0119 *** | 0.0026 | -4.5368 |
| *Production technique* | -0.0841 *** | 0.0283 | -2.9688 |
| *Distant to information sources* | -0.0052 | 0.0060 | -0.8703 |
| *Agricultural supporting staffs* | -0.9530 ** | 0.4032 | -2.3635 |
| *Dry-season production* | -0.0016 | 0.0016 | -1.0549 |
| *Small-land farmers* | -0.0007 | 0.0036 | -0.2056 |

Source: Estimated by FRONTIER 4.1c. * indicates significant at 10%, ** significant at 5%, and *** at 1%.

Rice production in Cambodia still seems to be vulnerable to natural disasters, such as floods and droughts. As being discussed previously, irrigation systems and good water management practices was not only the core factors for improving rice production in Cambodia, but also the main disaster prevention devices for protecting Cambodia from natural disasters. Although percentage of rice land area damaged by floods, drought, and insects was not significantly affect rice production TE during the study period, frequently-occurred natural disasters still indirectly affect the rice production due to lack of irrigation systems. For instance, disasters occurred in wet season of 2014 (flooded) and in 2015 (drought), had been destroyed thousands of hectares of rice fields caused the result of decreasing in total rice actual harvested *land* which was the second core input factor for increasing *rice output* after capital investment in agricultural *machineries*. Although average rice yield and rice price still continued to increase between 2014-2015, frequently-occurred of natural disasters still leaded the production of rice to decrease gradually from 2014 to 2015. Irrigation systems, therefore, should be the core factor to be considered and bring into actions by RGC and the related agencies. Conversely, the study established that there was no significant relationship between the factors of distant from information sources, dry-season production, amount of small-land farmers and rice production TE.

## 4.3. Conclusions of the case study

The results of the current case study indicated that the level of *rice output* in Cambodia (at the national level) varied according to the different level of capital investment in agricultural *machineries*, total rice actual harvested *area*, and technically *fertilizers* application within provinces. The mean TE of rice production is 0.784 which means that famers in this region produce 78.4% efficiently rice at best practice, at the current level of production inputs and technology. This means that *rice output* has the potential of being increased further by 21.6% at the same level of inputs if farmers had been technically efficient. However, during the study periods the TE of rice production recorded a 7% decreasing rate. Takeo province was the most effective province nationwide, while another 60% of provinces still had TE below the average mean efficiency in 2015.

Three main conclusions emerged from the case study's results. First, based on decomposing the SFA model, enlarging capital investment at provincial level into agricultural *machineries* is the core input factor influencing rice production in Cambodia, while the expansion of total rice *land* actual harvested area, and technically improvement of *fertilizers* application ranked as the second and third core input factors respectively. These results are not very surprising since they are straightforward techniques for increasing rice productivity in most developing countries in the world. Likewise, these results also confirmed the existing problems in Cambodian rice production sector which were previously addressed by relevant studies like (CDRI 2012), (ADB 2014), (Yu and Diao 2011), (Smith and Hornbuckle 2013) and (ADB 2012). Financial institutions (microfinances and commercial banks) are the major sources of credit for making machinery purchases of farmers. Conversely, due of Cambodia haven't had any agricultural bank to support credit scheme for buying farm machinery and equipment yet, hence, farmers have to use their own saving or borrow from existing financial institutions or dealers to buy new machines, where often provided relatively higher interest rate for loan (in average 24% per year) compared to its neighboring countries like Vietnam (less than 1% per year). Harvested area, on the other hand, had the highest elasticity among all input factors of rice production in Cambodia. It is clearly indicated that increasing in harvested area (i.e. *land* input) could cause the increasing of rice output in higher percentage than all other inputs. However, although the RGC had been trying to increase rice production by enlarging the total area of rice fields annually, this enlargement still remains far behind its enormous potential to increase rice productivity. Therefore, significant commitments and supported actions are required to address the problem.

Second, *production techniques* for rural farmers, technical skills and amount of *agricultural supporting staffs* are being as the most important influencing factors of rice production in Cambodia. Although SRI have been introduced since the prior of 2008, the percentage of farmers cultivating rice under this system still seemed to be low. Enlarging percentage of farmers cultivating rice under the SRI instead of traditional rice cultivating techniques by wider spread introducing of this system to rural farmers, altogether with the strengthening technical skills of agricultural supporting staffs, and building up stronger relationship between rural farmers and supporting staffs, as well as relationship between the related agencies, might be the great solution for this. Likewise, extra researches and developments in new production techniques of rice cultivation still always needed for improving rice productivity. Finally, agricultural sector as well as rice production in Cambodia always inevitably linked to development of *irrigation* systems and good water management practices. Nonetheless, several constraints in irrigation development still existing. *Irrigation* systems in Cambodia are still in development and not coverage for the whole country due to lack of supporting financial resources and technical experts. Moreover, most farmers' paddy fields are small and lack of road access system for the paddy fields far from the road, and lack of drainage systems for paddy field and sometimes rainfall during harvesting still also remains as constrains. Development of irrigation systems and good water management practices, is therefore a relevant magnitude to be muscularly considered by policy-makers for developing strategical policies geared towards enhancing rice production.

Therefore, the main factors affecting the output level of rice production in Cambodia appear to be capital investment in agricultural *machineries* as well as efficiency of machineries performances, actual harvested *area*, and *fertilizers* utilization while *irrigation* and good water management, *production techniques*, and technical *supporting staffs* serving as main factors affecting TE of rice production in Cambodia.

# CHAPTER 5. “TECHNICAL EFFICIENCY OF CAMBODIAN HOUSEHOLD RICE PRODUCTION”

## 5.1. The Rice Bowl of Cambodia

Rice is the most important food crop in Cambodia and its production is the most organized food production system in the country. Rice farming has an important role as a sector producing staple food for almost all of the population and provides a livelihood for millions of people in rural areas. “*The rice bowl of Cambodia*” is the moniker of a well-known leading rice-producing province of the kingdom, Battambang province, which was founded in the eleventh century by the Khmer Empire[10]. “Battambang” literally means “Loss of staff” in Khmer language, referring to the local legend of *Preahbat Dambang Kranhoung*. The province located in the far northwest bordering by Banteay Meanchey province to the north, Pursat to the east and south, Siem Reap to the northeast, and Pailin to the west. The northern and southern extremes of the province's western boundaries form part of the international border with Thailand. Furthermore, Tonle Sap Lake (or the Great Lake) forms part of the northeastern boundary between Siem Reap and Pursat (see Figure 22). In the eighteenth century, the provincial capital “Battambang city” was established as an important trading city with around 2,500 residents. The city today is the main hub of the northwest connecting the entire region with Phnom Penh and Thailand, and as such it’s a vital link to Cambodia. This province is currently subdivided into 14 districts (96 communes and 818 villages).

With the population of 1.2 million, Battambang was the third populous province in 2015 after the capital city “Phnom Penh” and Kandal province. Average annual population growth rate between 2011 and 2015 was about 2.2%, while the mean value of female-male ratio

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[10] The Khmer Empire was a powerful state in Southeast Asia, formed by Khmer people, lasting from 802 CE to 1431 CE. At its peak, the empire covered much of what today is Cambodia, Thailand, Laos, and southern Vietnam. Using the city of Angkor as capital, the Khmer empire expanded its territorial base mostly to the north (entering the Khorat plateau) and the west, to the Chao Phraya basin and beyond. To the east outcomes were different: several times the Khmer fought wars against two neighboring peoples with powerful kingdoms, the Cham (in today’s central Vietnam) and the Vietnamese (in today’s northern Vietnam). Despite some victories, as in 1145 CE, when Cham’s capital Vijaya was taken, the empire was never able to annex those lands. Conversely, Chams and Vietnamese enjoyed some victories of their own, the most spectacular of which was Cham’s humiliating revenge, looting Angkor (1177 CE) and pushing the empire to the edge of destruction (Plubins 2016).

between this period was 100.53, indicated that Battambang has more female population rather than male. This was not the surprising statistic for most provinces in Cambodia where the population of females exceed males, which was one of numerous results caused by the two-decades civil war of Cambodia within the past 30 years that voluminous Cambodian people have been killed, particularly male populations. In 2015, number of the total household in Battambang was almost 260 thousand (households) and 13.53% was leading by female. Although this percentage have been decreased from 14.35% in 2011, it still seems to be relatively high among provinces of Cambodia. In most cases, female household heads were expected to have lower productivity as well as lower efficiency (rather than male household heads) in the role of family management, particularly rice production families which often required the strength of man-power as an important factor of production. Additionally, mean average of family size in Battambang between 2011 and 2015 was about 4.8 persons per household, illustrated the common figure for families in Cambodia. Likewise, the provincial main labor forces i.e. population age between 18 and 60 years old in average accounted for only 51.6% between this 5-years period, while the young population age below 18 accounted for almost 40%, and the old population age over 60 years old accounted for less than 9%. Table 9 presents the demographical information of Battambang province between 2011 and 2015.


**Figure 22.** Map of Battambang province

**Table 9.** Demography of Battambang province from 2011 to 2015

| Description | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|
| Total population (person) | 1,093,793 | 1,120,907 | 1,155,038 | 1,173,414 | 1,205,050 |
| Annual growth rate (%) | 1.50 | 2.48 | 3.04 | 1.59 | 2.53 |
| Total male population | 540,570 | 555,501 | 569,947 | 584,690 | 602,056 |
| Total female population | 553,223 | 565,406 | 585,091 | 588,724 | 602,994 |
| Female-male ratio | 102.34 | 101.78 | 102.66 | 100.69 | 100.16 |
| Total household | 226,764 | 234,940 | 241,081 | 246,376 | 258,682 |
| Household with female leader (%) | 14.35 | 14.35 | 14.25 | 14.08 | 13.53 |
| Average family size (person/HH) | 4.82 | 4.77 | 4.79 | 4.76 | 4.66 |
| 0-17 years old population | 438,347 | 443,034 | 458,879 | 461,592 | 467,558 |
| % of 0-17 years old population | 40.08 | 39.52 | 39.73 | 39.34 | 38.80 |
| 18-60 years old population | 563,165 | 574,119 | 588,737 | 613,723 | 631,962 |
| % of 18-60 years old population | 51.49 | 51.22 | 50.97 | 52.30 | 52.44 |
| Over 60 years old population | 92,281 | 103,754 | 107,422 | 98,099 | 105,530 |
| % of Over 60 years old population | 8.44 | 9.26 | 9.30 | 8.36 | 8.76 |

Source: Battambang Provincial Profile 2015 and 2016 (BTB-PDP 2015; 2016)

**Table 10.** Percentage of population work in agriculture in Battambang province 2012-2015

| Description | | 2012 | 2013 | 2014 | 2015 | |
|---|---|---|---|---|---|---|
| | | % | % | % | % | Total People |
| Population work in agriculture | | 78.40 | 76.00 | 75.30 | 74.8 | 325,081 |
| included | Rice production | 55.22 | 48.65 | 48.65 | 47.34 | 205,721 |
| | Long-term crops | 3.50 | 5.07 | 5.07 | 4.95 | 21,507 |
| | Short-term crops | 14.05 | 14.79 | 14.79 | 15.70 | 68,208 |
| | Vegetables | 2.06 | 2.96 | 2.96 | 3.06 | 13,296 |
| | Fishery | 2.26 | 2.19 | 2.19 | 1.92 | 8,348 |
| | Animal husbandry | 1.18 | 1.59 | 1.59 | 1.79 | 7,767 |
| | Forest sub-sectors | 0.05 | 0.04 | 0.04 | 0.05 | 234 |

