SUSTAINABLE TEA PRODUCTION AT THE NORTHERN MOUTAINOUS REGION IN VIETNAM

グエン, ビッチ ホン

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DOCTOR THESIS

Nguyen Bich Hong

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SUSTAINABLE TEA PRODUCTION AT THE NORTHERN MOUTAINOUS REGION IN VIETNAM

By

NGUYEN BICH HONG

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DOCTOR OF PHILOSPHY IN AGRICULTURAL SCIENCE
Department of Agricultural & Resource Economics

Supervised by:

Professor Dr. Mitsuyasu **YABE**

Associate Professor Dr. Yoshifumi **TAKAHASHI**

Assistant Professor Dr. Goshi **SATO**

Faculty of Agriculture

Graduate School of Bioresource and Bioenvironmental Sciences

KYUSHU UNIVERSITY

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Abstract

Tea production has contributed significantly to economic development and poverty reduction in Vietnam, with millions of rural people, still depending on it for their living. However, problems and challenges such as: low productivity, low price and quality, depending on agro-chemical inputs, land degradation, water scarcity, and climate change have hindered sustainable development of Vietnamese tea sector. For this reason, Vietnamese government is actively seeking solutions to render tea production more sustainable. This study attempts to provide an insight into how Vietnamese tea small-scale farms can reallocate resources and adjust farm practices and management towards sustainability by assessing 243 tea farms at the Northern mountainous region from four aspects: technical efficiency, environmental efficiency, irrigation use efficiency and profit efficiency. Translog stochastic production and profit frontier models were used to measure efficiencies and separate Tobit models were applied to investigate determinants of efficiencies based on cross-sectional data in 2014.

Research results revealed that the improvement in economic, environmental, and social sustainability of the tea sector can be achieved by being more technically, environmentally, irrigation water use and profitably efficient. The mean of output and input-oriented technical efficiency were 92.29% and 82.21%, suggesting that inputs reduction strategy is superior to increasing output one, in term of sustainability improvement. All recent inputs application could be contracted by 17.79% without scarifying the current output level. Specifically, on average, comprehensive environmental efficiency of fertilizer and pesticide were found to be 69.80% and 55.89%, which imply that farmers can reduce use these environmentally detrimental inputs by 30.20% versus 44.11% without losing output. Similarly, the mean of irrigation water use efficiency was 42.19%, indicating that the observed output can maintain with saving of irrigation water use by 57.81%. Furthermore, 82.03% of profit efficiency indicated that there a room (17.97%) to increase tea farmers ‘profit by improving technical and allocative efficiency. Socioeconomic and psychological factors such as: gender, soil and water conservation practices, agricultural income, off-farm income, access to extension services, water scarcity perception, irrigation by well water, process machineries utilization, linkage with enterprises, direct product marketing activities, and market information access had significant influence on the efficiency measures of tea production. In order to sustain the tea sector, the policies that focus on these farms and farmers’ attributes are very essential.

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Chapter 1

Introduction

1.1. Background Information

Tea is the second most prevalent drink in the world, after water (Szenthe 2015). Tea consumption in the world increased by 60% in the period of 1993-2010, and considerable growth is predicted with more people becoming tea consumers (Brouder et al. 2014). Today, tea production plays a key role in socio-economic development in many poor countries. The Tea 2030 steering group stated that tea is going to become a 'hero' crop for 2030 which brings significant benefits to not only millions of stakeholders in the sector but also the world (Brouder et al. 2014).

As the demand for tea in the world market has increased significantly, tea production has also expanded. Global tea production reached 5.2 million tons in 2015. While tea is produced in more than 35 countries, only a handful - China, India, Sri Lanka and Kenya – are responsible for almost three-quarters of production. Other important producing countries are Turkey (4.5%), Viet Nam (3.7%) and Indonesia (3%).

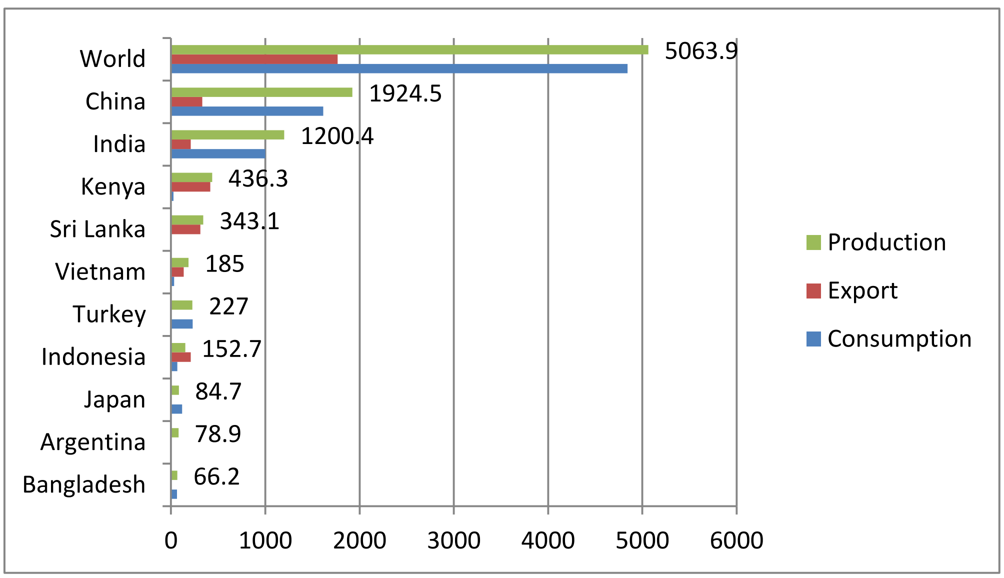


Figure 1.1: Production, export and consumption value in thousand tons of top 10 tea producing countries in 2013

Source: FAO Intergovernmental Group Secretariat, Chang (2015)

Tea is an important commodity in terms of export earnings and jobs. The major consuming countries are also the major producing countries—China and India, respectively accounting for 33.3% and 20.7% of global consumption in 2013 respectively. World tea exports reached 1.77 million tons and export earnings increased to USD 5.7 billion in 2013. The major exporting countries are Kenya, China and Sri Lanka, which together control almost 59.7% of world exports. Millions of livelihoods around the world depend on tea picking and processing. On estimation, there are 13 million workers involving in tea production worldwide, of which around 9 millions are smallholders (IDH 2010).

Vietnam has many favorable conditions for agricultural development, in which tea is one of the products with significant advantages. In Vietnam, tea has a long and glorious cultivation history up to three thousand years, rich in traditional and cultural significance. The Vietnamese people living in both rural and urban areas have an established custom of drinking tea. Tea is leading among Vietnam's cash crops and considered an important national sector with regard to job creation, foreign exchange earnings and poverty alleviation. The industry provides employment for about 400,000 small rural households (GSO 2011). Vietnamese tea products have made their presence in more than 100 countries and territories worldwide. At present, Vietnam is the fifth largest tea exporters in the world. Export turnover from 132,000 tons sold oversea in 2014 grossed 228.12 million (GSO 2014). Currently, Vietnam has more than 132,000 hectares of plantation land favorable for tea production spreading 39 provinces of 4 regions (GSO 2015). Although French companies tried to expand tea production throughout Vietnam, the northern mountainous and midland region remained the largest tea planted area which accounts for 72.4 % of the country (see Figure 1.2).

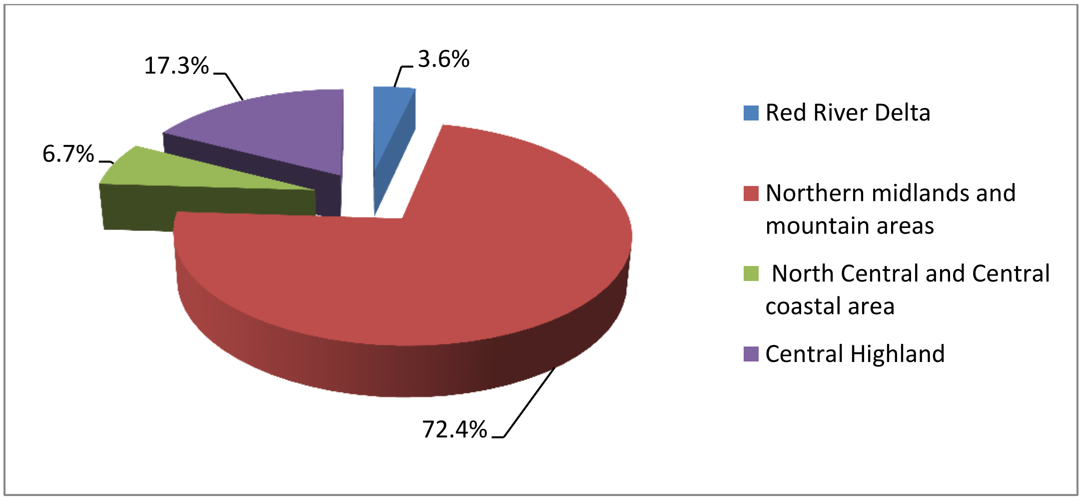


Figure 1.2: Tea plantation in Vietnam

Source: Vietnamese General Statistics Office (GSO 2015)

Tea production in Vietnam grew strikingly over the past decades. During the period 2006-2015, fresh tea production increased an average of 7.07 percent (see figure 1.3). The year 2015, saw a considerable growth in tea production with 237.5 tons compared with 2014.

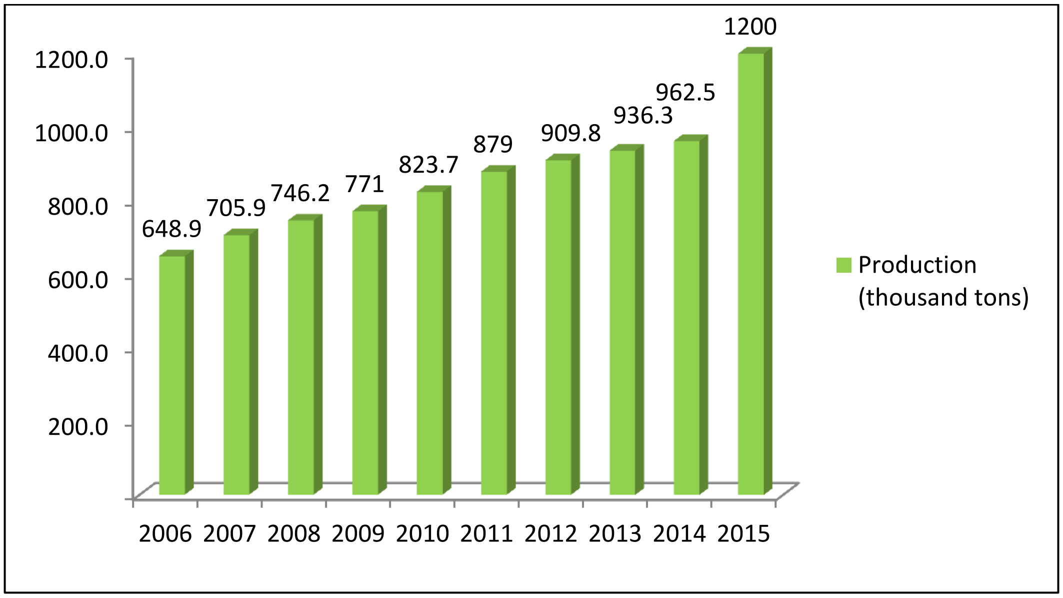


Figure 1.3: Tea production in Vietnam (2006-2015)

Source: Ministry of Agriculture and Rural Development (MARD 2016)

1.2. Problem Statement

Despite its importance to developing countries, global tea sector is hindered with serious social, economic, and environmental issues amid the finite of natural resources, rapidly growing populations and climate change (Onduru et al. 2012). This threatens the long term production capacity of the sector. Scientists and communities face the challenge of developing a new paradigm for tea industry, which captures the concept of sustainability to enhance production — both in terms of quantity and quality — without degradation of the production resources and the environment.

Sustainable tea production has become a major objective of Vietnamese agricultural policy. The government and populace have realized that sustainable development will decide the future of entire tea sector. It can increase economics viability through efficient resources use and high productivity. Furthermore, it can mitigate environmental degeradation and protect natural resoures such as water through reducing agro-chemical inputs application and efficient irrigation water use. From the social point of view, it can ensure income and improve the livelihood of Vietanmese tea small-scale growers through increase their profiatbility.

In response to sustainable agricultural development in general and the tea sector in particular, the Vietnamese government has formulated Strategic Orientation for Sustainable Development (Vietnam Agenda 21 on 17 August 2004) and a number of laws and regulations, including: Law of Agriculture, Law of Agricultural Environmental Protection, Law of Environmental and Resource Conservation, Law of Soil and Water Conservation and Law of Land Management. The main components of these laws are concerned with the importance of environmental and natural resource protection, and the role of the government and people in the environmental conservation process. At present, together with the international community, Vietnam is determined to, step by step; surmount all obstacles implementing sustainable development towards establishing a green agriculture.

Although significant achievements have been made in developing tea production in the Vietnam, some serious problems remain that restrict its sustainable development (Figure 1.4):

- Vietnamese tea sector is currently performing below its potential. Productivity is low and product quality is poor (Asian Development Bank 2004).
- Vietnamese tea production is hindered by rising production costs (labor, fuel and electricity), mismanagement, and age of tea bushes, high overhead costs, bad agricultural practices, low labor productivity, and dilapidated infrastructure. Additionally, for the smallholder tea sector, problematic issues include low farm gate prices, poor extension services, limited market channels, poor access to credit and low level of farmer organization (VanDer Wal 2008).
- The tea sector's environmental footprint is considerable, with reduced biodiversity due to habitat conversion and high energy consumption (mainly using logged timber) among other factors (Van Der Wal 2008). Furthermore, Vietnamese government formely adopted the policy incresing tea productivity at all costs through abundant use of agro-chemical inputs. In addition, the tea growers have a little knowledge and understanding about safety and effective use of these inputs. The excessive use of agro-chemicals in tea production not only

negatively affect production cost but also high risk to the environment and the health of the tea growers (Ngo et al. 2001; Asian Institute of Technology 2002).

- Besides, the tea industry also faces with the challenges from climate change and water scarcity. The International Panel on Climate Change report (2007) showed that Vietnam is one of the most vulnerable countries in connection with climate change. The rising shortage of water in Vietnam has been identified as one of the main obstacles for environmental conservation and poverty reduction. Water demand for Vietnamese agriculture may double or triple by 2100 compared to 2000. At the same time, there are constantly growing risks of severe droughts and water shortage for irrigation, also the changing climate is predicted to affect rather the North than the South (FAO 2011). Irrigated tea-based cropping systems which are among the major water users in Vietnam will be affected seriously.

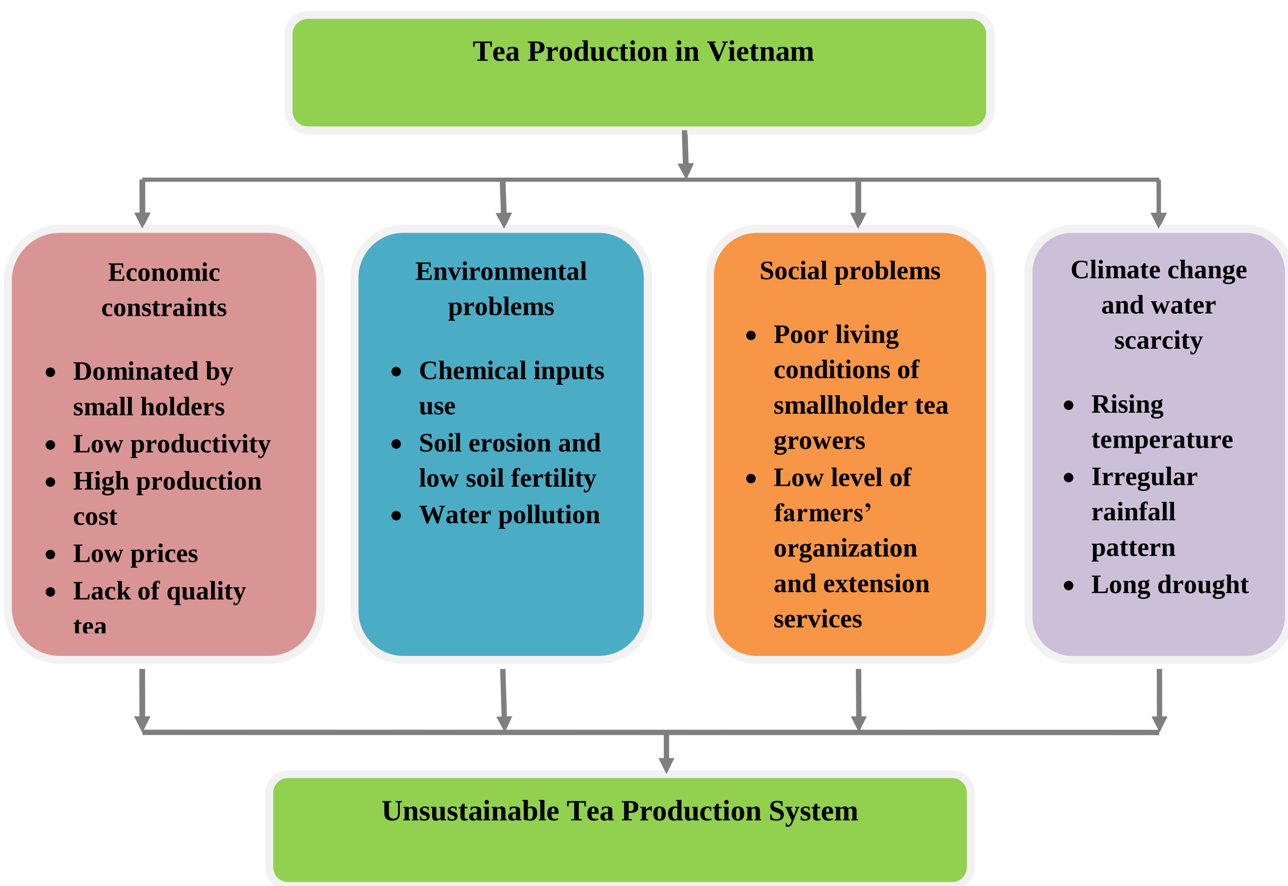


Figure 1.4: Constraints of tea production in Vietnam

Addressing the emerging issues requires adoption of alternative tea practices that takes into account environmental, social and economic impacts of tea activities when making improvements in the current farming systems. Sustainable tea production contributes to addressing this challenge. For a farm to be sustainable, Reganold et al. (1990) indicated that "… it must produce adequate amounts of high-quality food, protect its resources and be both environmentally safe and profitable… sustainable agriculture addresses many serious problems …: high energy costs, groundwater contamination, soil erosion, loss of productivity, depletion of fossil resources, low farm incomes and risks to human health and wildlife habitats."

The literature on tea production in developing countries can be found in Basnayake and Gunaratne (2000), Saigenji and Zeller (2009), Baten (2010), and Haridas et al. (2012). All of these studies focus on output-oriented technical efficiency which determines the ability of tea farms to maximize output with a given set of inputs. To the best of our knowledge, there have no prior studies conducted to evaluate the sustainability of tea production, specifically in examining the technical efficiency, environmental efficiency, water use efficiency and economic efficiency including socio-economic and environmental determinants. The present research hopefully fills this gap. The following research questions have been raised and try to answer by this research:

1) What are the existing farm practices and management situations of tea production at the Northern mountainous region in Vietnam?
2) Do farmers efficiently use the combination of inputs for producing tea?
3) What are the existing technical, environmental, irrigation water use efficiency, profit efficiency levels of tea production in the Northern mountainous region of Vietnam?
4) Are there any differences in efficiency among tea farmers?
5) What are the determinants of technical, environmental, economic and irrigation water use efficiency of tea production at the Northern mountainous region in Vietnam

1.3. Research Objectives

1.3.1. Overall objective

This study aims to recommend appropriate strategies and approaches for sustainable tea production at the Northern mountainous region in Vietnam.

1.3.2. Specific objectives

The specific objectives are:

1) To assess the technical efficiency of tea production and its determinants in the study area.

2) To evaluate the environmental efficiency of tea production and its determinanats in the study area.

3) To measure the irrigation water use efficiency of tea production and its determinants in the study area.

4) To analyze the profit efficiency of tea production and its determinants in the study area.

1.4. Significance of the study

This study provides insights apropos assessment of production resources state and associated causes, as well as the possible effects of current policies and interventions for Vietnamese tea farming. It also forms a point of reference for evaluating the sustainability of agricultural production based on efficiency theory. It generates the empirical evidence required to facilitate the improvement of technical, environmental, irrigation water use and profit efficiency, which will help improve the sustainability of small-scale tea farming at the Northern mountainous region in Vietnam. Equally, by expanding the empirical database and knowledge on tea farms' performance in the economic, social, and environmental aspects of their production, the study has further provided a decision-support to enhance the effective development and implementation of sustainable tea production policies in Vietnam.

1.5. Thesis outline

The study contains eight chapters (Figure 1.5). This chapter presents a background on tea production in the world and in Vietnam setting. It also introduces the problem statement, research's objectives, and the significance of the research. The next chapter, Chapter 2 explores and reviews theoretical background of sustainable agriculture and efficiency analysis. It begins with concepts and measurements of sustainable agriculture and then follows by theory of efficiency analysis and summary of stochastic frontier analysis and data envelopment analysis. The last section of this chapter ends with the literature surveys of empirical study on efficiency measurement of agricultural production, particularly tea production. Chapter 3 starts with background information of the study area and continues to giving the details of sampling method and sample sizes of primary data collection, environmental efficiency, irrigation water use efficiency and profit efficiency by using stochastic frontier analysis and Tobit model.

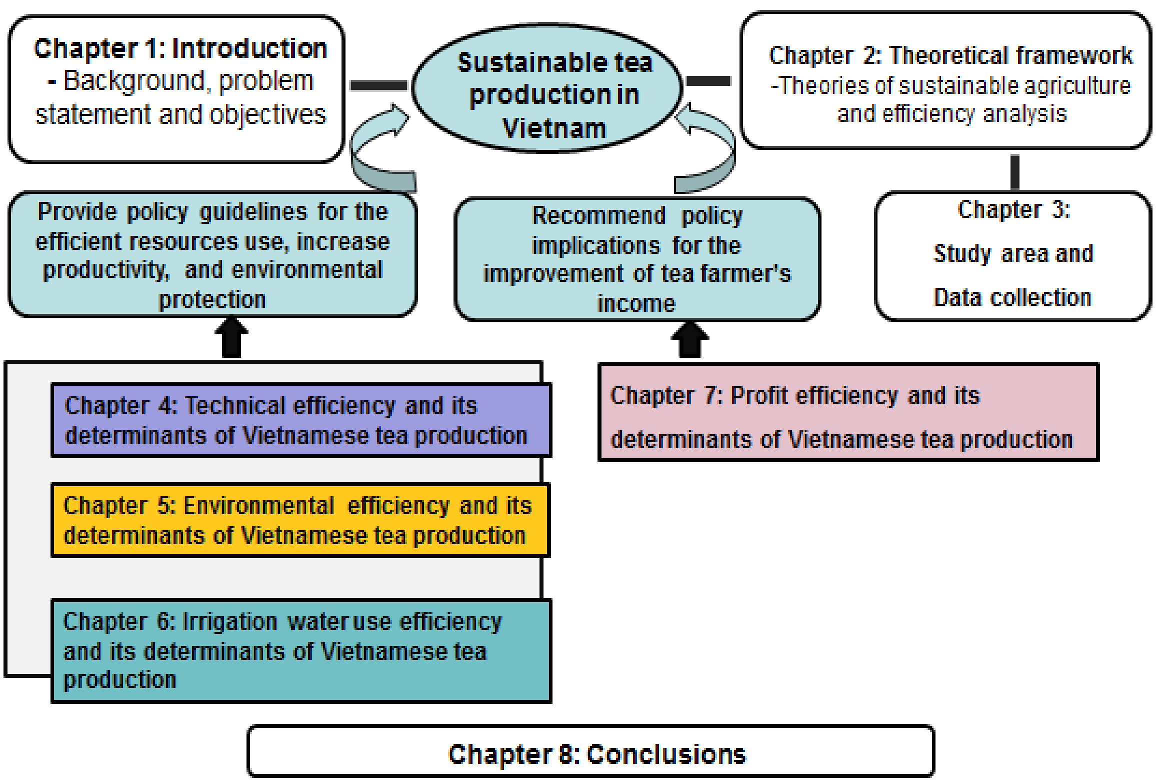


Figure 1.5: Structure of thesis

Chapter 4, 5, 6, and 7 present efficiency measures and their determinants. All these chapters have similar structure. The first section of each chapter introduces problem and the research's objective. The second section is analytical frameworks. The next section reports research's results. Discussion and policy recommendations are introduced in the next section. Conclusions are given in the final section. The detail content of each chapter is given as follows:

- Chapter 4: Technical efficiency and its determinants in Vietnamese tea production
- Chapter 5: Environmental efficiency and its determinants in Vietnamese tea production
- Chapter 6: Irrigation water use efficiency and its determinants in Vietnamese tea production
- Chapter 7: Profit efficiency and its determinants in Vietnamese tea production

Lastly, in Chapter 8 summarizes the main findings of the study and draws the policy recommendations. The last section of this chapter, limitations of the study and recommendations for further study are discussed.

Chapter 2

Theoretical framework

2.1. Introduction

From the initial step of propagating tea in a nursery to the industrial processing stage, a number of environmental sustainability issues are encountered, including the use of artificial fertilizers, pesticides, effluent discharge to natural water bodies and destruction of habitats for wild animals. These concerns are common to most types of agriculture, and have seen farmers in many parts of the world shifting their focus to more sustainable agriculture practices. This chapter introduces the concept and measurement of sustainable agriculture, conceptual framework of this study, frontier theory, and then discusses different ways of measuring efficiency and their advantages and disadvantages.

2.2. Theories of Sustainable Agriculture

2.2.1. Concept of Sustainable Agriculture

For decades, agriculture has been a primary source of production to ensure man‘s livelihood. Over a period of time, man has search for feasible methods of increasing food productivity and hence significantly changed practices in agriculture. This has resulted in a conventional agriculture which is highly specialized and inputs intensive. Conventional agriculture is heavily dependent on synthetic chemicals and other off-farm inputs (Schaller 1993). Attempts to increase production in a complex ecosystem have therefore led to various sustainability concerns as conventional agriculture is known to have adverse impacts on various segments of life. Some of the problems associated with conventional agriculture were identified by Schaller (1993) and Aldy et al. (1998), such as: contamination of ground and surface water from agricultural chemicals and sediments; hazards to human and animal health from pesticides and feed additives; adverse effects of agricultural chemicals on food safety and quality; loss of the genetic diversity in plants and animals; destruction of wildlife including bees and beneficial insects by pesticides; growing pest resistance to pesticides; reduced soil productivity due to soil erosion; over-reliance on non-renewable resources, and health and safety risks incurred by farm workers who apply potentially harmful chemicals. As a response to the deteriorating situation, more efforts are now directed towards achieving sustainable agriculture. There have many concepts about agricultural sustainability over last two decades.

