國立屏東科技大學熱帶農業暨國際合作系
Department of Tropical Agriculture and International Cooperation
National Pingtung University of Science and Technology

博士學位論文
Ph.D. Dissertation

蔬菜小農農家之效益分析：對提升尼泊爾農家所得之意涵

Efficiency Analysis of Smallholder Vegetable Farms: Implications for Improving Rural Household Income in Nepal

指導教授：黃文琪 博士 (Wen-Chi Huang, Ph.D.)

研究生：盧德拉(Rudra Bahadur Shrestha)

中 華 民 國 104 年 6 月 28 日

June 28, 2015

摘要

學號:P10122008

論文題目: 蔬菜小農農家之效益分析：對提升尼泊爾農家所得之意涵

總頁數：214頁

學校名稱：國立屏東科技大學系（所）別：熱帶農業暨國際合作系

畢業時間及摘要別：103學年度第2 學期博士學位論文摘要

研究生：盧德拉指導教授：黃文琪博士

論文摘要內容：

減少貧窮和飢餓是全球具長期挑戰性的問題，特別在發展中國家的尼泊爾更加明顯。增進蔬菜生產效率可幫助小農農家增加收入、減少貧窮並提高生計。本研究使用隨機邊界法（SFA）和資料包絡分析法（DEA）來評估尼泊爾蔬菜小農農家之效率。結果表示大多數的蔬菜小農農家效率都很低。低效率（經濟、技術、配置和規模）的情形在冬季較夏季嚴重，表示冬季仍有相當大的效率提高空間。由於效率低的緣故，產出和利潤的減少平均水準約達25%。若採用最佳技術及資源配置，可大幅降低潛在成本（約60%）。因此高效率農家因減少產出和利潤損失以及得以用較低的成本生產，得以提升家庭所得。低效率的來源主要包含：使用種子的來源類型（未使用改良的種子）、訓練和推廣服務成效不佳、支援服務（市場、信貸和基礎設施）不足及性別差異。若能獲得改良品種、農業貸款、農民的教育水準及推廣服務，蔬菜生產效率將可提升。本研究建議採用更好的種植技術、發展相關基礎設施、加強提供支援服務，特別是女性農民，以提高生產效率。雖然目前尼泊爾已經有部分的支援服務，但本研究認為，應著重在創造出更佳的市場進入條件、針對女性提供推廣服務以及教育訓練以持續大幅增加生產效率。這些支

援服務可增加農民所得、改善農家家庭經濟，並減少尼泊爾小農農家的貧窮問題。

關鍵字：蔬菜農家，低效率，小農，家庭收入，減少貧窮，尼泊爾

Abstract

Student ID: P10122008

Title of Thesis: Efficiency Analysis of Smallholder Vegetable Farms: Implications for Improving Rural Household Income in Nepal

Total Page: 214 Pages

Name of Institute: Department of Tropical Agriculture and International Cooperation, National Pingtung University of Science and Technology

Graduate Date: June 28, 2015 Degree Conferred: Doctoral Degree

Name of Student: Rudra Bahadur Shrestha Advisor: Wen-Chi Huang, Ph. D.

The Contents of Abstract in This Dissertation:

Poverty and hunger reduction are intertwined challenges and enduring issues in the world, particularly in developing countries and more pronounce in Nepal. Improvement in the efficiency in vegetable farming helps farmers increase per capita income, reduce poverty and eventually improve the livelihood of smallholder farmers.This study evaluates the efficiency of vegetable farms in Nepal using parametric stochastic frontier analysis (SFA) and non-parametric data envelopment analysis (DEA) approaches. The results reveal that there is a wide range and great extents of inefficiencies in vegetable farms. The inefficiencies (economic, technical, allocative, and scale) are higher in winter than in summer season implies that there is a considerable potential to improve efficiency in vegetable production in winter season. Because of the inefficiencies in vegetable farms, the farmers lost levels of outputs and profits is about 25 %. In addition, the farmers could have much higher levels of potential costs reduction (about 60 %), and such cost reduction comes by adopting the best technology practices of the efficient farms through the optimal resource allocation. The farms operate at the frontier levels could recover these levels of outputs and profit losses, and reduce the excessive use of input costs that improve the household income of vegetable farmers. The inefficiencies mainly caused by seed types (not using the improved varieties), ineffective training and extension services, inadequate support services (market, credit, and infrastructures), and gender discrepancy in vegetable farming. This study suggests that vegetable farms have substantial potential for improving vegetable production efficiency with greater access to improved seeds, agricultural credit, education levels of farmers, and extension services. This study recommends to adopt improved vegetable farming technologies, infrastructures development associated with vegetable farming, and support servicesfor farmers in general and women farmers in particular, to increase farm efficiency. While some of these support services are currently available, this study suggests that more focus be given to creating improved market access, to women focused extension, and to training packages for sustainable and substantial increase in production efficiency. These support services can lead to increase farm income, improve household economy, and eventually reduce poverty of smallholder farmers in Nepal.

Keywords: Vegetable farm, inefficiency, smallholder farmer, household income, poverty reduction, Nepal

Acknowledgement

This study has been carried out at the Department of Tropical Agriculture and International Cooperation (DTAIC), National Pingtung University of Science and Technology (NPUST), Taiwan. This is the outcome of knowledge that I received from this university, my tremendous efforts, and clear guidance of my adviser. I would like to thank DTAIC, NPUST for providing me this great opportunity to pursue my doctoral degree. I would also like to express my sincere gratitude to the Ministry of Agricultural Development, the Government of Nepal for granting me study leave in pursuing doctoral studies.

I would like to express my profound gratitude and heartfelt appreciation to my adviser Associate Professor Dr. Wen-Chi Huang for her invaluable contribution on constructive and overwhelming guidance throughout the research work.Her constantly intellectual directionand critical reviews of research outcomes helped me to find a right tract towards the right direction made possible the successful completion of this dissertation. I would like to greatly appreciate my advisory committee members: Dr. Jeun-Sheng Lin, Dr. Jin-Jou Dai, Dr. Ke-Chung Peng, and Dr. Chen-Te Huang for their critical and constructive guidance and continuous encouragement for successful accomplishment of this research work.

I would like to express my sincere thanks to Dr. Pai-Po Lee, Dr. Henry Chen, Dr. Joey Lee, Dr. Shwu-En Chen, Dr. Phillip Cheng, Dr. Albert Linton Charles, Dr. Kevin Yen, Dr. Yuan-Chih Liu, and Dr. Rebecca H. Chung for their encouragement and supports during study at NPUST. I would like to thank Barbara, Shau-Ling, Ya-Hui, Sophia, Joanna, Iris, andall DTAIC staffs for their supports in my study.

I would like to thank Dr. Haribabu Tiwari and staffs atABPMDD, Youbraj Pandey and staffs atDistrict Agriculture Development Office

(DADO) Dolakha, Hom Raj Bista and staffs at DADO Dhading, Baldhoj Khadka and Kokanath Ghimire at DADO Lalitpur, Ramswarth Mandal (DADO, Dhanusa), and Agriculture Market Management Office, Dhalkebar, Dhanusafor their great supports infield data collection. I would like to thank all farmers in study areasfor providing me supportive response and required information that helped me to accomplish my study.

I would like to express my sincere thanks to Dr. Yam Bahadur Thapa, Dr. Ganesh R. Joshi, Dr. YubakDhoj GC, and Mr. Anand Aditya for their suggestions and inspirations in pursuing this degree and the research work. I would like to thank Dr. Thomas G. Johnson, University of Missouri, and Dr. Shriniwas Gautam, AVRDC - The World Vegetable Center for their invaluable supports to accomplish this research work.I would like to thank my colleagues at NPUST: Edgardo,Omkar, Angel, Raju, Rupak, Diana, Nabin, and Johnson for their supports during entire study.

I am extremely grateful to my parents (Ratna Bahadur Shrestha and Lekha Laxmi Shrestha) and my family for their constant encouragements in pursuing my doctoral studies. Last but not the least, of course, my family, friends, and neighbors have been great support to accomplish my PhD degree. My wife, Ms. Upasana Pradhan Shrestha, who provided me continuous encouragements and untiring supports to my study, besides her office and taking care home and kids,without this great effort it would not be success. Didi Usha, whotook care of home, family and kids,my elder son Utsav Shrestha, and younger son Rupansh Shrestha, my brothers and sisters, and relatives who helped me in one way or the other for accomplishingthis degree would be a great gratitude.

Table of Contents

List of Tables

List of Figures

List of Abbreviation

ABPMDD:	Agribusiness Promotion and Marketing Development Directorate
AE:	Allocative efficiency
APMMC:	Agriculture Produce Market Management Committee
ASC:	Agriculture Service Center
CBS:	Central Bureau of Statistics
CIPM:	Community integrated pest management
CRS:	Constant returns to scale
DADO:	District Agriculture Development Office
DEA:	Data Envelopment Analysis
DMU:	Decision making unit
DOA:	Department of Agriculture
EE:	Economic efficiency
GDP:	Gross Domestic Product
Go:	Government organization
GON:	Government of Nepal
HCR:	Head count ratio
HDO:	Horticulture Development Officer
KFVM:	Kalimati Fruit and Vegetable Market
LP	Linear programing
LR:	Likelihood ratio
MDG:	Millennium Development Goal
MLE:	Maximum likelihood estimate
MOAD:	Ministry of Agricultural Development
NGO:	Non-governmental organization
No:	Number of observations/farms
OLS:	Ordinary least square
PE:	Profit efficiency
PHC:	Poverty head count

PTE:	Pure technical efficiency
SAARC:	South Asian Association for Regional Cooperation
SC	Standardized coefficient
SE:	Scale efficiency
SFA:	Stochastic Frontier Analysis
SFTPF:	Stochastic frontier translog production function
TC	Technical change
TE:	Technical efficiency
TFP	Total factor productivity
VDC:	Village Development Office
VRS:	Variable returns to scale

Chapter 1

Introduction

Poverty and hunger reduction are intertwined challenges and enduring issues in the world, particularly in developing countries and more pronounce in Nepal. The United Nations, through its Millennium Development Goal, (MDG 1), and the World Bank put high priority on ending poverty in the world by 2030 (World Bank, 2014). The feasibility of achieving absolute poverty reduction (based on the US$1 a day poverty line), and hunger reduction depend on the rate of average income growth and level of income inequality (Mehta and Shah, 2003). Improvement in farm productivity and productive efficiency of smallholder farmersin vegetable farming could be the best strategy in attaining these poverty alleviation and hunger reduction targets (Binswanger and Quizon, 1986; Islam, 2008).