Source: Battambang Provincial Profile 2015 and 2016 (BTB-PDP 2015; BTB-PDP 2016)

**Table 11.** Situation of rice production in Battambang province between 2012 and 2015

| Description | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|
| Total harvested area (ha) | 442,488.00 | 459,378.10 | 424,470.30 | 529,239.6 |
| Total output quantity (tons) | 945,336.60 | 946,297.10 | 756,431.30 | 911,805.6 |
| Rice yield (tons/ha) | 2.10 | 2.10 | 1.80 | 1.7 |
| Income of rice production per capita (USD) | 181.10 | 173.50 | 133.60 | 158.5 |
| Dry season rice available cultivated area (ha) | 31,450.00 | 33,140.00 | 32,785.00 | 33,735.00 |
| % dry season rice area actual cultivated | 73.15 | 75.78 | 77.11 | 81.42 |
| Dry season rice yield (tons/ha) | 2.69 | 2.82 | 2.81 | 2.59 |
| Dry season rice quantity (tons) | 61,970.34 | 70,803.30 | 71,043.82 | 71,162.42 |
| Wet season rice available cultivated area (ha) | 470,258.00 | 465,350.00 | 459,067.00 | 480,658 |
| % wet season rice area actual cultivated | 71.21 | 77.43 | 64.07 | 85.95 |
| Wet season rice yield (tons/ha) | 2.16 | 2.05 | 1.86 | 1.90 |
| Wet season rice quantity (tons) | 724,129.26 | 737,706.16 | 547,332.55 | 783,005.93 |
| Intensive rice harvested area (ha) | 49,900.00 | 65,358.00 | 84,664.00 | 84,933 |
| Intensive rice yield (tons/ha) | 5.57 | 5.22 | 4.85 | 4.93 |
| Intensive rice quantity (tons) | 138,000.80 | 164,047.19 | 199,724.13 | 203,253.29 |
| Up-land rice harvested area (ha) | 34,700.00 | 8,591.00 | 20,415.00 | 3,733.00 |
| Up-land rice yield (tons/ha) | 2.60 | 2.57 | 1.95 | 1.87 |
| Up-land rice quantity (tons) | 90,157.58 | 22,038.39 | 39,848.14 | 6,994.19 |
| Average rice output per capita (kg/person) | 904.85 | 861.09 | 731.16 | 883.30 |
| Average rice price (Riels/kg) | 859.06 | 847.32 | 829.28 | 837.83 |
| Average highest rice price (Riels/kg) | 970.84 | 970.07 | 941.12 | 951.14 |
| Average lowest rice price (Riels/kg) | 747.28 | 724.58 | 717.43 | 724.52 |

Source: Battambang Provincial Profile 2015 and 2016 (BTB-PDP 2015; BTB-PDP 2016)

Percentage of population work in agriculture in Battambang province between 2012 and 2015 has been decreased gradually from 78.4% (of total adult population, age between 18 and 60 years old, having primary occupation) in 2012 to 74.8% in 2015. As being showed in Table 10, rice production and short-term crops cultivation played as two main components of agricultural sectors which provided works for almost 70% of population (work in agriculture) between 2012 and 2015. Furthermore, within the period of 2012-2015 the district of Moung Russei was the district with highest population working in rice production (existing of almost 40 thousand of rice farmers) among all 14 districts of Battambang province, followed by Thmar Koul and Sangkhae district.

Table 11 reveals the status of rice production in Battambang province as whole between 2012 and 2015. Rice production in Cambodia was categorized into four categories according to the season and place of growing, i.e. wet-season rice, dry-season rice, intensive rice, and up-land rice. Total harvested area, which is the total of harvested area of all this four rice categories, increased by 3.8% from 2012 to 2013, but decreased by 7.6% from 2013 to 2014. Nevertheless, although drought have been occurred during the dry season of 2015, total harvested area still improved greatly in 2015 (25% between 2014 and 2015) due to great incensement of the percentage of wet season rice area actual cultivated (34% increased from 64% in 2014 to almost 86% in 2015). Total rice output quantity increased by only 0.1% from 2012 to 2013, but decreased tightly by 20.1% from 2013 to 2014 which reduced the rice yield from 2.1 tons/ha to only 1.8 tons/ha in 2014. In the year of 2015, due to the unfavorable weather condition, rice yield still continued to be lower at 1.7 tons/ha although total provincial rice output quantity increased to almost 912 thousand tons. Table 11 also reveals that in 2015 Battambang had lower rice production yield (compared to 2012) not only in wet-season rice cultivation but also in intensive rice and up-land rice production as well as dry season rice cultivation. Furthermore, between this 4-years period, percentage of wet-season rice area actual cultivated was only 74.7% in average, while percentage of dry-season rice area actual cultivated was 76.9% (in average), indicated that rice farmers in Battambang still not yet fully utilized their available land resources within the provincial territory. This means that actual rice cultivated area could have enlarged by further 23% to 26%. Among all the four rice categories, intensive rice produced the highest yield with the value of 5.14 tons/ha in average between 2012 and 2015. However, the total harvested area of intensive rice in average accounted for only 15% of the total harvested area between this 4-years period, which was a very tiny percentage.

## 5.2. Analysis of Household's Rice Production Technical Efficiency

### 5.2.1. Data and descriptive statistics

This case study is achieved through the estimation and analysis of the stochastic production frontier function (called SFA model), which is originally and independently proposed by Aigner et al. (1977), and Meeusen and Van den Broeck (1977). The case study applied FRONTIER version 4.1c (Coelli 1996) which is the most commonly used package for estimation of SFA model with the logarithmic form of translog production function for the analysis of TE. Coelli (1996) had developed the software FRONTIER 4.1c, which can be used to generate both the stochastic production frontier and the inefficiency model simultaneously. Moreover, the FRONTIER 4.1c was widely applied in different fields of research in the recent years, especially in agricultural studies like Battese and Coelli (1995), Balde et al. (2014), Heriqbaldi et al. (2014), Haryanto et al. (2015), Kabir et al. (2015), Nehal Hasnain (2015), Ueasin et al. (2015), Kea et al. (2016), Shinta et al. (2016) .etc.

Translog production function of SFA model can be written as:

$$Ln\, y_{it} = \beta_0 + \sum_j \beta_j Lnx_{jit} + \beta_t t + \frac{1}{2}\sum_j \sum_k \beta_{jk} Lnx_{jit} Lnx_{kit} + \frac{1}{2}\beta_{it} t^2 + \sum_j \beta_{jt} Lnx_{jit} t + v_{it} - u_{it} \quad (13)$$

To allow the estimation of rice’s TE at household-level, primary data were collected from a random sample of 301 rice production households from 10 communes (equal to 30 villages) in three selected districts of Battambang province by using structured questionnaires. The district of Thmar Koul, Moung Russei, and Sangkhae were purposively selected as the present study’s study areas, based on their total rice production area and total number of farmers with rice farming as primary occupation (rice farmers) in 2014, which ranked from the first to the third among all 14 districts of Battambang province. The field surveys were conducted in February and December of 2015 for gathering 3-years data of households’ rice production (2013, 2014 and 2015). Structured questionnaire designed to capture information related to the characteristics of rice farmers, their inputs allocated to the rice cultivation and its output(s). Furthermore, the collected primary data were supplemented with secondary data collected from various relevant sources.

The SFA model was constructed by one output variable (i.e. production *quantity* of rice) and five input variables included *land*, *labor*, *fertilizer*, *pesticide*, and *other capital*. Output variable measured as the total quantity of un-milled rice produced by individual households within the year or the sum of rice output produced in both wet and dry season by households (hereafter, *household rice output*), unit in kilograms (kg). *Land* input was the total area of rice actually harvested within the year, measured in hectares (ha). In agriculture, *land* always plays as an important input in production of (agricultural) crops, particularly rice. Farmers harvested larger *land* of rice tend to be able to produce higher amount of rice output than the farmers harvested on smaller land. Harvested area (i.e. *land* input), hence, was expected to have positive effect on total *household rice output*. *Labor* input, on the other hand, measured as total annual working days of adult family members (18-65 years old) on the rice field(s) included both male(s) and female(s), unit in days per person per year. In many developing countries, *labor* input tended to have negative relationship with *household rice output* since there were plenty of unskilled and low productivity labors existing, unskilled labors always spend higher (longer) time than more productive labors to produce the same level of output. Farmers in Cambodia, however, still seemed to be the lower productive farmers, since most them were not well educated yet. Thus, in the present study farmers were expected to spend over need of times in rice production. Therefore, *labor* input was expected to have negative effect on *household rice output*. Furthermore, *fertilizer* input measured as total amount of chemical and organic fertilizers' quantity using by households in their rice production annually (unit in kg), while *pesticide* input also measured as total amount of poisons for insects and grass's quantity (for both chemical and organic poisons) using by households, unit in kg. These two input variables were expected to be positively related to *household rice output* as followed by the concept of green revolution (Wikipedia 2016). Additionally, another input variable was determined as the variable of *other capital* investment on rice production, included investments on agricultural machineries, seeds, and other rental expenses within the year, measured as sum of depreciation of agricultural machineries (i.e. tractors, walking tractors or *koryons*, pumping machines, pesticide prayers) owned by households, altogether with total expenses on seeds purchasing and other rental such as wage paid for labors or equipment rentals during various stages of rice production (like plowing, seeding, transplanting, irrigating, harvesting, threshing, as well as transporting). Annual depreciation of a machinery was calculated as the division of its bought price by expected life usage. Expected life usage of tractors, walking tractors (or *koryons*), pumping machines, and pesticide prayers, were assumed to be 15 years, 10 years, 5 years and 5 years respectively in the present study according to the observations from farmers in the study area. The variable of *capital* investment was also expected to have positive effect on *household rice output* also, as farmers with more capital investment were believed to be able to generate higher opportunities for improving their rice production rather than farmers with lower available capital (for investment in family's rice production). Table 12 provides summary statistics of the output and inputs of households' rice production in three districts of Battambang (i.e. Thmar Koul, Moung Russei, and Sangkhae district) from 2013 to 2015.

Output *quantity* of households' rice production in Battambang was higher in 2014 than 2013 which increased 8.5% in average from 16.7 thousand kilograms to 18.1 thousand (kg). Nevertheless, *household rice output* has been decreased by 6.5% between 2013 and 2015 as the results caused by natural disasters occurred in wet season of 2014 (flood) and dry season of 2015 (drought) which reduced *rice output* to 15.6 thousand kg per household (in 2015). Rice area harvested by farmer households (in Battambang) ranged from the smallest of 1 ha to the largest of 82 ha annually. During the study period, in average farmers harvested around 7 ha (included for both wet season and dry season) in 2013, and increased by 1.2% from to 7.1 ha in 2014. However, average households' rice harvested area in 2015 has been slightly reduced to 7.05 ha. Furthermore, average annual working days of adult family members (18-

65 years old) for both male(s) and female(s) on the rice field(s) was 108 days per person in 2013, and increased to 110.5 days in 2014, then reduced to 106.7 days in 2015. Total quantity of chemical and organic fertilizers using by households in rice production (i.e. *fertilizer* input), on the other hand, increased by 2.5% between 2013 and 2015 from average of 772 kg (2013) to 791 kg (2015), while *pesticide* input which measured as total quantity of poisons for insects and grass (both chemical and organic) using by households in rice production also increased by 1.6% between the same period, from 70.8 kg to 72 kg in average. However, during the study period the level of households' *capital* investment showed the impressively deduction by 4%, particularly between 2014 and 2015 (*capital* input decreased by 12.6%), indicated the farmers' response to effects of natural disasters that reduced availability of rice area to be harvested.