“ A management strategy which helps the producers to choose hybrids and varieties, a soil fertility package, a pest management approach, a tillage system, and a crop rotation to reduce costs of purchased inputs, minimize the impact of the system on the immediate and the off-farm environment, and provide a sustained level of production and profit from farming.” (Francis et al. 1987);

Farming systems are sustainable if “they minimize the use of external inputs and maximize the use of internal inputs already existing on the farm.” (Carter 1989);

“ (a) The development of technology and practices that maintain and/or enhance the quality of land and water resources; and (b) the improvements in plants and animals and the advances in production practices that will facilitate the substitution of biological technology for chemical technology. ” (Ruttan 1988);

“An agriculture that can evolve indefinitely toward greater human utility, greater efficiency of resource use, and a balance with the environment that is favorable both to humans and to most other species.’ (Harwood 1990);

US Congress in the 1990 Farm Bill defined sustainable agriculture as:

“… an integrated system of plant and animal production practices having a site specific application that will, over the long term: (a) satisfy human food and fiber needs; (b) enhance environmental quality; (c) make efficient use of non-renewable resources and on-farm resources and integrate appropriate natural biological cycles and controls; (d) sustain the economic viability of farm operations; (e) enhance the quality of life for farmers and society as a whole” cited in (Aldy et al. 1998).

“Practices that meet current and future societal needs for food and fiber, for ecosystem services, and for healthy lives, and that do so by maximizing the net benefit to society when all costs and benefits of the practices are considered.” (Tilman et al. 2002).

In spite of various concepts on sustainable agriculture, it can be viewed from “ecological, social and economic perspectives, and should be assessed relative to all three” (Yunlong and Smit 1994). Three dimensions of sustainable agriculture are mentioned by EUCommission (2001) as follows:

1) The economic dimension relates to the efficient use of resources, the competitiveness and the viability of the sector as well as its contributions to the viability of rural areas. Efficient agricultural structures, appropriate technologies as well as the diversification of income sources for farm households are important elements of this dimension. Efficiency of resource use is an important basis for the viability of rural areas.
2) The ecological dimension refers above all to the management of natural resources with a view to ensure that they are available in the future. However, it also includes issues such as the protection of landscapes, habitats, biodiversity, as well as the quality of drinking water and air.
3) The social dimension relates to maintenance and creation of employment and access to resources and services of agricultural households compared to other economic agents in rural area. The issues of equal opportunities and society´s ethical concerns regarding agricultural production methods such as labor conditions, ethical production methods and animal welfare can also be considered as belonging to the social dimension of sustainable agriculture.

2.2.2. Agricultural sustainability measurement

A number of conceptual frameworks have been developed to help measure sustainability such as: Pressure-State-Response (PSR), Driving forces-Pressures-State-Impacts-Responses (DPSIR), pressure-State-Response-Effects (PSR/E), Pressure-State-Impacts-Response (PSIR)and Driving force-State-Response (DSR).For example, Organization for Economic Cooperation and Development (OECD) has developed a common framework called “driving force state response” (DSR) to help in developing indicators. Driving force indicators refer to the factors that cause changes in farm management practices and inputs use. State indicators show the effect of agriculture on the environment such as soil, water, air, biodiversity, habitat and landscape. Response indicators refer to the actions that are taken in response to the changing state of environment. Using the DSR framework, OECD (1997) identified 39 indicators of issues such as farm financial resources, farm management, nutrient use, pesticide use, water use, soil quality, water quality, land conservation, greenhouse gases, biodiversity, landscape, wildlife habitats, and farm's contextual information, including socioeconomic background, land-use, and output. Other conceptual framework for indicators useful in measuring sustainability of the social dimension is the Sustainable Livelihoods framework (SLF), which has been used by the United Kingdom (UK) Department for International Development (DFID) mostly in the rural areas (Figure 2.1)

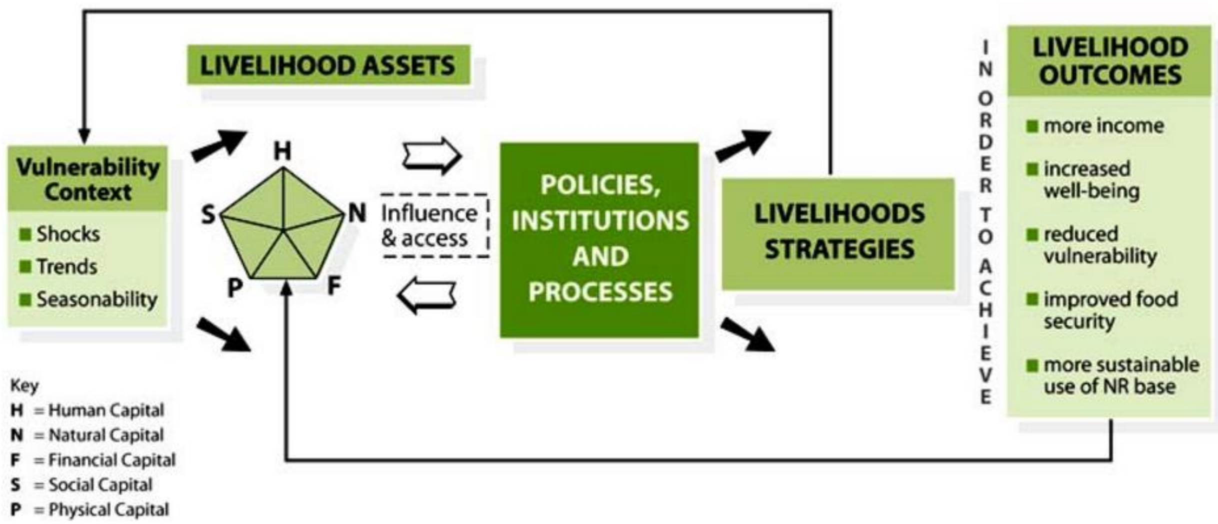


Figure 2.1: Sustainable livelihood Analytical Framework

Source: DFID (1999)

There are two main general approaches to measuring sustainability in agricultural production. The first involves the development of various indicators to describe differences among farms or systems while the second is based on the production frontiers to derive efficiency and productivity measures. Both approaches address the relative performance comparison as well as the analysis of inter temporal changes in performance. Relative performance comparison is useful in evaluating the performance of an individual farm relative to a number of other farms. Temporal analysis facilitates measurement of the dynamics of performance over time.

In the first approach, various parameters for measuring agricultural sustainability have been proposed by scholars. Hayati, Ranjbar, and Karami (2010, page 76) introduced a review of literature about scholars' emphasis and their tendency toward to social, economic and ecological components of agricultural sustainability (Table 2.1)

Table 2.1: Classification of scholars' emphasis and their tendency toward three components of agricultural sustainability according to a review of literatures (Hayati, Ranjbar, and Karami (2010)

Sources	Component	Parameters
Herzog and Gotsch (1998); Van Cauwenbergh et al. (2007)	**Social**	• The education level of the household members
Herzog and Gotsch (1998)		• Housing facilities
Herzog and Gotsch (1998)		• Work study
Herzog and Gotsch (1998); Rasul and Thapa (2003); Van Cauwenbergh et al. (2007)		• Nutritional/health status of the family members
Ingels et al.(1997); Pannell and Glenn (2000); Horrigan et al. (2002); Rasul and Thapa (2003)		• Improved decision making
Karami (1995); Ingels et al.(1997); Rezaei-Moghaddam (1998); Norman et.al (2007); Lyson (1998); Van Cauwenbergh et al. (2007)		• Improved the quality of rural life
Ingels et al.(1997); Van Cauwenbergh et al. (2007)		• Working and living conditions
Becker (1997); Ingels et al.(1997); Van Cauwenbergh et al. (2007)		• Participation/social Capital
Becker (1997); Rigby and Cáceres (2001); Rasul and Thapa (2003); Rasul and Thapa (2004)		• Social equity
Hayati (1995); Nambiar et al. (2001); Rasul and Thapa (2003)	**Economic**	• Average of crop production
Becker (1997); Herzog and Gotsch (1998)		• Expenses for input
Herzog and Gotsch (1998); Van Cauwenbergh et al. (2007)		• Monetary income from outside the farm
Herzog and Gotsch (1998); Pannell and Glenn (2000); Nijkamp and Vreeker (2000); Van Cauwenbergh et al. (2007)		• Monetary income from the farm
Becker (1997); Herzog and Gotsch (1998); Nijkamp and Vreeker (2000); Van Cauwenbergh et al. (2007)		• Economic efficiency
Karami (1995); Herzog and Gotsch (1998); Lyson (1998); Smith and McDonald (1997); Comer et al. (1999); Pannell and Glenn (2000); Rigby et al. (2001); De Koeijer et al. (2002); Rasul and Thapa (2003); Van Passel et al. (2007); Gafsi et al. (2006)		• Profitability
Herzog and Gotsch (1998)		• The salaries paid to farm workers
Herzog and Gotsch (1998); Rasul and Thapa (2003)		• Employment opportunities
Smith and McDonald (1998); Van Cauwenbergh et al. (2007)		• Market availability
Karami (1995); Nijkamp and Vreeker (2000); Van Cauwenbergh et al. (2007)		• Land ownership
Hayati (1995); Becker (1997); Ingels et al. (1997); Bouma and Droogers (1998); Pannell and Glenn (2000); Sands and Podmore (2000); Bosshard (2000); Nambiar et al. (2001); Horrigan et al. (2002); Rasul and Thapa (2003); Van Cauwenbergh et al. (2007)		• Soil management

Table 2.1 (continued)

Sources	Component	Parameters
Hayati (1995); Ingels et al. (1997); Gafsi et al. (2006); Van Cauwenbergh et al. (2007)	**Ecological**	• Improve water resource management
Hayati (1995); Rezaei-Moghaddam (1997); Ingels et al. (1997); Norman et al. (1997); Pannell and Glenn (2000); Rasul and Thapa (2004)		• Usage of pesticides, herbicides and fungicides
Saltiel et al. (1994); Hayati (1995); Norman et al. (1997); Bosshard (2000)		• Usage of animal/organic Manures
Senanayake (1991); Saltiel et al. (1994); Hayati (1995)		• Usage of green manures
Ingels et al. (1997); Herzog and Gotsch (1998))		• Physical inputs and efficient use of input
Herzog and Gotsch (1998); Rasul and Thapa (2003)		• Physical yield
Senanayake (1991); Saltiel et al. (1994); Ingels et al. (1997);Comer et al. (1999); Praneetvatakul et al. (2001); Nambiar et al. (2001); Horrigan et al. (2002); Rasul and Thapa (2003))		• Crop diversification
Saltiel et al. (1994); Rasul and Thapa (2003)		• Use of alternative crop
Saltiel et al. (1994)	**Ecological**	• Usage of fallow system
Saltiel et al. (1994); Hayati (1995); Comer et al. (1999); Horrigan et al. (2002); Rasul and Thapa (2003)		• Crop rotation
Nijkamp and Vreeker (2000); Rasul and Thapa (2003); Rasul and Thapa (2004)		• Cropping pattern
Smith and McDonald (1998); Van Cauwenbergh et al. (2007)		• Trend of change in climatic conditions
Hayati (1995); Rezaei-Moghaddam (1997); Ingels et al. (1997)		• Usage of chemical fertilizer
Hayati (1995); Ingels et al. (1997); Comer et al. (1999); Horrigan et al. (2002);		• Conservational tillage (no/minimum tillage)
Hayati (1995); Ingels et al. (1997); Rasul and Thapa (2003); Gafsi et al. (2006); Van Cauwenbergh et al. (2007)		• Control erosion
Senanayake (1991); Pannell and Glenn (2000)		• Microbial biomass within the soil
Senanayake (1991);); Ingels et al. (1997); Norman et al. (1997); Nambiar et al. (2001); Van Cauwenbergh et al. (2007))		• Energy
Ingels et al. (1997); Norman et al. (1997); Comer et al. (1999); Horrigan et al. (2002); Rasul and Thapa (2003)		• Cover crop/Mulch
Pannell and Glenn (2000); Sands and Podmore (2000); Van Cauwenbergh et al. (2007)		• Depth of groundwater table
Pannell and Glenn (2000)		• Protein level of crops
Comer et al. (1999); Praneetvatakul et al. (2001); Horrigan et al. (2002); Rasul and Thapa (2003)		• Integrated pest management

Table 2.1 showed that these parameters are simple to calculate and useful for describing the economic, environmental and ecological performances of differing agricultural production systems, but are not useful in guiding the changes to makes producers more sustainable. Those measures, which are based upon production frontiers, however, can overcome this shortcoming.

The frontier-based approach traditionally involves the assessment of an individual economic performance relative to the production technology that is used by all producers. These measures facilitate the identification of the sources of changes, which can in turn guide producers toward more efficient production practices. Particularly, De Koeijer et al. (2002) proposed a conceptual framework for quantifying sustainability on the basis of efficiency theory commonly used in economics. Sustainability was measured for a sample of Dutch sugar beet growers through estimating their technical efficiency, environmental efficiency, economic efficiency and profit efficiency. The study found that the technical efficiencies of the Dutch sugar beet growers were related to their economic and environmental efficiency and to their sustainable efficiency. Furthermore, the average technical efficiency of only 50% implied that there was considerable scope for improving sustainability even without any improvement of technology. Hoang and Alauddin (2012) also presented an input-orientated data envelopment analysis (DEA) framework which is one of two typical frontier methods to measurement and decomposition of economic, environmental and ecological efficiency levels in agricultural production across different countries. The application of the framework to an agricultural dataset of 30 OECD countries revealed that (i) there was significant scope to make their agricultural production systems more environmentally and ecologically sustainable; (ii) the improvement in the environmental and ecological sustainability could be achieved by being more technically efficient and, even more significantly, by changing the input combinations.

2.2.3. Conceptual framework

Following the literatures, particularly De Koeijer et al. (2002), sustainability of tea production in this study is evaluated through estimating technical efficiency, environmental efficiency, irrigation water use efficiency and profit efficiency. Sustainability of tea production is conceptualized as follows (Figure 2.2):

- Increased tea productivity via using resources more efficiently;

- Enhanced environmental quality, conserved natural resources, and produced safety products through reducing agro-chemical inputs in tea farming practices, increasing irrigation water use efficiency;
- Facilitated tea production adaptation to climate change via better water resource management
- Improved tea farmers' income and in turn their livelihood through increasing the profit efficiency of tea production;
- Promoted tea farmers' knowledge and attitudes about resource conservation.

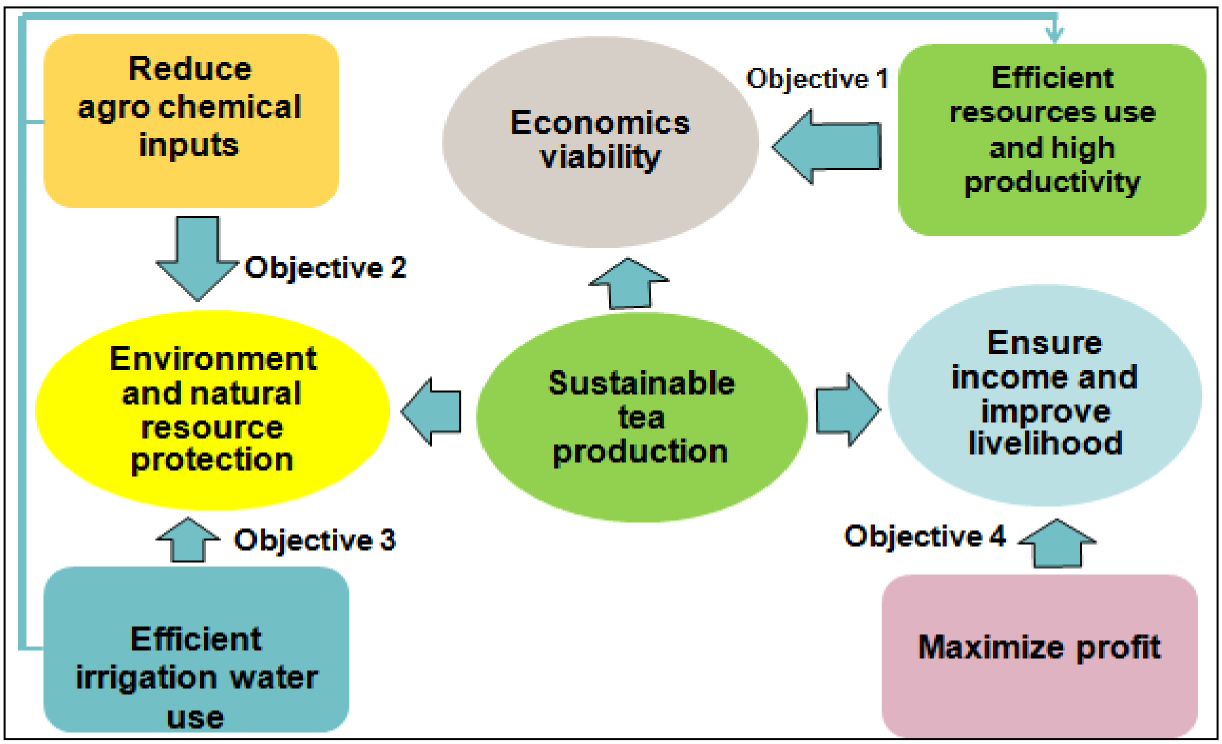


Figure 2.2: Conceptual framework

2.3. Theories of Efficiency analysis

2.3.1. Production frontier

The productive technology of a firm can be described using the production function:

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

Where: *y* represents output and *x* ia a vector of inputs

The properties of production function are:

F.1	*Nonnegativity:*	The value of $f(\mathbf{x})$ is a finite, non-negative, real number.
F.2	*Weak Essentiality:*	The production of positive output is impossible without the use of at least one input.
F.3	*Nondecreasing in* $\mathbf{x}$:	(or *monotonicity*) Additional units of an input will not decrease output. More formally, if $\mathbf{x}^0 \geq \mathbf{x}^1$ then $f(\mathbf{x}^0) \geq f(\mathbf{x}^1)$. If the production function is continuously differentiable, monotonicity implies all marginal products are non-negative.
F.4	*Concave in* $\mathbf{x}$:	Any linear combination of the vectors $\mathbf{x}^0$ and $\mathbf{x}^1$ will produce an output that is no less than the same linear combination of $f(\mathbf{x}^0)$ and $f(\mathbf{x}^1)$. Formally[3], $f(\theta\mathbf{x}^0 + (1-\theta)\mathbf{x}^1) \geq \theta f(\mathbf{x}^0) + (1-\theta) f(\mathbf{x}^1)$ for all $0 \leq \theta \leq 1$. If the production function is continuously differentiable, concavity implies all marginal products are non-increasing (i.e., the well-known law of diminishing marginal productivity).

A production frontier is denoted by Kumbhakar and Lovell (2003) as follows:

$$f(x) = \max\ \{y: y \in P(x)\} = \max\{y: x \in L(y)\} \tag{2}$$

Where: y is a scalar of output, x is a vector of inputs used in the production process

The production frontier reflects the current state of production technology. It provides the upper boundary of production possibilities, and the combination of input-output of each producer is located on or beneath production frontier. Producers operate either on that frontier, if they are technically efficient or beneath the frontier if they are not technically efficient (Figure 2.3)

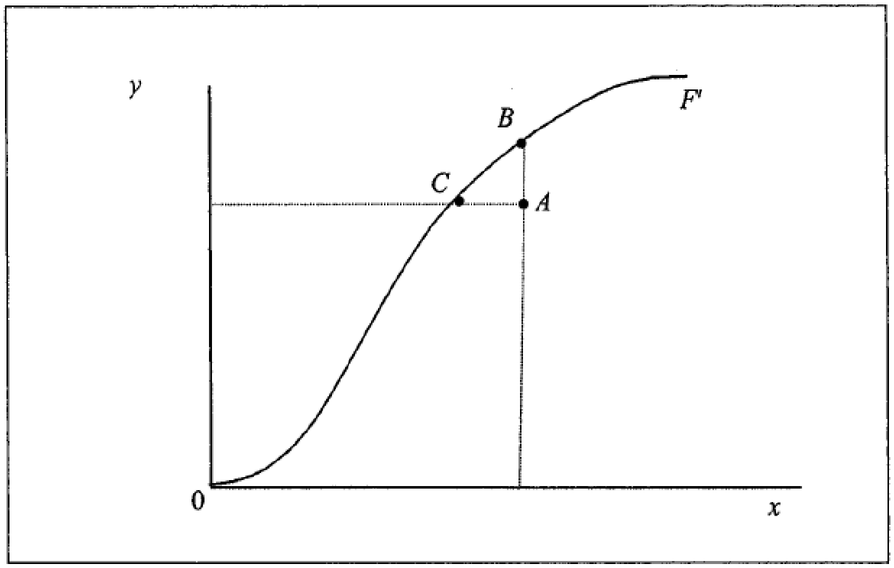


Figure 2.3: Production frontiers and technical efficiency

(Coelli et al. 2005)

The line OF' in Figure 2.3 represents a production frontier. Point A represents an inefficient point whereas points B and C represent efficient points. A producer operating at point A is inefficient because technically it could increase output to the level associated with the point B without requiring more input.

2.3.2. Profit frontier

In economic theory, the purpose of every producer is to allocate inputs and outputs to maximize profit. Profit is defined to be the difference between the revenue a firm receives and the cost that it incurs (Varian 1992). The profit function is given as following:

$$\pi(\mathrm{p}, \mathrm{w}) = max_{y,x} py - wx \quad (3)$$

Where: π is profit of each firm. p is a vector of output prices and w is a vector of input prices.

Irrespective of the properties of the underlying transformation function, the profit function will satisfy the following properties (Coelli et al.2005):

P.1 *Nonnegativity:* $\pi(\mathbf{p}, \mathbf{w}) \geq 0$

P.2 *Nondecreasing in* **p**: if $\mathbf{p}^0 \geq \mathbf{p}^1$ then $\pi(\mathbf{p}^0, \mathbf{w}) \geq \pi(\mathbf{p}^1, \mathbf{w})$.

P.3 *Nonincreasing in* **w**: if $\mathbf{w}^0 \geq \mathbf{w}^1$ then $\pi(\mathbf{p}, \mathbf{w}^0) \leq \pi(\mathbf{p}, \mathbf{w}^1)$.

P.4 *Homogeneity:* $\pi(k\mathbf{p}, k\mathbf{w}) = k\pi(\mathbf{p}, \mathbf{w})$ for $k > 0$.

P.5 *Convex in* (**p**, **w**): $\pi(\theta\mathbf{p}^0 + (1-\theta)\mathbf{p}^1, \theta\mathbf{w}^0 + (1-\theta)\mathbf{w}^1) \leq \theta\pi(\mathbf{p}^1, \mathbf{w}^1) + (1-\theta)\pi(\mathbf{p}^1, \mathbf{w}^1)$ for all $0 \leq \theta \leq 1$.

Kumbhakar and Lovell (2000) came up with the variable profit frontier function as:

$$v\pi(p, w, z) = max_{y,x}\{p^T y - w^T x\} \tag{4}$$

The variable profit frontier $v\pi(p, w, z)$ shows the maximum excess of total revenue over variable cost when producers were assumed to use variable input vector *x*, variable input prices *w*, fixed input quantities *z* to produce scalar of output *y* (y>0) with available output prices *p.* In other word, $v\pi(p, w, z)$ is the maximum variable profit obtained from given output and input prices with fixed input quantities.

If the firm produces only one output, the variable profit frontier function can be written as:

$$v\pi(p, w, z) = max\{pf(x, z) - wx\} \tag{5}$$

The first-order condition for single-output profit maximization problem is:

$$\frac{\partial y}{\partial \mathrm{x}_i} = \frac{w_i}{p} \quad i = 1, \ldots . n \tag{6}$$

This condition simply says that the value of the marginal product of each factor must be equal to its price. Particularly in the single-output case, it is frequently convenient to work with a normalized variable profit frontier. Since the variable profit frontier $v\pi(p, w, z)$ is homogeneous of degree (+1)[1] in (p,w), it is possible to divide maximum variable profit $v\pi(p, w, z)$ by p>0 to obtain a normalized profit frontier as:

$$v\pi(p, w, z)/p = max_{y,x}\left\{y - (\frac{w}{p})^T x\right\} \tag{7}$$

In determining its optimal policy, the firm faces market constraints which are those constraints that concern the effect of actions of other agents on the firm. The simplest kind of market behavior that firms will exhibit, namely that of price-taking behavior (Varian, H. R, 1992). Each firm will be assumed to take prices as given, exogenous variables to profit maximization problem. Thus, the firm will be concerned only with determining the profit-maximizing in the levels of output and input with given the input prices and the output prices they face.

2.3.3. Definition and measures of efficiency

Efficiency is an important objective in the production process. Farrell (1957) proposed that the efficiency of a firm consists of two components: technical efficiency and allocative efficiency.

Technical efficiency refers to the ability to obtain maximize output from a given set of inputs, or the ability to minimize inputs use in the production of a given set output (Koopman, 1951; Farell, 1957).

Allocative efficiency measures the ability to use inputs in optimal proportions, given their respective price and production technology (Coelli et al. 2005). It is concerned with choosing between different technically efficient combinations of inputs that are used to produce maximum feasible outputs.

The combination of technical efficiency and allocative efficiency provides a measure of total economic efficiency (Farell 1957, Coelli et al.2005). Economic efficiency refers to the

[1] A function is homogeneous of degree 1 if, when all its arguments are multiplied by any number t > 0, the value of the function is multiplied by the same number t.

ability to yield a given of outputs at minimum cost, or utilize a given of inputs to maximize revenue, or allocating inputs and outputs to maximize profit.

Following these definitions of efficiency, two measures of efficiency, the first being output-oriented measure and the second being input-oriented measure, are proposed by Debreu (1951) and Farell (1957).