The majorities of people in developing countries live in rural area and most of them are smallholders. The smallholders as those with a low asset base, and operating in less than 2 hectares of cropland as defined by World Bank (2003). Such smallholders are the most potential to contribute to intensify agriculture production, economic growth and reduce poverty (Hazell et al., 2010; Poulton et al., 2010).About 87 % of the world's 500 million smallholders are in Asia and the Pacific region (Thapa and Gaiha, 2011). In Nepalese context, about 80 % of farmers are smallholders and their livelihoods depend on subsistence type agriculture, and they are vulnerable in poverty incidence (MOAD, 2014a). In order to increase per capita income and improve household economy, vegetable farming is one of the best options for rural farmers.

Most of the farm households in Nepal, like those in many other developing countries, are frequently constrained by low literacy, low rates of technology adoption, and inefficient use of resources. This leads to high costs of production and lose of cost advantages compared to imported vegetables. With improvements in efficiency, Nepal could improve its comparative advantage in vegetable production and marketing. To improve its comparative advantage, Nepalese vegetable producers must achieve higher farm productivity and efficiency. Such increased efficiency could help close the current productivity gap in vegetable productivity (currently 12.8Mt/Ha., but potentially 17Mt/Ha.) (MOAD, 2014a) allowing vegetable farmers not only to meet the increasing domestic demand for vegetables but also to export vegetables to neighbouring countries.

Some reports indicate that poor quality seeds, inadequate fertilizers, and poor access to credit and markets limit the productivity of vegetable producers (NARC, 2010; Huong et al., 2013; MOAD, 2014a).While this is undoubtedly true, but such generalized statements do not provide specific policy prescriptions for a country where vegetables are grown in every seasons and in diversified agro-ecological regions. A study on the efficiency of vegetable production is quite complicated because of diversities in the varieties of vegetables grwon by farmers, different durations of crop harvesting, and wide ranges in scale of production and value of output.Therefore, there is a need for empirical study that estimate the efficiency levels of vegetable farms and analyze the relationship between inputs, technology related variables and socio-economic factors. Only focused research of this nature can be the basis of policies that promote productivity and efficiency in vegetable production.

In this milieu, this study therefore aimed to analyze the efficiency of smallholder vegetable farms and to suggest high priority areas for policy intervention designed to improve the efficiency of vegetable production, and lead to substantial and sustainable increases in farm income, improve rural economy, and reduce rural poverty in Nepal. This study adopted both parametric and non-parametric approaches to estimate the efficiencies with closer scrutiny into farm levels (household and plots), seasons (winter and summer), agroecological regions (mountain, hills, and terai), and gender perspectives.Some explanatory variables related to technology, farm-specific characteristics, and socio-economic factorswere introduced to indentify the potential factors affecting inefficiency in vegetable production.

This study is divided into five chapters: introduction, literature review, materials and methods, results and discussion, and conclusions and policy recommendations. This study consists of five separate studies: study I) technical efficiency of vegetable farms at household levels using stochastic Cob-Douglas production function; study II) technical efficiency of vegetable farms at plot levels in seasonal, agroecological, and gender perspectives using stochastic translog production function; study III) profit efficiency of vegetable farms at household levels using stochastic translog profit function; study IV) economic, technical, allocative, pure technical, and scale efficiency of vegetable farms at plot levels using input oriented data envelopment analysis; and study V) women's labor contribution on the efficiency of vegetable farms as a case study in mountain region in Nepal.

1.1 Background

1.1.1 Economy and rural poverty in South Asia

Asia, where more than half of the world's poor live, has a disproportionate distribution of poor with almost three-quarters of the continent's poor residing in South Asia (CBS, 2013; SAARC, 2014).The distribution of poverty head count (PHC) ratio at rural poverty line within the South Asian Association for Regional Cooperation (SAARC) members (eight countries) is also disproportionate. Nepal has the third highest incidence of poverty (27.40 %) after Afghanistan (37.50 %) and Bangladesh (35.16 %) (Table1). In Nepal, poverty incidence varies by geography; higher in the mountainous region (43.3 %) and lower in the hilly and terai regions (southern tropical plain) with rates hovering around 25 % (SAARC, 2014).

Table 1. Rural population, GDP growth rate, per capita income, and poverty incidence in South Asian countries, 2012

Countries	Rural population (%)	GDP growth (%)	GDP per capita income (US$)	Rural poverty line (%)
Afghanistan	76.14	14.39	651.00	37.50
Bangladesh	71.11	6.23	694.70	35.16
Bhutan	63.66	9.44	2365.50	16.70
India	68.34	3.24	1553.90	25.70
Maldives	57.76	3.42	6175.00	-
Nepal	82.66	4.85	681.20	27.40
Pakistan	63.45	4.02	1185.50	27.00
Sri Lanka	84.78	6.41	2827.80	9.40
Average	70.99	6.50	1420.40	25.60

PHC: Poverty Head Count.

Source: CBS (2013).

Table 1 show that the average annual growth rate of gross domestic product (GDP) in South Asia was 6.50% in 2012; while Nepal placed at the fifth position (4.85 %) after Afghanistan (14.39 %), Bhutan (9.44 %), Sri Lanka (6.41 %), and Bangladesh (6.23 %). With regard to GDP per capita income, the average of South Asian countries was 1,420.40 US$, while Nepal positioned at the second last (681.20 US$) after Afghanistan (651.00 US$). Given these facts, Nepal has been vulnerable in terms of poverty and economic development that suggest that there is urgent need to improve the economic situation of the country. The findings of this study recommend some policy implications that increase the household income of rural vegetable farmers in Nepal.

1.1.2 Vegetable production trends in Nepal

Vegetable farming is a strategic component for Nepalese rural economy because of its contribution in creating self-employment opportunities and generating income for millions of farmers in the country. About 3.2 million of total 4.64 million farmers cultivate vegetables in 0.25 million hectares of land, and produced 3.3 million tonnes of vegetables in 2012 (MOAD, 2013). The area of vegetable cultivation has been increased by double from 0.14 million hectares in 1993 to 0.25 million hectares in 2012 (Appendix 1). Figure 1 shows that the production has been augmented by triplefrom 1.2 million tonnes in 1993 to 3.3 million tonnes in 2012, and productivity increased from 8.52 mt/ha in 1993/94 to 13.40 mt/ha in 2012/13with annual growth rate 3 %during this period.

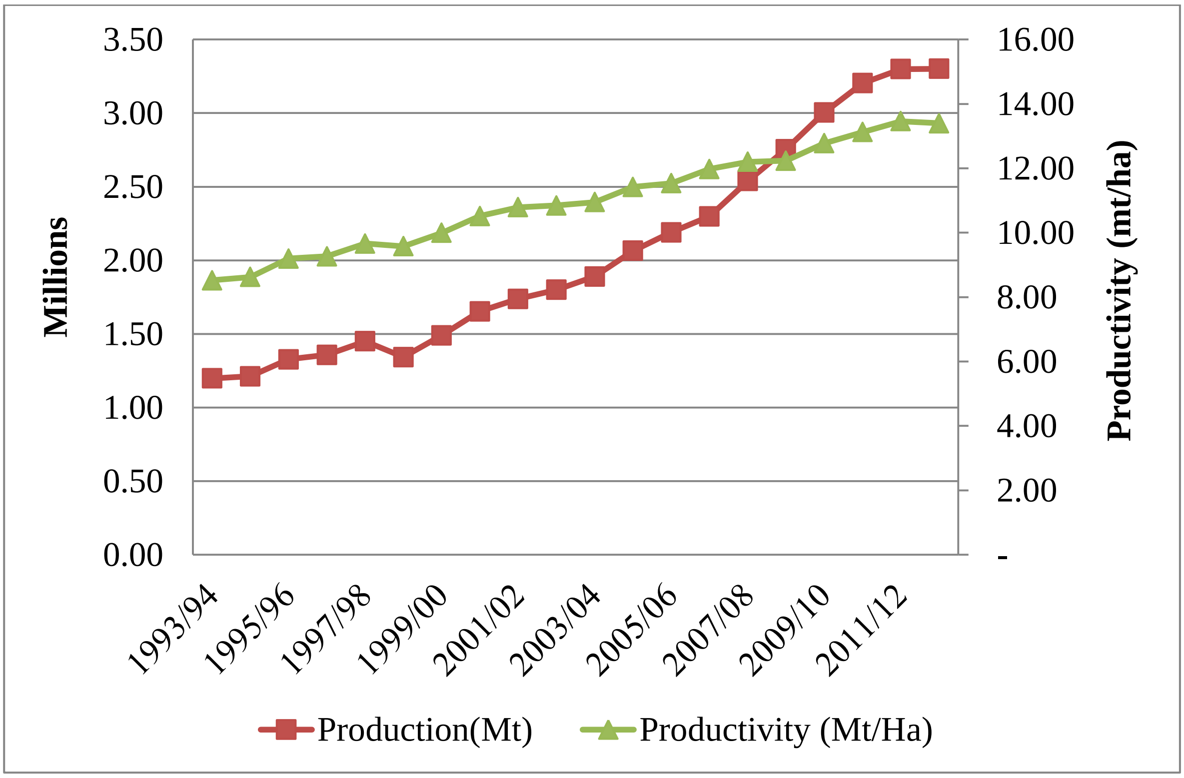


Figure 1. Production and productivity of vegetables in Nepal, 1993/94-2012/13

The domestic supply of vegetable for consumption is much lower than those that of demand, and the deficit quantities have been fulfilled by importing from neiboring countries, which was estimated at 77 million US$ (1US$ = Rs 86.93 as of February 2013) in a year (MOAD, 2013). However, there is a huge deficitent (60 %) per capita vegetable intake as 300gm/person/day is the standard requirement (Gautam and Bhattarai, 2006), which suggest to substantially increase in vegetable production in Nepal.

1.1.3 Constraints and opportunities for vegetable production in Nepal

Nepalese agriculture, particularly the vegetable sector has been encountered by several constraints and holds plenty of opportunities. Based on Thirteen Periodic Development Plan (NPC, 2014), Agriculture Development Strategy (MOAD, 2014a), and National Agriculture Policy (MOAD, 2004), some important constraints and opportunities in Nepalese vegetable production are listed below:

1.1.3.1 Constraints in vegetable production

1. Prevalence of small-land holding size negatively affect to increase the economics of scale and the efficiencies in vegetable production;
2. Scarcity of irrigation facilities in vegetable farming that reduce the level of efficiency in vegetable production;
3. Inadequate supply of basic agricultural production inputs such as improved seeds, chemical fertilizers, and plant medicines;
4. Agriculture extension systems are not effective and farmers are adopting traditional farming technologies that affected to reduce the efficiency in vegetable production;
5. Weak access to agricultural credits to smallholder farmers limiting to use required agricultural inputs that reduced the efficiency of vegetable farms;

6. Higher rates of youth out-migration toward foreign countries seeking better opportunities that affected to have scarcity of laborers for vegetable farming;
7. Inadequate infrastructure facilities such as agriculture road networks, cold storages, market infrastructures, and processing plants that affected on the efficiency in vegetable production;
8. Poor access to marketing facilities affected farmers to sell their products in a competitive prices that reduced the efficiency in vegetable production;
9. Higher levels of marketing margins; higher consumer prices and lower farm gate price of vegetables that discouraged farmers to increase vegetable production;
10. Ineffective marketing information services to farmers on price, quality, and quantity of inputs and outputs reduced the efficiency in vegetable production;
11. Higher rates of post-harvest losses(ranges 20 - 50 %),especially during handling, loading and unloading, transportation, and packaging of vegetables that reduced the farmers' profit and discouraged farmers to increase vegetable production;
12. Lack of competitiveness of vegetable products in terms of price, quality and quantity as compared to imported products reduce the efficiency in vegetable production;
13. Researches on vegetable sector is not in the priority list of government planning and budgeting systems;
14. Researches could not address the cross-cutting issues of vegetable production with technological, socio-economic, and environmental factors.