**Table 12.** Output and input summary statistics for households' rice production in Battambang, 2013-2015

| **Variables** | **2013** | | **2014** | | **2015** | |
|---|---|---|---|---|---|---|
| | Mean | S.E. | Mean | S.E. | Mean | S.E. |
| Output | | | | | | |
| *Quantity* [1] (kg) | 16,651.16 | 1,244.43 | 18,065.78 | 1,422.06 | 15,569.77 | 1,235.43 |
| Input | | | | | | |
| *Land* [2] (ha) | 6.99 | 0.53 | 7.07 | 0.53 | 7.05 | 0.52 |
| *Labor* [3] (days) | 108.27 | 5.58 | 110.45 | 5.66 | 106.69 | 5.32 |
| *Fertilizer* [4] (kg) | 771.73 | 55.02 | 792.09 | 55.98 | 790.72 | 55.87 |
| *Pesticide* [5] (kg) | 70.84 | 6.64 | 72.03 | 6.75 | 71.95 | 6.70 |
| *Other capital*[6] (USD) | 857.18 | 59.49 | 879.05 | 59.31 | 823.37 | 55.72 |

Source: Calculated by Ms. Office Excel 2016, S.E = Standard Error, [1] Rice *output quantity* measured as the total quantity of un-milled rice produced by individual households within the year or the sum of rice output produced in both wet season and dry season by households, unit in kilograms (kg). [2] *Land* was the total area (both in wet season and dry season) of rice actually harvested within the year, unit in hectares (ha). [3] *Labor* measured as total annual working days of adult family members (18-65 years old) on the rice field(s) included both male(s) and female(s), unit in days per person per year. [4] *Fertilizer* measured as total quantity of chemical and organic fertilizers using by households in rice production annually (in kg). [5] *Pesticide* measured as total quantity of poisons for insects and grass (both chemical and organic) using by households, in kg. [6] *Other capital* investment included investments on agricultural machineries, seeds, and other rental expenses within the year, measured as sum of depreciation of agricultural machineries (i.e. tractors, walking tractors or *koryons*, pumping machines, pesticide prayers) owned by households, altogether with total expenses on seeds purchasing and other rental such as wage paid for labors or equipment rentals during various stages of rice production (like plowing, seeding, transplanting, irrigating, harvesting, threshing, as well as transporting).

Figure 23 illustrates the percentage changes of output and input statistics of rice production of farmer households in three selected districts of Battambang for the periods 2013-2014, 2014-2015, and 2013-2015. The percentage changes within output and input variables from year to year indicated that entire inputs had been increased for 1% to 2.6% between 2013 and 2014 which leaded rice output to increase by 8.5%. However, between 2014 and 2015 all inputs used by households tended to decrease (particularly in labor and capital input which decreased by 6.8% and 12.6% respectively) due to effects of natural disasters in the recent years, caused *household rice output* to decrease greatly by almost 30% compared to the production of 2014.

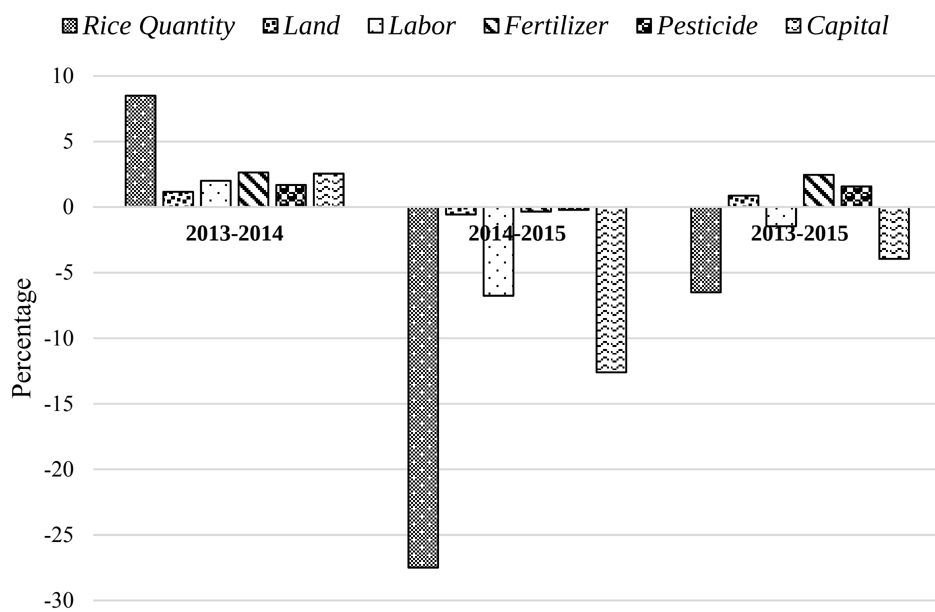


**Figure 23.** Percentage changes in output and input statistics for households’ rice production in Battambang for the periods 2013-2014, 2014-2015, and 2013-2015

The technical inefficiency (TI) model of household’s rice production can be expressed as the following form:

$$u_{it} = \delta_0 + \sum_{k=1}^{n} \delta_k z_{kit} + \omega_{kit} \quad (14)$$

Where, $u_{it}$ is the inefficiency effects that could be estimated by 2 stage estimation technique in FRONTIER 4.1c extemporaneously; $\delta_0$ represents the intercept term; $\delta_k$ is the parameter for $k^{th}$ independent variables to be estimated; $z_{kit}$ is the parameter of influencing factors affecting the TE of household’s rice production in period $t$; and $\omega_{kit}$ represents the stochastic noises. In this TI model, there were twelve influencing factors ($z_{kit}$) of household’s rice production TE to be considered in the current case study. $z_{1it}$ is the age of *household head* (years old). The age of household head might indicate the possibility of a given rice farmers (younger or older) to adopt innovation (such as new ideas and techniques) in rice cultivating. This variable is also a proxy for experience which represents human capital, revealing that farmers with more years of experience in farming will have more technical skills in management and thus higher efficiency than younger farmers (Balde et al. 2014). However, rice production in Cambodia still seems to be labor-intensive, which most works in rice cultivation often depends on man-power rather than machineries. Thus, farmers with older age tended to have lower body strength (man-power) than younger farmers. $z_{2it}$ represents *household head's sex* is the gender dummy variable of household head which value of zero if household head is male and one if female. $z_{3it}$ is the *education level of household head*, i.e. the education dummy variable with value of one if household head is illiterate, two if has primary school education, three if has secondary school education, four if has high school education, five if has bachelor education, six if has graduated education (Master or Ph.D.), seven for other type of education, such as vocational training or informal education system. Both education and age (which proxy for farming experience) are important variables that help to improve the managerial ability of the farmer (Abedullah and Mushtaq 2007). $z_{4it}$ represents *family size*, is the variable of the total number of family members in the household (persons). $z_{5it}$ denotes *female labor*, is the total number of female family member in the household age between 18-65 years old (persons). $z_{6it}$ is the *other crops' cultivated area*, i.e. the total production area of other crops beside rice such as corn, sugarcane, cassava, cucumber, pepper, wax melon, bitter melon, bean, eggplant, and other vegetables, measured in square meters ($m^2$). $z_{7it}$ is the*irrigated areas* measured as the percentage of rice production land located near water sources or benefited from irrigation systems to total annual cultivated land of rice. $z_{8it}$ symbolizes the *distance to water sources*, is the distance of rice production land from water source dummy variable with value of zero if production land is near (0-1 km), one if 1-2 km, two if 2-3 km, three if 3-4 km, four if 4-5 km, five if the production land is far ($\geqslant$5 km). $z_{9it}$ represents the*distance to district* is the variable of distance from the village to the district center, in kilometers (km). $z_{10it}$ is the*number of plot area*, i.e. the total number of plot lands owned and cultivated rice crops by farmers. $z_{11it}$ denotes the*number of cultivation per year* is the number of annual cultivation times that farmers can cultivate their rice crops (times). *Disaster* is symbolized by $z_{12it}$, is the dummy variable with the value zero if the farmers' rice fields did not affect by floods, droughts, or insects during the study period, and one if farmers' rice fields affected by floods, droughts, or insects.

**Table 13.** Descriptive statistics of technical inefficiency model's parameters, 2012-2015

| Variables | 2013 | | 2014 | | 2015 | |
|---|---|---|---|---|---|---|
| | Mean | S.E. | Mean | S.E. | Mean | S.E. |
| *Household head's Age* [1] | 47.39 | 0.69 | 48.39 | 0.69 | 49.39 | 0.69 |
| *Household head's Sex* [2] | 0.17 | 0.02 | 0.17 | 0.02 | 0.17 | 0.02 |
| *Household head's Education* [3] | 2.33 | 0.05 | 2.33 | 0.05 | 2.33 | 0.05 |
| *Family size* [4] | 5.16 | 0.11 | 5.17 | 0.11 | 5.17 | 0.11 |
| *Female labor (18-65yr)* [5] | 1.63 | 0.05 | 1.63 | 0.05 | 1.63 | 0.05 |
| *Other crops' cultivated area* [6] | 485.02 | 241.36 | 247.14 | 106.52 | 247.14 | 106.52 |
| *Irrigated areas* [7] | 16.82 | 1.22 | 17.35 | 1.23 | 17.30 | 1.24 |
| *Distance to water sources* [8] | 2.91 | 0.14 | 2.91 | 0.14 | 2.91 | 0.14 |
| *Distance to district* [9] | 15.89 | 0.43 | 15.89 | 0.43 | 15.89 | 0.43 |
| *Num. of plot area* [10] | 1.48 | 0.04 | 1.52 | 0.04 | 1.52 | 0.04 |
| *Num. of cultivation per year* [11] | 1.44 | 0.03 | 1.44 | 0.03 | 1.44 | 0.03 |
| *Disaster* [12] | 0.06 | 0.01 | 0.07 | 0.01 | 0.74 | 0.03 |

Source: Estimated by Ms. Office Excel 2016. "S.E": Standard Error.[1]*Household head's Age*: is the age of household head in years old. [2]*Household head's Sex*: is the gender dummy variable of household head which value of zero if household head is male and one if female. [3]*Household head's Education*: is the education dummy variable with value of one if household head is illiterate, two if has primary school education, three if has secondary school education, four if has high school education, five if has bachelor education, six if has graduated education (Master or Ph.D.), seven for other type of education, such as vocational training or informal education system; [4]*Family size*: is the variable of the total number of family members in the household; [5]*Female labor*: is the total number of female family member in the household age between 18-65years old.[6]*Other crops' cultivated area*: is the total production area of other crops beside rice i.e. corn, sugarcane, cassava, cucumber, pepper, wax melon, bitter melon, bean, eggplant, and other vegetables, measured in square meters ($m^2$).[7]*Irrigated areas*: is the percentage of rice production land located near water sources or benefited from irrigation systems to total annual cultivated land of rice. [8]*Distance to water sources*: is the distance of rice production land from water source dummy variable with value of zero if production land is near (0-1km), one if 1-2km, two if 2-3km, three if 3-4km, four if 4-5km, five if the production land is far (⩾5km).[9]*Distance to district*: is the distance from the village to the district center, in kilometers (km). [10]*Number of plot area*: is the total number of plot lands owned and cultivated rice crops by farmers. [11] *Number of cultivation per year*: is the number of annual cultivation times that farmers can cultivate their rice crops.[12]*Disaster*: is the dummy variable with the value zero if the farmers' rice fields did not affect by floods, droughts, or insects during the study period, and one if farmers' rice fields affected by floods, droughts, or insects.