The output-oriented approach to efficiency measurement is concerned with expanding the outputs, for a given level of inputs and production technology. The definitions of efficiency components based on an output-oriented approach are illustrated in Figure 2.4. Assume production involves two outputs (O_1 and O_2) and a single input (X). Assuming constant returns to scale, the technology is represented by a unit (of input) production possibility frontier, PP'. Take a point (A), which is operating below the PPF. The distance AC represents output-oriented technical inefficiency, which is the amount by which output could be expanded without adding extra input (George E Battese 1992). Output oriented TE is given by OA/OC (see Box 2.1), which indicates the deviation from the PPF. II' depicts the iso-revenue line, which is the different combination of quantities of outputs for a given amount of revenue. Then, for Point A, distance BC represents allocative inefficiency, which is the amount by which revenue could be increased if the producer at A was on the PPF at Point D. Thus, output-oriented allocative efficiency is = OC/OB. Output-oriented economic efficiency (also called revenue efficiency) is measured in terms of deviation from the iso-revenue line which is obtained by multiplying technical and allocative efficiency. Hence in Figure 2.2, economic efficiency = TE x allocative efficiency = OA/OB (Box 2.1).

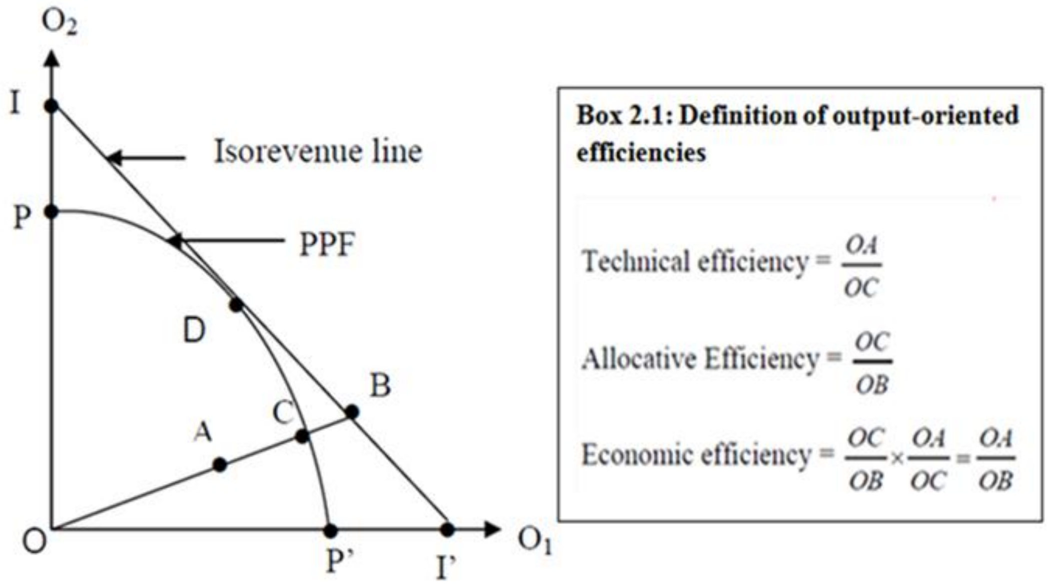
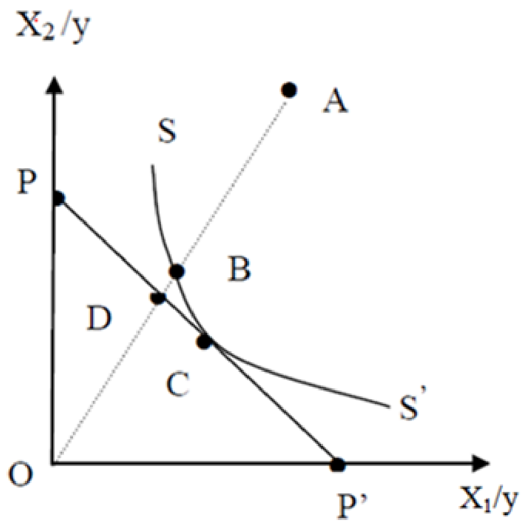


Figure 2.4: Output orientation efficiency measure

The input-oriented approach is concerned with how much contraction in inputs is possible in order to produce a given level of output. Input-oriented efficiency measures are illustrated graphically in Figure 2.5. Two inputs, X_1 and X_2, are used to produce a single output 'y' under the assumption of constant returns to scale. Assume curve SS'represents a unit isoquant of a fully efficient producer. If the producer is using quantities of inputs defined by Point A to produce a unit of output, then TE is given by the ratio OB/OA. The ratio indicates the proportional reduction in inputs to maintain the same quantity of output (lies along the unit isoquant). If PP' represents the input price ratio, then allocative efficiency is given by the ratio OD/OB. The ratio represents the potential reduction in cost if production were at Point C, which is allocatively and technically efficient. Economic efficiency is obtained by multiplying the technical and allocative efficiency, or the ratio OD/OA. Economic efficiency is also known as cost efficiency in the input-oriented case. Thus when a producer uses its resources allocatively and technically efficient then the producer is said to be economically efficient or cost efficient. Box 2.2 shows the mathematical expressions for technical, allocative and economic efficiencies.



Box 2.2: Mathematical expression of input-oriented efficiencies

Allocative efficiency = $\frac{OD}{OB}$

Technical efficiency = $\frac{OB}{OA}$

Economic efficiency = $\frac{\mathrm{OD}}{\mathrm{OB}} \times \frac{OB}{OA} = \frac{OD}{OA}$

Figure 2.5: Input orientation efficiency measure

A frontier production function approach to measure efficiency may not be appropriate when farms face different prices and have different factor endowments (Ali and Flinn 1989). This led to the application of stochastic profit frontier approach to estimate farm specific efficiency directly (Ali and Flinn 1989; Ali et al. 1994; Rahman 2003; Yotopoulos and Lau 1973). Within profit-function context, profit efficiency is the ability of a farm to achieve highest possible profit given the prices and levels of fixed factors of that farm (Ali and Flinn 1989). A measure of profit efficiency is provided by the ratio of actual profit to maximum profit:

$$\pi E(y, x, p, w, z) = (p^T y - w^T x) / \, v\pi(p, w, z) \qquad (8)$$

2.3.4. Methods for estimating efficiency

In literature, there have two typical techniques are applied to estimate efficiency such as: stochastic frontier analysis (SFA) and data envelopment analysis (DEA) (Bravo-Ureta et al. 2007; Coelli et al. 2005; Kumbhakar and Lovell 2003; Thiam et al. 2001). The former is a parametric approach or stochastic approach that simultaneously introduced by Aigner et al. (1977) and Meeusen and Van den Broeck (1977). The latter is a non-parametric approach or deterministic approach which proposed by Charnes et al. (1978). The deterministic model assumes that any deviation from frontier is due to inefficiency, while the stochastic model allows for statistical noise.

2.3.4.1. *Stochastic frontier analysis*

Aigner et al. (1977) and Meeusen & Broeck (1977) developed stochastic frontier model that assume that the output of a firm is a function of a set of inputs, inefficiency and random error. A general stochastic production function with a single output is given by:

$$y_i = f\left(x_{i;}\beta\right).\exp(\varepsilon_i) \tag{9}$$

$$\varepsilon_i = v_i - u_i$$

Where: y is output, x is a set of inputs, β is a set of parameters to be estimated and i denotes producers. ε_i is a composed error term consisting of two elements, v_i and u_i. The term v_i is a two-sided ($-\infty < v_i < \infty$) normally distributed random error ($v \sim N[0, \sigma_v^2]$) that represents the stochastic effects outside the farmer's control (e.g., weather; natural disasters, and luck), measurement errors, and other statistical noise. The term u_i is nonnegative random error term, independently and identically distributed as $N^+(0, \sigma_u^2)$ that represents the inefficiency effects of the farm (Coelli et al. 2005).

The stochastic frontier model is illustrated in Figure 2.6. Two producers (i and j) are considered for illustration. Producer i uses inputs xi and produces output Yi. If production had been under favourable conditions for which the random error vi is positive, and had been utilizing the inputs in an efficient way (u_i =0), production would have been $Y_i = [f(x_i; \beta).\exp(v_i)]$, which lies above the deterministic frontier $f(x; \beta)$. However, producer i is not utilizing inputs efficiently, hence production is y_i, which is below the deterministic frontier.

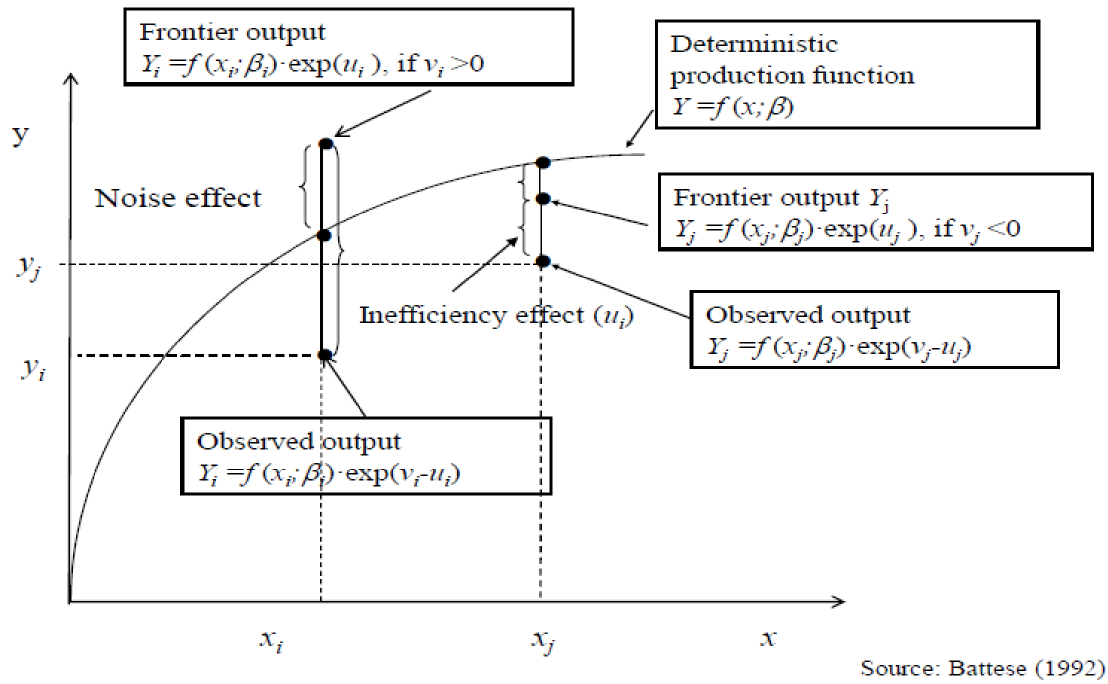


Figure 2.6: Illustration of Stochastic frontier analysis

On the other hand, producer j is producing output Y_j using inputs x_j, which is less than the value on the deterministic frontier $Y = [f(x; \beta)]$ because its productive activities are associated with unfavourable conditions, for which the random error is negative (v_j<0). In addition, producer j is not utilizing its inputs efficiently ($u_j \geq 0$). Observed production is Y_j which is given by $f(x_{i;}\beta).\exp(v_i - u_i)$ and reflects both random error and inefficiency.

In both cases, the observed production values are less than the corresponding frontier output values, and the frontier production values lie below or above the deterministic production function. Thus, the frontier itself is stochastic because of the presence of the 'exp(v)' stochastic component in the function $[f(x; \beta) \cdot \exp(v)]$ (Aigner et al. 1977; Schmidt & Knox Lovell 1979). Observed outputs lie below the deterministic frontier in both cases presented here, and there is the possibility that the observed output lies above the deterministic frontier $[f(x; \beta)]$ if $v_i > u_i$ (Battese 1992).

One of most important issues of stochastic frontier analysis is the prediction of inefficiency effect of individual farm. It can be estimated by using conditional distribution of u_i given the fitted values of ε_i and respective parameters (Jondrow et al. 1982). If we assume that v_i and u_i are independent each other, the conditional mean of u_i given ε_i is identified by:

$$E(u_i|\varepsilon_i) = \sigma^* \left[\frac{f^*(\varepsilon_i\lambda / \sigma)}{1 - F^* (\varepsilon_i\lambda / \sigma)} - \frac{\varepsilon_i\lambda}{\sigma}\right] \quad (10)$$

Where: $\sigma^{*2} = \sigma_u^2\sigma_v^2 / \sigma^2$, f^* is the standard normal density function, and F^* is the distribution function, both functions being estimated at $\varepsilon\lambda/\sigma$.

2.3.4.2. Data envelopment analysis

Following Farrell's input-oriented frontier model (Farrell 1957) Charnes et al. (1978) generalized the concept of two inputs and one output into the multiple outputs and inputs case and developed the data envelopment analysis. This technique involves the use of linear programming to calculate the production frontier (Thiam et al. 2001). The DEA technique is illustrated in Figure 2.7, which considers a case of two inputs (X_1 and X_2) and one output (Y).

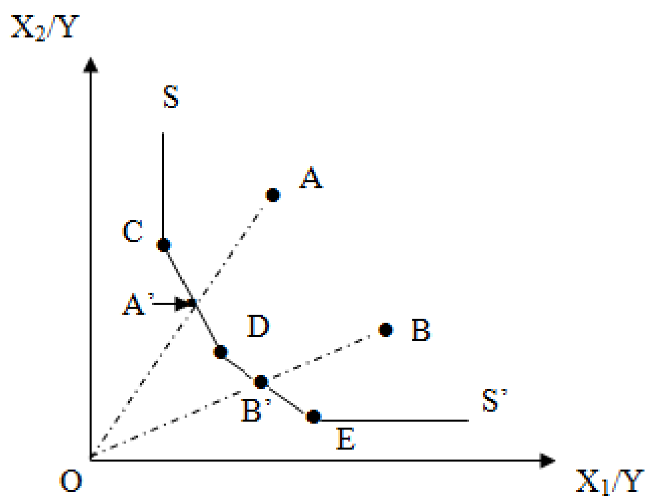


Figure 2.7: Illustration of Data envelopment analysis

A, B, C, D and E are five producers. The curve SS' represents the efficient frontier. Producers C, D and E are technically efficient, whereas producers A and B are away from the efficient frontier and, therefore these producers are inefficient. The level of inefficiency of A and B is determined by comparing the inputs (X_1 and X_2) used to produce a unit of output (Y), to the producer lying on the efficient frontier. The technical efficiency (TE) of producers A and B is given by their deviation from the efficient frontier, and hence, TE of A = OA’/OA, and

TE of B = OB’/OB.

The efficiency of producer A is evaluated by comparing it with a composite producer indicated by A’. The composite producer is a hypothetical producer derived from other efficient producers. For example, composite producer A’ is a weighted average of inputs of producers C and D.

The example used in Figure 2.7 has two inputs and one output. This makes it possible to illustrate the efficient frontier graphically. However, when multiple inputs and outputs are encountered in real world cases, linear programming is used to calculate the efficient frontier (Nyshadham and Rao 2000).

2.3.4.3. Strength and weakness of Stochastic frontier analysis and Data envelopment analysis

Stochastic frontier analysis and Data envelopment analysis have partial advantages and disadvantages (Table 2.2).

Table 2.2: Strengths and weaknesses of Stochastic Frontier Analysis and Data Envelopment Analysis method

Stochastic frontier analysis	Data envelopment analysis
❖ **Strengths** • Allowing separation of the shortfall in production due to random factors (such as variation in weather conditions and variations in measurement), from variations due to technical inefficiency (Coelli et al. 2005). • Since this model applies statistical theory for estimating efficiency, a formal statistical testing of hypotheses, parameters and the construction of confidence intervals is possible (Chen 2007; Hjalmarsson et al. 1996). It offers for a richer specification, particularly in the case of panel data ((Hjalmarsson et al. 1996)	❖ **Strengths** • Does not require any initial assumption about specific functional form linking inputs and outputs (Cooper et al., 2006), thus alleviating potential discrepancies due to assumptions regarding the use of specific functional forms (Coelli, 1995). • Handle multiple inputs and outputs together (Ondrich and Ruggiero 2001).
❖ **Weaknesses** • Require assumption of a probability distribution for the inefficiency term for which there is no theoretical justification (Murillo-Zamorano 2004). The distributional assumption influences the measure of efficiency (Coelli et al., 2005). For example, since half normal and exponential distributions have modes at zero, assuming inefficiency is distributed either half normally or exponentially, it implies that most of the producers are efficient and most efficiency values would be near one (Kumbhakar & Lovell, 2000; Murillo-Zamorano, 2004). • The SFA method is not applicable for the study of multiple outputs, particularly when outputs are jointly produced (Avkiran 2001).	❖ **Weaknesses** • Efficiency scores calculated using DEA are sensitive to outliers and number of observations (Nyshadham & Rao, 2000, Bravo-Ureta et al.,2007). • When using the DEA method, it is difficult to identify the correct set of inputs and outputs. This problem especially appears when a producer is using multiple inputs and outputs (Diaz-Balteiro et al. 2006). Use of a large number of inputs may shift the compared units towards the efficient frontier, resulting in a large number of units with high efficiency scores (Wagner and Shimshak 2007). • The DEA method assumes that the entire deviation of a producer from the production frontier is due to inefficiency and that there is no random error such as measurement error or error due to weather conditions (Coelli, 2005). This assumption has enormous implications in efficiency calculations. For example, if there is sampling variation and the input-oriented model is used, then the efficiency estimates are likely to be biased towards higher scores (i.e. towards 1) (Jun-Yen 2005). This bias will further increase if more efficient producers are not contained in the sample and only inefficient producers form the frontier (Latruffe et al. 2005) . • Parameters are not estimated in the DEA method. Parameters are important for the economic interpretation of a production process, by calculating economic characteristics such as elasticity of substitution, marginal products and returns to scale.

Since tea production is a case of single output and multiple-inputs production and frequently affected by weather conditions, diseases, and other exogenous random factors (noise effects), stochastic frontier analysis was applied for this study to calculate technical, environmental, irrigation water use, and profit efficiency.

2.3.5. Tobit model to analyze determinants of efficiency

To analyze factors which could have influence on efficiency, the Tobit model is often applied instead of Ordinary Least Square that might produce biased results (Bravo-Ureta and Pinheiro 1997).

The Tobit model is a statistical model proposed by Tobin (1958) to describe the relationship between a non-negative dependent variable y_i and an independent variable (or vector) x_i.

The model supposes that there is a latent (i.e. unobservable) variable y_i^*. This variable linearly depends on x_i via a parameter (vector) β which determines the relationship between the independent variable (or vector) x_i and the latent variable y_i^* (just as in a linear model). In addition, there is a normally distributed error term u_i to capture random influences on this relationship. The observable variable y_i is defined to be equal to the latent variable whenever the latent variable is above zero and zero otherwise.

$$y_i = \begin{cases} y_i^* \text{ if } \mathrm{y_i^*} \geq 0 \\ 0 \text{ if } \mathrm{y_i^*} \leq 0 \end{cases} \tag{11}$$

Where: y_i^* is a latent variable. $y_i^* = \beta x_i + u_i\, , u_i \sim N(0, \sigma^2)$

2.3.6. Applications of frontier functions method for estimating efficiency of agricultural production

The literature on agriculture production's efficiency using production frontier function methodology is abundant. Researches on tea production are however relatively scarce and results obtained from existing studies are very heterogeneous. We will focus on studies concerning agriculture and, in particular, the tea sector. The results obtained for other crops can be reasonably applied to tea.

Reviews of technical efficiency estimation in agriculture production using stochastic frontier production can be found in George E Battese (1992), Bravo-Ureta et al. (2007), and Thiam et al. (2001). Battese (1992) reviewed production frontier models in three sub-sections involving deterministic frontiers, stochastic frontiers and panel data models and conducted a survey of empirical applications in agricultural economics. The study showed that frontier production functions have been applied in the analysis of farm-level data in a large number of developed and developing countries. In particular, Thiam et al. (2001) analyzed 32 frontier studies using farm level data from 15 different developing countries. The author indicated that most attention from frontier researchers are in Asia (India and Philippines) and the farm level technical efficiency scores range from 17% to 100% with an average of 68%. Furthermore, Bravo-Ureta et al. (2007) reviewed 167 studies applied frontier analysis to farm level data around the world. The average output-oriented technical efficiency computed from all the studies reviewed is about 76.6%. The study revealed that most of studies applied stochastic frontier model, panel data, Cobb-Douglas functional form, and a primal representation of technology.

A number of studies have been undertaken to address the various aspects of profit efficiency. Most of these studies concentrated on estimating profit efficiency of rice production in some developing countries (Abdulail and Huffman 1998; Adesina and Djato 1996; Ali and Flinn 1989; Kolawole 2006; Rahma 2003). Profit efficiency has been measured various functional form (*i.e.* Cobb-Douglas, translog) using stochastic frontier method.

Regarding tea production, Basnayake and Gunaratne (2000) showed that the average technical efficiency of small tea producers in Sri-Lanka was 65%. The results of the study indicated that farmer's age, education level, occupation, crop variety, and farmer's experience can have significant impacts on efficiency. For Bangladesh, Baten (2010) found that the average technical efficiency was about 59%. For India, the average technical efficiency was 84.53% (Haridas et al. 2012). Concerning tea production in Vietnam, Nghia (2008) showed that organic tea production has a very high technical efficiency, about 99%. In their work, Saigenji and Zeller (2009) showed that the technical efficiency was on average 60%. They also indicated that contracted farming gained significantly higher technical efficiency compared to non-contracted farming. More specifically, technical efficiency of farms having a contract with a state-owned firm, a private firm or a cooperative, and those having no contract is on average 69%, 58%, and 47%, respectively. Other variables affecting technical efficiency were also examined, such as total land owned by the household, number of plots, age of tea tree weighted by area, number of extension usage, distance to the collecting point of tea leaves, use of motorbike to collecting point, poverty index. Karki et al. (2012) investigated factors determining the conversion to organic tea producing in Nepal. The authors observed that farmers who are better trained and have larger farm areas were more likely to adopt organic production. Results showed that farmers located in a distance from regional markets, older in age, better trained, affiliated with institutions and having larger farms are more likely to adopt organic production. Using factor analysis, the authors shows that environmental awareness, bright market prospects, observable economic benefit and health consciousness were the major factors influencing farmers' decisions on the conversion to organic production. Maity (2012) evaluated technical efficiency for tea production in West Bengal, India and found that increasing the size of tea gardens enhance efficiency.

In conclusion, all these studies showed clearly output-oriented technical efficiency of tea production which determined tea farms' possibility to maximize output levels with given set of inputs, but their limitation were not to estimate the input-oriented technical efficiency as well as environmental efficiency and profit efficiency. Furthermore, although irrigation water is becoming an important input for tea production in the context of climate change, there have no studies analyzing the efficiency of irrigation water use of tea production using frontier analysis in the world in general and in Vietnam in particular. The present study hopefully would fill this gap.

Chapter 3

Study area and Data

3.1. Introduction

This chapter provides details of fieldwork undertaken to collect data related to tea production in the Northern mountainous region of Vietnam. This chapter first presents the analytical framework, and then followed by a description of study area and data collection procedure.

3.2. Study area and data collection

As mentioned in the first chapter of this dissertation, tea in Vietnam is mostly produced in the Northern mountainous region which is one of the poorest areas in Vietnam (GSO 2013). In recent years, tea cultivation has been the primary motivator of the region’s economic growth. It has a total of 93,000 ha under tea, accounting for 71.6 percent of the nation‘s total cultivation area, and 64.7 percent of the country's total tea output (GSO 2013). In addition, in this area, tea production is dominated by small-scale households and ethnic minority people who face many difficulties, including inadequate access to land, water, agricultural support services and off-farm jobs. Therefore, boosting tea production in the Northern mountainous region is expected to motivate economic growth and have a positive impact on livelihood of poor people.

Besides, due to geographically disadvantaged settings, the reduction of natural water in the North mountainous region is more serious than other regions (Vien 2011). Furthermore, there are constantly growing risks of severe droughts and water shortage for irrigation use. The changing climate is also predicted to affect the North rather than the South of Vietnam (FAO 2011). Cook (2006) also pointed out that most water-scarce regions coincide with regions where most of the poor and food-insecure people live. Therefore, the Northern mountainous region of Vietnam is a typical case to study irrigation water use efficiency at micro-level. The results and conclusions drawn from the study are useful for two reasons. First, they could provide an important reference for other regions under a state of water shortage at present or in the future. Second, they are valuable for the sustainable water management in Vietnam in general and in the Northern mountainous region in particular, since they could help guide policies towards high irrigation water use efficiency.

The field survey was conducted in Thai Nguyen province, which first ranks in planting and producing tea in the Northern mountainous region with 17,300 ha of tea trees yielding about 184,400 tons per year (GSO 2013). Four representative communes of two famous tea-producing districts (Dong Hy district and Thai Nguyen city) in Thai Nguyen province were chosen to collect a cross-sectional data on tea production (Figure 3.1).

Figure 3.1: Study locations at the Northern mountainous region in Vietnam

The selected tea farms are representative of topographical conditions in tea production areas of Thai Nguyen province. Tan Cuong is well known for having the highest quality tea in Vietnam. Most of the tea farms are situated along the Cong River where fields are flatter (with 20% slope), whereas the farms in Phuc Xuan commune are grown on hillsides and uplands. Two communes, Minh Lap and Song Cau, are in Dong Hy district. Minh Lap commune is located about 24 km east of Thai Nguyen town (the center of Thai Nguyen city) and borders the sides of the Cau River. Most of the tea farms in the Minh Lap commune are on uplands and hillsides with slopes ranging from 15% to 30%. Song Cau commune, in contrast, is located in the northeast and about 20 km from Thai Nguyen town. Tea farms in the Song Cau commune are similar to those in the Minh Lap.

As the tea is a widely grown crop in the study region, a questionnaire was used to gather data during the harvesting period of 2014. A pre-test was made to revise the questionnaire before the formal survey. A total of randomly 280 tea growers were face-to-face interviewed by enumerators. Since it was difficult for farmers to recall information about their annual farming activities accurately, recording notebooks were also provided to all interviewees at the first survey meeting and were collected at the follow-up survey meeting as a source for cross-checking and re-calculating survey data. During the survey, the information regarding household characteristics, farm activities, quantities and value of tea output, quantities and costs of inputs was included. Regarding the input of water, the farmers were asked to report for the total number of irrigations, and per irrigation the date, duration, irrigation equipment applied, volume, and management practices. 37 respondents were excluded from the analysis because they failed to provide all the requested information. Finally, the sample used for technical, environmental and irrigation water use efficiency estimation consisted of 243 households. Because there had more 5 households getting negative profit, 238 observations were used for profit efficiency estimation.