In this study, the constraints in vegetable farming were surveyed from individual sample farmers. The constraints were categorized into seven groups such as constraints in inputs availability (improved seed, fertilizers, and pesticides), labor availability, irrigation facilities, transportation services, technical supports (improved farming practices and crop management), information services (price, demand and supply of inputs and outputs), and market access. The major constraints encountered by farmers in different districts in decreasing order were for irrigation facilities, followed by market access, technical support, information services, input availability, labor availability, and transport services (Appendix 2).

1.1.3.2 Opportunities in vegetable production

1. The Nepal government, non-governmental organizations (NGOs), and different supporting agencies have been working in agriculture development;
2. Larger numbers with different capacities of technicians are working in disseminating improved technologies, extension services, and back-stopping to the farmers in vegetable production;
3. Farmers, entrepreneurs, and traders are working associated with their respective commodity associations or professional associations or farmers' group and cooperatives that increase the collective power in promoting vegetable production;
4. Diverse agroecological regions (mountain, hills, and terai) and associated climatic conditions are favorable environment to produce vegetables throughout the year;
5. Gradual development of agro-based industries in the country;
6. Greater possibilities to increase the levels of productivity of different vegetable crops;
7. Greater potentialities to export fresh vegetables in the markets of neighboring countries;
8. Increase in demand of fresh vegetable products, particularly organic products because of health consciousness to the people;

1.1.4 Government policies for vegetables production in Nepal

The government of Nepal started its first periodic development plan in1956. In each successive period development plans, particularly from the eighth plan (1990), poverty alleviation and food security have been the major goals where agriculture as the main priority sector in Nepal. In general, there are two types of development plans and policies formulation processes: first, long-term policies for 20 years and; second, short-term or periodic policies for 3-5 years. The long-term policies with regards to agricultural development are Agriculture Perspective Plan 1995-2015(NPC, 1995), National Agriculture Policy (MOAD, 2004), Agribusiness Promotion Policy (MOAD, 2005), and Agriculture Development Strategy (MOAD, 2014a). The short-term policies are: Thirteenth Interim Development Plan (NPC, 2014), and Food and Nutrition Security Plan of Action (MOAD, 2014b).

The current periodic plan, the Thirteenth National Development Plan (NPC, 2014), has a target of reducing the poverty head count ratio (HCR) below 18 % with annual economic growth sustained at 6.0 % (agriculture: 4.5: non-agriculture: 6.7) and employment growth at 3.2 %. To realize these objectives and targets, high-value crops including vegetables are identified as priority areas. Indeed, vegetables play an important role in reducing hunger and malnutrition for billions of people around the world (AVRDC, 2010). The vegetable sector offers great opportunities for poverty reduction through employment and income generation (Weinberger and Lumpkin, 2007; Tiwari et al., 2008). On the basis of MOAD (2004), MOAD (2005), MOAD (2014a) and NPC (2014), the policies for vegetable development in the country are as follows:

1. Promote improved seed varieties of vegetable crops in seasonal and agroecological perspectives by encouraging private sectors;

2. Construct and manage irrigation systems for vegetable farming through groundwater, surface water, micro-irrigation, rain water harvest technologies, and small irrigation program scheme;
3. Subsidize farmers in fertilizer costs;
4. Sustainable use of productive resources such as land and water resource management and technical assistance program;
5. Farmers' access to financial resources through agriculture credit programs by encouraging agriculture development banks, commercial banks and cooperatives;
6. Practical and results-oriented technologies development;
7. Promote integrated approach of researches, extension services, and education programs;
8. Decentralization and strengthening the researches and extension services towards farmers;
9. Enhance marketing capacity of farmers by establishing different types of market infrastructures, market information services, and marketing linkage among producer, traders, input suppliers;
10. Management marketing systems and regulate markets to be ensured that farmers could get market access;
11. Prioritize infrastructures development on agricultural road networks that link production areas to markets, and establish agro-processing plants;
12. Promote, strengthen, and involvement of women at least 33 % in each socio-economic activity.

1.2 Statement of the problems

Nepalese vegetable sector has been constrained by limited resources, inefficient use of available resources, inadequate infrastructures (agriculture road networks, irrigation facilities, cold storage facilities, and marketing facilities, for example), technological advancement, and various socio-economic factors. The smallholder vegetable farmers have weak access to markets that led vegetable farms to be inefficient. Pokhrel (2010) reported that farmers are mandatory to sale their products whatever the price fixed by traders because of perishable nature of the products, and ineffective marketing systems. In developing countries, smallholder farmers are frequently handicapped by ineffective extension services (Akobundu et al., 2004) and poor access to agriculture credit (Fletschner, 2008) that lead vegetable sector to be inefficient. One of the main concerns in vegetable farming in developing agriculture is gender discrimination (FAO, 2011); women are the one who usually involve in farming activities which is not accounted in household economy. As a consequence, vegetable production system has been inefficient that led to be higher cost of production, which is the main cause of importing higher quantity of vegetables from neighboring countries to meet the domestic demand. If continuation of such problems for long-term would have downbeat effects not only on vegetable production but also effect on the overall economy in the country. In fact, since the technological development is a slow process, the increase in agriculture growth depends on improving the technical efficiency (Hussain et al., 2012). Efficiency gains would have positive impacts on raising farm income of resource poor farmers and that improve the household economy (Rahman, 2003).

The production, productivity, and efficiency differ in diverse agroecological regions and seasons because of natural environment (agro-climatic conditions), different levels of support services, technology adoption, farm-specific characteristics, and socio-economic factors. Only the focused study with regard to efficiency in vegetable production in relation with these stated variables would infer policies that increase per capita income of farmers and that eventually reduce rural poverty.

Therefore, there is a need of empirical study that could derive policies on inputs prioritization, costs minimization, and outputs optimization in vegetables production where the frontier analysis is the best approach. Previous researches (Pudasaini, 1984; Dhungana et al., 2004; Bhatta et al., 2008; Adhikari and Bjørndal, 2009; Paudel and Matsuoka, 2009; Piya et al., 2012) estimated the efficiencies on agricultural commodities but not the vegetable sector. Indeed, there is a dearth of study in estimating the efficiency of vegetable farms and associated issues of farm-specific socio-economic factors, and cross-cutting issues with household income. This study therefore was designed to analyze the efficiency of smallholder vegetable farms in seasonal, agroecological, and gender perspectives using both parametric and non-parametric approaches and derived policies to enhance the efficiency in vegetable production that contribute for improving household income and reducing poverty in Nepal.

1.3 Objectives of the study

The main objective of this study was to analyze the efficiency of smallholder vegetable farms and to derive policies for improving the rural household income in Nepal. The specific objectives of this study were:

1. To evaluate the technical efficiency of vegetable farms at household levels;
2. To estimate the technical efficiency of vegetable farms at plot levels and compare the efficiency performance between seasonal, agroecological and gender perspectives;
3. To measure the profit efficiency of vegetable farms at household levels;
4. To estimate the economic, technical, allocative, pure technical and scale efficiency of vegetable farms at plot levels in seasonal perspective;
5. To estimate output-loss, profit-loss and potential cost reduction in vegetable farms;
6. To determine the factors affecting inefficiency in vegetable farms and recommends policies to enhance the efficiency in vegetable production and improve the rural household income in Nepal.

1.4 Scope of the study

This study evaluated the efficiency of vegetable farms closer scrutiny into seasonal, agroecological, and gender perspectives with regard to explanatory variables (technology related, farm-specific characteristics, and socio-economic factors). The main outcome of this study is to infer policies in improving the rural household income by enhancing the efficiency in vegetable production.

In a developing agriculture when the land is inelastic, resources are very limited, and extension services are ineffective, the efficiency analysis is very useful to optimize the production and minimize the costs. Inefficiency increases the cost of production, loss of outputs and profits to farmers, and reduces the household income that making it a genuine concern for policy analysts. The analysis of different factors influencing the efficiency is very much helpful in formulating adequate policies that can potentially optimize in production with the minimum costs that increase per capita income of farmers. Such policies make vegetable sector more competitive and efficient. The specific scopes of this study are as follows:

1. Evaluate the technical efficiency and profit efficiency of vegetable farms at household levels;
2. Estimate the economic, technical, allocative, and scale efficiency of vegetable farms at the plot levels;
3. Compare the farm efficiencies between seasons (winter and summer),agroecological regions (mountain, hill and terai), and gender (women and men) of vegetable farms at plot levels;
4. Assess the variable inputs used in vegetable farming;
5. Assess farm-specific characteristics and socio-economic variables that influence the levels of efficiencies in vegetable production;

6. Estimate the optimum levels of outputs and output-loss, the minimum level of cost and potential cost-reduction, and the optimum level of profit and profit-loss in vegetable farming;
7. Recommend policies to prioritize variable inputs, and different factors related to farm-specific characters and socio-economic variables to optimize the vegetable production;
8. Suggest policies to increase income, improve rural economy, and reduce poverty by enhancing efficiency in vegetable production.

1.5 Contribution of the study

This study evaluated the efficiencies (economic, technical, allocative, and scale) of vegetable farms (household and plot levels) in seasonal, agroecological, and gender perspectives. Based on the empirical results of this study, some important policies are recommended to enhance the efficiency in vegetable production with optimizing outputs and minimizing inputs. The increased efficiency in vegetable production would increase the levels of per capita income of farmers, improve household economy, and that contribute to reduce rural poverty in Nepal. Specifically, the contributions of this study are as follows:

1. This study represents three agroecological regions and two major seasons. Thus, the policies recommendations of this study generalize the policies to enhance vegetable production in whole country;
2. The findings of this study help policymakers to prioritize the variable inputs and address farm-specific characteristics and socio-economic factors to enhance vegetable production;
3. The farmers would be able to appropriate use of scare resources in vegetable farming that reduce the cost of production, reduce the price of products, increase vegetable consumption, and that eventually contribute in food and nutrition security;

4. Vegetable farmers would be encouraged in vegetable farming, increase rural employments, increase per capita income, improve household economy, and eventually reduce the rural poverty;
5. Policy recommendations of this study help to optimize the vegetables production and potentially increase export toward the neighboring countries, and that eventually contribute to improve the national economy of the country;
6. It helps to empirical and theoretical contribution in frontier production frontage proving that parametric and non-parametric analysis can be an appropriate tool to estimate efficiency of smallholder vegetable farms;
7. This study adds the literatures in the field of frontier production analysis of vegetable farms that is applicable in the similar agroecological and socio-economic conditions in other countries.