Descriptive statistics of rice production technical inefficiency model’s parameters between 2012 and 2015 are given in Table 13. Most of variables remain insignificant changed between this three-years period. The overall statistics reveal that the average *age of household’s head* was 49.4 years old in 2015 ranged from 21 to 83 years old, in which 17% were female household head. Moreover, the average education level was 2.33, indicating that most of rice farmers’ household head just only giant education at secondary school (i.e. grade 7-9) in Cambodian education system. The results also reveal that average family size of rice farmers in Battambang province is about 5.17 persons per household (ranged from 2 to 12 persons per household), presenting the general figure of rice farmers in the rural Cambodia nationwide. Additionally, female labor (age between 18 and 65 years old) existing in Battambang’s rice households during the study period in average was about 1.63 persons per household.

The total cultivated area under other crops beside rice such as corn, sugarcane, cassava, cucumber, pepper, wax melon, bitter melon, bean, eggplant, and other vegetables, was about 485 square meters ($m^2$) in average in 2013. However, this amount had been decreased (by almost 50%) to 247 $m^2$ in 2014 and 2015. Furthermore, *irrigated areas*, which is the percentage of rice production land located near water sources or benefited from irrigation systems to total annual cultivated land of rice, was about 16.8% in 2013 average, and had been increased to 17.35% in 2014. Water shortage in 2015, nonetheless, had been leading this percentage to decrease a little bit to 17.3% (in average). These percentages disclose the lack of irrigation facilities and water management policies, since almost 85% of farmers’ rice cultivated areas still not benefit from irrigation systems and remain as rain-fed agricultural lands that are very vulnerable to the global climate change. In average, rice production lands of rural farmers in Battambang located around 2.91 km from the water sources (or the nearest irrigation systems). This distance is quite far and often causes inability for farmers to use water from existing water sources and irrigation systems. Likewise, the results also show that only 39% of farmers’ rice fields that located less than 1 km from water sources (or the nearest irrigation systems), thus, other more than 60% of rice fields still located far from the water sources. *Distance to district*, on the other hand, measured as the distance from the village to the district center in kilometers, is the proxy variable of farmers’ accessibility to information sources (related to rice production such as price information, as well as adoption of new production techniques). Within the study areas, most villages located in average of 15.9 km from the center of district, (range from 1 km to 28 km).

Rice farmers in Battambang in average cultivated on 1.48 plot lands (in 2013), and increased to 1.52 in 2014 and 2015. The statistics reveal that around 63% of farmers cultivated on only one plot land of rice (during the study period). Furthermore, there are only 44% of farmers who able to cultivate rice crops more than once per year. More importantly, between 2013 and 2014, only 6-7% of rice farmers reported the affecting by natural disasters (i.e. droughts, floods, and insects) on their rice fields. Nevertheless, in 2015, almost 75% of famers' rice fields had been reported affecting by natural disasters, particularly the drought during 2015's dry season.

### 5.2.2. SFA Model Estimation

In the stochastic production frontier model (i.e. SFA model), a test whether there is technical inefficiency exist or not can be conducted by testing the null hypothesis $H_0$: $\gamma = 0$, versus alternate hypothesis $H_1$: $\gamma \neq 0$. Coelli (1995a) argued that maximum likelihood (ML) shall be estimated by the calculation of the critical value for one-sided likelihood ratio (LR) test. The critical value for a test of size $\alpha$ is equal to the critical value of the $x^2$ distribution for a standard test of size $2\alpha$. Thus, one-sided likelihood ratio test has suitable range, where $H_0$ is rejected when $LR \geq x^2(2\alpha)$ for a test of size $\alpha$. At α=1% significant level, $x^2(2\alpha)$ has value of 100.62. In our frontier model, however, LR test of the one-sided error has value of 171.80, which is bigger than $x^2(2\alpha)$. Therefore, the null hypothesis, $H_0$: $\gamma = 0$, was rejected, indicates that technical efficiency effect exists in our model.

Table 14 lists parameters estimation results by implementing the maximum likelihood estimation method in FRONTIER version 4.1c econometrics software of Coelli (1996). The variance ratio parameter, gamma (γ), had a value of 1.00 significant at $\alpha = 1\%$, shows that the variation of the composite error term, was mainly from the technical efficiency ($u_i$) almost 100%, and the variation of random error ($v_i$) less than 1%, indicated that the efficiency of households' rice production in study area between 2013 and 2015 mainly comes from the technical efficiency of the production.

Almost all estimated coefficients have the expected signs. As being showed in Table 14, *land* input i.e. total household's annual harvested land had positive coefficient and significant at $\alpha = 1\%$, while *fertilizer* and *pesticide* input both had positive coefficients but significant at $\alpha = 5\%$, indicates positive contribution of these three input variables to *household rice output*. These results designated that enlarging the area of harvested *land*, increasing quantity used of *fertilizer*, and *pesticide* input, could cause the increasing of *household rice output*. Furthermore, with the estimated coefficient of 0.83, total area (both in wet season and dry season) of rice actually harvested within the year was the main input factor driving extra output for household's rice production in Battambang province compared to *fertilizer* and *pesticide*(input). This means farmers who cultivate additional lands have the ability to maintain reasonable levels of the necessary inputs; otherwise, additional area does not increase rice production output if the levels of inputs are not maintained. Yu and Diao (2011), Smith and Hornbuckle (2013) and some researches of Asian Development Bank (ADB 2012; ADB 2014) also have similar results. Area of cultivated *land* can be increased by expanding *irrigation* that permits multiple season cropping. Despite the importance of rice farming in the Cambodian landscape, it has traditionally been dependent on rainfall. Rice is predominately grown in the wet season which produces 80% of the total crop, and *irrigation* is mainly used for dry season rice and to complete wet season rice if necessary. Furthermore, it is also an essential component to ensure that farmers can crop during the dry season, and helps to better regulate water inputs which is essential for improved yields (Eng 2004; Smith and Hornbuckle 2013). Production efficiency, nevertheless, is constrained by low rates of irrigation (ADB 2014). Most Cambodian farmers are able to cultivate rice only once in a year because of inadequate irrigation system and good water management practices. Lack of water during dry season rice farming is significantly constraint and has occasionally caused conflict among farmers (CDRI 2012). Yu and Diao (2011) argued that Cambodia has a huge potential to increase rice production since it is known for its abundant agricultural land and water resources. Such natural resource potential has been underutilized: less than 30% of potential arable land is under cultivation, and a much smaller portion of area suitable for irrigation is actually irrigated. Thus, expansion of farmland area and *irrigation* development can be a straightforward way to increase rice production [which is quite similar to the situation in other developing countries like India (Battese and Coelli 1992)].

In addition to farmland area expansion and irrigation development, rice yield can also substantially be increased through crop intensification techniques including both increased use of *fertilizer* and better farming practices such as those identified under the System of Rice Intensification (SRI)[11]. Increase use of *fertilizers* and *pesticides* are the main characteristics of the Green Revolution in rice agriculture, which spread throughout the Southeast and East Asia during the past 30 years, could increase productivity of rice (ADB 2012; ADB 2014; Eng 2004; Smith and Hornbuckle 2013). This is undoubtedly supported by the sturdy significant of *fertilizer* and *pesticide* input variables in the SFA model of the current case study.

[11] System of Rice Intensification (SRI) was introduced by Ministry of Agriculture, Forestry and Fisheries (MAFF) of Cambodia with the support of CEDAC (Cambodian Center for Study and Development in Agriculture: Centre d’ Etude et de Dévelopment Agricole Cambodgien). Under SRI, various rice cultivation techniques with less utilization of modern inputs and inexpensive method of planting in relatively dry area could result in an average yield of 3.6 ton/ha, while under a similar situation the yield with traditional farming practice is only 2.4 ton/ha (CEDAC 2008).

**Table 14.** Parameters estimated for the SFA model

| Variables | Coefficient | Standard Error | t-ratio |
|---|---|---|---|
| *Constant* | 8.2818 *** | 1.0064 | 8.2288 |
| *ln(land)* | 0.8276 *** | 0.2232 | 3.7085 |
| *ln(labor)* | -0.0485 | 0.2297 | -0.2112 |
| *ln(fertilizer)* | 0.0945 ** | 0.0402 | 2.3490 |
| *ln(pesticide)* | 0.0694 ** | 0.0339 | 2.0494 |
| *ln(capital)* | 0.0323 | 0.1892 | 0.1708 |
| *t* | 0.1083 | 0.0971 | 1.1152 |
| *Land* × *Labor* | 0.0341 | 0.0433 | 0.7876 |
| *Land* × *Fertilizer* | -0.0248 | 0.0210 | -1.1796 |
| *Land* × *Pesticide* | 0.0089 | 0.0189 | 0.4701 |
| *Land* × *Capital* | -0.0054 | 0.0269 | -0.1992 |
| *Labor* × *Capital* | -0.0034 | 0.0425 | -0.0801 |
| $t^2$ | -0.0163 | 0.0248 | -0.6570 |
| $\gamma$ | 1.0000 *** | 0.0994 | 10.0565 |
| $\sigma^2$ | 0.0993 *** | 0.0047 | 20.9696 |
| log likelihood function | | | -235.2186 |
| LR test of the one-sided error | | | 171.8042 |

Source: Estimated by FRONTIER 4.1c. * indicates significant at 10%, ** at 5%, and *** at 1%.

Most developing countries have an unused *labor* surplus i.e. simple, low-cost, labor-extensive, and low-yielding agricultural production (Eng 2004). In general case, workers drop out of agriculture only if they are assured that they can purchase food at attractive prices. If food is not imported in greater amounts, workers remaining in agriculture will have to maintain or increase agricultural production, to produce the food surplus for the non-agricultural workers in exchange for non-agricultural goods and services. *Labor* input tends to have a positive effect on output yield for small farmers; which is in the contrast view to large-scale (commercial) farmers in the picture of improvement of mechanization. Nonetheless, *labor* input of the SFA model in the present case study has negative coefficient but not significant at any $\alpha$ level, reveals that there was no any significant relationship between *labor* input and *household rice output* in the three districts of Battambang province during the study period. Furthermore, the present case study also established no significant relationship between *household rice output* and level of household’s *capital* investment in household’s rice production.