In the analysis, the output variable was the total fresh tea yield which was measured in kilogram. The environmentally detrimental inputs considered were fertilizer including nitrogenous, phosphate, potash, complex, and others (measured in kilogram); pesticides (measured in litter), while conventional inputs are labor (measured in man days), irrigation water (measured in m^3), capital consisting of machine expenses (measured in thousand VND), and other costs in tea production (measured in thousand VND). It was noted that land is the foundation of agricultural production, where other inputs must depend on. In this sense, land was considered as the fixed factor in agricultural production and other inputs as variable factors. Therefore, the input and output variables were identified by per hectare terms, with the purpose of separating land and variable inputs in this study.

Table 3.1 presents a brief of the variables in frontier production models. Explanatory variables in Tobit model are described in Table 3.2. Both stochastic production frontier model and Tobit regression model are analyzed by STATA software version 11.

Table 3.1: Descriptive statistics of variables in production and profit frontier models

Variables	Mean	S.D	Min	Max
Fresh tea yield (kg/ha)	14,319.76	1,340.90	10,028.64	17,740.02
Fertilizer (kg/ha)	1,069.74	226.21	506.17	1,768.52
Pesticide (liter/ha)	120.82	23.30	62.95	200.00
Labor (man-day/ha)	398.05	132.11	169.75	976.86
Capital (thousand VND/ha)	2,384.98	2,238.39	164.99	17,045.00
Other cost(thousand VND/ha)	5,072.08	708.89	3,395.06	6,983.02
Irrigation water (m^3/ha)	1,580.46	556.11	429.98	3,018.21
Dried tea yield (kg/ha)	2865.55	267.49	2005.72	3548.00
Dried tea price (thousand VND/kg)	125.13	41.77	53.00	350.00
Profit (million VND/ha)	264.00	125.00	193.52	877.79
Fertilizer price (thousand VND/kg)	10.66	2.28	5.00	18.00
Pesticide price (thousand VND/liter	242.68	46.29	126.00	400.00
Labor wage(thousand VND/man-day)	111.11	33.31	50.00	210.00

Source: Estimation of the author

The results showed that the average tea yield was 14,319.76 kilograms (S.D=1,340.90 kilograms) and range from 10,028.64 kilograms to 17,740.02 kilograms. The large variability in standard deviation revealed that the sample farmers used inputs in different ways, which tended to affect their yield levels. Fertilizer is an important input to increase the productivity of tea. The mean fertilizer level per farm was 1,069.74 kilograms. There was a high variation in the amount of fertilizer application per farm with the range from 506.17 kilograms to 1,768.52 kilograms. The average use of pesticide is approximately 120.82 liters per hectare, with a range from 62.95 liter to 200 liters, representing a large variability among farms. This variability may depend on farm size and farmers` attitude and preference regarding the application of pesticide. The average utilization of human labor per hectare including hired and family labors was 398.05 man-days and range from 169.75 man-days to 976.86 man-days, indicating that farming activities are highly labor intensive. The range of irrigation water per hectare was from 429.98 m3 to 3,018.21 m3, with a mean of 1,580.46 m3, suggesting a wide range variation among farms.

In table 3.2, the average education level is around 10 years, suggesting that most of tea farmers graduated secondary school in Vietnamese education system. The results also show that farmers have longer experience on tea cultivation with the mean about 20 years. The average production area is around 0.26 ha and a range from 0.05 ha to 0.59 ha, suggesting the big variability of sizes among tea farmers in Vietnam. The results reveal that tea farmers in the Northern mountainous region of Vietnam have basic education level and longer experience in tea production, but mostly engaged in small-scale tea farming. The mean age of tea plant in the sample is quite young (around 15 years). According to Do and Le (2000), the most productive period of the tea age's life is from 10 to 30 years old. The tea age in the sample had stands ranging from 3-36 years old suggesting that most survey tea farms are in the most productive period. Farmers earned an average of 675.81 million VND per hectare from tea farming. They also earned an off-farm income at 0.08% of the total household income. This result suggests that tea production brings major income for farmers in the region.

Table 3.2: Descriptive statistics of farm – specific variables

Variables	Mean	S.D	Min	Max
Age (year)	45.02	9.42	21	70.50
Gender (1= male, 0=female)	0.66	0.48	0	1
Education (education level of household head in year)	10.10	2.15	5	16
Ethnicity (ethnicity of household head, 1=Kinh, 0= otherwise)	0.20	0.40	0	1
Experience (household head' farming experience in year)	19.74	9.38	5	50
Cooperative (1= if farmer participate in cooperative, 0=otherwise)	0.31	0.46	0	1
Household size (family member's number in person)	4.36	1.10	2	8
Tea age (years)	14.86	7.72	3	36
Soil and water conservation (SWC) (1= if farmer practices SWC technologies on the field, 0=otherwise)	0.41	0.19	0	1
Farm value (agricultural income in million VND/ha)	675.81	415.35	130.65	2,574.20
Non-agricultural income share	0.08	0.13	0	0.59
Extension (1 = if farmer accesses to extension services, 0= otherwise	0.84	0.37	0	1
Farm size (ha)	0.26	0.14	0.05	0.6
Water scarcity perception (1= if farmer recognizes water scarcity in the field, 0=otherwise)	0.18	0.39	0	1
Well water (1=irrigating tea field by well water, 0= otherwise)	0.50	0.50	0	1
Stream water (1=irrigating tea field by stream water, 0=otherwise)	0.15	0.36	0	1
Process machineries utilization (1= yes,0=no)	0.63	0.37	0	1
Linkage with enterprises (1=yes, 0=no)	0.69	0.41	0	1
Direct product marketing activities (1=yes, 0=no)	0.50	0.50	0	1
Market information access (1=yes, 0=no)	0.33	0.47	0	1

Source: Estimation of the author

Chapter 4

Technical efficiency and its determinants in Vietnamese tea production[2]

[2] Reprinted from: Hong, N.B. and Yabe, M. 2015. Resource Use Efficiency of Tea Production in Vietnam: Using Translog SFA Model. *Journal of Agricultural Science*, 7 (9), 160-172. doi:10.5539/jas.v7n9p160 .

4.1. Introduction

Vietnamese tea production is faced with many challenges. Vietnam remains a small player in the world tea market. In 2011, Vietnamese tea production accounted for 7 percent of global tea market, much lower than China (16 percent), India (16 percent), Sri Lanka (16 percent), and Kenya (15 percent) (Potts et al. 2014). As Vietnam continues its drive onward into twenty-first century tea production, it is increasingly forced to compete with those top producers, many of which are achieving comparatively higher yield and more efficient production. In fact, the tea industry in Vietnam is performing below its potential: yields and productivity are low (Asian Development Bank 2004). Addressing the emerging issues requires alternative adoption of technologies and practices that are easily accessible to and effective for tea farmers and can lead to improvements in tea productivity. Many researchers and policy makers have focused their attention on the impact that adoption of new technologies can have on increasing farm productivity and income (Hayami and Ruttan 1971). In Vietnam, considerable work is being done to improve technology and yield in tea production. However, the implementation of these practices is lagging (Wenner 2011). The problem is that tea production is dominated by small-scale rural farms. Most of rural farmers are not exposed to these new technologies and do not have access to basic resource. In cases where they have been exposed to it, financial constraints will not afford them the opportunity to use the technology. Hence, most tea farmers still depend on their conventional methods for farming. Furthermore, when farmers cultivate their crops with the existing technology inefficiently, applying new technologies is less cost-effective than using the existing technology (Shapiro and Müller 1977). Therefore, in short run, Vietnamese tea productivity should be increased by using the existing production technology. In this context, an understanding of the level technical efficiency and its determinants may contribute to the design of programs to increase the productivity of Vietnamese tea industry with given existing technology. The objective of the study is to estimate technical efficiency and its determinants of tea production in Vietnam using stochastic frontier approach. Based on technical details, the study will provide useful information on the direction in which farms should utilize resources efficiently toward improving tea productivity in the research site.

4.2. Analytical frame work

4.2.1. Technical efficiency

Technical efficiency (TE) is measured as the ratio between the observed output to the maximum output, under the assumption of fixed inputs, or, alternatively, as the ratio between the minimum input to the observed input, under the assumption of fixed outputs (Farell, 1957; Coelli et al., 2005). Two models of TE are primarily used in the efficiency literature. These are: (i) input-oriented (IO) technical efficiency, (ii) output-oriented (OO) technical efficiency. There are some basic differences between the IO and OO models so far as features of the technology are concerned. The models of technical efficiency graphically in case of a single input and a single output is described in Fig 4.1

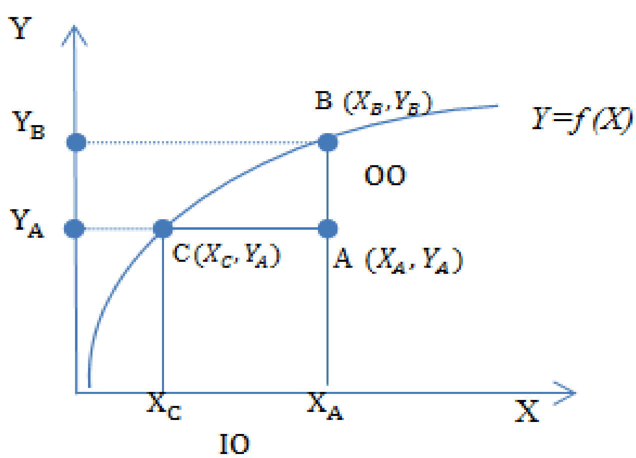


Figure 4.1: Technical efficiency concepts in the production frontier framework

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).

Aigner et al. (1977) and Meeusen and Van den Broeck (1977) developed the stochastic frontier analysis (SFA) to estimate output – oriented TE of firms/producers using parametric econometric techniques. Reinhard et al. (1999) followed the approach of Aigner et al. (1977) and Meeusen and Van den Broeck (1977), and then extended their approach to estimate environmental efficiency (EE) which measures the potential reduction of environmentally detrimental inputs. The authors also considered input-oriented technical efficiency by applying the similar manner of environmental efficiency measurement. Along the line of Aigner et al. (1977), Meeusen and Van den Broeck (1977), and Reinhard et al. (1999), this study estimates technical efficiency of tea production based on both output-oriented TE and input-oriented TE orientation.

We assume that a tea farm produces a vector of single output denoted as Y, with $Y \in R_+^M$ by using inputs X ($X \in R_+^N$). The stochastic production frontier function of the i-th tea farm is defined as following:

$$Y_i = f(X_i, \alpha)\exp(\varepsilon_i) \tag{1}$$

Where: All farms are indexed with a subscript i; Y_i denotes the fresh tea yield level; X_i is a vector of inputs (with X_{i1} is the fertilizer, X_{i2} is the pesticide, X_{i3} is the capital, X_{i4} is the irrigation water, X_{i5} is the labor , X_{i6} is the other cost); α is parameters to be estimated; ε_i is the composed error term, which is equal to $v_i - u_i$. The term v_i is a two-sided ($-\infty < v_i < \infty$) normally distributed random error ($v \sim N[0, \sigma_v^2]$) that represents the stochastic effects outside the farmer's control (e.g., weather; natural disasters, and luck), measurement errors, and other statistical noise. The term u_i is nonnegative random error term, independently and identically distributed as $N^+(0, \sigma_u^2)$ that represents the technical inefficiency of farm (Coelli et al. 2005).

Equation (1) estimated by the maximum likelihood analysis creates consistent estimators for $\alpha, \lambda,$ and σ. Where $\lambda = \sigma_u/\sigma_v$, $\sigma^2 = \sigma_u^2 + \sigma_v^2$.

According to Battese and Corra (1977), the ratio variance parameter γ which relates to the variability of u_i to total variability σ^2 can calculate in the following manner:

$$\gamma = \sigma_u^2/\sigma^2 \tag{2}$$

Such $0 \leq \gamma \leq 1$

If the value of γ is equal to zero, the difference between actual farmer yield and the efficient yield is entirely due to statistical noise. On the other hand, a value of one would indicate the difference attributed to the farmers' less than efficient use of technology i.e. technical inefficiency (Coelli et al., 2005).

The technical inefficiency of individual farm can be estimated by using conditional distribution of u_i given the fitted values of ε_i and respective parameters (Jondrow et al., 1982). If we assume that v_i and u_i are independent of each other, the conditional mean of u_i given ε_i is identified by:

$$\mathrm{E}(u_i|\varepsilon_i) = \sigma^* \left[\frac{f^*(\varepsilon_i\lambda \,/\, \sigma)}{1 - F^*\,(\varepsilon_i\lambda \,/\, \sigma)} - \frac{\varepsilon_i\lambda}{\sigma}\right] \tag{3}$$

Where: $\sigma^{*2} = \sigma_u^2\sigma_v^2 \,/\, \sigma^2$, f^* is the standard normal density function, and F^* is the distribution function, both functions being estimated at $\varepsilon\lambda/\sigma$.

The output-oriented technical efficiency of i-th tea farm is determined by the follow function:

$$TE_i = \frac{y_i}{f(X_i, \alpha)\exp(v_i)} = \exp(-E(u_i|\varepsilon_i)\,) = \exp(-\hat{u}_i) \tag{4}$$

Where: y_i is the observed fresh tea yield level of the *i*-th tea farm, $f(X_i, \alpha)\exp(v_i)$ is the maximum feasible of tea yield adjusted for statistical noise. TE_i score is between 0 and 1. A farm is fully efficient if TE equals to 1 and fully inefficient if its value is 0.

With the assumption of half-normal model, a simple z-test will be used for examining the existence of technical inefficiency, the null and alternative hypotheses are: H_0: $\lambda = 0$ (Coelli et al., 2005). The test statistic is:

$$z = \frac{\tilde{\lambda}}{se(\widetilde{\lambda})} \sim N(0,1) \tag{5}$$

Where: $\tilde{\lambda}$ is the maximum likelihood estimator of λ and $se(\widetilde{\lambda})$ is the estimator for its standard error.

To obtain a stochastic model of the input-oriented technical efficiency measure, a stochastic production frontier function needs to be specified. In this study, we used a flexible translog functional form to avoid excessive misspecification and ensure input-oriented TE measure based on random output elasticities and inefficiency effect (Reinhard et al., 1999). Equation (1) is written in translog form as follows:

$$\ln Y_i = \alpha_0 + \sum_j \alpha_j \ln X_{ij} + \frac{1}{2}\sum_j \sum_k \alpha_{jk} \ln X_{ij} \ln X_{ik} + v_i - u_i \tag{6}$$

Where: $\ln Y_i$ represents for the natural logarithm of tea yield of the *i*-th tea farm, *j*=1… 6, k =1,…,6 ; $\alpha_{jk} = \alpha_{kj}$

The logarithm of tea yield of an output-oriented technically efficient farmer apart from the statistical noise captured by the error term v_i is obtained by setting u_i =0 in (6). The logarithm of tea yield of an input-oriented technically efficient farmer apart from the statistical noise is obtained by replacing X_i with $X_{iF} = \delta_i X_i$ and setting u_i =0 in (6), where X_{iF} is minimum input, δ_i is input-oriented TE. The input-oriented specification is given by:

$$\ln Y_i = \alpha_0 + \sum_j \alpha_j \ln(\delta_i X_{ij}) + \frac{1}{2}\sum_j \sum_k \alpha_{jk} \ln(\delta_i X_{ij}) \ln(\delta_i X_{ik}) + v_i \tag{7}$$

Setting the output-oriented specification in equation (6) equal to the input-oriented specification in equation (7) permits the isolation of the logarithms of the stochastic input-oriented TE measure:

$$\sum_j \alpha_j \ln \delta_i + \frac{1}{2}\sum_j \sum_k \alpha_{jk} \left[(\ln \delta_i)^2 + \ln\delta_i\left(\ln X_{ij} + \ln X_{ik}\right)\right] + u_i = 0 \tag{8}$$

Resulting in

$$\frac{1}{2}\sum_j \sum_k \alpha_{jk} (\ln\delta_i)^2 + b_i(\ln\delta_i) + u_i = 0 \tag{9}$$

Where: $b_i = \sum_j \alpha_j + \frac{1}{2}\sum_j \sum_k \alpha_{jk} (\ln X_{ij} + \ln X_{ik})$

Application for the quadratic equation formula (9) gives the solution for the variable $\ln\delta_i$:

$$\ln\delta_i = \frac{-b_i \pm \sqrt{b_i^2 - 2u_i \sum_j \sum_k \alpha_{jk}}}{\sum_j \sum_k \alpha_{jk}} \tag{10}$$

According to Reinhard et al. (1999), a farm which is technically efficient from output-oriented perspective [u_i =0 in equation (6)] must also be technically efficient from an input-oriented perspective [$\delta_i = 1$ in equation (7)].

Thus, input-oriented TE in equation (10) is measured by using positive sign as follows:

$$\delta_i = \exp(\frac{-b_i + \sqrt{b_i^2 - 2u_i \sum_j \sum_k \alpha_{jk}}}{\sum_j \sum_k \alpha_{jk}}) \tag{11}$$

4.2.2. Determinants of technical efficiency

As efficiency scores from stochastic production frontier analysis varied between 0 and 1, the ordinary least square would produce biased and inconsistent estimates (Greene 2003; Bravo-Ureta and Pinherio 1997) . Thus, to investigate the relationship among farms' efficiencies and various farmers' socio-economic factors and specific farm characteristics, a two-limit Tobit regression model was applied in this study. The model is estimated as a function of various attributes of the farmers within the sample, indicating which aspects of the farm's human and physical resources might be targeted by public investment to improve efficiency (Wadud and White 2000, Speelman et al. 2008). Tobit model can be specified in the following form:

$$TE_i = \omega_0 + \sum_{s=1}^{16} w_{is} K_{is} + e_i \tag{12}$$

Where: TE_i is a scalar of efficiency scores of the *i*-th tea farm including output and input oriented technical efficiency; K_{is} represents social and economic features of the *i*-th farmers and tea farms including: Age (*s*=1), Gender (s=2), Education (*s*=3), Ethnicity (*s*=4), Experience (*s*=5), Cooperative (*s*=6); Household size (*s*=7), Tea age (*s*=8), Soil and water conservation (SWC) *s*=9), Farm value (*s*=10), Non-agricultural income share (*s*=11), Extension (*s*=12), Farm size (*s*=13), As an explanatory variable of irrigation water use efficiency, *water scarcity perception* variable (*s=14)* is proposed. As an explanatory variable of irrigation water use efficiency, we proposed *Water scarcity perception* variable. This assumption is based on the mechanism that perception increases intrinsic motivation which enhances environmentally friendly behavior (Lindenberg 2001). The status of water availability serves as an environmental stimulus, which must be intensive and frequent enough to trigger perception of water scarcity. In keeping with Tang et al. (2013), a farmer perceived water scarcity if he/she reports about facing water scarcity problems in irrigating farmland and understand that the problem may happen in the future. Based on this definition, *Water scarcity perception* is measured as a dummy variable (1=farmer who recognize water scarcity in the study site, 0= farmer who does not recognize);

In addition, since tea farms in the study site use three irrigation water sources (well, stream, and public irrigation system), two dummy variables for water source were added: Well water (*s*=15), Stream water (*s*=16). e_i is error term.

4.3. Results

4.3.1. Tea production function specification

Before estimating stochastic production frontier model, it is very essential to determine inputs that significantly affect output by using ordinary least square (OLS) (Bravo-Ureta and Pinheiro 1997). The OLS results show that *Fertilizer*, *Pesticide*, *Labor*, *Irrigation Water*, and *Capital* have considerable relationship with tea output at 5% level of significance, while the variable *Other Costs* was insignificant. As such, this variable was excluded from production model. Next, we tested multicollinearity and heteroskedasticity which cause the estimation in the model biased using Variance Inflation Factor (VIF) and Breusch-Pagan/Cook-Weisberg test (Wooldridge 2012). The results show that there have no multicollinearity[3] and heteroskedasticity[4] in the model. Furthermore, we specified the production functional form. The Cobb-Douglas function $(\text{null hypothesis: } \mathrm{H}_0)$ against the translog function $(\text{alternative hypothesis: } H_1)$ was tested using the log likelihood test (Coelli et al.2005). The likelihood ratio test statistic was equal to 50.07 which is greater than $\chi^2_{(15,0.5)} = 31.31$, thus Cobb-Douglas function form was rejected at 5 % level. With it, the translog production model with five significant inputs was used in this study. The estimates of translog production function ordinary least square (OLS) and maximum likelihood estimation (MLE) are presented in Table 4.1.

[3] Mean value of VIF is equal to 1.27

[4] Prob> chi-square =0.8080, indicating that the null hypothesis of constant variance is accepted

Table 4.1: Translog production function estimation

Variables	**OLS**		**MLE**	
	Coefficient	Std.error	Coefficient	Std.error
Fertilizer	7.354***	1.975	6.640***	1.685
Pesticide	-0.624	1.142	-0.887	0.943
Labor	1.516	1.001	1.960**	0.830
Irrigation water	0.551	0.869	0.533	0.678
Capital	-0.328	0.391	-0.373	0.325
Fertilizer. Fertilizer	-1.061***	0.284	-1.039***	0.231
Fertilizer. Pesticide	-0.056	0.159	0.028	0.136
Fertilizer. Labor	-0.081	0.104	-0.112	0.085
Fertilizer. Irrigation water	0.012	0.091	0.035	0.079
Fertilizer. Capital	0.100***	0.048	0.122***	0.039
Pesticide. Pesticide	-0.054	0.201	-0.022	0.188
Pesticide. Labor	0.010	0.085	0.058	0.083
Pesticide. Irrigation water	0.083	0.069	0.064	0.056
Pesticide. Capital	0.031	0.036	0.015	0.031
Labor. Labor	-0.040	0.092	-0.102	0.077
Labor. Irrigation water	-0.138**	0.056	-0.109**	0.050
Labor. Capital	-0.013	0.027	0.002	0.022
Irrigation water. Irrigation water	0.010	0.063	-0.023	0.055
Irrigation water. Capital	-0.028	0.023	-0.026	0.019
Capital. Capital	-0.030***	0.013	-0.048***	0.011
Constant	-20.778**	9.126	-18.623**	7.671
R^2	0.4268			
σ_v			0.034	0.006
σ_u			0.104	0.009
σ^2			0.012	0.002
$\lambda = \sigma_u/\sigma_v$			3.091	0.014
$\gamma = \sigma_u^2/\sigma^2$			0.901	

Note. **, *** indicate statistical significance of the 0.05, 0.01 level

Source: Estimation of the author

The R^2 is equal to 0.427, showing that around 42.7 percent of the variation of output is explained by inputs in the model. The presence of technical inefficiency effect in tea production was tested using z test. Using the results reported in Table 4.1 and function (5), we obtain $z_{statistic}=\frac{\tilde{\lambda}}{se(\tilde{\lambda})}=\frac{3.091}{0.014}=220.79$. This test statistic exceeds the critical value $z_{0.99}=2.334$, thus the null hypothesis that inefficiency effects were absent in the production model was rejected at 1 % level of significance, suggesting that the tea farms in the study site were technically inefficient. The results also pointed that 90.1 % of the variance of output was explained by technical inefficiency effects ($\gamma=0.901$).

Prior to estimate efficiency, the return to scale of existing tea production technology was considered. Table 4.2 reports the output elasticity per individual input.

Table 4.2: Output elasticity per specific input

Input	Fertilizer	Pesticide	Labor	Capital	Irrigation water	**Sum**
Elasticity	0.0454	0.1229	0.0679	0.0125	0.0754	0.3241

Source: Estimation of the author

The variable with the highest elasticity was *Pesticide* (0.1229), followed by *Irrigation water* (0.0754), *Labor* (0.0679), *Fertilizer* (0.0454), and *Capital* (0.0125). The sum of output elasticity (0.3241) is less than 1, indicating that Vietnamese tea production is under decreasing returns to scale. This means that equiproportional increase all inputs in tea production leads to a less than proportionate increase in output.

Parameters from maximum likelihood estimation of translog production model (Table 4.1) were used to estimate technical efficiency, environmental efficiency and irrigation water use efficiency.

4.3.2. Technical efficiency

We estimated output-oriented TE and input-oriented TE with the former calculated by using equation (4) and the latter by equation (11). The estimation results are summarized in Table 4.3.

Table 4.3: Output and input oriented technical efficiency distribution

TE levels	Output orientation			Input orientation		
	No of farm	**Percent**	**Cumulative**	**No of farm**	**Percent**	**Cumulative**
≤ 60	0	0.00	0.00	9	3.70	3.70
60-70	1	0.41	0.41	25	10.29	13.99
70-80	5	2.06	2.47	52	21.40	35.39
80-90	50	20.58	23.05	97	39.92	75.31
≥ 90	187	76.95	100.00	60	24.69	100.00
Mean		92.29			82.21	
Median		93.59			83.82	
Min		69.67			50.68	
Max		98.85			98.49	

Source: Estimation of the author

The average output-oriented TE was 92.29%, with the variation from 69.67% to 98.85%. This result suggests that the possibility of increasing current average output level, with given inputs is 7.71%. None of farms have TE score lower than 60%, indicating that most of tea farmers in the study site achieve rather high output-oriented technical efficiency. Due to decreasing returns to scale, input-oriented TE is expected to be lower than that of output-oriented TE. Respectively, the average input-oriented TE score is 82.21%, which is about 10.08% smaller than output-oriented TE. The tea farmers have the potential to reduce 17.79% observed levels of all inputs without compromising the current output level (Figure 4.2).