1.6 Definition of the operational terms

The following terms are defined in this study:

1. Smallholder vegetable farms: Smallholder vegetable farms are those with a low asset base and operating the farms in less than 2 hectares of cropland as defined by World Bank (2003). In this study, the farm size less than 2 hectares was considered as the smallholder vegetable farmers.
2. Agroecological regions: Agroecological regions are characterized in terms of altitudes: mountain (2000m to 2600m), hills (1000m to 1900m), and terai (250m to 500m) in this study (detailed agroecological features are discussed in Table 9).
3. Seasonal vegetable farming: In this study, the seasons for vegetable farming in Nepal are broadly classified into two: winter and summer. The winter season vegetables that are

harvested during September to February, and summer season vegetables that are harvested during March to August.

4. Household level vegetable farm: A household level vegetable farm was considered as the sample unit as a part of this study, which included several vegetable farm plots of different types of vegetables produced by household.
5. Plot level vegetable farms: Vegetable farm plot was undertaken as sample unit as a part of this study. Thus, one household might have more than one vegetable farm plots.
6. Farm-specific and socio-economic variables: Those explanatory variables that might affect the efficiency in vegetable production. Such variables are technology related (improved or local seeds, training and extension services), support services (credit access, information, market or infrastructure), socio-economic factors (age, gender and education levels of farmers).
7. Farm manager: The farm manager is considered as a person in the farm household who was the main decision-maker and responsible to manage the vegetable farms.
8. Agriculture Service Center (ACS): ASC is a government institution at the field level, which is responsible for disseminating vegetable farming technologies to the farmers.
9. External support: The support services from government organizations (GOs), non-governmental organizations (NGOs), and cooperatives in terms of providing fertilizers, irrigation facilities, improved seeds, pesticides, production materials, extension services, and post-harvest materials to the farmers.

Chapter 2

Literature Review

2.1 Nepalese agriculture

The summary of literatures on Nepalese agriculture is presented in Table 2. Enhancing the efficiency in agriculture is only the option to feed the growing population (1.35 %) in Nepal from the inelastic land and limited resources. In developing countries, the major challnges are how to meet the food and nutrition requirements for growing population, and how to reduce the rural poverty incidence of smallholder resource poor farmers. In Nepalese context, the majority of the farmers (more than 80 %) are smallholders, and they are frequently constrained with resources in terms of improved seeds, fertilizers and poor access to agriculture credits to the farmers (Shrestha et al., 2014). Further, they are handicapped with less adoption of technologies, less access to markets, and low levels of education (MOAD, 2014a). USAID (2011) reported that the major constraints in vegetable farming are: lack of knowledge among the producers of proper usage of fertilizers and pesticides; lack of irrigation facilities; labor shortage; and higher rate of post-harvest losses. Pokhrel (2010) reported that vegetable farmers are highly constraints with road networks, market structures and cold storages.

The government policies (NPC, 1995; MOAD, 2004; MOAD, 2014a; NPC, 2014) have a main objective to reduce poverty and ensure food and nutrition security of the people in the country thorough increasing the levels of production, productivity and efficiency of agricultural commodities. The Agriculture Perspective Plan (NPC, 1995) and Agriculture Development Strategy (MOAD, 2014a) are the major guiding policy documents; which clearly pointed out the priority sectors, high-value crops, particularly the vegetable crops, to achieving the targets of poverty reduction. However, the government put agriculture as the most prioritized sector in its plans (MOAD, 2014a; NPC, 2014) to meet plan’s targets; the budget allocation has been proportionately very low. Such types of miss-match planning and programming practices ultimately happened to be failed to attain targeted objectives. Indeed, the budget allocation for agriculture sector development in each periodic plan has been around 2-3% of the total budget, which is far below its contribution in national economy. According to the rule of Thumb, the budget should be proportionately allocated as the levels of contribution of the respective sector. As the share of agriculture in GDP is 35 % (MOAD, 2013; NPC, 2014), the budget need to be allocated the same proportion. Vegetable farming is the most productive sector that has multiplier effects on the economy. The national investment policies need to be focused on such types of most productive sector. Dillon et al. (2011) argued that public investment in rural road and irrigation are the most productive than in other sectors that had greater impacts on economic growth.

Pudasaini (1983) conducted a study on impacts of education on agriculture, and reported that higher levels of education had a significant role in modernizing agriculture and higher payoff. Further, Pudasaini (1984) revealed that levels of education, labor, bullocks and fertilizers had positively impact on crop production (rice, wheat, maize, and sugarcane) in both terai and hill regions. While both of these studies may not have implications in the context of socio-economic and technological changes. Dhungana et al. (2004) conducted a study on measuring economic, allocative, technical, pure technical and scale inefficiencies of Nealese rice farms using Data Envelopment Analysis (DEA). The variations in outputs was determined by farmers' level of risk attitude, gender of farm manager, ageand education of manager, and family labour. A study of Bhatta et al. (2008) was focused on effects of extension services on the technical efficiency of crop production using Stochastic Frontier Analysis (SFA), and revealed that the technical efficiency was positively determined by agricultural extension services provided by NGOs but not by thegovernmental organisations.

Adhikari and Bjørndal (2009) conducted a study on the technical efficiency in agriculture (Cereal, pulses, and other crops) using stochastic distance function and data envelopment analysis, and reported two main results: one, medium sized farms achieved a higher level of technical efficiency than large and small-farm; second, production frontier was increased by land ownership, land quality, education levels of farmers, and irrigation facilities. Piya et al. (2012) revealed that land, chemicals, seeds, degree of commercialization, and age of farmers had positive effects on the technical efficiency of rice production. Agricultural commercial reduces the cost per unit of inputs and increase the economics of scalethat help to increase the efficiency in production. Agricultural commercialization was determined by chemical fertilizer, tractor-ploughing, pump-set irrigation, and size of land holding (Nepal and Thapa, 2009).

Paudel and Matsuoka (2009) estimated the cost efficiency using stochastic frontier cost function on maize, revealed that the cost efficiency was positively determined by cost of tractor, animal power, labour, fertilizers, manure, seeds and outputs of maize. Tiwari et al. (2008) compared the vegetable crops with traditional cereal crops, and revealed that the farmers significantly improved their household economy and reduced the levels of poverty through vegetable farming than those that of cereal crops.

On the review of these literatures, we can certain that there is a dearth of studies addressing issues of the efficiency in vegetable production in relation with the cross-cutting issues of socio-economic factors, rural household income, and poverty reduction. Because of which there is a great problem to formulate appropriate policies to increase vegetable production.

Table 2. Summary of literatures on Nepalese agriculture

Author	Commodity/Issue	Country	Methodology	Main results
Dillon et al., 2011	Public investment	Nepal	Hedonic, and marginal cost	Rural roads and irrigation are the most productive public expenditures.
Pudasaini, 1983	Agriculture	Nepal (terai and hill)	Production function	Education contributes to productivity and efficiency in agriculture.
Pudasaini, 1984	Rice, wheat, maize, sugarcane	Nepal (terai and hill)	Cobb-Douglas production	Education, labor, bullocks and fertilizer contributed positively in crop production.
Dhungana et al., 2004	Rice farmers	Nepal	DEA and Tobit regression	Efficiency determined by risk attitude, gender, age, education and family labour.
Bhatta et al., 2008	Crop farms	Far-western, Nepal	SFA	Positive effect of extension service provided by NGOs on the TE.
Adhikari and Bjørndal, 2009	Cereal, pulses, and other crops	Nepal	SDF and DEA	Medium size farms achieve a higher TE than large and smaller.
Piya et al., 2012	Rice farms	Chitwan and Dhading, Nepal	SFA	Land, chemicals, seeds, degree of commercialization, and age of farmer positive effects on outputs and TE.

Table 2. Continue……

Author	Commodity/Issue	Country	Methodology	Main results
Nepal and Thapa, 2009	Agriculture	Morang, Nepal	Regression	Fertilizer, tractor-ploughing, pump-set irrigation and size of landholding determined commercialization.
Paudel and Matsuoka, 2009	Maize	Chitwan, Nepal	Stochastic frontier cost function	Cost of tractor, animal power, labour, fertilizer, manure, seed, and maize output had positive effects on cost efficiency.
Tiwari et al., 2008	Vegetables and cereals	Mountain Nepal	Crop yield index, cropping diversification	Farmers improved their income, and reduced poverty by vegetable farming.
Shrestha et al., 2014a	Tomato	Nepal	Price cointegration	Negative price shock in market hurt producers that reduced the efficiency.
Mishra and Kumar, 2005	Vegetables	Nepal	Market cointegration	Perishability and longer distance affect to be lesser the market integration.
Aryal et al., 2009	Organic product	Mid-hill, Nepal	WTP, Probit regression	Willingness to pay 30 % premiums for training CIPM.
Atreya et al., 2012	Vegetable farming	Nepal	Regression	Consumers likely to pay 53-79 0% price for organic vegetables.

2.2 Vegetable production systems in Nepal

The summary of literatures on vegetable production system in Nepal is presented in Table 2. Vegetable farming in Nepal is one of the major components for generating income, and supplying nutrients to the farmers in rural communities in Nepal. It is broadly classified into two seasons, winter and summer, where 72.1 % and 68.8 % of households grow vegetables in these seasons, respectively (CBS, 2011). The winter season vegetable farming is characterized by dry and cold weather, less rain, and lack of irrigation facilities, while the summer season vegetables exist with sufficient rain water, irrigation facilities, and relatively hot weather. The common winter season vegetable crops are cauliflower, tomato, cabbage, radish, bean, cowpea, and eggplant, while summer season vegetable crops are gourds (bitter, bottle, pointed and sponge), pumpkin, cucumber, cowpea, tomato, and cabbage (CBS, 2010). The majority of the farmers cultivate vegetables in their own land, they use both manual and animal power intensively, most of them purchase seeds from nearby markets, majority of them apply compost instead of fertilizer, and most of the farmers work with farmers' group or cooperatives.

Nepal has divese agroecological conditions: mountain (northern temperate mountainous regions), hills (sub-tropical), and terai (southern tropical plain) and this climatic variation offers Nepalese farmers with a rare opportunity to produce vegetables throughout the year. Terai has better access to roads, markets, infrastructures, extension services, and public services than hill; and hill is relatively accessible than the mountain. Adhikari and Bjørndal (2009) reported that terai region is more efficient in agriculture production than those that of hills and mountains.