**Table 15.** Input elasticities of household's rice production in Battambang province, Cambodia from 2013 to 2015

| Year | Ln (Land) | Ln (Labor) | Ln (Fertilizer) | Ln (Pesticide) | Ln(Capital) |
|---|---|---|---|---|---|
| 2013 | 0.8259 | -0.0175 | 0.0562 | 0.0831 | 0.0087 |
| 2014 | 0.8256 | -0.0171 | 0.0559 | 0.0833 | 0.0085 |
| 2015 | 0.8253 | -0.0169 | 0.0559 | 0.0833 | 0.0086 |

Source: Calculated by Ms. Excel 2016.

Table 15 illustrates the input elasticities of household's rice production in Battambang province of Cambodia between 2013 and 2015. From this table, it is clearly demonstrated that all inputs, except *labor*, have had the increasing return to scale to *household rice output*. *Land* input had the highest elasticities value among entire input factors, following by *pesticide* and *fertilizer* input. Elasticities of actual harvested area of household rice production had the value of 0.83 in average during the study period, indicating that 1% increase of harvested land (of rice) could cause *household rice output* to increase by 83%. Similarly, with the elasticities value of 0.083 and 0.056 (in average) respectively of pesticide and fertilizer inputs, revealing that 1% increase in these two inputs could cause the increasing of *household rice output* by 8.3% and 5.6% respectively. The elasticities of *capital* input, on the other hand, had the value of 0.0086 in average, showing that 1% increasing in capital investment to agricultural machineries (such as walking tractors or *koryons*, tractors, pumping machine, etc.) as well as other rentals for rice production could also cause the increasing of *household rice output* (by 0.86%).

The negative input elasticities of *labor* are not only explained the overused of labors for household's rice production but also showing the inefficiency performance of existing labors in the rice fields. Although *labor* input were not significantly affecting the *household rice output* in the current study, its negative coefficient in the SFA model (presented previously in Table 14) also clearly revealed the over and inefficient used of *labor* forces. Therefore, additional special policies or regulations might be needed for snowballing efficiency of rice production's existing labor forces, in the purpose of improving Cambodian rice production for sustainability social development as large.

### 5.2.3. Technical Efficiency of Household's Rice Production

The technical efficiency (TE) and technical efficiency change (TEC) between 2013-2014 and 2013-2015 of household's rice production is being showed in Table 16, categorized by districts and communes. The findings revealed that the overall mean technical efficiency of rice production is estimated as 0.34 (ranged from 0.097 to 0.913) which indicated that households in the study areas produce 34% of rice at best practice at the current level of production inputs and technology. In other words, *household rice output* could have been increased further by 66% at same levels of inputs if farmers had been technically efficient. As being showed in Table 16, all rice production households in Battambang produce 35.2% of rice at best practice in 2013. In 2015, however, due to affecting of the natural disasters (particularly drought during the dry season of 2015 that affected rice production of Cambodia nationwide) and other influencing factors (will be discussed in further details in the next section), the TE of household's rice production in selected districts of Battambang had been decreased gradually from 0.352 (in 2013) to 0.302 in 2015 (decreased by 14.3% between this three-years), indicating that in 2015 rice farmers produced only 30.2% of rice at best practice at their existing inputs level and technology. Thus, there is still a huge gap for improving rice productivity in the high potential province of rice production like Battambang, since *household rice output* of rice farmers in this province still have been able to increased further by almost 70% at the current levels of inputs (in case the farmers had been technically efficient).

Sangkhae district had the highest TE score among three selected districts in all years of the study period (2013, 2014 and 2015). In 2013, rice farmers in Sangkhae district produced 38.2% of rice at best practice (at the current level of production inputs and technology), while farmers in Thmar Koul and Moung Russei district produced only 35.5% and 32.7% of rice (at best practice) respectively. In 2015, rice farmers in Sangkhae district continued to be able to utilize their resources in rice production more efficiently than farmers in the other two districts, by produced almost 40% of rice at best practice, while the rice production of farmers in Thmar Koul and Moung Russei district became worse, in which respectively produced only 29.7% and 24% of rice.

Between 2013 and 2014, TE score of farmers' rice production in Moung Russei district increased by 2.98% from 0.327 to 0.336, claimed as the highest increasing percentage among three districts (between this two-years). Nonetheless, in 2015, the TE of household's rice production in this district declined sharply to 0.24 (diminished by 27% between 2013-2015, and also the highest declining percentage among three districts). However, during the study period, farmers' rice production in Thmar Koul district had the decreasing trend of TE score from 0.355 in 2013 to 0.342 in 2014, then continued to decrease to 0.297 in 2015 (decreased by 16.3% between 2013-2015). In contrast with the situation in Thmar Koul district, household's rice production of farmers in Sangkhae district had the increasing trend of TE score from 0.383 in 2013 to 0.387 in 2014, and still continued to increase to 0.389 in 2015 (1.65% increased between 2013 and 2015).

At the commune-level, the statistical results reveal that the production of rice of farmers' household in Reang Kesei commune had the highest TE score among all communes in Sangkhae district during the study period by producing around 50% of rice at the best practice of its current inputs level and technology. Farmers' rice production in Thmar Koul district, on the other hand, the commune that have had the highest TE score in all years between 2013 and 2015 was Boeng Pring commune, which produced around 26-36% at the best practice. Likewise, the production of rice in Prey Svay commune of Moung Russei district was also the commune production with the highest TE score in the district, by producing 26-35% at best practice (at the existing level of inputs and technology).

**Table 16.** Technical efficiency (TE) and technical efficiency change (TEC) of household's rice production in Battambang province of Cambodia, from 2013 to 2015

| District | 2013 | | 2014 | | 2015 | | TEC (%) | |
|---|---|---|---|---|---|---|---|---|
| | Mean | S.E. | Mean | S.E. | Mean | S.E. | 2013-14 | 2013-15 |
| **Moung Russei** | **0.3267** | **0.01** | **0.3364** | **0.01** | **0.2396** | **0.01** | **2.98** | **-26.66** |
| Moung | 0.3056 | 0.02 | 0.3086 | 0.02 | 0.2054 | 0.01 | 0.98 | -32.79 |
| Prey Svay | 0.3503 | 0.01 | 0.3614 | 0.01 | 0.2673 | 0.01 | 3.17 | -23.70 |
| Ruessei Krang | 0.3287 | 0.02 | 0.3238 | 0.02 | 0.2502 | 0.02 | -1.49 | -23.89 |
| Kakaoh | 0.3220 | 0.01 | 0.3517 | 0.01 | 0.2354 | 0.01 | 9.21 | -26.89 |
| **ThmarKoul** | **0.3550** | **0.01** | **0.3415** | **0.01** | **0.2971** | **0.01** | **-3.80** | **-16.31** |
| Anlong Run | 0.3273 | 0.02 | 0.3296 | 0.02 | 0.2808 | 0.02 | 0.72 | -14.20 |
| Ta Meun | 0.3528 | 0.02 | 0.3291 | 0.02 | 0.2857 | 0.02 | -6.70 | -19.01 |
| Boeng Pring | 0.3840 | 0.02 | 0.3651 | 0.02 | 0.3239 | 0.02 | -4.94 | -15.66 |
| **Sangkhae** | **0.3827** | **0.02** | **0.3865** | **0.02** | **0.3890** | **0.02** | **1.00** | **1.65** |
| Ta Pon | 0.3370 | 0.03 | 0.3407 | 0.02 | 0.3338 | 0.02 | 1.10 | -0.94 |
| Kampong Preah | 0.3067 | 0.02 | 0.3205 | 0.02 | 0.3359 | 0.02 | 4.51 | 9.53 |
| Reang Kesei | 0.5044 | 0.03 | 0.4983 | 0.03 | 0.4973 | 0.03 | -1.21 | -1.41 |
| **All households** | **0.3520** | **0.01** | **0.3529** | **0.01** | **0.3016** | **0.01** | **0.27** | **-14.30** |

Source: Estimated by FRONTIER 4.1. "S.E." = Standard Error; "TEC" = Technical Efficiency Change

Figure 24 illustrates the distribution of technical efficiency of Cambodian household's rice production in Battambang province from 2013 to 2015. The study indicates that individual household's TE ranged from a low of 12.6%to a high of 82.5% with a mean technical efficiency of 35.2% in 2013, while in 2014, household's TE ranged from a low of 14.6%to a high of 86.7% with a mean technical efficiency of 35.3% (increased by 0.27%). TE of household's rice production in 2015, on the other hand, ranged from a low of 9.7%to a high of 91.3% with a mean technical efficiency of 30.2% (decreased by 14.3% in average between 2013 and 2015). Thus, rice production of farmers in Battambang performed better during 2013 and 2014 than in 2015, for which around 33-37% of households had TE score between 0.31-0.40 compared to 2015 that had only 25% (due to affecting of drought). However, in 2015, most households had the TE score between 0.21-030 (accounted for almost 38%). These percentages indicated a huge gap (between 62-75%) of rice farmers in Battambang to increase their production using the current levels of inputs and technologies.

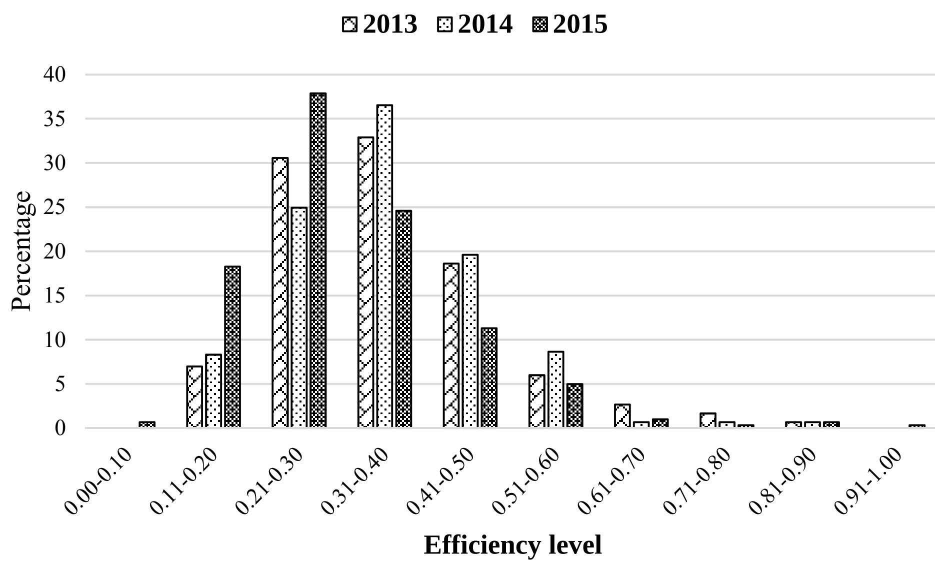


**Figure 24.** Technical efficiency distribution of household's rice production in Battambang province of Cambodia, 2013-2015

### 5.2.4. Technical Inefficiency Model and Affecting Factors

The maximum likelihood (ML) estimates coefficients of the explanatory variables in the model for the technical inefficiency (TI)of household's rice production in Battambang province, and these TI estimated coefficients are of interest and have implication as shown in Table 17 A negative sign on a parameter explaining the positive effect of the variable on TE(negative impact on the technical inefficiency TI), means that the variable is improving TE, while for a positive sign, the reverse is true. The results indicated that the *sex of household's head*, the *education level of household's head*, *family size*, the *cultivated area of other crops* (beside rice), *percentage of rice cultivated area benefited from irrigation systems*, *number of plot area*, and *disasters* (droughts, floods, insects) are significant determinants of the technical efficiency in the Cambodian rice production.