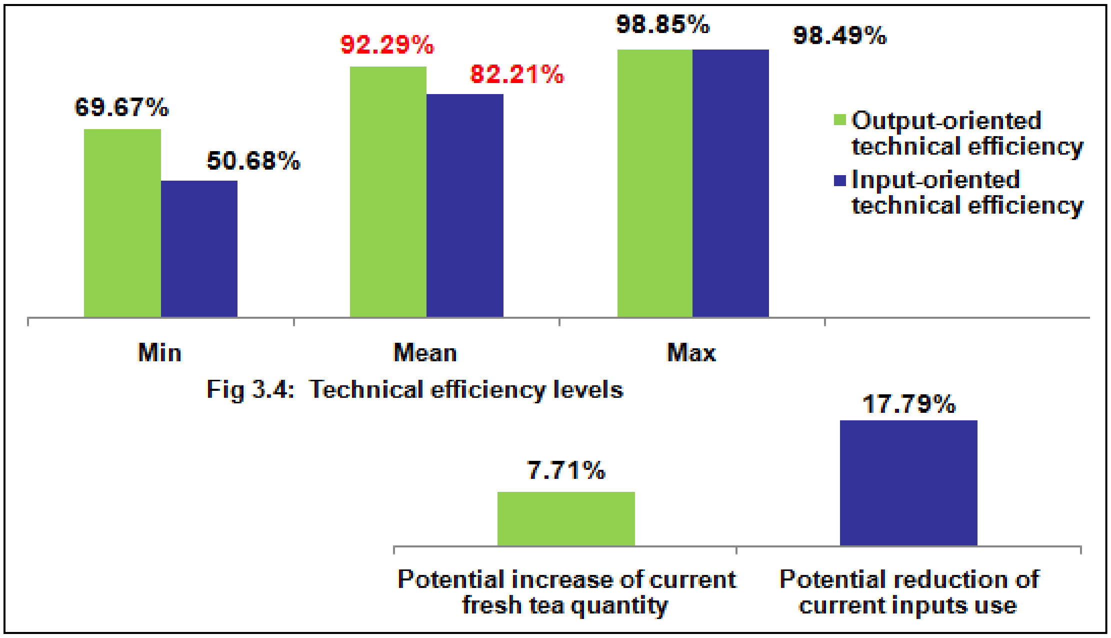


Figure 4.2: Technical efficiencies, potential increase of output and potential reduction of inputs

4.3.3. Factors affecting technical efficiency

The Tobit model was applied to determine the factors affecting TE of tea production instead of the OLS estimate producing biased results, often toward to zero (Bravo-Ureta & Pinheiro 1997). As shown in the equation (28), TE was used as dependent variable and the socio-economic characteristics of the farmers were used as independent variables.

The sign of the variables in the Tobit model is very important in explaining the observed level of technical efficiency of the farmers. A positive sign on the coefficient implies that variables had an effect in increasing technical efficiency, while a negative coefficient signifies the effect of reducing technical efficiency. The results shows that variables such as: gender, experience, soil and water conservation, farm value and extension have positive impact on technical efficiency.

Table 4.4: Determinants of technical efficiency in Tobit model

Variables	Explanation	TE_o	TE_i
		Coef.	Coef.
Age	HH age (years)	-0.0003	0.0003
Gender	HH gender (1=male, 0=female)	0.0382***	0.0201
Experience	HH experience in tea farming (years)	0.0005**	0.0009
Soil and water conservation	1=farmer employed SWC technology,0=otherwise	0.0021**	0.0149***
Farm value	Total value of agricultural product in natural logarithm	0.0137	0.0673***
Extension	1= farmer access to extension service, 0=otherwise	0.0573***	0.0859***
Water scarcity perception	1= farmer recognizes water scarcity in the study site, 0= farmer does not recognize water scarcity	-0.0020	0.0289**
Education	HH education level (years)	-0.0002	-0.0020
Household size	Number of member per household	0.0016	0.0021
Ethnicity	HH ethnicity (1=Kinh, 0= otherwise)	0.0010	0.0010
Tea age	The age of tea tree in years	0.0001	0.0004
Non-agricultural income share	Proportion of total income from non-agricultural sources	0.0090	-0.0003
Cooperative	1= farmer join cooperative, 0=otherwise	-0.0144	-0.0392
Farm size	Ha	-0.0137	0.0163
Well water	1=well water, 0=otherwise	0.0023	-0.0064
Stream water	1=stream water, 0=otherwise	0.0013	0.0148
Constant		0.8158**	0.3421**

Note. HH means household head, TE_o and TE_i indicate output-oriented TE and input- oriented TE, ** * and ** indicate statistical significance of the 0.01 and 0.05 level

Source: Estimation of the author

4.4. Disccusion and policy recommendations

We employed the translog stochastic frontier production function for cross-sectional data sets of 243 tea farms in 2014 to estimate technical efficiency in the Northern mountainous region of Vietnam. We also characterized tea farmers in to social and economic classes and evaluate their impact on resource use efficiency. The results showed that these tea farms have an average output- oriented TE level of 92.29 %, suggesting that farmers can still increase the current output level by 7.71%, given fixed inputs. However, the mean sum of output elasticity with respect to specific inputs is 0.323, indicating that those tea farms are decreasing return to scale. The average input-oriented TE score is 82.21 %, which is much less than that of output-oriented TE, indicating that those tea farms in the study site could reduce the use of inputs by 17.79% without compromising the current output level.

Although tea production in the study site is facing with the over utilization of inputs, the farmers seem to focus more on increasing output level than contracting input use. The proof of this affirmation is that 76.95% of the farmers have output-oriented TE above 90% while only 24.69% in case of the input-oriented TE (Figure 4.3).

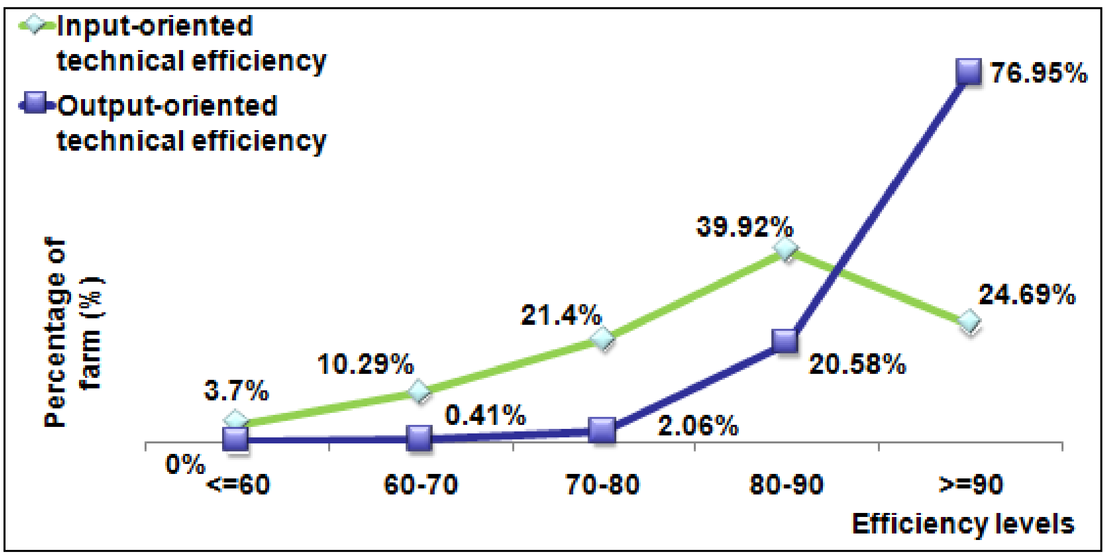


Figure 4.3: Distribution of technical efficiencies

In fact, the tea yield in the Northern mountain region is the highest compared with other region (GSO 2013). Under this context, input-orientation tea production technology which contract the utilization of inputs, especially environmentally detrimental inputs seems to be more appropriate in the region. This direction will promote tea production in the Northern mountainous region of Vietnam sustainably. This finding provides a empirical proof to persuade tea farmers to change their conventional farming practices which focus on increasing productivity by using inputs as much as possible.

The farmers' socio-economic and farm characteristics such as: gender, experience , applying soil and water conservation technology, accessing extension services, agricultural income, and water scarcity recognition were found to have significant influence on technical efficiency of tea production in the region.

Gender variable had positive effect to output-oriented technical efficiency. The positive sign of *Gender* variable shows that male head households have more ability to increase output than their female counterparts. This result is consistent with the findings of Due and Gladwin (1991) and Adesina and Djato (1997). Many factors explain the weakness of women's productivity. Women farmers often lack access to cash or credit to acquire modern yield-increasing inputs of production, they tend to produce less (Gladwin 2002). The level of productivity of women is constraint because most agricultural technologies are designed based on the assumption that farm mangers are men (Balakrishnan 2000). In reality, women farmers in the study site lack access to inputs, credit, and extension training because most of their time is spent doing housework like cooking, cleaning, washing, and caring children, apart from plucking and weeding possibly during the lean season. Most work in tea cultivation such as: buying inputs, fertilizing, pruning, spraying, managing fund, joining training courses is done by male farmers. Therefore, to improve women farmers' productivity in the region, women need to be better supported by increasing access to factors of production such as: land, credit, inputs, information and technology.

Experience variable also had positive effect to output-oriented technical efficiency. Farmers with much experience in tea farming can produce more output with given inputs as compared to those with less experience. This result is consistent with the finding of Basnayake and Gunaratne (2000).

The *Soil and water conservation* variable also had statistically positive effect on both types of efficiency. The effect is positive and significant at the 5% and 1% levels for output and input-oriented technical efficiency respectively. This indicates that famrers adopting of SWC technologies had more potential to expand output and to reduce inputs, compared with those who did not adopt these technologies. This result is consistent with Dang (2008), and Solis et al. (2006). In recent years, soil erosion resulting from bad farming practices on sloping lands, without attention to soil conservation, has been known to be a serious problem in the Northern mountainous areas of Vietnam. Soil erosion causes loss of productivity at all levels in this region (Thao 2001). Therefore, the promotion of soil and water conservation practices is very important measure to produce tea efficiently and sustainably.

Farm value had significant positive impact on input-oriented technical efficiency. The positive sign of *Farm value* suggests that for farmers with higher agricultural income, their productive efficiency will be increased through reduction of inputs. With higher income, farmers can have more chance to improve knowledge of modern cultivation techniques or buy good machines, which lead to inputs saving in production process.

It is clearly shown from Table 4.4 that *Extension* variables had positive significant effects on both types of technical efficiency at the level of 1 percent, implying that accessing extension services can help tea farmers not only increase output but also save inputs use. Kalirajan (1991), Xu and Jeffrey (1998), Seidu (2008), Saigenji and Zeller (2009), and Nyagaka et al. (2010) also found that agricultural extension services could help improving technical efficiency. Agricultural extension policy was designed in Vietnam to develop agriculure production in a sustainable way. Tea production is one of the most important sectors implementing this policy. Extension service includes serveral features such as: training courses or technical instruction on tea cultivation (land preparation, planting etc.), training on modern techniques of application of fertilizer and pesticde, training on harvesting and conservation, provision of information on tea market and sale skills. Extension service is important tool in educating farmers and it could bring positive behavioral changes among farmers. Thus, it is essential for Vietnamese tea farmers to have easy access to extension services in order to optimize on-farm technical efficiency, given the limited resources available.

Water scarcity perception had significant positive impact on input-oriented technical efficiency. This implies that farmers recognize water scarcity in the study site will tend to improve production efficiency by reducing the use of inputs, specifically in irrigation water use. This finding is consistent with Tang et al. (2013). The finding has the important policy that changing behavior, such as improving irrigation water use efficiency should be stimulated through spreading information about water scarcity to farmers.

4.5. Conclusions

As one of the most important economic activities to small households of Vietnam, tea production is hindered by low productivity, rising of production costs, and bad agriculture practices. To sustain tea production, the near-term strategy is to improve the efficiency of resource utilization. In this study, we employed the translog stochastic frontier production function for cross-sectional data sets of 243 tea farms in 2014 to estimate resource use efficiency in the Northern mountainous region of Vietnam. We also characterized tea farmers in to social and economic classes and evaluate their impact on resource use efficiency. The results showed that these tea farms have an average output- oriented TE level of 92.29%, suggesting that farmers can still increase the current output level by 7.71%, given fixed inputs. However, the mean sum of output elasticity with respect to specific inputs is 0.323, indicating that those tea farms are decreasing return to scale. The average input-oriented TE score is 82.21%, which is much less than that of output-oriented TE, indicating that those tea farms in the study site could reduce the use of inputs by 17.79% without compromising the current output level. This analysis yielded an important finding that changes tea farmers' opinion. Conventionally, the farmers often think that the best way to improve productivity is to increase output by using inputs as much as possible. In fact, the tea farms in the Northern mountainous region of Vietnam should make an effort on reducing inputs, which will help the farmers not only save production cost but also improve the environmental quality. This direction will promote tea production in the Northern mountainous region of Vietnam sustainably.

The farmers' socio-economic and farm characteristics such as: applying soil and water conservation technology, accessing extension services, increasing agricultural income, and raising water scarcity recognition were found to be significant in increasing resource use efficiency of tea production in the region. To improve resource use efficiency, the government should encourage the practice of soil and water conservation technology, implement extension services widely, and promote farmers' awareness on water scarcity. The study also reveals that women tea farmers tend to produce less efficiently than their male counterparts. Policies which aim at increasing female farmers' access to production inputs as well as extension services will be useful for increasing output-oriented technical efficiency of tea production.

Chapter 5

Environmental efficiency and its determinants in Vietnamese tea production[5]

[5] Reprinted from: Hong,N.B and Yabe, M. 2016. Environmental efficiency aand Economic losses of Vietnamese tea production: Implications for cost savings and environmental protection. *J.Fac.Agr.Kyushu Univ*.,61(2),383-390.

5.1. Introduction

Despite its importance to the economic development developing countries, like any intensive monocropping, tea production's environmental impact is considerable. In a review of six major tea producing countries (India, Indonesia, Sri Lanka, Kenya, Vietnam and Malawi), Van Der Wal (2008) reports that abundant application of chemical inputs is negatively affecting the local and wider environment in some countries such as India, Sri Lanka and Vietnam. Pesticides and chemical fertilizers are often used in tea farming to restore nutrients used by tea bush and to fend off parasites. The resulting soil degradation is a major issue that farmers usually address by using even more fertilizers and chemicals, which further compounds the soil degradation problem. Chemical runoff into waterways can also be a problem. The negative impact of excessive pesticide and agrochemical use in tea production on productivity, environment and human health (indirectly by retaining residues in tea products, water and soils) poses a grave threat to the sustainability of the tea farming system. This raises the challenge to reduce environmental pollution resulting from using agro-chemical inputs while sustaining tea productivity levels with the given sets of technology. Thus, the integration of environmental performance into technical and economic efficiency measures of tea production is essential. The objective of the present study is to analyze the environmental efficiency of Vietnamese tea farming using a stochastic frontier approach. Environmental efficiency examines the producers' ability to reduce the environmentally detrimental inputs applied (Reinhard et al .1999). The findings will provide insights into possible tea production improvements toward environment-friendly and sustainable development.

5.2. Analytical framework

5.2.1. Environmental efficiency

Diverse environmental performance indexes have been proposed in the past based on the adjustment of conventional productivity measures. They can be classified on the basis of whether they treat environmental impacts as inputs or outputs. The indexes are also categorized into those estimated using deterministic techniques, which can be either parametric or nonparametric, and those measured using stochastic techniques, which are only parametric.

Pittman (1983) was the first to develop an index of productivity change considering environmental effects as additional undesirable outputs. The author derives a translog multilateral productivity index that includes undesirable outputs (water and air pollution) as well as desirable outputs when assessing pulp and paper mills' productivity. Pittman's study not only made significant progress in multilateral productivity comparisons across firms, industries and countries but also suggested a valuable methodology for pollution control. However, the study ignores the bad inputs that are also pollutants. In addition, Pittman's productivity index calculation requires shadow prices because well-defined market prices do not exist for undesirable outputs.

Fare *et al.* (1989) also consider environmental effects as undesirable outputs. Utilizing the Pittman data, they include pollution measures in the production model and propose an "enhanced hyperbolic production efficiency measure" that examines the producers' ability to maximize desirable outputs and minimize either undesirable outputs and inputs or just inputs. They use nonparametric techniques known as Data envelopment analysis (DEA) to estimate their hyperbolic production efficiency. Different from a multilateral productivity index, the hyperbolic efficiency estimation uses output quantities and undesirable output emissions instead of shadow prices and considers the reduction of not only undesirable outputs but also bad inputs.

Pittman (1981) develops an environmental performance index in which pollution is modeled as an input in the production function. The author suggests that the relation between environmentally detrimental inputs and outputs is similar to the relation between conventional inputs and outputs. Following this approach, Reinhard et al. (1999) study the effects of nitrogen pollution on intensive dairy farms in the Netherlands. They utilize a stochastic translog production frontier model in which nitrogen surplus (pollution variable) is treated as an additional input variable. They estimate technical efficiency (TE) and environmental efficiency (EE). Technical efficiency is calculated in conventional output orientation as the ratio of observed to maximum feasible output. The measurement of environmental efficiency is the input-oriented technical efficiency of a single input, as the ratio of minimum feasible to observed use of nitrogen surplus, conditional on observed levels of the desirable output and conventional inputs. Reinhard et al. (2000) repeat this analysis with an extension to multiple environmentally detrimental inputs such as nitrogen surplus, phosphate surplus and energy using both stochastic frontier analysis (SFA) and data envelopment analysis (DEA). Similarly, this paper estimates the environmental efficiency of tea production with multiple environmentally detrimental inputs using stochastic production frontier model.

The first step of environmental efficiency estimation is to calculate technical inefficiency, which measures the failure of a firm/producer to achieve the maximum output with given and obtainable technology (Farrell 1957; Coelli et al., 1957). We assume that a tea farm produces a vector of single output denoted as Y, with $Y \in R_{+}^{M}$ using two types of inputs: conventional inputs (also known as normal inputs) X ($X \in R_{+}^{N}$), and environmentally detrimental inputs (also known as bad inputs) Z ($Z \in R_{+}^{L}$). The stochastic production frontier function of the *i*-th tea farm is defined as the following:

$$Y_i = f(X_i, Z_i, \alpha, \beta, \delta)\exp(\varepsilon_i) \tag{1}$$

Where: All farms are indexed with a subscript i; Y_i denotes the fresh tea yield level; X_i is a vector of conventional inputs (with X_{i1} is the labour, X_{i2} is the water, X_{i3} is the capital, X_{i4} is the other cost); Z_i is a vector of environmentally detrimental inputs (with $Z_{i1}$is the chemical fertilizer, $Z_{i2}$is the pesticide) (data were introduced in Table 3.1); α, β, δ are parameters to be estimated; and ε_i is the composed error term, which is equal to $v_i - u_i$. The term v_i is a two-sided (-∞ $< v_i < \infty$) normally distributed random error ($v \sim N[0, \sigma_v^2]$) that represents the stochastic effects outside the farmer's control (e.g. weather, natural disasters and luck), measurement errors, and other statistical noise. The term is a nonnegative random error term, independently and identically distributed as $\mathrm{N}^{+}(0, \sigma_u^2)$, that represents the farm's technical inefficiency (Coelli *et al.* 2005).

Equation (1) is calculated by the maximum likelihood estimation (MLE) in order to create consistent estimators for $\alpha, \beta, \delta, \lambda,$ and σ, where $\lambda = \sigma_u/\sigma_v$, $\sigma^2 = \sigma_u^2 + \sigma_v^2$.

The technical inefficiency of an individual farm can be estimated using conditional distribution of u_i given the fitted values of ε_i and respective parameters (Jondrow et al. 1982) (Equation 3).

To obtain a stochastic model of the environmental efficiency measure, the specification form of stochastic production frontier function needs to be specified. In this study, we use a flexible translog functional form to avoid excessive misspecification and ensure an environmental efficiency measure based on random output elasticities and inefficiency effect (Reinhard et al. 1999; Reinhard et al. 2000). Equation (1) is written in translog form as follows:

$$\ln Y_i = \alpha_0 + \sum_n \alpha_n \ln X_n + \sum_l \beta_l \ln Z_l + \frac{1}{2}\sum_n \sum_k \alpha_{nk} \ln X_n \ln X_k + \frac{1}{2}\sum_l \sum_h \beta_{lh} \ln Z_l \ln Z_h + \sum_n \sum_l \delta_{nl} \ln X_n \ln Z_l + v_i - u_i \tag{2}$$

Where: $\ln Y_i$ represents for the natural logarithm of tea yield of the i-th tea farm, $\alpha_{nk} = \alpha_{kn}$, $\beta_{lj} = \beta_{jl}$.

The logarithm of the tea yield of a technically efficient farmer apart from the statistical noise captured by the error term v_i is obtained by setting u_i =0 in (2). The logarithm of the tea yield of an environmentally efficient farmer apart from the statistical noise is obtained by replacing Z_i with $EE_i Z_i$ and setting u_i =0 in (2) to obtain:

$$\ln Y_i = \alpha_0 + \sum_n \alpha_n \ln X_n + \sum_l \beta_l \ln(EE_i Z_l) + \frac{1}{2}\sum_n \sum_k \alpha_{nk} \ln X_n \ln X_k + \frac{1}{2}\sum_l \sum_h \beta_{lh} \ln(EE_i Z_l) \ln(EE_i Z_h) + \sum_n \sum_l \delta_{nl} \ln X_n \ln(EE_i Z_l) + v_i \tag{3}$$

The output of the farm under consideration is defined in (2) to be equal to the output of the environmentally efficient farm defined in (3). Setting (2) and (3) equal permits the isolation of the logarithm of the stochastic environmental efficiency measure:

$$\sum_l \beta_l \ln EE_i + \sum_n \sum_l \delta_{nl} \ln X_n \ln EE_i + \frac{1}{2}\sum_l \sum_h \beta_{lh} \left[(\ln EE_i)^2 + \ln EE_i (\ln Z_l + \ln Z_h)\right] + u_i = 0 \tag{4}$$

resulting in

$$\frac{1}{2}\sum_{l}\sum_{h}\beta_{lh}\,(\mathrm{ln}EE_i)^2 + \varphi_i(\mathrm{ln}EE_i) + u_i = 0 \qquad (5)$$

Where: $\varphi_i = \sum_l \beta_l + \sum_n \sum_l \delta_{nl} \ln X_n + \frac{1}{2}\sum_l \sum_h \beta_{lh}\,(\mathrm{ln}Z_l + \mathrm{ln}Z_h)$. The φ_i term is equal to $\sum_l(\partial \mathrm{lnY}/\,\partial Z_l)$, the sum of output elasticities with respect to the environmentally detrimental inputs (Reinhard and Thijssen, 2000).

Application for the quaratic equation formula (5) gives the solution for the variable $\mathrm{ln}EE_i$:

$$\mathrm{ln}EE_i = \frac{-\varphi_i \pm \sqrt{\varphi_i^2 - 2u_i \sum_l \sum_h \beta_{lh}}}{\sum_l \sum_h \beta_{lh}} \qquad (6)$$

According to Reinhard et al. (1999), Reinhard and Thijssen (2000), environmental efficiency is caculated using the positive sign of the quadratic equation (6) because the technically efficient farm is essentially environmentally efficient. Finally, the environmental efficiency is estimated as follows:

$$EE_i = \exp(\frac{-\varphi_i + \sqrt{\varphi_i^2 - 2u_i \sum_l \sum_h \beta_{lh}}}{\sum_l \sum_h \beta_{lh}}) \qquad (7)$$

To get insights, it is essential to consider economic loss for each tea farm due to environmentally inefficiency. Total economic loss of the *i*-th tea farm is calculated in a manner similar to Tu (2015):

$$EL_i = (1 - EE_i)TC_i \qquad (8)$$

Where: EL_i is economic loss, EE_i is the environmental efficiency, and TC_i is total cost of bad inputs such as fertilizer and pesticide.

5.2.2. Determinants of environmental efficiency

The relationship among environmental efficiency, tea farmers' characteristics and farms' features (data were presented in Table 3.2) is also investigated by applying Tobit model. The specific model is:

$$EE_i = \omega_0 + \sum_{s=1}^{16} w_{is} K_{is} + e_i \tag{9}$$

Where: EE_i is environmental efficiency scores of the i-th tea farm; K_{is} represents social and economic features of the i-th farmers and tea farms including: Age (s=1), Gender (s=2), Education (s=3), Ethnicity (s=4), Experience (s=5), Cooperative (s=6); Household size (s=7), Tea age (s=8), Soil and water conservation (SWC) s=9), Farm value (s=10), Non-agricultural income share (s=11), Extension (s=12), Farm size (s=13), water scarcity perception (s=*14);* Well water (s=15), Stream water (s=16). e_i is error term.

5.3. Results

5.3.1. Environmental efficiency

The environmental efficiency of all bad inputs as well as individual inputs can be derived using equation (7). Table 4.5 gives the frequency distribution and cumulative distribution of the efficiency estimates.

Table 5.1: Environmental efficiency distribution

Environmental efficiency (%)	All bad inputs	Fertilizer	Pesticide
≤40	0 (0.00)	4 (1.65)	67(27.57)
40-50	5 (2.06)	10(4.12)	34 (13.99)
50-60	25(10.29)	50(20.58)	28 (11.52)
60-70	46(18.93)	58(23.87)	35 (14.40)
70-80	66(27.16)	56(23.05)	47 (19.34)
80-90	69(28.40)	50(20.58)	30 (12.35)
≥ 90	32(13.17)	15(6.17)	2 (0.82)
Mean	76.03	69.80	55.89
Min	46.26	37.17	7.07
Max	97.09	96.61	90.31

Note. EE indicates Environmental efficiency; the numbers in parentheses indicate percentages

Source: Estimation of the author

As shown in Table 5.1, the mean EE of all bad inputs is 76.03%, indicating that, tea farms in the study site overused fertilizer and pesticide. Conditional on observed levels of conventional inputs, tea farms could reduce by about 23.97% their consumption of environmentally detrimental inputs, such as chemical fertilizer or pesticide, without changing the current output level. Environmental efficiency scores range from 46.26% to 97.09%, suggesting that there is great variation among tea farms. The average environmentally efficient farm in the sample could reduce about 21.69% (i.e., 1-[76.03/97.09]) of the consumption of bad inputs. Similarly, the least environmentally efficient could also restrict use of bad inputs by 52.35% (i.e., 1-[46.26/97.09]). The average EE scores of *Fertilizer* and *Pesticide* are 69.80% and 55.89%, respectively. These results show that, if the farms focus on individual bad input, they may reduce either 30.20% of present fertilizer use or 44.11% of current pesticide use, while conserving observed output. In order to show clearly the differences about EE scores of fertilizer and pesticide, figure 5.1 ilustrates the percentage distribution of EE scores of these inputs.