Nepalese agriculture is subsistence type with small-scale land holding. The average size of holding is less than 0.7 hectares (CBS, 2011). However, recently, an increasing number of Nepalese farmers are going into commercial vegetables production, especially in the peri-urban areas or areas with good roads and market access (Sapkota, 2004). Midmore and Jansen (2003) argued that peri-urban area is more suitable for vegetable production because of pre- and post-vegetable production support services are available.

In the recent years, there is a growing concern of organic vegetable, pesticide risks to human health, and natural environment and ecosystems. A study of Kafle (2011) reported that farmers' participation in training and visit programs influenced the organic vegetable production. The organic product should require standard procedures in the production process that involve additional costs, and hence the prices of such products are also quite higher than the normal products. Aryal et al. (2009) revealed that farmers had willingness to pay about 30 % price premiums for the organic products. In addition, Atreya (2012) reported that consumers were likely to bear additional economic costs (between 53 and 79%) to protect their health and environment. The farm households had willingness to pay additional price premium for community integrated pest management (IPM) training because of health and safety of the organic products(Atreya, 2007).It showed that the producers and consumers are conscious on their health and environment issues; thus the organic farming has been increasing. However, there is required a standard procedure to produce organic products that need additional costs of production, and that the additional cost premium add the consumer's price. Because of standard procedures and additional costs requirement, very few farmers produce organic products, while there is still doubt if they clearly follow the required procedure.

The effficiency levels can be different between household and plot levels. The policies recommendation for household levels may not be appropriate for plot levels farms. Tonsor and Featherstone (2009) argued that optimal adjustments for enhancing efficiency may not be homogeneous across the industries. And most of the studies either focused on commodity (Murthy et al., 2009; Nyagaka et al., 2010; Obare et al., 2010; Gbigbi, 2011; Enwerem and Ohajianya, 2013) or household levels (Parikh et al., 1995; Wang et al., 1996; Chavas et al., 2005; Nisrane et al., 2011). The policy implications based on the results of either only household levels or plot levels would be difficult to generalize the household income. Thus it would be much useful to assess the efficiency analysis including both perspectives households and plots levels farms.

2.3 Vegetable marketing systems in Nepal

Efficient marketing system stabilizes the price of commodities that help to improve the efficiency in production. Market access to the smallholder farmers is one of the major constraints in developing countries because of limited numbers of vegetable markets available nearby the production areas, and lack of farmer's friendly rule and regulations (Minten et al., 2010; Shrestha et al., 2014a) that hindered farmers to increase the levels of vegetable production. Mishra and Kumar (2005) found that there was inverse relationship between parishability of vegetable products and market cointegration; as higher the perishability, the lesser the cointegration among markets. The market cointegration has positive relationship with production efficiency; as the market is cointegrated that help to improve the efficiency in production.

In developing countries, vegetable marketing system is complicated because of greater market power exists with limited traders and involves larger numbers of marketing intermediaries. A lengthy marketing channel adds more marketing costs that increase the price of commodities (Shrestha and Pandey, 2010). There are mainly three types of vegetable markets in Nepal such as vegetable collection centers, wholesale markets, and retail markets (MOAD, 1996; USAID, 2011). The most of the collection centers and wholesale markets are managed by agriculture produce market management committee represented by farmers, traders, and local government offices (MOAD, 1996), while retail markets (vegetable shops along the roadside, daily and weekly markets, and Riksa/bicycle markets) are operated by private sectors. In general, collection centers are located nearby the vegetable production areas and wholesale markets (about 16 numbers in the country) situated at different market hubs, which are linked with production areas or collection centers, and retail markets. The smallholder farmers, who produce less quantity of vegetable, sell in local markets, while commercial farmers who produce larger quantity sell in distance wholesale markets through lengthy marketing channels. The common marketing intermediaries in the study areas were producer, local collector, larger brokers/commission agents, wholesalers, retailers, bicycle traders, and consumers (Figure 2).

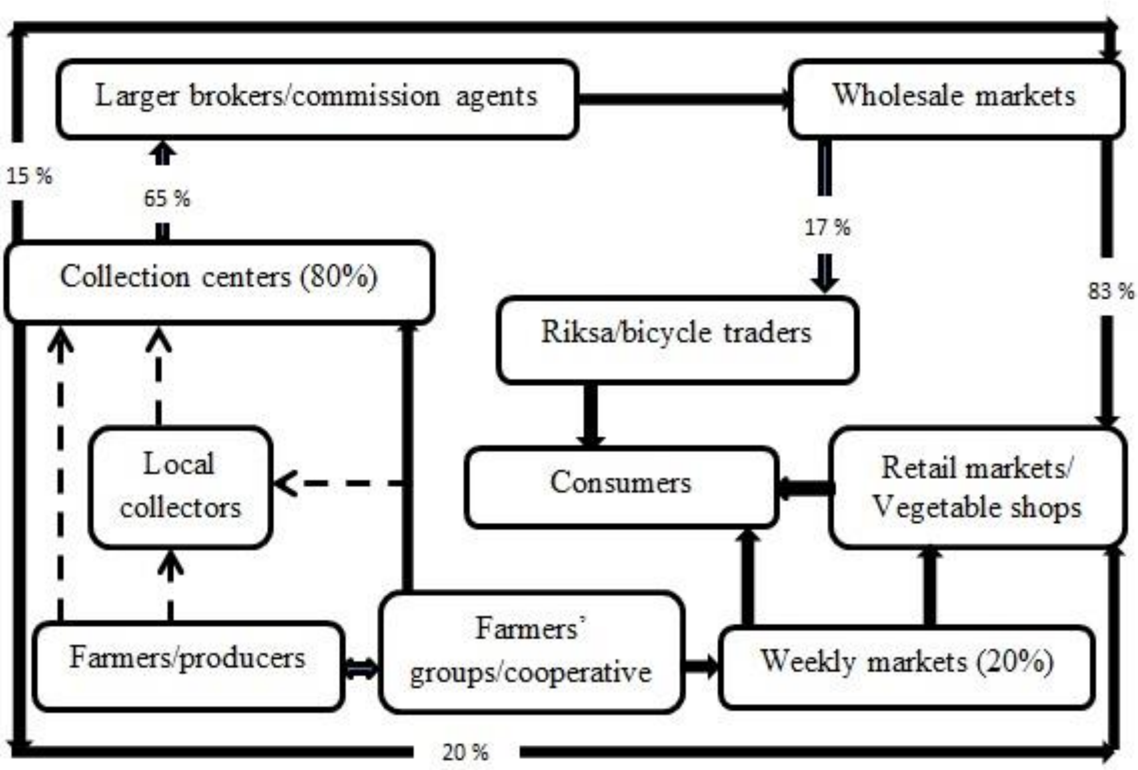


Figure 2.Vegetable marketing channel in the study areas

Figure 2 shows that majority of vegetables (80 %) produced in the study areas supply to the collection centers, and about 20 % supply to weekly markets. Out of 80 % at collection centers, 65 % vegetable supply to wholesale markets by larger brokers or commission agents, about 15 %

vegetables supply to the wholesale markets directly by wholesalers or local collectors, and about 20 % vegetables supply to retail markets. The total vegetables collected at the wholesale markets supply to consumers through retail markets (83 %), and through Riksa or bicycle traders (17 %).

The main vegetable wholesale market in Nepal is “Kalimati Fruit and Vegetable Market (KFVM)”, which is located in Kathmandu (capital city of Nepal). This market has been operating since 1987 that supplies vegetables for more than 2 million people with daily transaction ranges 600-700mt/year (KFVMDB, 2013). The sources of vegetables in this market are neighboring districts (80 %) where sample districts in this study are the major areas to supply vegetables, and neighboring countries (20 %).

One of the burning issues in vegetable sector is high marketing margin; higher price gap between the price received by producers and price paid by the consumers. The prices of vegetables in production areas or in local markets are much lower, while the consumers’ prices in different market hubs, particularly in capital city are much higher. This situation has been a big concern among producers, consumers, Medias and policymakers in the country. It could happen when larger numbers of marketing intermediaries involved in lengthy marketing channels (USAID, 2011). The negative price shocks at Kathmandu market adversely affect farmers to adjust speedy price movement that hurt and discourage farmers in vegetable farming (Shrestha et al., 2014a) that also could be one of the causes of inefficiency in vegetable production. On the basis of these literatures review we intended to assess the relationship of market related variables and efficiency in vegetable production. Therefore, this study focused on the major vegetable production areas associated with Kathmandu market.

2.4 Productivity and efficiency: Similarity and difference

Production is the function of inputs. The relationship between inputs and output is referred as the production function, where alternative combinations of inputs are applied to get the optimum level of outputs (Nicholson, 2005). Production plan is efficient if there is no way to produce more outputs with the same inputs or to produce the same outputs with the minimum inputs (Varian, 1992). In micro-economic theory, production function is bounded with some typical functions such as a production function represents the maximum outputs attainable from a given set of inputs; a cost function represents the minimum costs, given input prices and outputs; and a profit function represents the maximal profits, given inputs and output prices (Coelli, 1995).

In general, empirical works in the field of economics and agricultural economics have been dominated by ordinary least squares (OLS) regression, which fit a line of best fit through the sample data. The frontier function is more appropriate to analyze the performance of farms rather than OLS (Coelli, 1995).The frontier production function has two main benefits rather than average (e.g., OLS) functions (Farrel, 1957; Battese and Coelli, 1995). First, estimation of an average function provides a picture of the shape of technology of an average farm, while the estimation of a frontier function profoundly determined by the best performing farms and hence reflect the technology they are using; second, the frontier production function represents a best-practice technology against which the efficiency of farms can be measured within the industry. The use of second benefit is the greatest motivation for the estimation of frontier functions in this study.

Efficiency and productivity are often used interchangeably; however they have precisely different meanings. For instance, farms are operating at the frontier if they are perfectly efficient or beneath the frontier if they are inefficient. The productivity improvements can be attained adopting two ways

(Coelli, 1995; Coelli et al., 2005): i) one can improve the state of the technologies by inventing new ploughs, fertilizers, pesticides, rotation plans, etc., which is commonly referred to as technological change and can be represented by an upward shift in the production frontier; ii) one can implement procedures such as improved farmers' education and farmers' training to ensure farmers use the existing technology more efficiently.

A measurement of productivity is tonnes per hectare have a serious deficiency; only consider the land input and ignore all other inputs (for example, labor, machinery, fuel, fertilizers, pesticide, and etc.). Policy formulations using this measure are likely to result in excessive use of those inputs which are not included in the measurement (Coelli, 1995; Coelli et al., 2005). Therefore, the measurement of farm performance using productivity would be miss-guiding in policy formulation as farmers use different inputs and technologies.