As being showed in Table 17, it is noticeable that the variable of *disaster* and *other crops' cultivated area* both had positive coefficient signs and were significant at 1%, while *education of household head* and *family size* also had positive coefficient signs but significant at 10%, indicating negative relationships of these factors to TE of household's rice production (positive impact on the TI), means that these factors are decreasing TE. With the highest coefficient of 0.27, *disaster* was the core influencing factor leads to decreasing TE of household's rice production, while the *education of household head* and *family size* are the second and the third factors with the estimated coefficient value of 0.03 and 0.01 respectively. These results indicate that 1% increasing in *disaster*, *education of household head* and *family size* will cause the decreasing of TE by 27%, 3% and 1% respectively. The impact of *education level of household's head* is negatively significant on the efficiency (TE) of household's rice production, implying that less educated rice farmers are more efficient than better educated farmers. It means being an educated rice farmer was not enough to significantly attain greater levels of efficiency. This result, thus, is consistent with the finding of Balde et al. (2014), who found that education level was significant and negatively affecting the TE of Mangrove rice production in the Guinean coastal area.Kabir et al. (2015), who estimate the impact of bio-slurry to Boro rice production in Bangladesh, also found the same negative sign of coefficient of education relation to production inefficiency of rice. Besides, the variable of *family size* also has a negative and significant impact (on TE). This result implies that farmers with fewer family members seem to perform better than those with more members. Additionally, the negatively significant of *other crops' cultivated area* variable, indicating that reducing rice's cultivated area for growing other crops beside rice like corn, sugarcane, cassava, cucumber, pepper, wax melon, bitter melon, bean, eggplant, and other vegetables, etc. might cause the TE of household's rice production to decrease. However, the value of this variable's coefficient is quite tiny, reflecting the very little effect of *other crops' cultivated area* on TE.

The variable of *irrigated area* had negative coefficient sign and significant at 1%, while *number of plot area* and the *sex of household head* also had negative coefficient signs but significant at 5%, indicating the positive impact of these factors on TE of household's rice production (negative impact on the TI), means that these factors are increasing TE. With the similar estimated coefficient value of 0.07, *number of plot area* and the *sex of household head* are the two core factors increasing TE of rice production at household-level, signposted that 1% increase in these factors could cause the TE to increase by 7%. The key messages from this finding are that farmers who cultivated on additional plot lands might have extra opportunities to obtain further benefits from their rice production. This could be explained in some ways.

For example, farmers who cultivated 2 or more plot lands, sometimes one of his plot lands affected by natural disasters (droughts, floods, or insects) while the other (of his plot lands) not. Thus, he still could be able to gain output of rice production from the plot(s) that did not affected by disasters. Likewise, the similar reason might be able to applied to the plot land that benefiting from irrigation systems as well. For the farmers cultivated more than one plot land, sometimes one of his plot lands does not benefit or located near irrigation systems or water sources such as rivers, lakes, or ponds (that cannot be cultivated during dry season) while his other plot land located near water sources (or benefiting from irrigation systems) which allow him to expand his production by expanding the annual cultivated area through dry season cultivation on plot land that benefiting from irrigation systems. These could be the benefits of cultivating on more plot lands compared to farmers who cultivated on only one plot land. The positively significant of *sex of household head* on TE of household's rice production, on the other hand, is not only explain the imperative roles of female in rice production as well as family management, but also reveals the limited abilities of existing male household's head and inefficiency used of male labors in their household's rice production. Thus, some further extraordinary strategies or procedures might need to be put in place to enhance the efficiency of labor utilization or allocation.

**Table 17.** Rice production technical inefficiency model parameters

| Variables | Coefficient | Standard Error | t-ratio |
|---|---|---|---|
| *Constant* | 1.3048 *** | 0.2213 | 5.8954 |
| *Household head's Age (years old)* | 0.0007 | 0.0010 | 0.6266 |
| *Household head's Sex (0:male/1:female)* | -0.0657 ** | 0.0327 | -2.0097 |
| *Household head's Education* | 0.0295 * | 0.0159 | 1.8614 |
| *Family size (total family members)* | 0.0123 * | 0.0070 | 1.7672 |
| *Female labor (total females 18-65yr)* | 0.0161 | 0.0139 | 1.1639 |
| *Other crops' cultivated area* | 0.0000 *** | 0.0000 | 3.4658 |
| *Irrigated area* | -0.0087 *** | 0.0017 | -5.2380 |
| *Distance to water sources* | -0.0264 | 0.0210 | -1.2547 |
| *Distance to district* | 0.0004 | 0.0017 | 0.2602 |
| *Number of plot area* | -0.0678 ** | 0.0273 | -2.4867 |
| *Number of cultivation per year* | -0.0581 | 0.1091 | -0.5322 |
| *Disaster* | 0.2664 *** | 0.0344 | 7.7360 |

Source: Estimated by FRONTIER 4.1. * indicates significant at 10%, ** at 5%, and *** at 1%.

Strongly significant of *irrigated area* variable, which is the percentage of rice production land located near water sources or benefited from irrigation systems (i.e. irrigated rice land) to total annual cultivated land of rice, showing that the greater percentage of irrigated rice land could lead to increasing in TE of household's rice production. This result highlights the important of irrigation systems in Cambodian rice production, particularly in the high potential province for rice production like Battambang. Therefore, focusing on irrigation development and improvement as well as good water management systems are the key factors to increase rice productivity in the northwest region of Cambodia (especially in Battambang province) that might need to be concerned and developed gradually.

## 5.3. Conclusions of the case study

The aim of this case study are to measure the technical efficiency (TE) of Cambodian rice farmers in the northwest region (i.e. the region of Tonle Sap river plain, the second largest rice production region after Mekong river plain), and to determine its main influencing factors by using the stochastic frontier production function. The study utilized primary data collected from 301 rice farmers in three selected districts of Battambang province (Northwest Cambodia) by structured questionnaires. The empirical results indicated that the level of rice production output varied according to the differences in production techniques and differences in the efficiency of the production processes. The mean technical efficiency of rice production in Battambang province is 0.34 (ranged from 0.097 to 0.913) which means that famers in this region produce 34% efficiently rice at best practice at the current level of production inputs and technology, indicates that rice output has the potential of being increased further by 66% at the same level of inputs if farmers had been technically efficient. Furthermore, during the study periods the technical efficiency of household's rice production recorded a -14.3% decline rate which diminished from 35.2% in 2013 to 30.2% in 2015 due to highly affected of drought during the dry season of 2015.

Three main conclusions emerged from the study's results. First, based on decomposing the SFA model, increasing harvested land area (particularly in dry season through the development of irrigation facilities, irrigation systems and good water management practices, for gaining benefit from multi-cropping systems) is the major influencing factor of household's rice production of farmers in Battambang province which is the rice bowl of Cambodia, while the increased *fertilizers* and *pesticides* application are the second and third influencing factors respectively. These results are not identical surprising, since these are the straightforward techniques for increasing rice productivity in most developing countries. Similarly, this also confirmed the existing problems in Cambodian rice production sector which were previously addressed by relevant studies, such as ADB (2012), ADB (2014), CDRI (2012), Smith and Hornbuckle (2013), and Yu and Diao (2011). Second, the calculation of input elasticities reveals that all inputs, except *labor*, have had the increasing return to scale to *household rice output*, while *land* input had the highest elasticities value among entire input factors, following by *pesticide* and *fertilizer* input. The negative input elasticities of *labor* are not only explained the overused of labors for household's rice production but also showing the inefficiency performance of existing labors in the rice fields. Finally, the decomposing of the technical inefficiency (TI) model reveals that the core influencing factors lead to decreasing TE of household's rice production (in Battambang) are *disaster* (i.e. droughts, floods, and insects), *education level of household's head*, number of people in the family (i.e. *family size*) and *cultivated area of other crops* such as corn, sugarcane, cassava, cucumber, pepper, wax melon, bitter melon, bean, eggplant, and other vegetables. Conversely, the main influencing factors that lead to increasing TE are *irrigated area*[12], *number of plot area* and the *sex of household's head*.

[12] *Irrigated area*, measured as the percentage of rice production land located near water sources or benefited from irrigation systems to total annual cultivated land of rice.

# CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

## 6.1. Conclusions

This dissertation was carried out for studying the efficiency and productivity of rice production in Cambodia, since rice is a dominant staple food crop in Cambodia and plays an important role not only in the purpose of combating food insecurity, but also for sustainable economic and social development of the country.

The main purpose of the study was to estimate the technical efficiency of rice production in Cambodian and determine its main influencing factors for both at the national and household level by using the stochastic frontier production function (i.e. SFA model). For the national analysis, the present study utilized four-years dataset generated from the Royal Government of Cambodia (RGC)'s document "Profile on Economics and Social" of all 25 provinces between 2012 and 2015, while in the analysis at the household-level, the primary three-years data (2013, 2014, and 2015) collected from 301 rice farmers in three selected districts of Battambang province (Northwest Cambodia) by structured questionnaires was applied. The results indicate that the level of *rice output* in Cambodia varied according to the different level of capital investment in agricultural *machineries*, total rice actual *harvested area*, and technically *fertilizers* application within provinces. Furthermore, the level of *household rice output* varied according to the differences in the efficiency of the production processes, differences in production techniques, total annual rice actual *harvested land*, and technically application of *fertilizers* and *pesticides* of the farmers. The overall mean TE of rice production at the national-level is 0.784 which means that Cambodian famers produce 78.4% efficiently rice at best practice, at the current level of production inputs and technology, which means that national *rice output* has the potential of being increased further by 21.6% at the same level of inputs if farmers had been technically efficient. However, the TE analysis at the household-level reveals that the overall mean TE of household's rice production (in Battambang province) is only 0.34 which means that *household rice output* has the potential of being extra increased by 66% at the same level of inputs, indicates that farmers in Battambang province still having a huge gap of the potential to increase rice output by improving their efficiency used of the current existing resources in rice production.

During the study periods the TE of rice production recorded a -7% decreasing rate at the national-level and -14.3% at the household-level, due to highly affected of natural disasters and various environmental and social factors. *Takeo* province was the most effective province nationwide (with the TE score of 0.987 between 2012 and 2015 in average), while another

60% of provinces still had TE below the average mean efficiency in 2015.Battambang province, on the other hand, just had the TE score in average of 0.817 between 2012 and 2015, since TE score of Battambang’s provincial rice production was quite low in 2015 (0.674), compared to Takeo province (0.999) in the same year. These statistics reveal that natural disasters (especially drought in dry season of 2015) had affected most farmers’ rice fields in Battambang province, caused the TE of rice to critically decrease.

*There are three main conclusions emerged from the study’s results:*

First, based on decomposing the SFA model, enlarging capital investment at provincial level into agricultural *machineries* is the core input factor influencing national rice production of Cambodia, while the expansion of total rice land actual *harvested area*, and technically improvement of *fertilizer* application rank as the second and third main input factors respectively for rice production development in Cambodia at both national and household-level. Furthermore, *pesticide* is another important input factor for improving household’s rice production. These are the straightforward techniques for increasing rice productivity in most developing countries in the world. Moreover, these results also confirmed the existing problems in Cambodian rice production sector which were previously addressed by relevant studies like CDRI (2012), ADB (2012), ADB (2014), Yu and Diao (2011) and Smith and Hornbuckle (2013).