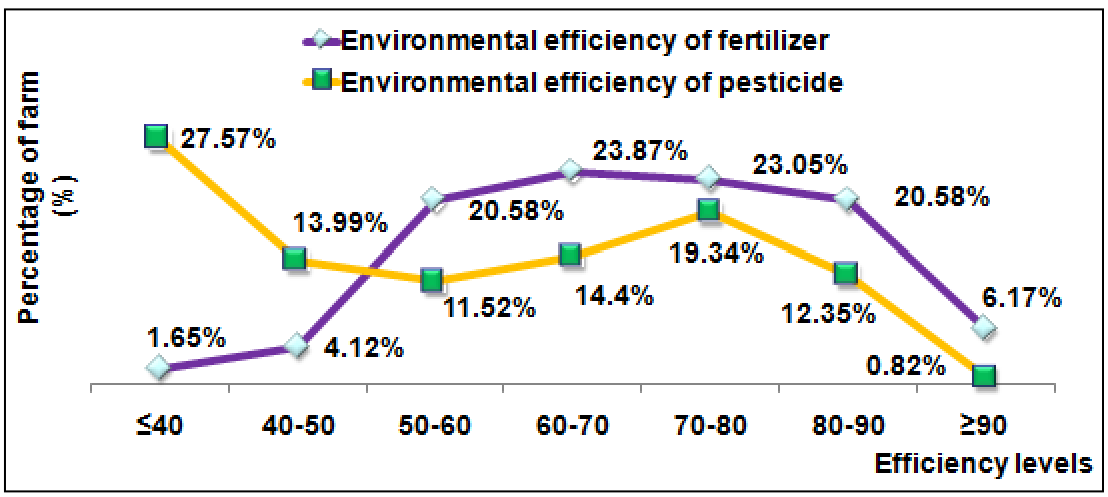


Figure 5.1: Distribution of environmental efficiencies of fertilizer and pesticide

As can seen from figure 5.1, 27.57% of tea farms got the efficiency of pesticide use less than 40%, while only 1.65% of the farms had the efficiency of fertilizer at that range. In higher efficiency ranges, percentage of the farms attained EE of fertilizer increased and higher than EE of pesticide. This result shows that pescide was overused more seriously than fertilizer.

To get insight into losses that tea farms suffer from environmentally inefficient production, we continue by estimating total economic loss using equation (8). The results are depicted in Table 5.2.

Table 5.2: Descriptive statistic of economic loss due to environmentally inefficient production

Economic loss per ha	Mean	75th percentile	Min	Max
(Thousand VND)	10,443.82	14,449.25	968.60	34311.52

Source: Estimation of the author

The mean economic loss of tea farms was 10,443.82 thousand VND (466 USD[6]) per hectare. Furthermore, 75% of the farms may save 14,449.25 thousand VND (646 USD) per hectare if environmental inefficiency is removed.

5.2.2. Determinants of environmental efficiency

The result of Tobit regression about the factors affecting to environmental efficiency was presented in Table 5.3.

Among explanatory variables, soil and water conservation, farm value, extension, and well water have significantly positive impact on environmental efficiency comparing insignificant remaining variables. The results suggest that the improvement in these factors can increase the efficiency of environmentally detrimental inputs such as chemical fertilizers and pesticide in tea production in the research site.

[6] 1 USD=22,411 Vietnamese dong (VND)

Table 5.3: Determinants of environmental efficiency in Tobit model

Variables	Environmental Efficiency	Fertilizer Efficiency	Pesticide efficiency
Age	0.0003	0.0003	-0.0004
Gender	0.0146	-0.0074	0.1841***
Education	-0.0020	-0.0024	0.0033
Household size	0.0021	0.0017	0.0002
Ethnicity	0.0015	-0.0024	0.0339
Experience	0.0010	0.0015	0.0006
Tea age	0.0009	0.0009	-0.0001
Soil and water conservation	0.0206***	0.0243***	0.0007
Farm value	0.1194***	0.1405***	0.0751
Non-agricultural income share	-0.0542	-0.0769	0.0958
Extension	0.0762***	0.0757***	0.1060***
Cooperative	-0.0517	-0.054 4	-0.0930
Farm size	0.0579	0.0861	-0.0874
Water scarcity perception	-0.0167	-0.0051	-0.1031
Well water	0.0345**	0.0316**	0.0471**
Stream water	0.0575	0.0605	0.0372
Constant	-0.0321*	-0.2101*	-0.0184*

*Note: *, **, *** indicate 10%, 5%, 1% of significance level*

Source: Estimation of the author

5.3. Discussion and policy recommendations

In recent years, the tea industry has brought tremendous change to Vietnam. The resulting economic growth has prompted poverty reduction and job creation for millions of poor households, but it has also provoked growing concerns about environmental pollution and ecological deterioration because of environmentally detrimental inputs, which threatens product safety and human health. At present, Vietnamese tea is known in the world market to be of low quality and to have high chemical residue. In this context, the tea sector should be reviewed and adjusted make economically efficient use of environmentally detrimental inputs like chemical fertilizer and pesticide, reduce environmental pollution, ensure food safety and increase its competiveness in international market. By applying stochastic frontier analysis, we obtain tea production's environmental efficiency, based on data collected from 243 Vietnamese tea farmers. The findings in our study may provide policy makers with useful information about the relative performance of chemical fertilizer and pesticide used in tea farming as well as possible ways to improve such performance.

High environmental inefficiency (23.97%) of both chemical fertilizer and pesticide inputs indicates a potential for substantial reduction of these environmentally detrimental inputs. Through such an adjustment in production operation, on average 10,443.82 thousand VND (466 USD) per hectare could be saved from the cost of inputs. These findings provide empirical evidence for the need to decrease chemical fertilizer and pesticide application in Vietnamese tea production. They contribute to clearing the way for green production in this nationally strategic sector, marked for green growth in the 2011–2020 period and in the vision for 2050 (Decision 1393/QD-TTg approved on September 25th, 2012 by the Prime Minister). Another implication of environmental efficiency scores is that tea farms within the study area have been intensively using agrochemical inputs. When considering specific input, pesticide is the least environmentally efficient, indicating that it is overused more seriously than chemical fertilizer. This result is consistent with the study of Lamers et al. (2013).

Variables such as soil and water conservation, extension, and farm value have also positive influences on environmental efficiency, which is similar with their impact on technical efficiency. These results reconfirm that promoting the application of soil and water conservation techniques on tea farms in the NMR region and improving extension services system play very important role in restructuring tea production sustainably. It is observed during the field survey that, although farmers recognize the overuse of bad inputs, they feel too vulnerable and insecure to change the current practices. Therefore, they still choose to apply these inputs to avoid crop losses. Focus group discussion and interviews with key informants reveal that the main reasons for this problem are farmers' expectation of high yield from small land holdings and lack of awareness about the risks involved in the overuse of inputs in addition to knowledge about how to use them correctly, which is similar to the findings of Ngo et al. (2001). Other reasons are insufficient guidance and training in inputs use and poor awareness of resource scarcity. Cheap prices, various brands, and easily accessible input markets all encourage farmers to use excessive doses of chemical fertilizer and pesticide. This fact suggests that substantial reduction of environmentally detrimental inputs can be attained through raising awareness among farmers about the negative influences of the overuse of agrochemicals and the scarcity of resources. Furthermore, eco-friendly agriculture and integrated pest management practices must be strengthened in the study site. Training programmes and technical activities about the principles and techniques of proper input handling together with demonstration on plots should be better held in the area. It is also essential to promote the use of natural fertilizers such as green compost and manure in tea farming. Finally, increased monitoring of the agrochemical inputs market plays important role in encouraging tea farmers to reduce these inputs.

5.4. Conclusions

This study utilizes stochastic frontier analysis to measure the environmental efficiency of Vietnamese tea farms, taking explicitly into account the economic effects of chemical fertilizer and pesticide on tea production. We found that these environmentally detrimental inputs are overused in the farms, and there is considerable scope for decreasing their application with the current technology. Agricultural policies target in widening soil and conservation techniques application and improving extension services will assist tea farmers to increase environmental efficiency which not only conserves environment but also saves production costs.

Chapter 6

Irrigation water use efficiency and its determinants in Vietnamese tea production[7]

[7] Reprinted from: Hong, N.B. and Yabe, M. 2016. Improvement in irrigation water use efficiency: a strategy for climate change adaptation and sustainable development of Vietnamese tea production. *Environment, Development and Sustainability*, Springer: Netherland, 1-17. doi 0.1007/s10668-016-9793-8.

6.1. Introduction

The global tea production is confronting with unprecedented challenges, particularly from climate change and water scarcity, which threatens the future of this favored drink. Increasing temperatures and changing rainfall patterns, which cause drought and water scarcity, have already affected the quantity and quality of tea production, further threatening the livelihood security of susceptible tea smallholders in many major tea-producing countries such as China (Ahmed 2014), India (Dutta 2014), Kenya (Kabubo-Mariara and Karanja 2007), Sri Lanka (Wijeratne et al. 2007), and Vietnam (Krechowicz et al. 2010).

In many climate change-affected regions where dry season becomes longer, tea growers have to depend on irrigation instead of rainfed amid the global severe water scarcity. Irrigated tea-based cropping systems are among the major water users in Vietnam. The total irrigated tea area was 62,551 hectares in 2005 (FAO 2015). Irrigation plays an important role in Vietnamese tea production, especially during dry season starting November to May (VietnameseTeaAssociation 2009). Water scarcity in Vietnam has worsened due to climate change, aside from challenges brought by agriculture production and rapid industrialization and urbanization (Giang et al. 2012). Water demand for Vietnamese agriculture may double or triple by 2100 relative to 2000. At the same time, the severe drought and water shortage for irrigation are constantly growing. The changing climate is also predicted to affect the Northern part of Vietnam seriously (FAO 2011). The increasing scarcity of water and competing claims on water by other sectors necessitate a more efficient use of water resources for agriculture in general and tea production in particular. This study aims to estimate tea production's irrigation water use efficiency and detect its determinants. It is highly relevant given the increased pressure on water resources and limited supplies of irrigation water in tea production. It not only raises awareness on water use inefficiencies in tea sector but also suggests ameliorations for this problem through analyzing the factors affecting these inefficiencies.

6.2. Analytical framework

6.2.1. Irrigation water use efficiency

Increasing *water use efficiency* is considered as a crucial mitigation in water resource management under the context of global water scarcity, climate change and food demand rising (Allan 1999, Gleick 1993, Pereira 2009, Rockstrom and Barron 2007). Literatures on measurements of irrigation water use efficiency are found in Barker et al. (2003), Billi et al. (2007), Molden et al. (2010), Pereira et al. (2012), Scheierling et al. (2014), Schoengold and Zilberman (2007), Sharma et al. 2015, Seckler et al. (2003), Van Halsema and Vincent (2012), and Viaggi et al. (2014). These studies summarized that there have two major methods used to measure water use efficiency including: hydrological or engineering approach and the economic approach.

In hydrological science, irrigation water use efficiency is given by the ratio of crop yield to actual water consumption, i.e., yield per m^3 (Billi et al. 2007, Sharma et al. 2015, Wang et al. 2010, Zhang et al. 2004). However(97), this physical measurement overlooked that output is influenced by multiple inputs (fertilizers, pesticide, seeds, machine, labor, water) and not only by a single input (water) (Scheierling et al. 2014, Wichelns 2014). Speelman et al. (2008) indicated that such measure considers agricultural production as a process using only water to produce output and explains very little the differences among farmers. In addition, T. Coelli et al. (2002) argued that irrigation water efficiency, as defined above, is little applied when the utilization of non-water inputs among farms are different, and it does not fully reflect the efficiency of resource utilization in agricultural production as compared with the economic approach named technical efficiency which is introduced by Farrell (1957). Technical efficiency denotes the farmer’s ability to maximize output from a given set of inputs (output-orientation) or to minimize inputs used to yield a given output level (input-orientation). Hence, it is essential to measure irrigation water use efficiency using economic method.

According to economic point of view, irrigation water efficiency can be denoted as a single-factor input-oriented technical efficiency which is the proportion of the minimum possible amount of water to the actual volume of water used, given observed output, and other inputs (Karagiannis et al. 2003). The concept of single-factor input-oriented technical efficiency was devised by Kopp (1981) (100) and Atkinson and Cornell (1994). (101) (78) (101) Specifically, irrigation water use efficiency *(IE)* is given as:

$$IE = [\min\{\lambda: f(X, \lambda W; \alpha) \geq Y\}] \rightarrow (0,1) \quad (1)$$

Where: λ is the irrigation water use efficiency. W is the actual volume of irrigation water used, λW is minimum possible amount of irrigation water. X represents other inputs (fertilizer, pesticide, labor, capital, other costs…etc). Y is the observed output. α is a vector of unknown parameters.

This definition focuses on economic aspect of the irrigation water use instead of engineering aspect (Karagiannis et al. 2003). It provides information on amount of water reduced without changing the quantities of output produced and other inputs used. Figures 6.1 and 6.2 described the measure of technical and irrigation water use efficiency.

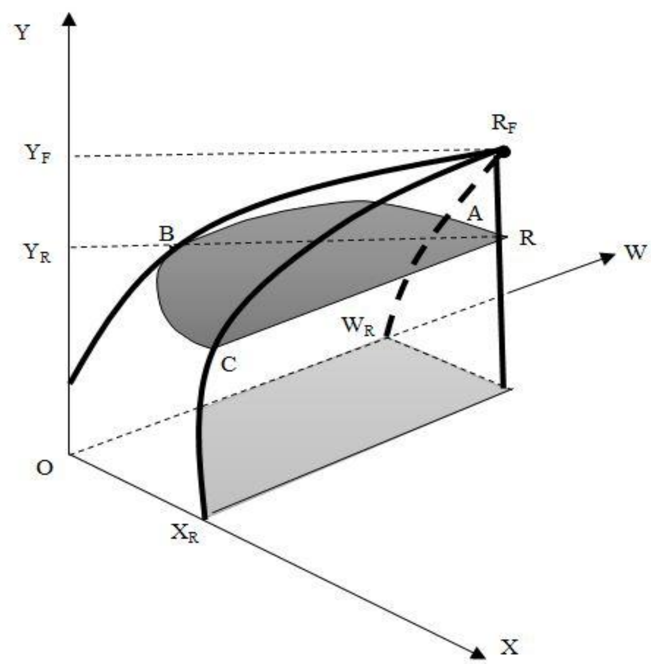


Figure 6.1: 3-D graphical illustration of technical efficiency measures

Note: Figure 6.1 is based on Reinhard et al. (1999)

Figure 6.1 illustrates the production of output (Y) by using irrigation water use (W) and other used inputs *(X)*, such as fertilizer, pesticide, labor, capital, etc. The surface $OX_RR_FW_R$

describes the production frontier[8]. The point R_F presents the best production performance with maximum possible output (Y_F) produced by using irrigation water (W_R) and other inputs (X_R), while the point *R* depicts observed farm *R* producing the actual output (Y_R). The surface *ABCR* represents the output quantity identity, Y_R , as farm *R*. In figure 1, the observed farm *R* is technically inefficient, since it does not produce the maximum output level as R_F and overuse inputs compared with *B* or *C* which produce identical output level. The technical inefficiency can be improved by: increasing output level from *R* to R_F (output-oriented orientation) or reducing the level of all inputs used from *R* to *B* (radial input-oriented orientation) or contracting the level of a single input given other inputs from *R* to C (non-radial input-oriented orientation). In figure 2, a radial input-oriented technical efficiency, which considers the reduction of all inputs, is measured by $|OB| / |OR|$. Since irrigation water use efficiency is a non-radial input-oriented technical efficiency, which considers the contraction of single input as water, conditional on other inputs and observed output, it is measured by $|X_RC| / |X_RR|$=$|OW_F| / |OW_R|$. Fare (1978) indicated that the non-radial measure is less than or equal to radial efficiency measure.

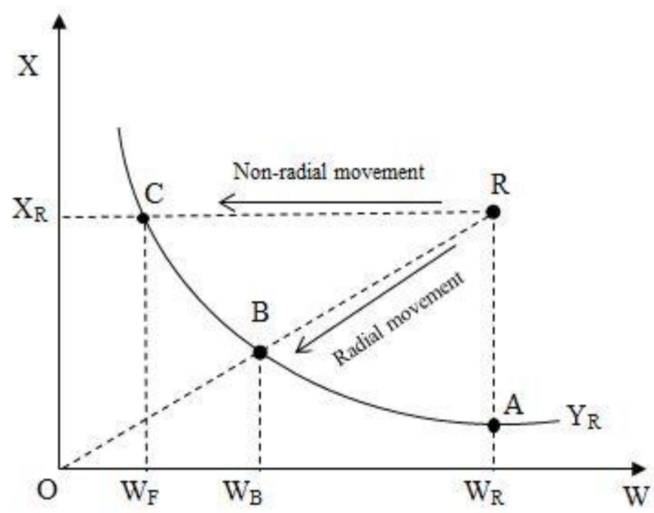


Figure 6.2: Cross-sectional graph of input-oriented technical and irrigation water use efficiency measures

Note: Figure 6.2 is based on (Karagiannis et al. 2003)

In economic literature, two methods are widely-used to estimate irrigation water use efficiency. First is the econometric approach named Stochastic Frontier Analysis (SFA), which is

[8] Production frontier shows maximum output possibilities that can be produced with a given of inputs used (Gans et al. 2011)

devised by Aigner et al. (1977) and Meeusen and Van den Broeck (1977). Reviews of using stochastic frontier analysis to estimate irrigation efficiency water use can be found in Dhehibi et al. (2007), Karagiannis et al. (2003), McGuckin et al. (1992), Tang et al. (2014), and Watto and Mugera (2015). For instance, Karagiannis et al. (2003) proposed SFA to estimate irrigation water efficiency of 50 off-season vegetable growing farms in Crete, Greece. The study showed that irrigation water efficiency, on average, is 47.20%, suggesting that 52.8% saving of water use could be achieved without affecting current quantity of vegetables and given other inputs. In addition, the most significant factors having influence on irrigation water efficiency of vegetable farms are modern greenhouse technologies, education, extension, farming concentration, chemical utilization, and ratio of rental land. Meanwhile, Tang et.al 2014 analyzed irrigation water use efficiency of 800 farmers in the Guanzhong Plain, Shaanxi, China in the period 1999-2005 and found that mean irrigation water use efficiency for a period of 6 years is 15.77%. Water price and disclosure of water use and water price management procedures affect water use efficiency positively. Second is the non-parametric method named Data Envelopment Analysis (DEA). This method used to estimate irrigation water use efficiency in some studies, such as M. K. Ali and Klein (2014), Frija et al. (2009), Gadanakis et al. (2015), Speelman et al. (2008), and (Wang 2010). For example, Speelman et al. (2008) used DEA to analyze water use efficiency of 60 farmers in the North-West province, South Africa and revealed that the mean efficiency of water use is 43% under constant returns to scale and 67% under variable returns to scale, indicating that a considerable quantity of water use could be saved. The size of farm, land right, fragmentation, the feature of irrigation system, the selection of crop, and irrigation methods were found to be significantly related to the efficiency of irrigation water. Moreover, Gadanakis et al. (2015) applied DEA to evaluate the efficiency of water use of 66 horticulture farms in England. The author showed that the average water use efficiency of the farms is 65%, hence 35% reduction in water use could be achieved while maintaining the present output. The study also revealed that the factors having positive influence on water use efficiency are the use of a decision support tool, recycling water, and the installation of trickle/drip/spray/lines irrigation. On contrary, the negative-affecting determinant is the use of overhead irrigation system.

We suppose that a farm yields a quantity of fresh tea Y ($Y \in R_{+}^{M}$) by using a vector of inputs X ($X \in R_{+}^{N}$, X including fertilizer, pesticide, labor, capital, other costs) and irrigation water W. The stochastic frontier production function of the farm is given by:

$$Y_i = f(X_i, W_i, \alpha)\exp(\varepsilon_i \equiv v_i - u_i) \tag{2}$$

Where: α is a vector of unknown parameters; ε_i is the composed error term. Particularly, the term v_i denotes statistical noises and random factors (weather, natural disasters, luck…), while the term u_i indicates the inefficiency effects (Coelli et al. 2005)

On the basis of maximum likelihood estimation for equation (2), estimates of $\alpha, \lambda,$ and σ were created. Where $\lambda = \sigma_u/\sigma_v$, $\sigma^2 = \sigma_u^2 + \sigma_v^2$.

It is very essential to specify stochastic production frontier function in the measure of irrigation water use efficiency. In the line with Reinhard et al. 1999, a flexible translog frontier production function was applied for this study. The equation (2) is written as follows:

$$\ln Y_i = \alpha_0 + \alpha_w \ln W_i + \sum_{j=1}^{5} \alpha_j \ln X_{ij} + \frac{1}{2}\sum_{j=1}^{5}\sum_{k=1}^{5} \alpha_{jk} \ln X_{ij} \ln X_{ik} + \sum_{j=1}^{5} \alpha_{jw} \ln W_i \ln X_{ji} + \frac{1}{2}\alpha_{ww}(\ln W_i)^2 + v_i - u_i \tag{3}$$

Where: Y_i represents the fresh tea yield of the *i*-th tea farm. The inputs consist of: (1) X_{i1}, Fertilizer; (2) X_{i2}, Pesticide; (3) X_{i3}, Labor; (4) X_{i4}, Capital (5) X_{i5}, Other costs; and (6) W_i, Irrigation water (data was introduced in Table 3.1).

A farm gets irrigation water use efficiency when using minimum possible irrigation water denoted as W_i^F while conserving the actual output (Y_i). According to the constraint by Reinhard et al. (1999), an efficient irrigation water use farm is essentially to achieve technical efficiency ($u_i = 0$). Thus, production function of irrigation water efficient farm *i*-th is given by:

$$\ln Y_i = \alpha_0 + \alpha_w \ln W_i^F + \sum_{j=1}^{5} \alpha_j \ln X_{ij} + \frac{1}{2}\sum_{j=1}^{5}\sum_{k=1}^{5} \alpha_{jk} \ln X_{ij} \ln X_{ik} + \sum_{j=1}^{5} \alpha_{jw} \ln W_i^F \ln X_{ji} + \frac{1}{2}\alpha_{ww}(\ln W_i^F)^2 + v_i \tag{4}$$

Setting equation (3) and equation (4) equal, we obtain

$$\alpha_w \ln W_i + \sum_{j=1}^{5} \alpha_{jw} \ln W_i \ln X_{ji} + \frac{1}{2}\alpha_{ww}(\ln W_i)^2 - u_i = \alpha_w \ln W_i^F + \sum_{j=1}^{5} \alpha_{jw} \ln W_i^F \ln X_{ji} + \frac{1}{2}\alpha_{ww}(\ln W_i^F)^2 \tag{5}$$

Irrigation water use efficiency (*IE*) for *i*-th tea farm is defined as:

$$IE_i = \frac{W_i^F}{W_i} \tag{6}$$

Where: W_i^F is minimum possible quantity of irrigation water, W_i is real volume of irrigation water used

Manipulating equation (6) results in

$$W_i^F = IE_i \times W_i$$

$$\text{So } \ln W_i^F = \ln IE_i + \ln W_i \tag{7}$$

From equation (5) and equation (7), we receive

$$\frac{1}{2}\alpha_{ww}(\ln IE_i)^2 + (\alpha_w + \sum_{j=1}^{5}\alpha_{wj}\ln X_{ij} + \alpha_{ww}\ln W_i)\ln IE_i + u_i = 0 \tag{8}$$

Solving quadratic equation (8), irrigation water use efficiency for specific tea farm *i*-th can be got as:

$$IE_i = \exp\left(\frac{-b_i \pm \sqrt{b_i^2 - 2\alpha_{ww}u_i}}{\alpha_{ww}}\right) \tag{9}$$

Where: $b_i = \alpha_w + \sum_{j=1}^{5}\alpha_{wj}\ln X_{ij} + \alpha_{ww}\ln W_i$. b_i is also the output elasticity in regard to irrigation water; u_i is the technical inefficiency of the *i*-th tea farm; and α_{ww} is the parameter estimated from translog frontier function (Eq.3).

According to Reinhard et al. (1999), in the condition of weak monotonicity, an efficient irrigation water use farm is also technical efficient, implying that irrigation water use efficiency is calculated by only using positive sign of equation (9).

6.2.2. Determinants of irrigation use efficiency

To investigate the relationship among irrigation water use efficiency and various farmers' socio-economic factors and specific farm characteristics (data were presented in Table 3.2), a two-limit Tobit regression model was also applied. Tobit model can be specified in the following form:

$$IE_i = \omega_0 + \sum_{s=1}^{16} w_{is} K_{is} + e_i \tag{10}$$

Where: IE_i is irrigation water use efficiency of the i-th tea farm; K_{is} represents social and economic features of the i-th farmers and tea farms including: Age (s=1), Gender (s=2), Education (s=3), Ethnicity (s=4), Experience (s=5), Cooperative (s=6); Household size (s=7), Tea age (s=8), Soil and water conservation (SWC) s=9), Farm value (s=10), Non-agricultural income share (s=11), Extension (s=12), Farm size (s=13), water scarcity perception (*s=14)*. Well water (s=15), Stream water (s=16). e_i is error term.

6.3. Results

6.3.1. Irrigation water use efficiency

Irrigation water use efficiency is estimated by equation 9. The results are summarized in Table 6.1.

Table 6.1: Irrigation water use efficiency distribution of Vietnamese tea production

Efficiency score (%)	Number of farms	Percentage	Cumulative
≤ 50	144	59.26	59.26
50-60	31	12.76	72.02
60-70	34	13.99	86.01
70-80	24	9.88	95.88
80-90	9	3.70	99.59
≥ 90	1	0.41	100.00
Total	243	100.00	
Mean		42.19	
Min		2.02	
Max		93.33	

Source: Estimation of the author

The average irrigation water use efficiency was 42.19%. The efficiency levels considerably vary among tea farms, ranging from 2.02% to 93.33%. The obtained mean efficiency level infers that the present output of tea farms could have been conserved using 57.81% less irrigation water, while fixing other inputs.

The cumulative distribution of the efficiency estimates indicates that most farmers (59.26 %) achieved irrigation water use efficiency less than 50%. Only about 4% of those surveyed achieved irrigation water efficiency higher than 80%, suggesting that many tea farmers were highly inefficient in the use of water (Figure 6.3).