Efficiency is defined as the maximum of ratios of weighted outputs to weighted inputs subject to the condition that similar ratios for every decision making unit (DMU) is less than or equal to unity (Cooper et al., 2011). The efficiency then is relative to output to input ratio of the most efficient DMU. Further, efficiency deals with the difference between the distance of observed input-output combinations and the best practice frontier attainable from each input level (Kumbhakar and Bailey, 1989; Coelli et al., 2005). Efficiency can be measured by three ways (Farrel, 1957): technical, allocative, and scale efficiency. The economic efficiency (EE) of a farm is the product of technical and allocative efficiency. It focuses on the ability of firms to utilize the best available technology and to allocate resources productively. The technical efficiency (TE) measures the ability of the farms to obtain the maximum outputs from a given sets of inputs, while the allocative efficiency (AE) measures the ability of farms to use inputs in the optimal proportions given their prices and production technology (Coelli et al., 2005). Chavas et al. (2005) argued that allocative efficiency holds when resource allocation decisions can minimize cost, maximize revenue, or maximize profit, given the market prices. The scale efficiency (SE) defined the appropriate size of farms so that no industry reorganization will improve output or earnings. SE is the potential outputs gain from achieving optimal size of farms. The summary of the major literatures on productivity and efficiency analysis are presented in Table 3.

Table 3.Summary of literatures on productivity and efficiency analysis

Author	Commodity/Issue	Country	Methodology	Main results
Coelli, 1995	-	-	SFA and DEA	Recent development: theory contribution
Coelli et al., 2005	-	-	SFA and DEA	Book: Efficiency and Productivity Analysis
Cooper et al., 2011	-	-	DEA	Handbook on data envelopment analysis
Farrell, 1957	-	-	SFA and DEA	Productive efficiency: theory contribution
Fare et al., 1994	-	-	DEA	Theory contribution
Murillo-Zamorano, 2004	-	-	SFA and DEA	Selection of SFA or DEA based on objectives, data, and characteristics of the framework.
Chavas and Aliber, 1993	Wisconsin farms	USA	DEA	Economies of scale on very small farms, and of diseconomies of scale on larger farms.
Coelli and Battese, 1996	Agriculture	Indian farmers	SFA	Age, education, farm size were significant factors on efficiency of agriculture.
Hjalmarsson et al., 1996	-	-	DEA, DFA and SFA	DEA, DFA and SFA-Comparison
Sharma et al., 1997	Swine	Hawaii	SFA vs. DEA Output-oriented	TE from SFA was higher than those from the DEA.
Sharma et al., 1999	Swine	Hawaii	SFA vs. DEA Input oriented	TE, EE higher in SFA than CRS, while similar with VRS DEA.

2.5 Frontier production functions

A measurement of farm efficiency has been a popular approach in production economics to evaluate the performance of farms which used more than one factors of production (Fare, 1994; Cooper et al., 2011). Indeed, agriculture production is the function of more than one factor such as land, labor, seeds, fertilizers, pesticides, and etc. Only the approach which is applicable to consider all these factors can give appropriate analysis. Because of which this study adopted frontier analysis to analyze the efficiency of vegetable farms.

There are two main measurement tools in frontier analysis framework to analyze the efficiency: parametric and non-parametric production function. Both of these approaches have advantages and disadvantages in analyzing efficiency. The selection of estimation methods either parametric or non-parametric is based on the objectives of the research, data sets, and of the intrinsic characteristics of the framework (Murillo-Zamorano, 2004). Some of frontier studies found in the literature used both approaches comparing the efficiency level difference using same data set (for example, Ferrier and Lovell, 1990; Kalaitzandonakes and Dunn, 1995; Drake and Weyman-Jones, 1996; Hjalmarsson et al., 1996; Sharma et al., 1997; Coelli and Perelman, 1999). The main literatures reviewed related to frontier production function is presented in Table 3.

2.5.1 Parametric approach production analysis

The parametric approach is econometric modeling can be analyzed using the Stochastic Frontier Analysis (SFA) framework. This approach is the most consistent framework to analyze efficiency (Chavas and Aliber, 1993) and the most popular to measure the technical efficiency because it accounts two error terms, measurement error and error because of technical inefficiencies (Aigner et al., 1977; Kumbhakar, 1987; Coelli, 1996b; Kumbhakar and Lovell, 2000). In production economics, three models under the parametric approach are commonly used: i) stochastic frontier Cobb-Douglas production function, ii) stochastic frontier translog production function, and iii) stochastic frontier translog profit function. The main strengths of the parametric approach are that it deals with stochastic noise and permits statistical tests of hypotheses pertaining to production structure and the degree of inefficiency (Coelli, 1995; Coelli and Battese, 1996; Sharma et al., 1999).

The stochastic frontier function can be estimated using two procedures either a one-step or a two-step. For the one-step procedure, the dependent variable is regressed against both the input variables and farm-specific characteristics or socio-economic variables at the same time. Wang and Schmidt (2002) argued that such model specifies both stochastic frontier and one-sided half normal error can be estimated in a single step, while the two-steps procedure is biased. Adopting two-step procedure, the first step is biased for regression parameters if input variables and socio-economic variables are correlated. Even if input variables and socio-economic variables are uncorrelated, when estimated inefficiencies are regressed by explanatory socio-economic variables, this renders the second-step estimate biased. However, Battese and Coelli (1995), Sharif and Dar (1996) and Wang et al. (1996), and Joachim et al. (2004) adopted two-step approach and found consistent results. The literature review related to parametric approach is presented in Table 4.

2.5.1.1 Stochastic Cobb-Douglas and translog production analysis

The stochastic frontier Cobb-Douglas production function is commonly used in production economics. Battese and Coelli (1995) conducted a study on agricultural production of Indian farmers using a stochastic frontier Cobb-Douglas production function with a two–stage procedure. The results of this study revealed that age of farm household, level of education of the farmers, and farm size significantly determined the level of efficiency in agriculture.

Parikh et al. (1995) analyzed the behavioral and stochastic translog cost frontier to estimate cost inefficiency using dual cost function in paddy farms in Pakistan. The results revealed that the small farms were more efficient than large farms, and the cost efficiency was explained by size of land holding, education levels of farmers, and credit access.

Joachim et al. (2004) estimated the technical efficiency among small holder farmers in the slash and burn agriculture zone of Cameroon using two-step procedure of stochastic frontier Cobb-Douglas production function. Results revealed that there was higher degree of inefficiency. The efficiency difference was explained significantly by credit access, soil fertility, social capital, distance of farm to road, and extension services. Bogale and Bogale (2005) compared the potato production efficiency under the traditional and modern irrigation system using stochastic translog production function, and revealed that the technical efficiency was much higher under traditional irrigation systems than modern systems. The efficiency was determined by irrigation experience, commodity rate of production and size of livestock.

Oladeebo and Fajuyigbe (2007) examined the technical efficiency of upland rice production by men and women farmers in Nigeria using the stochastic frontier Cobb-Douglas production function. The results showed that women farmers were more efficient than men farmers. The age and years of education of farmers had positive influence on the level of technical efficiency.

Bozoglu and Ceyhan (2007) estimated that the technical efficiency of the vegetable farms using one-step procedure of stochastic frontier Cobb-Douglas production analysis. The mean of technical efficiency was 0.82, and identified the explanatory variables such as schooling of farm household, experience of farmers, credit availed in vegetable farming, women participation index, and information index positively affected the technical efficiency, while age, family size, off-farm income and farm size showed a negative relationship with efficiency. Similarly, Ojo et al. (2009) examined the implication of resource productivity and farm level technical inefficiency in yam production in Nigeria using the stochastic frontier Cobb-Douglas production function. Results showed that farmers' educational level, years of farming experience, and access to extension service significantly positive influenced the farmers' efficiency. Obare et al. (2010) estimated Irish potato production efficiency in Nyandarua using stochastic frontier Cobb-Douglas production function. The results revealed that there was decreasing returns to scale, and the mean of the allocative efficiency was 0.57. The explanatory variables such as experience, access to extension, access to credit, and membership in a farmers' association positively determined the allocative efficiency.

Ukpong and Idiong (2013) estimated the technical efficiency of leafy vegetables in Southern Nigeria using stochastic Cobb-Douglas production function with one-step procedure. The results of maximum likelihood estimates of the Cobb-Douglas stochastic production frontier function indicated that age of vegetable producers have a negative influence, while educational level, farming experience, farm size, household size and soil quality have positive effects on the technical efficiency. The summary of literatures on stochastic frontier production analysis is listed in Table 4.

Table 4.Summary of literatures on stochastic frontier production analysis

Author	Commodity/Issue	Country	Methodology	Main results
Coelli, 1996b	-	-	SFA	Guide of Frontier Version 4.1
Kumbhakar, 1987	-	-	SFA and profit function	Modeling of TE and AE.
Parikh, et al., 1995	Rice	Pakistan	Behavioral, and stochastic translog cost	Holding size, education, and credit explained the cost efficiency. Small farms were more efficient than large farms.
Khumbhakar and Lovell, 2000	-	-	SFA	Book: Stochastic Frontier Analysis
Wang and Schmidt, 2002	-	-	SFA	One-step and two-step estimation effects of exogenous variables on TE.
Joachim et al., 2004	Slash- burn agriculture	Cameroon	SFA	Efficiency explained by credit, soil fertility, social capital, distance of farm to road and extension.

Table 4. Continue……

Author	Commodity/Issue	Country	Methodology	Main results
Bozoglu and Ceyhan, 2007	Vegetable	Turkey	SFA	Schooling, experience, credit, women participation, information score negatively affected inefficiency.
Oladeebo and Fajuyigbe, 2007	Upland rice production	Nigeria	SFA	Women farmers more efficient than men. Age and education positive influenced on TE.
Ukpong and Idiong, 2013	leafy vegetables	Southern Nigeria	SFA	Age effects negative, while education, experience, farm size, household size and soil quality positive effects on TE.
Ojo et al., 2009	Yam	Nigeria	SFA	Educational, experience and extension service positively affected the efficiency.
Obare et al., 2010	Irish potato	Nyandarua	SFA	Experience, extension, credit, and association positively influenced allocative efficiency.

2.5.1.2 Stochastic frontier translog profit function

The summary of literatures on stochastic frontier translog profit function is listed in Table 5. Production efficiency deals with the combination of three components such as technical, allocative and scale efficiency. Among the production efficiency measurements, the technical efficiency component is a popular approach to measure efficiency (Battese and Coelli, 1995; Sharif and Dar, 1996). Technical efficiency deals with the capacity of farm that produces the optimum level of output in the given level of inputs, while inefficiency is the level of output below the frontier line (Ali and Flinn, 1989). A farm is allocatively efficient when the combination of inputs in the optimal proportion with the minimum costs that produce given quantity of outputs (Coelli et al., 2005). The scale efficiency is as the ratio of the technical efficiency measured under constant returns to scale (CRS) to the corresponding measure under variable returns to scale (VRS). Thus the scale inefficiency exists due to the presence of either increasing or decreasing returns to scale.