Second, the calculation of input elasticities reveal that *harvested area* had the highest elasticity among all input factors of rice production in Cambodia (at both national and household-level), which is clearly indicated that increasing in *harvested area* (i.e. *land* input) could cause the increasing of *rice output* in higher percentage than all other inputs. Currently, the RGC had been trying to increase rice production by enlarging the total area of rice fields annually, this enlargement, however, still remains far behind its enormous potential to increase productivity of rice, due to limitation of land resources. Moreover, irrigation facilities, irrigation systems and good water management practices (which is the key factor for enlarging rice cultivated area through multi-cropping systems) in Cambodia still remain low and inefficiency. Therefore, significant commitments and supported actions are required to address the problem.

Third, *production techniques* for rural farmers, technical skills and amount of *agricultural supporting staffs* are being as the most important influencing factors of national rice production in Cambodia. However, production of rice in Cambodia is very vulnerable to natural disasters like floods, droughts, and insects, due to lack and inefficient performance of irrigation system (which is also playing the crucial role as the disasters prevention device in most cases). Thus, development of *irrigation* systems and good water management practices, is a relevant magnitude to be powerfully considered by policy-makers for developing strategical policies geared towards enhancing rice production at both national and household-level.

Therefore, the main factors affecting the output level of rice production in Cambodia appear to be capital investment in agricultural *machineries* as well as efficiency of *machineries* performances, actual *harvested area*, *fertilizers* and *pesticides* utilization while *irrigation* and good water management, *production techniques*, and technical *supporting staffs* serving as main factors affecting TE of national rice production in Cambodia, while the core influencing factors lead to decreasing TE of household's rice production are *disaster* (i.e. droughts, floods, and insects),*education level of household's head*, number of people in the family (i.e. *family size*) and *cultivated area of other crops* such as corn, sugarcane, cassava, cucumber, pepper, wax melon, bitter melon, bean, eggplant, and other vegetables. However, the main influencing factors that lead to increasing TE are *irrigated area*, *number of plot area* and the *sex of household's head*.

## 6.2. Recommendations

In order to improve rice productivity in Cambodia, the present study recommends the development of:

- *Irrigation systems and good water management practices* should be strongly considered and bring into more effective actions by the central government as well as related agencies for preventing frequently-occurred natural disasters and increasing actual harvested area, particularly in dry-season.
- Increase *capital investment* on agricultural machineries, particularly on large-scale machineries, in high potential province of rice production.
- Improving *technical skills* of support staffs and rural farmers.
- Some special strategies or procedures might need to be put into place to enhance the efficiency of *labor utilization and allocation*.
- Further researches on new *production techniques* (such as SRI) are required, and should be widely spread to rural rice farmers.
- Encourage the enlargement of *fertilizers* and *pesticides* application for farmers' household rice production, while more efficient management techniques of imported *fertilizers* and *pesticides* might also require for avoiding inefficiency uses. Additionally, it might be a worthy point if Cambodia could be able to produce *fertilizers* and *pesticides* for agriculture by itself (thus, Cambodia need

not to import great amount of *fertilizers* and *pesticides* from neighboring countries, which high costs always existed in).

## 6.3. Discussion

### 6.3.1. Important of research

As insights into factors influencing rice production TE enable to come up with more effective policies and strategies for enhancing sustainable rice production, and obtain what technical progress policies should be chosen for improving rice sector in Cambodia, the results of the present study will be useful for both rice producers and policy makers in government and all other stakeholders along the rice value-chain including development agencies, non-government organizations (NGOs) and many other related parties working towards improving rice production and the agricultural sector at large. Additionally, the outputs of the present study were expected to be able to be used as a tool, an example, or a case study which might help next young-generation researchers like university students who are interested in food security, agricultural development, total factor productivity, technical efficiency or rice productivity terms, to understand more about Cambodian rice production sector.

### 6.3.2. Scope of research

Among various components of agricultural sector in Cambodia, the present study mainly focused on only rice production, which is the economic and food staple crop for Cambodian. Although rice is grown in every provinces of Cambodia, the study has selected only one province (i.e. Battambang province) located in the northwest region of Cambodia (i.e. Tonle Sap river plain region) as the study area. Therefore, characteristics of rice production TE of farmers in different regions of Cambodia might not be similar.

### 6.3.3. Future research prospective

Although rice production is the main components of Cambodia agriculture, characteristic of rice farmers might not be able to represent the characteristic of the whole agricultural sector. Moreover, situation in one region might not plenty enough to represent the whole country. Thus, the recommendation for future researches on productivity and efficiency of rice production in other provinces as well as in other regions like Mekong river plain where high potential of rice crop production existing in, in order to supplement the lack of information on Cambodian rice production, which might be useful for the policies makers of RGC as well as related parties for improving rice productivity in Cambodia, in the purpose of social and economic sustainable development as large. More importantly, further future productivity and efficiency researches in any other components of Cambodian agricultural sector, such as rubber, pepper, palm sugar, cassava, sugarcane, watermelon, tea, fish products, forest products, and other short and long-term crops. etc. still also important for Cambodian during the current developing stage of the nation.

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# APPENDIX

## *Appendix A. Questionnaire*

Research location: Battambang province, Cambodia. Questionnaire code: ________________

□1. Moung Russei district, commune: ________________, village: ________________

□ 2. Thmar Koul district, commune: ________________, village: ________________

□ 3. Sangkhae district, commune: ________________, village: ________________

Research date: (dd/mm/yyyy) ________________/________________/________________

Interview time: started______________________, finished __________________________

Interviewer's name: _________________________, Telephone: ____________________________

Interviewee's name: _________________________, □ 0. Male □ 1. Female

Interviewee's phone number (if have): _________________________________________

### 1. Household's information

1.1. Head of household: Age: ____________ □ 0. Male □ 1. Female

1.2. Head of household's education: (graduated/studying)

□ 1. Didn't attend school □ 2. Primary school

□ 3. Secondary school □ 4. High school

□ 5. Bachelor degree □ 6. Master/Ph.D degree

□ 7. Other: ___________________________________________________

1.3. Head of household's main occupation ________________________________________

1.4. Family members

| Family members | 2013 | | 2014 | | 2015 | |
|---|---|---|---|---|---|---|
| | Male | Female | Male | Female | Male | Female |
| 1. Total | | | | | | |
| 2. Dependent | | | | | | |
| 3. Independent (self-feed) | | | | | | |
| 4. Labor force (15-64yr) | | | | | | |

Note: Dependent: those who still under financial supports from parents.

Independent: those who are NOT under any financial supports from parents, have already had job, married …

1.5. Family members’ education: (Excluded the head of household)

| Education level | 2013 | | 2014 | | 2015 | |
|---|---|---|---|---|---|---|
| | Male | Female | Male | Female | Male | Female |
| 1. Didn’t attend school | | | | | | |
| 2. Primary school | | | | | | |
| 3. Junior high school | | | | | | |
| 4. Senior high school | | | | | | |
| 5. Bachelor degree | | | | | | |
| 6. Master degree | | | | | | |
| 7. Other: ______________ | | | | | | |

1.6. Source of income

1.6.1. Beside rice, do you grow any other crops? □ 0. Yes □ 1. No

| Other crops | 2013 | | 2014 | | 2015 | |
|---|---|---|---|---|---|---|
| | $m^2$ | kg | $m^2$ | kg | $m^2$ | kg |
| 1. | | | | | | |
| 2. | | | | | | |
| 3. | | | | | | |
| 4. | | | | | | |
| 5. | | | | | | |
| 6. | | | | | | |
| 7. | | | | | | |

Note: $m^2$: How much grow? kg: How much gain?

1.6.2. For self-feed members, what are their jobs? How much they earn per month?

| Job titles | Monthly earned ($)? | | |
|---|---|---|---|
| | 2013 | 2014 | 2015 |
| 1. | | | |
| 2. | | | |
| 3. | | | |
| 4. | | | |
| 5. | | | |
| 6. | | | |

Note: “Monthly earned?” included salary, over time (OT), and any other benefits in average.

**2. INPUTS of Rice production**

2.1. LAND:

2.1.1. Rice production area:

| Land | 2013 | 2014 | 2015 |
|---|---|---|---|
| 1. Wet season cultivated land (ha) | | | |
| 2. Dry season cultivated land (ha) | | | |
| 3. Wet season harvested land (ha) | | | |
| 4. Dry season harvested land (ha) | | | |

2.1.2. Distant from nearest water source ______________________________ meters

2.2. LABOR:

2.2.1. Family labor work on rice production:

| | 2013 | | | 2014 | | | 2015 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Labor Amount | | Work Days | Labor Amount | | Work Days | Labor Amount | | Work Days |
| | M | F | | M | F | | M | F | |
| Plowing | | | | | | | | | |
| Base fertilizer | | | | | | | | | |
| Seeding | | | | | | | | | |
| Transplanting | | | | | | | | | |
| Add fertilizer | | | | | | | | | |
| Irrigating | | | | | | | | | |
| Weed control | | | | | | | | | |
| Pest control | | | | | | | | | |
| Harvesting | | | | | | | | | |
| Threshing | | | | | | | | | |
| Transport | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

2.2.2. In case of rent, please details:

| | 2013 | | 2014 | | 2015 | |
|---|---|---|---|---|---|---|
| | Daily wage | Days rent | Daily wage | Days rent | Daily wage | Days rent |
| 1. Plowing | | | | | | |
| 2. Harvesting | | | | | | |
| 3. Threshing | | | | | | |
| 4. | | | | | | |
| 5. | | | | | | |
| 6. | | | | | | |

2.3. FERTILIZER, PESTICIDE, and SEEDS:

| Other Inputs Used | | 2013 | 2014 | 2015 |
|---|---|---|---|---|
| Chemical Fertilizer | Amount used (kg) | | | |
| | Price ($/kg) | | | |
| | Gross amount ($) | | | |
| Bio.Fer. | Amount used (kg) | | | |
| | Equivalent money ($) | | | |
| Pesticide | Amount used (kg) | | | |
| | Price ($/kg) | | | |
| | Gross amount ($) | | | |
| Seeds | Amount used (kg) | | | |
| | Price ($/kg) | | | |
| | Gross amount ($) | | | |

2.4. Machinery

| Items | Year bought | Bought price |
|---|---|---|
| 1. Koryon | | |
| 2. Tractor | | |
| 3. Pumping machine | | |
| 4. | | |
| 5. | | |
| | | |
| | | |
| | | |