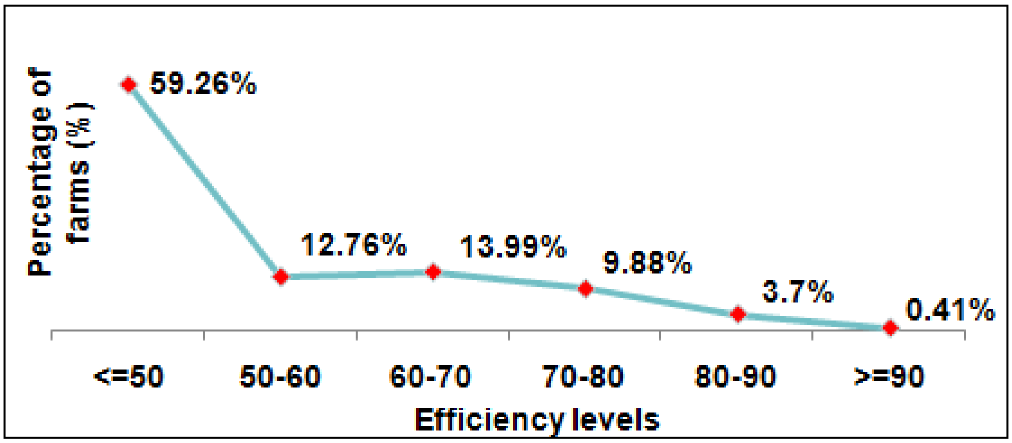


Figure 6.3: Distribution of irrigation water use efficiency of tea farms

6.3.2. The contributing factors of irrigation water use efficiency

The factors affect irrigation water use efficiency of tea farms are presented in Table 6.2. In the consideration of contributing factors of irrigation water use efficiency, socio-economic characteristics of tea farmers and tea farms such as age, education, ethnicity, experience, joining a cooperative, household size, tea age, farm value, farm size, and stream water were found to be insignificant impact, whereas gender, water scarcity perception, soil and water conservation, non-agricultural income share, extension, and well water were significant influence at the 1% and 5% levels of significance. The variable well water negatively affects irrigation water use efficiency, whereas remain variables had significantly positive impact on the efficiency level.

Table 6.2: Tobit estimates on determinants of irrigation water use efficiency

Variables	Explanation	IE
		Coefficient
Gender	*1= male, 0=female*	0.1914***
Water scarcity perception	*1=farmer recognizes water scarcity in the tea fields,* *0= otherwise*	0.1359***
Soil and water conservation (SWC)	*1= if farmer practices SWC technology on the tea field, 0= otherwise*	0.0245***
Non-agricultural income share	*Non-agricultural income share*	0.1960**
Extension	*1 = if farmer accesses to extension services,* *0= otherwise*	0.1092**
Well water	*1= irrigating tea field by well water, 0= otherwise*	-0.0973***
Age	*Age of household head in year*	0.0003
Education	*education level of household head in year*	-0.0003
Ethnicity	*1=Kinh ethnicity,0= otherwise*	0.0158
Experience	*experience in tea production of household head in year*	0.0012
Cooperative	*1= farmer participates in cooperative, 0=otherwise*	0.0331
Household size	*family members' number in person*	0.0006
Tea age	*Year*	-0.0018
Farm value	*Agricultural income in natural log*	-0.0118
Farm size	*Farm size (ha)*	-0.0634
Stream water	*1= irrigating tea field by stream water, 0=otherwise*	-0.0468
Constant		0.1689*

*Note. IE represents irrigation water use efficiency, ** * and ** represents 1% and 5% level of significance*
Source: Estimation of the author

6.4. Discussion and policy recommendations

Climate change and water scarcity are just two of the challenges faced by the tea industry at present and in the coming years. Tackling these challenges requires the development and implementation of efficient irrigation systems that have high water use efficiency and are affordable for tea farmers.

In the analysis, the mean irrigation water use efficiency was 42.19% which is much lower than overall input-oriented technical efficiency (82.19%). This is consistent with the theory mentioned by Fare (1978). The result pointed that tea farms in the study site have poor performance in term of water use efficiency. Thus, it is essential to promote irrigation water use efficiency of tea production efficiency amid climate change which not mentioned in the literatures (Basnayake and Gunaratne 2000; Nghia 2008; Saigenji and Zeller 2009; Baten 2010; Haridas et al. 2012). The reason for low efficiency of water use in tea production might be the unsuitable price mechanism on irrigation water in Vietnam. Currently, the farmers' water consumption in Vietnam at small-scale irrigation scheme is supported. Since 2008, the government has implemented an irrigation fee exemption policy for agricultural production (Decree. No 115/2008/ND-CP). While there is success in supporting farmers to reduce production cost, the policy also has some disadvantages. For instance, it reduces farmer's responsibility in the management, protection, and use of water resources. As a result, farmers have little economic stimulus to use water efficiently or to apply the irrigation technologies that save water. Therefore, re-imposing proper irrigation fee in the future can probably prompt tea farmers to use water more efficiently. This direction is discussed by Tang et al. (2014) who found that higher price can increase the efficiency of water use which promote the sustainability of agricultural production in the long term. Another implication of low irrigation water use efficiency is that 57.81 % reduction in water use for tea production can be attained with the present state of technology while maintaining observed output. With increasing the present irrigation water use efficiency of tea production, a significant portion of the water could be reallocated to other sectors, significantly reducing pressure on water resource in the study site.

The relationship among irrigation water use efficiency and various attributes of tea farms and farmers was then analyzed. Results of Tobit model showed that gender, water scarcity perception, soil and water conservation, non-agricultural income share, extension, and well water have a significant impact on irrigation water use efficiency.

Farmer's gender affected irrigation water efficiency positively. Male farmers were more technical efficient water use than their female counterparts. The popular reasons for discrepancy in agricultural water resource management between men and women are social gender labor division and gender norms, which women are assigned a lot of water-related duties whereas men are given most water-related powers and rights (Zwarteveen 1997, Van Koppen 1998, Singh et al.2006, IFAD 2007). This study results thus corroborated the fact that there are persisting problems regarding women involvement in water management. Although women in the study site undertake a lot of work in tea production, their rights to use productive resources such as land, fertilizer, credit, and other inputs, particularly water remains limited due to lacking acknowledge their role. Furthermore, while the majority of water users are women, only men are trained and learned techniques on operation, maintenance, and how to use irrigation systems efficiently. Thus men become more skillful in these aspects than women. In conclusion, Vietnamese policymakers should raise awareness on the role of women in agricultural production in general and in water use in particular, and address their unequal access to water as well as productive resources, extension services, and decision-making spheres related to water management. This can potentially improve livelihoods and reduce water wastage in poor rural areas.

The results also revealed that the perception or acknowledgment of water scarcity has a positive and significant impact on irrigation water use efficiency. This means that the farmers who recognize the insufficiency of water seemed to use it more efficient than the others. This is in line with the results of Tang et al. (2013). This finding suggests that disseminating the water scarcity to tea farmers is very an important policy targeting their behavior change toward efficient water use.

Other significant variable *soil and water conservation* had positively affect water use efficiency. This result shows that it is very essential to widen soil and water conservation practices in tea farms to improve irrigation water use efficiency.

It was found that the estimated coefficient of *non-agricultural income share* also had a positive impact on irrigation water efficiency. This suggests that a rise in off-farm income would encourage farmers to invest more in advanced irrigation technologies, which leads to a more efficient utilization of water resources.

Moreover, the study confirms the importance of agricultural extension services in increasing the technical efficiency of tea production as asserted by von Bülow and S∅ rensen (1993), Iqbal et al. (2006), and Saigenji and Zeller (2009). Vietnamese extension program aims to support agriculture production develop sustainably, in general, and tea production, in particular. Farmers can broaden their knowledge about land preparation, planting, and practicing soil and water conservation techniques through extension program. Thus, the improvement of extension services access can help Vietnamese tea farmers optimize technical efficiency, particularly water use.

Meanwhile, the dummy for well irrigation exhibited a negative impact on irrigation water use efficiency. It seems that farmers irrigating their plantations by water well are much less efficient than those using public irrigation water. The reason for this problem is that a price is charged for the latter. This is in agreement with the findings reported by Karagiannis et al. (2003). Furthermore, well irrigation method, which has two typical characteristics such as flexible irrigation time, short distance of water delivery might lead to farmers using water less efficiently. These findings suggest that water conservation could be achieved through better management. Specifically, imposing an irrigation water fee and utilizing suitable irrigation systems are an important issue in putting into practice better water management.

6.5. Conclusions

This study investigates irrigation water use efficiency of Vietnamese tea production. The tea farmers were found to be inefficient irrigation water consumption. The low water use efficiency estimate (42.19 %) suggests that a 57.81 % reduction in current water use for tea production could be achieved given existing technology, without compromising output. Therefore, further improvement in irrigation water use efficiency is indispensable to tea production in Vietnam under context of climate change and water scarcity.

The relationship among irrigation water use efficiency and tea farmer and farm attributes is analyzed by Tobit model. We found that gender, water scarcity perception, soil and water conservation, non-agricultural income share and extension service positively affect the efficiency of irrigation water use, while using irrigation water from well has negative influence on it. To increase water use efficiency, the government should ensure equitable right to use water, trainings and involvement in water management for female farmers. Furthermore, it is essential for the government to initiate the dissemination of information on water scarcity to farmers, promote the application of soil and water conservation techniques in tea farms, strengthen extension services and advocate the appropriate use of irrigation systems for better water management.

Chapter 7

Profit efficiency and its determinants in Vietnamese tea production

7.1. Introduction

Tea production has contributed considerably to income of thousands of smallholder farmers who produce most of the tea in Vietnam. However, visible serious problems in the sector such as: outdated production and consumption practices, low and fluctuating prices for the product, and increasing input prices jeopardize tea production' profit which lead to reduce already-low incomes of small holder tea farmers and pushing them into further poverty. Under this circumstance, the challenge of increasing the profit of tea production in order to secure higher income for the tea farmers is significant given. This study aims to estimate profit efficiency of tea production in the Northern mountainous region of Vietnam as well as its relationship with market indicators and farm's characteristics using stochastic profit frontier and Tobit models. The findings will point out the potential profit maximization of tea farms in the study site with given existing production technology and essential changes from the farms' practices and management as well as supports from government to achieve that objective.

7.2. Analytical framework

7.2.1. Profit efficiency

Tea profit efficiency as defined in this study is the profit gained from operating on the profit frontier taking into consideration variable input prices and quasi-fixed input quantities. A tea farm is assumed to operate by maximizing profit subject to perfectly competitive input and output market and a given output technology. To estimate tea profit efficiency, the stochastic variable profit frontier function was applied in this study. The function is written as:

$$\pi_i = f(P_i, Z_i)\exp(\varepsilon_i) \tag{1}$$

Where: π_i normalized profit of the *i*th tea farm defined as gross revenue less variable cost, divided by farm-specific output price; P_i is the vector of variable input prices faced by the *i*th farm divided by output price; Z_i is the vector of fixed factor of the *i*th farm; ε_i is an error term.

The error term ε_i is assumed to behave in a manner consistent with the frontier concept (Ali and Flinn, 1989), i.e.

$$\varepsilon_i = v_i - u_i \tag{2}$$

Where: v_i represents the impact of statistical noise on normalized variable profit. v_i is assumed to be independently and identically distributed $N\ (0, \sigma_v^2)$. u_i is non-negative random variables, associated with inefficiency in production, which are assumed to be independently distributed as truncations at 0 of the normal distribution with mean μ_i and variance σ_v^2 $(N(\mu_i, \sigma_v^2)$.

The profit efficiency of tea farm *i* in the context of stochastic frontier profit function is:

$$PE_i = E[\exp(-u_i)|\varepsilon_i] \tag{3}$$

Where: E is the expectation operator. This is achieved by obtaining the expressions for the conditional expectation $u_i$upon the observed value of ε_i. The method of maximum likelihood is used to estimate the unknown parameters, with the stochastic frontier and the inefficiency effects functions estimated simultaneously. The likelihood function is expressed in terms of the variance parameters, $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u^2/\sigma^2$ (Battese and Coelli, 1995).

As usual, the first step in estimating profit efficiency is to specify a functional form for $\pi\ (.)$ in equation (1). The stochastic translog variable profit frontier model was used in this study. The detail function, dropping the *i*th subscript for the farm, is defined as:

$$\ln\pi' = \alpha_0 + \sum_{j=1}^{3} \alpha_j \ln W'_j + \frac{1}{2}\sum_{j=1}^{3}\sum_{k=1}^{3} \tau_{jk} \ln W'_j \ln W'_k + \sum_{j=1}^{3}\sum_{m=1}^{2} \emptyset_{jm} \ln W'_j \ln Z_m$$
$$+ \sum_{m=1}^{2} \beta_m \ln Z_m + \frac{1}{2}\sum_{m=1}^{2}\sum_{n=1}^{2} \varphi_{mn} \ln Z_m \ln Z_n + v - u \tag{4}$$

Where: π' is the normalized profit (total revenue less total cost of variable inputs) divided price of output (P_y); W_j' is the normalized price of the *j*th variable inputs divided price of output (P_y), in which *j* is the fertilizer price (1); labor wage (2); and pesticide price (3); Z_m is the quantity of fixed inputs, where *m* is farm capital used (1); other costs (2); *v* is the two-sided random error representing statistical noises; *u* is the one-sided error reflecting profit inefficiency effects. α_0, α_j, τ_{jk}, $\emptyset_{jm}$, β_m, and φ_{mn} are the parameters to be estimated.

Tobit model was also applied to investigate determinants of profit efficiency (data were presented in Table 3.2). The detail model is given as:

$$PE = \delta_0 + \sum_{d=1}^{20} \delta_d \, S_d + \omega \tag{5}$$

Where: PE is profit efficiency score of individual farm. S_d is a vector of variables representing socio-economic characteristics of the farm to explain inefficiency, where d from 1-16 are similar explanatory variables in analysis of determinants of technical efficiency; environmental efficiency; irrigation water use efficiency, tea process machineries (17), linkage with traders (18), product marketing activities (19), and market information access (20). δ_0, and δ_d are the parameters to be estimated.

In translog profit frontier model, the profit elasticity with respect to specific variable input prices and other fixed inputs, which is different from that of Cobb-Douglas form, is calculated as follows:

$$\frac{\partial ln\pi'}{\partial lnW'_j} = \alpha_j + \sum_{j=1}^{3}\sum_{k=1}^{3} \tau_{jk} \ln W'_k + \sum_{j=1}^{3}\sum_{m=1}^{2} \emptyset_{jm} \ln Z_m \tag{6}$$

$$\frac{\partial ln\pi}{\partial lnZ_m} = \beta_m + \sum_{j=1}^{3}\sum_{m=1}^{2} \emptyset_{jm} \ln W'_j + \sum_{m=1}^{2}\sum_{n=1}^{2} \varphi_{mn} \ln Z_n \tag{7}$$

To understand the economic burden that tea farms suffer from profit inefficiency, the profit loss of *i*-th farm is estimated as follows:

$$PL_i = (1\text{-}PE_i)PM_i \tag{8}$$

Where: PL is profit loss. PE is profit efficiency score. PM is maximum profit which is computed by dividing the actual profit of individual farm by its profit efficiency score.

7.3. Results

7.3.1. Profit efficiency

Prior to estimate profit efficiency, it is essential to specify the form of profit frontier function. The Cobb-Douglas function $(\text{null hypothesis}: \mathrm{H}_0)$ against the translog function $(\text{alternative hypothesis}: H_1)$ was tested using the log likelihood test (LR) (Coelli et al. 2005).

The LR test statistic was equal to 194.35 which is greater than $\chi^2_{(15,0.5)} = 31.31$, thus Cobb-Douglas function form was rejected at 5 % level. Therefore, the translog profit frontier model with five significant inputs was used in this study. The maximum likelihood estimation of the model defined by (Eq.4) was obtained using STATA software version 11. The results of the profit frontier function are presented in Table 7.1.

Table 7.1: Maximum-likelihood estimates of profit frontier function

	Coefficient	S.E	Variables	Coefficient	S.E
ln W_1	-2.7738**	1.2972	ln W_3 . ln Z_1	0.0165	0.0209
ln W_2	-2.8350***	1.0741	ln W_3. ln Z_2	0.4665***	0.1798
ln W_3	-3.3267**	1.4351	(ln Z_1. ln Z_1)/2	-0.0069	0.0102
ln Z_1	0.5084	0.5263	ln Z_1. ln Z_2	-0.0553	0.0643
ln Z_2	14.6838***	4.8652	(ln Z_2 .ln Z_2)/2	-1.5028***	0.5776
(ln W_1. ln W_1)/2	-0.2543***	0.0860	Constant	-63.8573***	20.9961
ln W_1 . ln W_2	0.0973**	0.0377	*Variance parameters*		
ln W_1. ln W_3	0.1937**	0.0753	σ_v	0.0169	0.0040
ln W_1. ln Z_1	0.0013	0.0169	σ_u	0.1111	0.0064
ln W_1. Ln Z_2	0.2433	0.1565	σ^2	0.0126	0.0014
(ln W_2. ln W_2)/2	-0.7712***	0.0697	$\lambda = \sigma_u/\sigma_v$	6.5810	0.0088
ln W_2. ln W_3	0.1163	0.0722	$\gamma = \sigma_u^2/\sigma^2$	0.9774	
ln W_2. ln Z_1	0.0315**	0.0128	Log-likelihood	324.7744	
ln W_2. ln Z_2	0.2767**	0.1272	Wald χ^2 value	3822.7700	
(ln W_3. ln W_3)/2	-0.6172***	0.1262	LR test σ_u=0	75.5100	

Note: W_1, W_2, W_3, Z_1, Z_2 are fertilizer price, labor wage, pesticide price, capital, and other costs.

*, **,and *** *indicate the significance level of 10%, 5%, and 1%*

Source: Estimation of the author

Table 7.1 reports the results of testing the hypothesis that efficiency effects jointly estimated with the profit frontier function are not simply random errors. The null hypothesis that σ_u=0, which means that inefficiency effects are not present in the model, is rejected at the 5% level of significance (LR statistic 75.51>$\chi^2_{2,0.95}$ =14.85).

Further, the key parameters $\gamma = \sigma_u^2/\sigma^2$, which is the ratio of the errors in Eq. (32) and is bounded between 0 and 1, where if γ =0, inefficiency is not present, and if γ =1, there is no random noise (Battese and Coelli, 1995). The estimated γ is 0.9774 and is significantly different from 0, thereby, suggesting that 97.74% of the differences between observed and the maximum frontier profits for modern tea farming are due to the inefficiencies. Thus, a significant part of the variability in profits among farms is explained by the existing differences in the level of technical and allocative inefficiencies.

Based on the estimates of profit frontier function, we computed profit elasticities with respect to changes in variable input prices and fixed inputs defined by Eq. (6 and7). Results are shown in Table 7.2.

Table 7.2: Estimated profit elasticities

With respect to	**Profit elasticity**
Fertilizer price	-0.0762
Labor wage	-0.3310
Pesticide price	-0.1698
Capital	0.0061
Other costs	-0.3451

Source: Estimation of the author

The results indicate that 1 % increase in price of fertilizer will reduce profitability by 0.0762% followed by labor wage (0.3310%), pesticide price (0.1698%) and other costs (0.3451%), respectively. On the other hand, the elasticity estimate reveals that a 1% increase in farm capital will raise profits by 0.0061%.

The distribution of profit efficiency of tea farming is presented in Fig. 7.1.

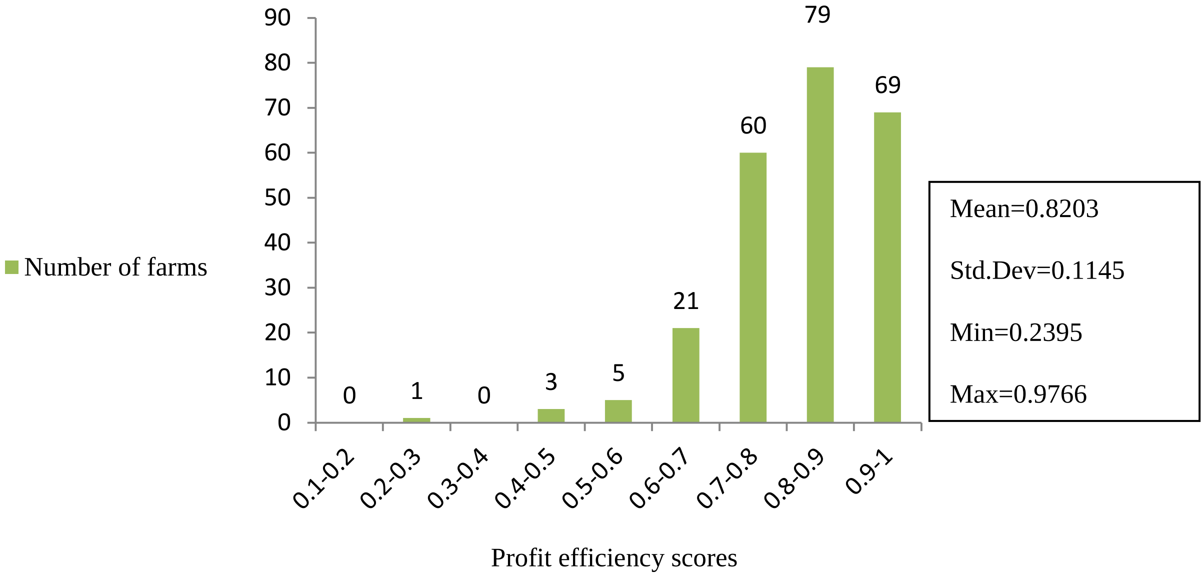


Figure 7.1: Profit efficiency of tea farms

The mean profit efficiency score is 82.03% implying that tea farms could averagely increase current profit levels by 17.97% by improving their technical efficiency and allocative efficiency. Tea farmers exhibit a wide range of profit efficiency, ranging from 23.95% to 97.66%. Despite wide variation in efficiency, about 87.39% of tea farms seem to be skewed towards profit efficiency level of 70% and above (Fig. 7.1), suggesting most tea farms got relatively high profit efficiency.

Estimation of profit-loss given prices and fix factor endowments is shown in Table 7.3.

Table 7.3: Descriptive statistic of tea farms' profit losses

Profit loss per ha (Thousand VND)	Mean	Stv.Dev	Min	Max
	55,912.98	44,915.11	5,501.08	280,855.80

Source: Estimation of the author

The results indicate that tea farms are losing to 55,912.98 thousand VND per ha (2,508.82[9] USD) which could be recovered by eliminating technical and allocative efficiency. The profit loss of the farms per ha ranges from 5,501.08 thousand VND to 280,855.80 thousand VND (246.83 USD – 12,602.00 USD).

[9] 1 USD=22,286.6058 VND (exchange rate on 18/5/2016)

7.3.2. Factors affecting profit efficiency

The impact of socio-economic factors on profit efficiency of tea farming is listed in Table 7.4.

Table 7.4: Tobit estimation on determinants of profit efficiency

Explanatory variables	**Coefficient**	**Std.Err.**
Age (year)	-0.0002	0.0003
Gender (1= male, 0=female)	-0.0002	0.0138
Education (education level of household head in year)	0.0004	0.0012
Ethnicity (ethnicity of household head, 1=Kinh, 0= otherwise)	-0.0057	0.0067
Experience (household head' farming experience in year)	0.0002	0.0004
Cooperative (1= if farmer participate in cooperative, 0=otherwise)	-0.0029	0.0151
Household size (family member's number in person)	0.0003	0.0024
Tea age (years)	0.0006	0.0004
Soil and water conservation (SWC) (1= if farmer practices SWC technologies on the field, 0=otherwise)	0.0248^{*}	0.0145
Farm value (agricultural income in million VND/ha)	0.0013	0.0015
Non-agricultural income share	0.0372^{*}	0.0214
Extension (1 = if farmer accesses to extension services, 0= otherwise	0.0368^{***}	0.0098
Farm size (ha)	0.0110	0.0203
Water scarcity perception (1= if farmer recognizes water scarcity in the field, 0=otherwise)	0.0033	0.0082
Well water (1=irrigating tea field by well water, 0= otherwise)	-0.0018	0.0063
Stream water (1=irrigating tea field by stream water, 0=otherwise)	0.0075	0.0098
Process machineries utilization (1= yes,0=no)	0.0224^{***}	0.0074
Linkage with enterprises (1=yes, 0=no)	0.0301^{**}	0.0129
Direct product marketing activities (1=yes, 0=no)	0.0196^{**}	0.0076
Market information access (1=yes, 0=no)	0.0605^{***}	0.0137
Constant	0.9430^{***}	0.0747

*Note. ** *, **, and * represents 1%, 5%, and 10% level of significance*
Source: Estimation of the author

Explanatory variables, such as: soil and water conservation, extension, non-agricultural income share, process machineries utilization, linkage with traders, direct product marketing activities, and market information access were found to have significantly positive influence on profit efficiency, while remain variables are insignificant relation.

7.4. Discussion and Policy recommendations

The previous parts focused on investigating the *technical efficiency* performance of Vietnamese tea farms, but the ability to transform input(s) into output(s) only reveals the existing physical production technology utilization, the financial aspects of production are not addressed. Ensuring and enhancing farm profitability requires effective management of both financial and physical resources.

For a tea farm, with a profit maximizing business objective, effectively utilizing physical resources is essential. Correctly identifying the optimal input and output mix at current market prices is also a part of the decision making process that is nowhere less important than the physical production planning. The success of achieving the best economic outcome hinges on both and can be measured by *profit efficiency* (PE), which is the ratio of maximum profit attainable to actual profit obtained. At the aggregate level, average PE is critical in predicting the future structure of tea production following possible policy changes. At the farm level, PE evaluation is crucial in signaling profit potential and identifying areas for improvement.

Results of this study indicate that a considerable amount of profit (17.97%) can be increased by improving technical and allocative efficiency in Vietnamese tea production. The profitability of the farms is vulnerable to changes in prices of major variable inputs such as: fertilizer, labor and pesticide and other costs, conforming to the theoretical hypothesis that there is a negative relationship between profit and input prices and observations made earlier by Ali and Flinn (1989), Abdubai and Huffman (2000) and Kolawole (2006). It means that in a consistently situation of rising fertilizer price, pesticide price and labor wage as well as other costs, the declining effect of profitability in tea farming is more clear. Therefore, a policy response aimed at stabilizing price fluctuations of these inputs would make tea farmers' profit increase. We suggest that the government should focus on following issues: intensifying quality control of fertilizers and pesticides circulated on the market, controlling the fertilizer and pesticide production activities; regulating and balancing the supply and demand of fertilizers and pesticides through fertilizer and pesticide reserves, regulating the fertilizer and pesticide import resources through tax policies and having support policies to improve the capacity of the distribution system to ensure that fertilizer and pesticide are circulated from production and import to the farmers as well as avoid overlapping and reduce unnecessary intermediate cost. In addition, the government needs to organize routine inspection and control of the market to prevent the violation of trade fraud, speculation of fertilizer and pesticide and raising the prices unreasonably. On the other hand, profitability increases with increase in farm capital which was also found in Rahman (2003). This finding suggests that more capital investments which take from farms themselves together with credit supports of government and other organizations can lead to the increase in tea production's profit.