The production function approach to measure efficiency may not be appropriate when farmers face different prices and have different factor endowments; and thus profit efficiency could be the best approach that captures all types of measurements (Ali and Flinn, 1989).In a profit maximizing framework, scale efficiency exists if farm produces output levels by equating the product price with marginal cost (Kumbhakar et al., 1989). Recent empirical development combined all these measures (technical, allocative, and scale efficiency) into a single system that enables more efficient estimates can be obtained by simultaneous equation system using a profit function framework (Ali et al., 1996; Kumbhakar et al., 1989). In this functional framework any errors in the production decision are assumed to be translated into lower profits or revenue for the producer (Ali et al., 1994).

Profit efficiency, therefore, is defined as the ability of a farm to achieve highest possible profit given the prices and levels of fixed factors of that farm and profit inefficiency is defined as loss of profit from not operating on the frontier (Ali and Flinn, 1989). The author estimated the profit inefficiency of Basmati rice producers in Pakistan using stochastic frontier translog profit function, and found the mean of inefficiency was 28%. Socio-economic factors related to profit-loss were education levels of farm household head, non-agricultural employment, credit constraint, water constraint and the late application of fertilizer.

Estimating the profit efficiency in agriculture is more crucial to understand the performance of farms in terms of the optimal levels of profit that the farmers could earn with the given level of input costs. Kumbhakar (1996) modeled the technical and allocative inefficiencies in both cost minimizing and profit maximizing frameworks with special emphasis on multiple inputs and multiple outputs. Kumbhakar (2001) argued that the profit would not be at maximum level because of the presence of either technical inefficiency or allocative inefficiency or both. In order to maximize the profit efficiency, the farms need to be economically efficient.

Sharif and Dar (1996) and Wang et al. (1996) used two-step profit function where predicted efficiency indices were regressed against a number of farm-specific characteristics to explain the observed differences in efficiency among farms. Battese and Coelli (1995) extended the stochastic production frontier model by suggesting that the inefficiency effects can be expressed as a linear function of explanatory variables, reflecting farm-specific characteristics.

Kumbhakar and Bhattacharya (1992) conducted study on price distortions and resource-use efficiency in Indian agriculture using a restricted profit function approach incorporating price distortions resulting from imperfect market conditions, socio-political, and institutional constraints as well as technical and allocative inefficiency. The levels of education reduced the price distortions, and therefore that helps to improve allocation of inputs and outputs. Wang et al. (1996) used a shadow-price (with price distortions) profit frontier model to examine production efficiency of Chinese farm households. The shadow prices and shadow profit were derived through a behavioral profit function. Results revealed that farmers' resource endowment and education levels of farmers influence their allocative efficiency. Family size, per capita net income, and family members operating as village leaders were positively related to households' production efficiency. It was suggested that reducing market distortions should increase farm households' production efficiency.

Rahman (2003) conducted a study to provide a direct measure of production efficiency of the Bangladeshi rice farmers using a stochastic profit frontier and inefficiency effects model. The results showed the mean level of the profit efficiency was 77%. The efficiency differences were explained largely by infrastructure, soil fertility, experience, extension services, tenancy and share of non-agricultural income.

Wadud and Rashid (2011) examined profit efficiency of rice farmers in Bangladesh using a translog profit frontier for the rice farmers. The profit frontier had negative elasticities with price of fertilizers, while that had positive elasticities with wage rates, price of seeds, and area of land cultivated. Ogunniyi (2008) estimated profit efficiency among maize producers in Oyo State, Nigeria employing a stochastic frontier profit function. The results showed that profit efficiency of the farmers was 41.4%. The explanatory variables such as education, experience, and extension and non-farm employment were significant factors influenced profit efficiency.

Table 5.Summary of literatures on stochastic translog profit analysis

Author	Commodity/Issue	Country	Methodology	Main results
Ali and Flinn, 1989	Basmati Rice	Pakistan	Stochastic frontier profit function	Profit efficiency captures TE, AE, SE. Education, nonagricultural employment, credit constraint, water constraint, late fertilization determined profit losses.
Kumbhakar et al., 1989	Dairy	Utha, India	Stochastic production frontier	Positive effect of education, labor, capital on efficiency. Larger farms more efficient than small and medium.
Ali et al., 1994	-	-	Behavioral and stochastic cost	TE, AE, and SE can be analyzed by simultaneous equation system using a profit function framework.
Wang et al., 1996	Agriculture	Chinese agriculture	Shadow-price profit frontier	Family size, per capita income, and village leaders are positively related to production efficiency.
Battese and Coelli, 1995	-	-	Modeling of SFA	Extended stochastic production frontier. Inefficiency effects as a linear function of explanatory variables.
Kumbhakar and Bhattacharya, 1992	Agriculture	Indian	Profit function approach	Education reduces the price distortions and improve allocation of inputs and output.
Kumbhakar, 2001	Agriculture	Salmon farms	Profit function modeling	Input demand, output supply, elasticities, and returns to scale affected by inefficiencies.

2.5.2 Non-parametric production analysis

The data envelopment analysis is a non-parametric deterministic mathematical programming approach developed by Farrell (1957), which attributes all the deviations away from the frontier technology to inefficiency. The efficiency analysis under DEA model is mainly categorized into two approaches: i) input oriented, and ii) output oriented. Both of these approaches can be analyzed under constant returns to scale (CRS), as in Charnes et al. (1978), and variable returns to scale (VRS) as in Banker et al. (1984). The constant returns to scale (CRS) assumption proposed by Charnes et al. (1978) gives the overall technical efficiency score. An alternative approach developed by Banker et al. (1984) assumes variable returns to scale (VRS), which commonly exists in agriculture. Given these possibilities, this study analyzed the efficiency of Nepalese vegetable farms using both CRS and VRS DEA approaches.

The main advantages of the DEA approach are that it avoids parametric specification of technology as well as the distributional assumption for the inefficiency term (Coelli, 1995, 1996b; Coelli and Battese, 1996; Sharma et al., 1999). In addition, the non-parametric approach can be used for technologies involving multiple inputs and multiple outputs, and can estimate technical, allocative, pure technical, economic and scale efficiencies. According to Varian (1984), the parametric analysis has a weakness that the stated hypothesis under this approach can never be detected directly; thus non-parametric is appropriate in order to analyze efficiency. While, since the DEA model has not been applied frequently in agriculture (Coelli, 1995); thus our study tends to demonstrate its applicability in agriculture, particularly in small-scale vegetable farms.

Sharma et al. (1997) examined the productive efficiency of swine producers in Hawaii by estimating a stochastic frontier production function and output-oriented DEA models under both constant returns to scale (CRS) and variable returns to scale (VRS). The author found that the technical efficiency was found to be higher from stochastic frontier than those obtained from the DEA analysis. In addition, Sharma et al. (1999)measured technical, allocative and economic efficiency of swine producers in Hawaii using the parametric and input oriented non-parametric approaches. The results from both approaches showed considerable inefficiencies in swine production. The mean of technical and economic efficiencies obtained from the parametric technique were higher than those from CRS DEA models but quite similar for VRS models, while allocative efficiencies were generally higher in DEA.

Chavas and Aliber (1993) conducted a study on non-parametric analysis of technical, allocative, scale, and scope efficiency in agricultural production of Wisconsin farmers. The results showed that the existence of economies of scale on small farms, and diseconomies of scale for the larger farms, which was inconsistent with the principle of economics of scale. Chavas et al. (2005) investigated the economic efficiency of farm households in Gambia, and the results revealed that the technical efficiency was fairly higher; indicated that access to technology is not a severe constraint for most farm households. The imperfections in markets for financial capital and non-farm employment contribute to significant allocative inefficiency.

Murthy et al. (2009) estimated the technical and scale efficiencies of tomato-producing farms in Karnataka using DEA. The resultsshowed that the technical efficiency was explained by land, productivity of labour and levels of farmer’s education. Watkins et al. (2014) analyzed the technical, allocative, economic, and scale efficiency in rice research program using DEA. The results revealed that there was higher degree of inefficiencies. The allocative and economic efficiencies could be improved with better variety selection and better irrigation management. The summary of literatures on production efficiency analysis using non-parametric approach is listed in Table 6.

Table 6.Summary of literatures on non-parametric production analysis

Author	Commodity/Issue	Country	Methodology	Main results
Charnes et al., 1978	-	-	DEA	Developed of CRS DEA
Banker et al., 1984	-	-	DEA	Developed of VRS DEA
Chavas et al., 2005	Household farms	Gambia	DEA and Tobit	Market imperfection in financial capital and nonfarm employment contribute allocative inefficiency.
Coelli, 1996b	-	-	DEA	Guide to DEAP Version 2.1
Sharma et al., 1997	Swine	Hawaii	SFA vs. DEA Output-oriented	TE from SFA was higher than those from the DEA.
Sharma et al., 1999	Swine	Hawaii	SFA vs. DEA Input oriented	TE, EE higher in SFA than CRS, while similar with VRS DEA.
Murthy et al., 2009	Tomato	India	DEA	Medium farm performed the best TE, explained by land, labour productivity and education.
Watkins et al., 2014	Rice	University of Arkansas	DEA and Tobit	AE and EE could be improved with better variety selection and better irrigation management.

2.6 Women's contribution on the efficiency of agriculture

The Millennium Development Goal (MDG 3) of the United Nations promote gender equality and empower women has target to eliminate gender disparity. Rural women and smallholders play an important role in reducing poverty and achieving food and nutrition security by generating income through agriculture farming (UN et al., 2012). There is considerable contribution of women labor to enhance efficiency in agriculture, food systems and rural economies (ILO, 2008; Rahman, 2010). The majority of the working women were participating in diverse agricultural activities including sowing, harvesting and picking, and they have significant contribution in increase their family income in Pakistan (Nazir et al., 2013; Naz et al., 2014), while they were facing gender discriminating problems. Further, women's labor contributes in agriculture and food production between 60 and 80 % in developing countries, and the rates in South Asian countries hovering at 63% (FAO, 2011, 2013). However, they are the most vulnerable group in poverty and hunger in developing countries.

In Nepalese context, an average share of women's labor force in agriculture estimated at 63 % versus men 27%, and in terms of working hours, women 10.8 hours/day versus men 7.5 hours/day (FAO, 2000). Furthermore, women are responsible to carry out most of the household works including taking care family and kids, which are not accounted in household economy (Spieldoch, 2011). One of the common questions is whether they are as efficient as men, is a hotly debated issue (Rahman, 2010). On the other hand, women are facing several gender discriminating problems in agriculture and rural household economy that affects them to be inefficient and less productive. Gender discrimination exists on accessed to energy, technology, transport, education and health service that effects to decreases women's productivity and efficiency (Warth and Koparanova, 2012). Heath (2014) argued that less bargaining power of women face increased risk of domestic violence, low rates of land ownership that significantly obstruct them access to financial assets, and weaken them in decision-making processes. A study conducted by Alkire et al. (2013) in Guatemala, Uganda and Bangladesh focusing women's empowerment in agriculture index (WEAI), and suggested that women can be empowered by giving opportunities to control production resources and encourage them in decision making process. In addition, Allendorf (2007) reported that women's land rights are increasingly put forth as a means to promote development by empowering women, increasing productivity, and improving welfare. Women, who own land, are significantly more likely to have household decisions, a measure of empowerment.