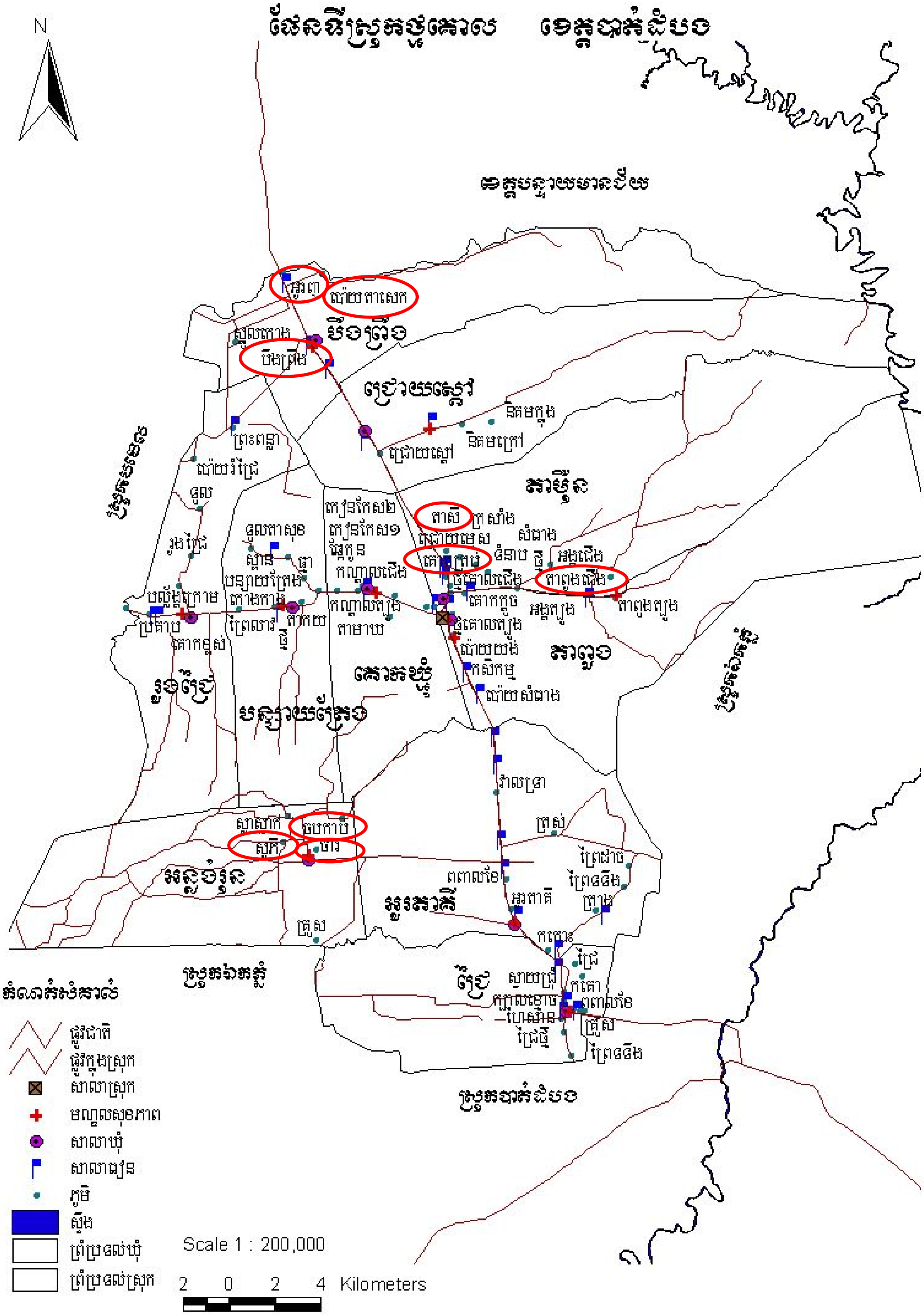
### 3. OUTPUT of Household's rice production

| Rice type | 2013 | | 2014 | | 2015 | |
|---|---|---|---|---|---|---|
| | Quantity | Price | Quantity | Price | Quantity | Price |
| 1. Wet season | | | | | | |
| 2. Dry season | | | | | | |

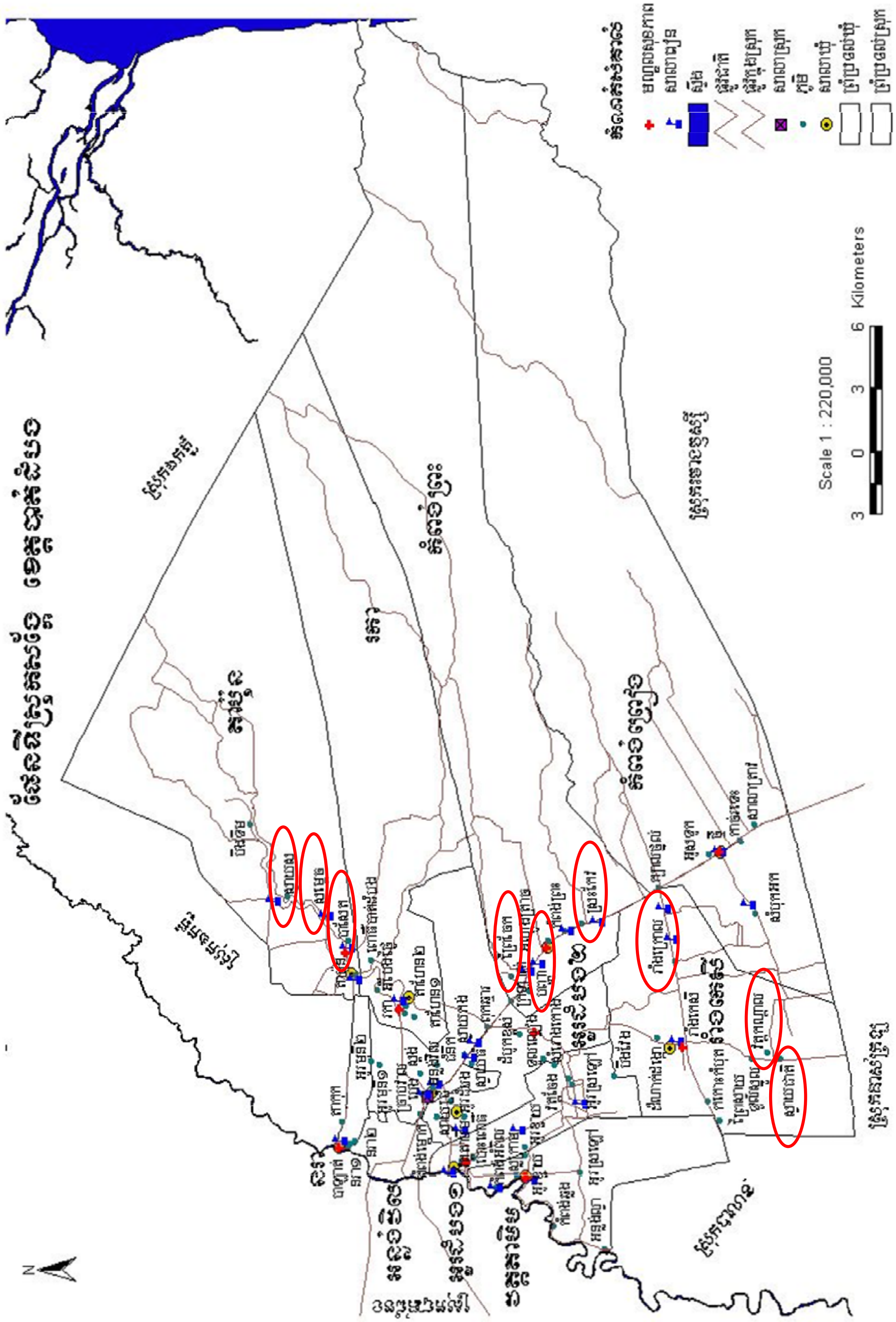
Additional Note:

## *Appendix B. Maps of Study Areas*

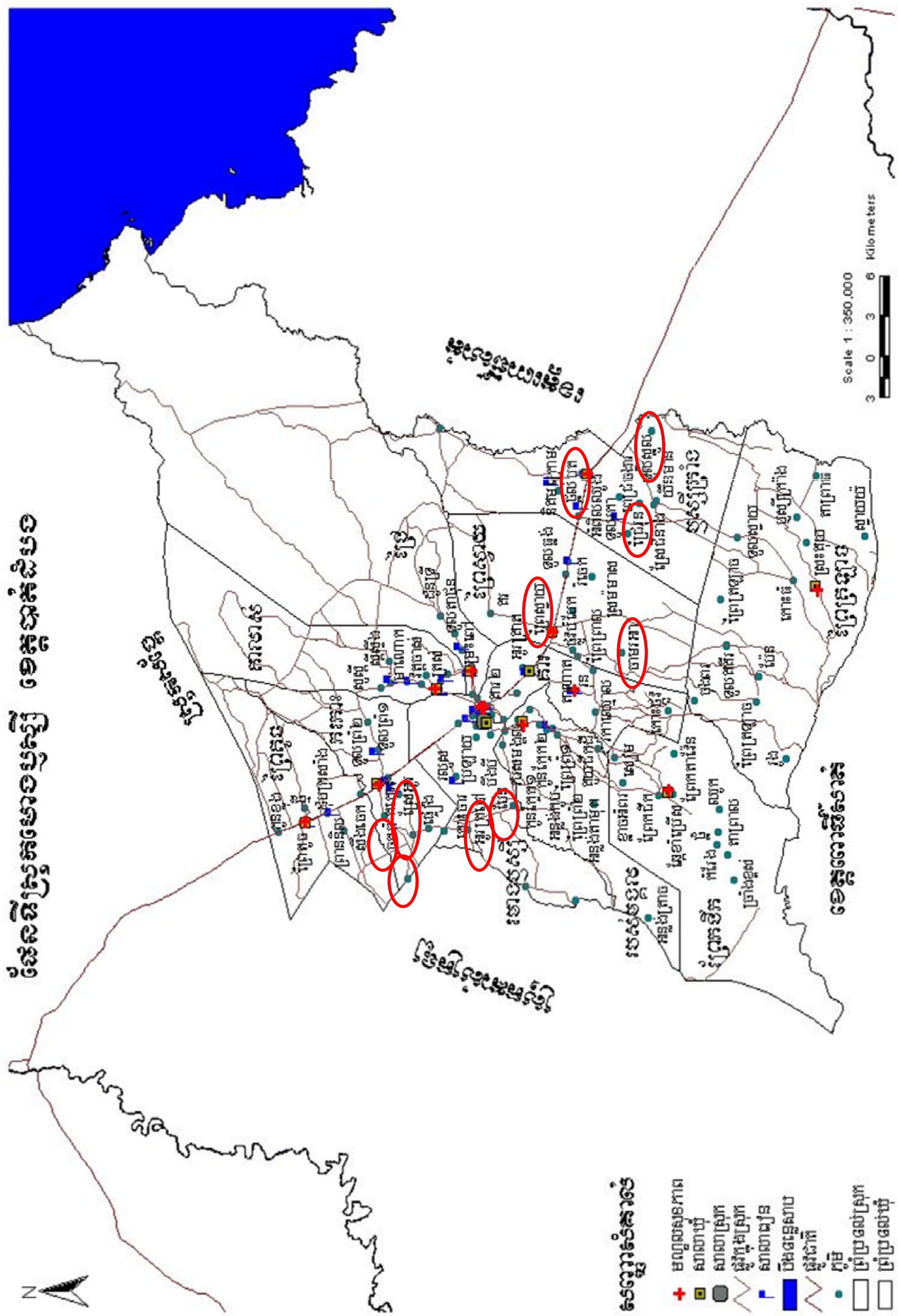
**Map B.1.** Study Areas in Thmar Koul district, Battambang province



**Map B.2.** Study Areas in Sangkhae district, Battambang province



**Map B.3.** Study Areas in Moung Russei district, Battambang province



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## Publishing

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