Among farms and households' attributes, present study clearly reveals that tea farms applying soil and water conservation measures operate at higher level of profit efficiency as compared to those who do not. This result is consistent with Adgo et al. (2013) who indicated that soil and water conservation practices increase crop production and land productivity which in turn contribute to food security, and household income. Hobbs et al. (2008) also pointed that adopting conservation agriculture can raise production sustainably and profitably. Therefore, more efforts are needed from decision-makers to promote and support the adoption of conservation practices in order to secure land tenure and initiate a more sustainable development in the research area where most of farmers have to intensify agricultural production onto steep slopes and environmental problems such as soil erosion, landslides, and declining soil fertility have become severe over the past years.

Similarly, the farmers who had contact with extension services, which primary aims are to promote sustainable farms' practices and managements, produces at high level of profit efficiency. This result is sufficient to make a strong case in favor of strengthening the agricultural extension system to promote farmer profitability.

The ratio of income earned off-farm included to reflect the relative importance of non-agricultural work in the household. The positive estimated coefficient points towards a situation where those households who have higher off-farm income are affordable to invest in tea production relative to other farmers. In addition, spending time off the farm might improve farmer's ability through the acquisition of information and knowledge and hence farm performance. Otieno et al. (2012) found a positive relationship between off farm income and profit efficiency and argue that there is considerable re-investment of off- farm earnings into farm production. However, this result is contractive with the findings of Ali and Flinn (1989) and Rahman (2003) who reported that farms with off-farm employment exhibit higher inefficiency as compared to the full-time farmers.

It is evident that tea farms utilize machines in tea process get higher profit efficiency than other farmers, implying that mechanization of processing activities could either increasing the amount of finished product or to improve the net economic value of the product. Traditionally, many processing activities in the survey areas (winnowing, withering, fermentation, shaping, and drying) were carried out manually, almost entirely by women. Many farmers reported that the manual processing methods are tiresome, take considerable time of all the household members, and low yield and quality, but it is difficult to change these methods as process machineries are very expensive. Therefore, they seem to sustain the use of indigenous methods of tea processing. Processing fresh leaves after harvesting is as important as the correct maturity for the quality of made tea and profitability, since careless processing will add impurities and damage the green shoots and thus, increase post harvesting losses. The current manual processing practices deprive the farmers, particularly women, of the opportunity to diversity the market options and be profitably rewarded. From the policy perspectives, national agricultural development strategies to help smallholders improve their financial capability to mechanize tea processing could be the pathway of higher and more stable income. Appropriate processing machines and tools of varying scales will reduce processing time, labor, and crop losses, and will have a significant impact on women since they are chiefly involved in tea processing.

This study also found that the tea farms linking with enterprises in product consumption earn significantly higher profit efficiency than others. As observed in the survey, the common linkage for tea production in the NMR is vertical coordination between farmers and enterprises. In the marketing stage, many farmers often stick with a certain state enterprise or a commercial enterprise which is also bolstered by government policies such Decision 80/2002/QDTTg of the Prime Minister which enterprises of all sectors are encouraged to sign contracts on sales of farm produce with producers in order to link production with processing and consumption of commodity farm produce to develop production in a stable and sustainable manner. This coordination ensures a good sale and reduces associated marketing risks which help the farmers get higher profit. This is consistent with the findings of Saigenji and Zeller (2009) who investigated the effect of contract farming on production and income of tea farmers in north-western Vietnam. They found positive impact of contract farming in tea production in Moc Chau district in terms providing higher income to households. The result suggests that further institutional measures are necessary to facilitate tea farmers coordinating with enterprises in production and consumption for further development of the Vietnamese tea sector and income improvement of tea small holders.

Implementation direct product marketing activities such as: packing, labeling, advertising, and direct sale to consumers seemed to play their parts to some extent in increasing profit efficiency in modern tea farming. It was observed that some farms in the research site have adopted direct marketing activities to consumers as an alternative to sustain business vitality, obtain higher prices, and maintain a competitive edge in the market. These direct marketing tea farms were found to be more profitably than others. This result is consistent with the finding of Gale (1997) who reported that direct selling has positive impact on economic and social aspects of rural communities. Among the direct-marketing methods (roadside markets; farmers' markets; pick-your-own; community supported agriculture; catalog sales, internet sales; and other methods, including direct order/custom sales), these tea farms with direct-marketing activities generally used one to two ways to retail their products. Three most commonly used direct-marketing methods were roadside markets, farmers' markets, and pick-your-own. The changing farming environment is pressuring tea farmers to shift from traditional farming to market-oriented farming. In addition, growing interest in food quality and origin further fueled consumers direct purchasing products from tea farmers. Under this circumstance, direct marketing is one of important strategies to increase profitability for farms. As such, the tea farms need more attention to marketing activities to ensure future income. However, to be successful in marketing activities, farmers require knowledge of farm business management. Currently, there is a significant gap in the provision of marketing support of outputs for farmers. Through interview, typical support for tea farms was found to be technical farming methods training. Thus, policies aiming to promote direct marketing activities in the tea farms and improve the farmers’ knowledge about farm business management are advocated.

The investigation of market information access and its positive effect indicate that farmers accessing market information are more efficient. Farmers uninformed of market tea prices may suffer a loss when they transact with traders who are superior to the farmers in terms of market information access. Second, it is highly likely that smallholder tea farmers lacking sufficient information to predict the tea price fluctuations may overinvest or underinvest in their farms. As a result, they can be burdened with a heavy debt and possibly even abandon their tea farms. The provision of market and price information can assist producers with farm-gate marketing decisions: linked to training both to help them interpret and act upon that information, and to organize collectively, it can also help them to understand marketing processes more fully and to develop strategies to achieve better and more stable prices for their agricultural produce. However, such information must be location-specific, timely and accurate, dynamic, and locally available and in a language understood by all of the rural population. The result suggests that introducing the market information systems and providing adequate and timely information about the market situations to the tea farmers in the region are very essential.

7.5. Conclusions

The study used translog profit frontier model to analyze profit efficiency of tea production in the Northern mountainous region of Vietnam and then applied Tobit model to investigate it determinants. The results showed that the average profit efficiency of the tea farms is 82.03%, suggesting that 17.97% of tea production’s profit can be increase if the farms are more technically and allocatively efficient. Increasing of chemical fertilizer, pesticide, labor wage, and other production costs lead to significantly decrease the farms’ profit. Conversely, the profit increases with increase of the farms ‘capital. These results imply that stabilizing input prices policies and capital support from government are essential.

Soil and water conservation, extension, non-agricultural income share, process machineries utilization, linkage with enteprises, direct product marketing activities, and market information access were found to have significantly positive influence on profit efficiency. From above results, the government should encourage tea farmers to adopt soil and water conservation techniques; mechanize tea process; link with enterprises, and increase direct marketing products. Improvement of extension service and market information accessing to tea farmers also play important role in rising the farms’ profit.

Chapter 8

Conclusions

8.1. Introduction

The main findings of this study address in summary the selected indicators of economic sustainability, environmental sustainability, and socio-institutional sustainability such as: technical efficiency, environmental efficiency, irrigation water use efficiency, and profit efficiency. The findings, conclusions and recommendations are based on the field survey and farmers' perceptions and are supplemented by review of the overall situation in the study area using rigorous stochastic frontier analysis.

8.2. Main findings and Policy recommendations

8.2.1. Efficiency estimation

Vietnam has many favourable conditions for agricultural development, in which tea is one of the products with significant advantages. Despite its importance to job generation and poverty eradiation in Vietnam, sustainability of tea production is hindered by low productivity, rising of production costs, depending on agro-chemical inputs which detrimetal to environment, and low price. But for a long time, the Vietnamese tea industry has not had a good structure and clear, consistent strategies to solve these problems. How to improve sustainability in terms of economy, environment and society of the tea industry is the major concern for policy makers and the challenge for researchers.

Based on efficiency theory, stochastic frontier analyis and Tobit model, this study assessed technical, environmental, irirgation water use and profitable performances of Vietnamese smallholder tea farming and their determinants in order to provide insights for policy makers about the current state, show the direction and indentify sources of changes, which can inturn guide the tea growers more efficienct and sustainable production.

The analysis to cross-section dataset of 243 Northern moutainous tea farms reveals that there was significant scope to make their current production systems more sustainable. The improvement in economic, environmental, and social sustainability of the sector can be achived by being more technically, environmentally, irrigation water use and profitably efficient. The efficiency levels of tea production were described in Figure 8.1.

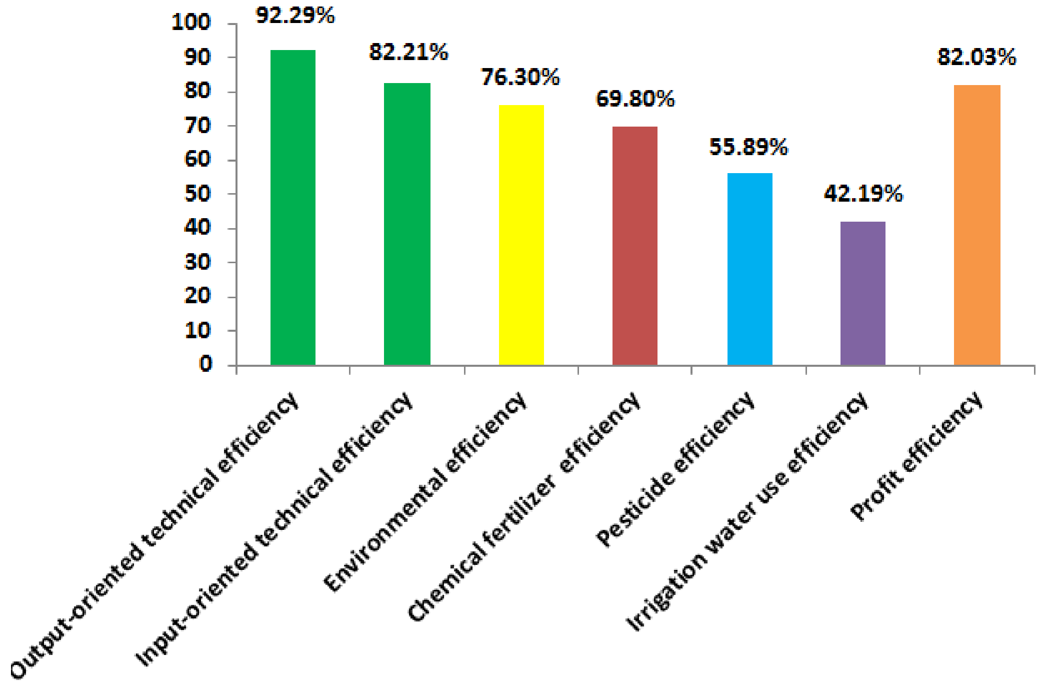


Figure 8.1: Efficiency levels of tea production at the Northern mountainous region in Vietnam

Two models of technical efficiency including output and input orientation were simultaneously evaluated in order to find the correct direction for resources use level targeting productivity which lead to tea production in the study site efficiently and sustainably. The results showed that these tea farms have an average output- oriented TE level of 92.29%, suggesting that farmers can still increase the current output level by 7.71%, given fixed inputs. However, the mean sum of output elasticity with respect to specific inputs is 0.323, indicating that those tea farms are decreasing return to scale. The average input-oriented TE score is 82.21%, which is much less than that of output-oriented TE, indicating that those tea farms in the study site could reduce the use of inputs by 17.79% without compromising the current output level. This analysis yielded an important finding that changes tea farmers' opinion. Conventionally, the farmers often think that the best way to improve productivity is to increase output by using inputs as much as possible. In fact, the tea farms should make an effort on reducing inputs, which will help the farmers not only save production cost but also improve the environmental quality. Therefore, the strategy minimising the input level given output is superior to the strategy maximising output given input level, interms of improving the sustainability of tea producion in the Northern mountainous region of Vietnam. The potential reduction of inputs applied in the current tea farming was presented in Figure 8.2.

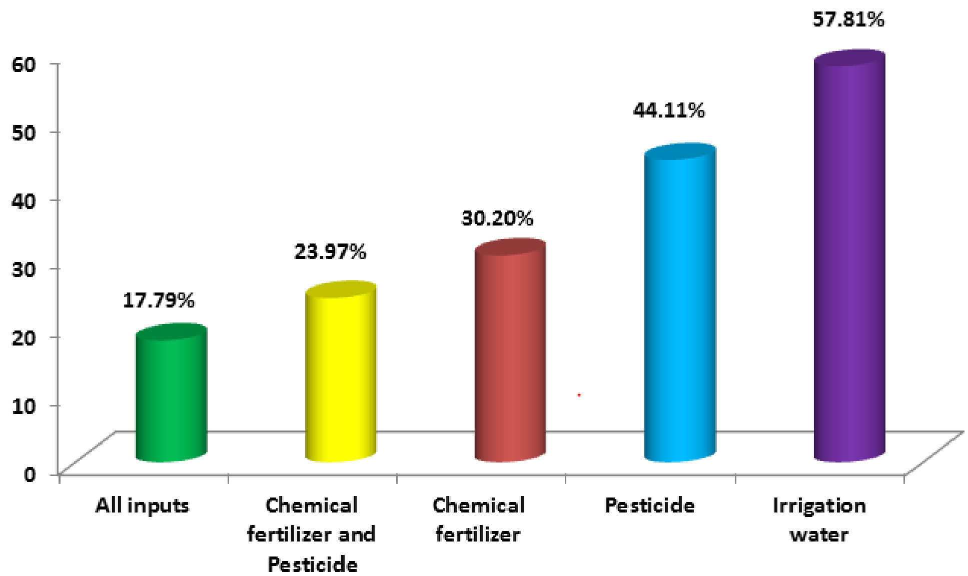


Figure 8.2: Potential reduction of inputs of tea production at the Northern mountainous region in Vietnam

Pesticides and chemical fertilizers are often used in tea farming to restore nutrients used by tea bush and to fend off parasites. Howerver, excessive pesticide and chemical fertilizer use have negative impact on productivity, environment and human health (indirectly by retaining residues in tea products, water and soils) which poses a grave threat to the sustainability of the farming system. To have better understanding about the present state of chemical fertilizer and pesticide application in tea production and the potential contraction of theses environmentally detrimental inputs, this study estimated environmental efficiency. Results in figure 5.1 show that the tea farms applied chemical fertilizer and pesticide inefficiently. These bad inputs, particularly pesticide, are overused by the farmers in the research site. The mean environmental efficiency estimate (76.03%) indicates that 23.97% reduction in current chemical fertilizer and pesticide application in tea production could be achieved given existing technology without compromising output (Figure 5.2). The average environmental efficiency scores of fertilizer and pesticide are 69.80% and 55.89%, respectively. These results show that, if the farms focus on individual bad input, they may reduce either 30.20% of present fertilizer use or 44.11% of current pesticide use, while conserving observed output. Suitable policies that focus on contracting these bad inputs' environmental spillovers may benefit tea farmers by decreasing their production cost (10,443.82 thousand VND or 466 USD per hectare) and improving environmental quality.

Irrigation is indispensable to overcome insufficient rainfall and to achieve a stabilized yield for tea production. As the severe scarcity of water resources because of climate change, water conservation through efficient irrigation has turned into a vital strategy for tea sector in solving this rising challenge. This study analyzed irrigation water use efficiency of small-scale tea farms to intesigate the ability of the farms to save this natural resource in exsiting production technology. Results showed that the mean irrigation water use efficiency was 42.19% (Figure 8.1), indicating the existence of substantial water waste. If farmers become more efficient in using water, saving 57.81% (Figure 8.2) of irrigation water is possible unaccompanied by reducing the observed output. In this way, substantial fraction of irrigation water can be reallocated to other sectors which significantly reduce pressure on water resource. It appears that tea farmers have little incentives to use water efficiently in the exemption of irrigation fee. In this sense, the gradual re-imposing proper irrigation fee for the coming years could be a trigger for more efficient water use.

Tea farmers not only need to reduce inputs consumption in their production activities, but also to be responsive to market indicators, so that the scarce resources are utilized efficiently to increase productivity as well as profitability, which will have a positive impact on improving their income. This study estimated profit efficiency of tea farms in Northern moutainous region of Vietnam which indicates the ability of a farm to maximize profit with current production technology. The mean profit efficiency score in modern tea farming is 82.03%, implying that there a room (17.97%) to increase profit by improving technical and allocative efficiency. Based on the result of profit elasticity, tea farms are highly responsive to changes in prices of major inputs such as chemical fertilizer (-0,0762), pesticide (-0.1698), labor (-0.3310), capital (0.0061), and other costs (-0.3451). The policies stabilizing price fluctuations of fertilizer, pesticde, labor as well as increasing farms'capital would make tea farmers' profit increase.

8.2.2. Factors affecting to efficiency levels

A second step of this study consists of analyzing the factors affecting efficieny measures. Separate Tobit models were estimated as a funtion of various socioeconomic characteristics of the tea farmers and farms, allowing to deduce which aspects of the farms'human and physical resources might be targeted by public investments to improve sustainable efficiency. The determinants of tea production's efficiency levels are summarized in Table 8.1. The results revealed that factors such as: gender, soil and water conservation practices, agricultural income, off-farm income, access to extension services, water scarcity perception, irrigation by well water, process machineries utilization, linkage with enterprises, direct product markerting activities, and market information access have significant influence on the efficiency measures of tea production. In order to sustain the tea sector, the policies that focus on these farms and farmers' attribute are very essential. The specific impact of these determinants on different efficiency kinds was concluded in the next parts.

Table 8.1a: Determinants of efficiency measures of tea production

Determinants	TE_o	TE_i	EE	IE	PE
Age of household head	-0.0003	0.0003	0.0003	0.0003	-0.0002
Gender (1= male, 0=female)	**0.0382*****	0.0201	0.0146	**0.1914*****	-0.0002
Education level of household head (year)	-0.0002	-0.0020	-0.0020	-0.0003	0.0004
Ethnicity of household head (1=Kinh, 0= otherwise)	0.0010	0.0010	0.0015	0.0158	-0.0057
Tea farming experience (year)	0.0005**	0.0009	0.0010	0.0012	0.0002
Cooperative participation (1=yes, 0=no)	-0.0144	-0.0392	-0.0517	0.0331	-0.0029
Household size (family member's number in person)	0.0016	0.0021	0.0021	0.0006	0.0003
Tea age (years)	0.0001	0.0004	0.0009	-0.0018	0.0006
Soil and water conservation (1= if farmer practices on the field, 0=otherwise)	**0.0021****	**0.0149*****	**0.0206*****	**0.0245*****	**0.0248***
Farm value (agricultural income in million VND/ha)	0.0137	**0.0673*****	**0.1194*****	-0.0118	0.0013
Non-agricultural income share	0.0090	-0.0003	-0.0542	**0.1960****	**0.0372***

Source: Estimation of the author

TE_o and TE_i indicate output and input oriented technical efficiency. EE, IE, and PE are environmental efficiency, irrigation water use efficiency, and profit efficiency. *, **, and *** present significant levels of 10%, 5%, and 1%.

Table 8.1b: Determinants of efficiency measures of tea production

Determinants	TE_o	TE_i	EE	IE	PE
Extension (1 = if farmer accesses to extension services, =otherwise)	**0.0573*****	**0.0859*****	**0.0762*****	**0.1092****	**0.0368*****
Farm size (ha)	-0.0137	0.0163	0.0579	-0.0634	0.0110
Water scarcity perception (1= if farmer recognizes water scarcity in the field, 0=otherwise)	-0.0020	**0.0289****	-0.0167	**0.1359*****	0.0033
Well water (1=irrigating tea field by well water, 0= otherwise)	0.0023	-0.0064	**0.0345****	**-0.0973*****	-0.0018
Stream water (1=irrigating tea field by stream water, 0=otherwise)	0.0013	0.0148	0.0575	-0.0468	0.0075
Process machineries utilization (1= yes,0=no)					**0.0224*****
Linkage with enterprises (1=yes, 0=no)					**0.0301****
Direct product marketing activities (1=yes, 0=no)					**0.0196****
Market information access (1=yes, 0=no)					**0.0605*****
Constant	0.8158**	0.3421**	-0.0321*	0.1689*	0.9430***

Source: Estimation of the author

TE_o and TE_i indicate output and input oriented technical efficiency. EE, IE, and PE are environmental efficiency, irrigation water use efficiency, and profit efficiency. *, **, and *** present significant levels of 10%, 5%, and 1%.

8.2.2.1. Determinants of technical efficiency

The farmers' socio-economic and farm characteristics such as: applying soil and water conservation technology, accessing extension services, increasing agricultural income, and raising water scarcity recognition were found to be significant in increasing resource use efficiency of tea production in the region. To improve technical efficiency, the government should encourage the practice of soil and water conservation technology, implement extension services widely, and promote farmers' awareness on water scarcity. The study also reveals that women tea farmers tend to produce less efficiently than their male counterparts. Policies which aim at increasing female farmers' access to production inputs as well as extension services will be useful for increasing technical efficiency of tea production.

8.2.2.2. Determinants of environmental efficiency

The common factors affecting the environmental efficiency of all tea farms were similar to the results of factors affecting the technical efficiency. Soil and water conservation, farm value, extension, and well water have significantly positive impact on environmental efficiency. These results reconfirm that promoting the application of soil and water conservation techniques on tea farms in the NMR region and improving extension services system play very important role in restructuring tea production sustainably.

8.2.2.3. Determinants of irrigation water use efficiency

The relationship between irrigation water use efficiency and tea farmers and farm' attributes provide insights for policy makers on how to better aim efforts to improve water use efficiency. We found that gender; water scarcity perception; soil and water conservation; non-agricultural income share and extension service positively affect the efficiency of irrigation water use, while using irrigation water from well has negative influence on it. In the strategic context of water conservation, the government should ensure equitable access to water, trainings and participation in water management of female farmers. Furthermore, it is very essential for the government to spread information about water scarcity to farmers, promote the application of soil and water conservation techniques in tea farms, strengthen extension services, and appropriate use of irrigation system in implementing a better water management.

8.2.2.4. Determinants of profit efficiency

The farm-specific variables used to explain efficiencies indicate that those farmers who practices soil and water conservation techniques in the tea fields, better access to extension and market information, mechanizing tea process, directly marketing products to consumers, and those who have high off-farm income and link with enterprises tend to be more profitably efficient.

The policy implications are clear. Profit efficiency in tea farming can be increased significantly by encouraging soil and water conservation practice and strengthening extension services. Also, measures to promote direct marketing activities in the tea farms and improve the farmers' knowledge about farm business management will enhance efficiency. Introducing the market information systems and providing adequate and timely information about the market situations to the tea farmers in the region play very important role in rising profit. It is also essential to facilitate tea farmers coordinating with enterprises in production and consumption. Furthermore, strategies to help smallholders improve their financial capability to mechanize tea processing could be the pathway of higher and more stable income.

8.3. Research contributions

Application four different efficiency analytical models: technical, environmental, irrigation water use and profit efficiency in an integrated framework to assess the sustainability of tea farming is new. Although there have been some studies on tea production efficiency estimation in developing countries (Basnayake & Gunaratne, 2000; Baten et al., 2010; Haridas et al., 2012), particularly in Vietnam such as Saigenji and Zeller (2009). Most of these studies concentrated on estimating output orientation technical efficiency which determines tea farms' possibility to maximize output levels with given set of inputs but their limitation were not to estimate the input-oriented technical efficiency. The input-oriented technical efficiency is defined as the feasible of minimum to observed level of inputs, conditional on observed levels of outputs. Combination of two technical efficiency models in this study provides comprehensive information for tea producers in making their decision on changing their current resources use. To sustain tea production, the input orientation is more strategic than output one. Tea farmers have a considerable opportunity to reduce present inputs without scarifying observed output. Furthermore, analysis of environmental efficiency sheds the light on the current application state of environmentally detrimental inputs such as chemical fertilizer and pesticide and shows empirical data about the tea farms' ability to reduce these bad inputs in their practices which in turn protect environment and improve the safety of tea product. Moreover, improving water use efficiency is an important strategy for addressing future water scarcity, which is particularly driven by increasing human population and potential climate changes. Although an understanding of water use efficiency is required to develop improved water management strategies, little is known about it in tea irrigated systems in the world and Vietnam. Value estimates for tea production's water use efficiency not only raises awareness on water use inefficiencies in tea sector but also provides a partial basis for sustainable water management policies in Vietnam, particularly northern mountainous region and an important reference for other regions experiencing water shortage at present or in the future. Finally, profit efficiency estimation contributes to point out the potential increase of tea production' profit which plays an important role in the improvement of tea famers' income and their livelihood.

Investigation determinants of efficiency measures in term of both socioeconomic and psychological aspects provides a foundation for developing policies that improve tea farm management practices, increase tea famers' welfare and strengthen the Northern mountainous region's smallholder tea sector.

In the global tea market, demand for tea has increased significantly over the past decade. Tea production has also expanded while Vietnamese tea is still being sold primarily in traditional markets, e.g., China, Taiwan and Russia. The potential for exporting tea is expanding due to recent publicity about the usefulness of green tea in preventing ulcers and stomach cancer. However, the world market for tea has also demanded higher quality products. In order to compete in the world market, tea from Vietnam should be more competitive not only in terms of price but more importantly in terms of product quality. This challenge has sparked a movement towards the application of food safety and good agriculture practices stands such as: Global gap, Rainforest, UTZ …etc or the transition to organic farming in long- term tea production which are the ways to improve tea quality standards by satisfying demands for higher quality products and improving health conditions in a highly competitive market. However, not all conventional tea farmers can immediately get these certification or switch to organic production because of financial constraints, loss of tea yield and profit in the transition period, lacking of outside support in the form of extension services, technical training, and payment of certification costs (Nghia 2008). Therefore, the findings of this study on the potential reduction of inputs application in the present tea production technology in the research site while conserving the output will help tea farmers' readiness in terms of production adjustments and attitude changes as they move toward food safety and good agriculture practice certification and organic tea production later.

8.4. Limitations and Recommendations for further studies

Although findings of this research provide useful information on tea farms' performance in terms of technical, environmental, irrigation water use, and profit efficiency which are important indicators for assessing the sustainability of tea production, it limited in geographical areas of the Northern mountainous region. Expanding this study to other tea growing areas of Vietnam to test the findings before applying them at the national level is necessary. Lack of reliable time-series data on tea cultivation activities in the study site limited the study to the use of cross-sectional data. Likewise, the limited period and funds did not allow a larger sample size for the study. Other limitations were inadequate data on the quantity of on-tea farm water-use. Consequently, it was not possible to decompose the water-use inefficiency into water lost through the irrigation conveyance system, the field bunds, and inefficient field application.

With time and resource constraints, this research focused primarily on the supply side of tea production, another area for further research is the demand side. Research on the demand side should include, but not be limited to: What are consumers' preferences to tea products in domestic markets? What marketing schemes could tea producers utilize in order to expand their market share domestically and globally?

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