Thus, gender-perspective planning and development approach could be the best strategy to empower women and enhance efficiency in vegetable production that support to decrease poverty of rural smallholder farmers. An appropriate labor division system to women and men on the basis of their labor productivity in each farming activity would gain higher levels of efficiencies in vegetable farming. There are some studies have been carried out on gender perspective agriculture and women empowerment in general, but not on small-scale vegetable farm's efficiency in particular, which is the most important endowment to improve the rural household economy in developing countries. Therefore, this study focused on women's labor contribution on the efficiency of vegetable production. The summary of important literatures on women's contribution on the efficiency of agriculture is presented in Table 7.

Table 7.Summary of literatures on women, efficiency and household economy

Author	Commodity/Issue	Country	Methodology	Main results
FAO, 2011	Agriculture	Nepal	Descriptive	Women contribution
Rahman, 2010	Agriculture	Bangladesh	Input distance function	Women labor to enhance productivity and efficiency in agriculture.
Nazir et al., 2013	Women contribution	Pakistan	-	Women contribution sowing, harvesting and picking, and increase family income
Warth and Koparanova, 2012	Empower women	-	-	Gender discrimination in resource reduce the efficiency and productivity
Heath, 2014	-	Bangladesh	Probit model	Increased bargaining power of women
Alkire et al., 2013	Agriculture	Guatemala, Uganda, Bangladesh	Empowerment in Agriculture Index	Women's Empowerment in Agriculture Index
Allendorf, 2007	Women	Nepal	-	Women's land rights empower women
Mehta and Shah, 2003	Poverty	India	-	Per capita income, inequality, and poverty determine economy

Table 7. Continue…….

Author	Commodity/Issue	Country	Methodology	Main results
Roberts et al., 2013	Household economy	Podlaskie, Poland, UK Scotland	Probit model	Household economy has positive relationship with farm efficiency
Amores and Raa, 2014	Economy	-	DEA and linear programing	Positive relationship of firm efficiency with industry performance and economy
Altieri et al., 2011	Efficiency and economy	Cuba, Brazil, Philippines, Africa	-	Smallholder farmers are efficient and contributions to food sovereignty
AVRDC, 2010	Vegetable and economic development	Developing countries	-	Vegetable is source of rural employment, income, reduce poverty, and develop rural economy

2.7 Farm efficiency and rural household income

The summary of literatures related farm efficiency and household income is presented in Table 7. Households appear to be one of the main economic entities, whose economic performance influence on economic development of the country. Economic development depends on the rate of per capita income growth, inequality, and the levels of poverty incidence of people (Mehta and Shah, 2003). However, there is higher disproportionate in income distribution among the people in rural and urban, occupational based (farm-income and non-farm), and agroecological based that determine the household economies. A household income may perform better if the farms are more efficient, better organized, and improved allocation of resources (Roberts et al., 2013; Amores and Raa, 2014).

In developing counties, majority of the households are smallholders, and they have higher rate of poverty incidence with lower levels of household income. Nepal is one of the most vulnerable countries in term of poverty and food insecurity (CBS, 2013; SAARC, 2014). The smallholder farmers adopt integrated economic systems consisting of different varieties of crops (vegetables, cereals, fruits, and cash crops), chickens, animals, and non-farm income as their source of household economy (Altieri et al., 2011). This types of farming system is efficient, environmentally friendly, and economically viable (Ralevil et al., 2010).There is a positive relationship between economic development in the country with improvements in farm efficiency and household income. Improved farm efficiency enhances the household income, and that lead to improve national economy.

A sustainable economic development is not possible unless improving the farm efficiency and household income (Amores and Raa, 2014). The level of household income is determined by the levels of household production, consumption, expenditure pattern, saving behavior. Agriculture production, particularly the high-value crops, vegetable crops, determines the levels of household income of farmers. However, the vegetable production in developing agriculture is inefficient because of high cost of production, lower rates of adoption of superior technologies, and inappropriate allocation of resources that lead to output-loss and profit-loss (Rahman, 2003). Further, Lamb (2002) argued that market structure for inputs and outputs determine the farm household economy; open market economy significantly contributes to increase agriculture production and increase the household income of farmers.

Vegetable farming is the most potential source of rural employment and income that reduce the poverty incidence (AVRDC, 2010). This sector is one of the major contributing areas to the Nepalese economy that has comparative advantage in domestic labour-resource endowment. The government policies (MOAD, 2014a; NPC, 2014) have main objective as to develop sustainable economy and alleviate poverty, where vegetable farming identified as the prioritized sector. Despite these policies, the vegetable sector lags behind expectations because of inadequate policy set-up, particularly at the farm operational levels (NPC, 2014). Efficient use of productive inputs and similarly addressing farm-specific characteristics and socio-economic factors would improve the efficiency in vegetable production, increase household income, and eventually contribute to sustainable rural household economy.

In conclusion, there are many studies conducted on efficiency analysis of agriculture in different countries, particularly focused on rice, maize, wheat, etc. Very limited studies have been carried out on vegetable production efficiency and these are focused on either household specific or crop specific. While in developing countries farm household produce different types of vegetables in different plots and every plot could have different level of efficiencies because the farm efficiency is context-specific. The level of efficiency differs by means of farm size, management practices, support services, technologies used, support services availed, and agroecological variables. The household income differs because of differences in the efficiency of farm plots.

Reviewing these literatures above there are some research gaps: i) plot level vegetable farm efficiency analysis; ii) seasonal and agroecological perspective analysis of vegetable farms; iii) profit efficiency analysis of vegetable farms; and iv) there are no any study related to efficiency analysis of vegetable farms in Nepal.

In order to fill the gap, this study focused both household and plot level farms in seasonal and agroecological perspectives that could explain the actual efficiency of vegetable farmers and could determine the income of households. Analyzing the profit efficiency of vegetable farms is very important; thus, this study would contribute on estimating profit efficiency of vegetable farms in Nepalese smallholder farms. Coelli (1995) argued that estimating efficiency in agriculture using DEA approach is very rare, thus this study would be important to prove that DEA can be appropriate tool for analyzing efficiency, particularly in smallholder farms. In Nepalese context, this study could be milestone that there is no any study conducted in vegetable farm efficiency. The policies implications to improve the household income through enhancing the efficiency level of vegetable farms should focus on plots and household levels, major seasons, agroecological regions, and genders perspectives. Therefore, this study tends to analyze these endowments and address the issues of efficiency, household income and poverty reduction. The literature map of this study is presented in Figure 3.

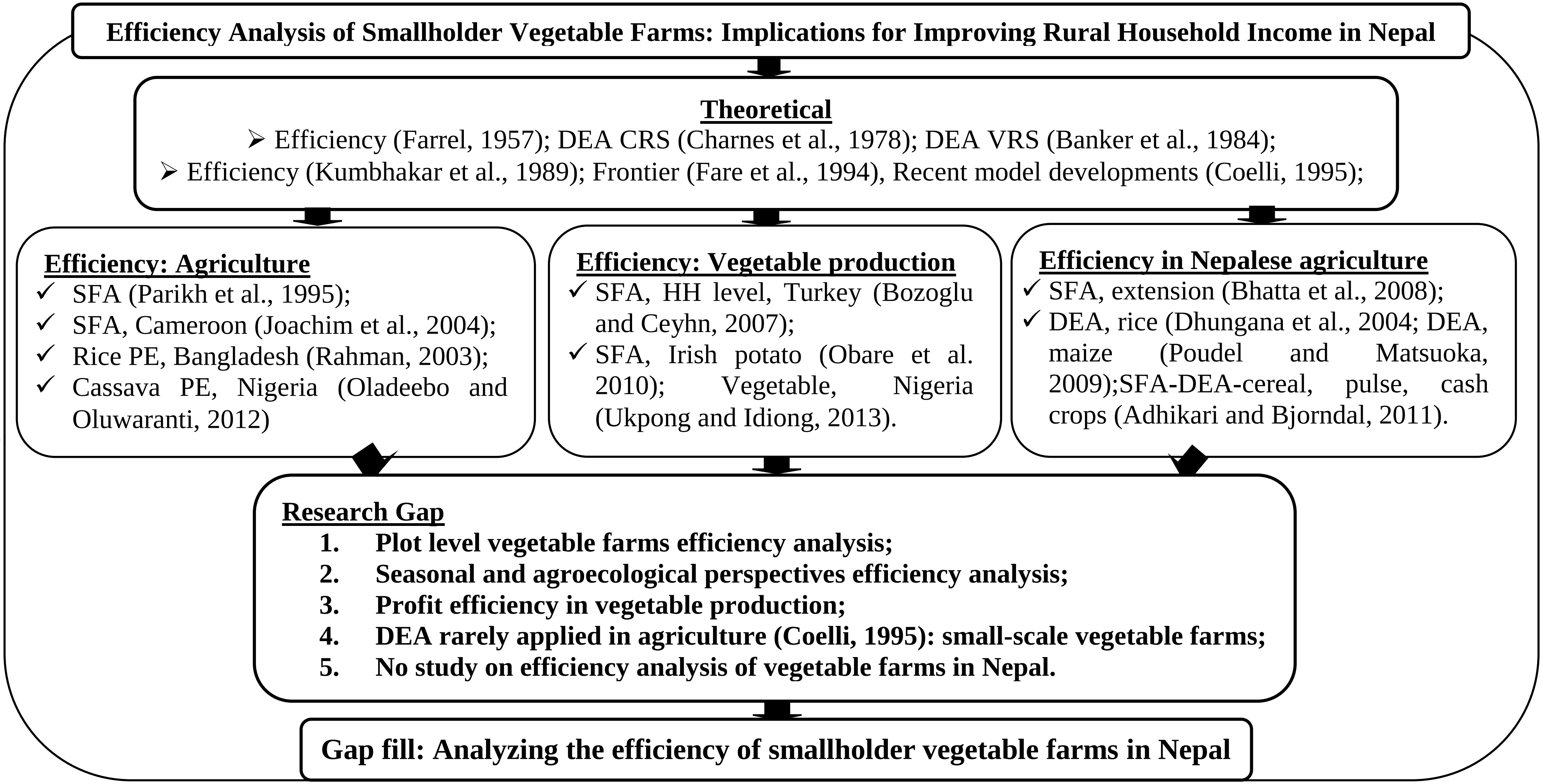


Figure 3: Literature map on the analysis of efficiency for vegetable farms in Nepal.

Chapter 3

Materials and Methods

3.1 Study area and sampling design

This study adopted a multi-stage (four stages) sampling procedure consisting of the selection of region (among five development regions: eastern, central, western, mid-western, and far-western), districts, villages (Village Development Committees), and farmer's respondents. The flow chart of sampling design is presented in Figure 4.

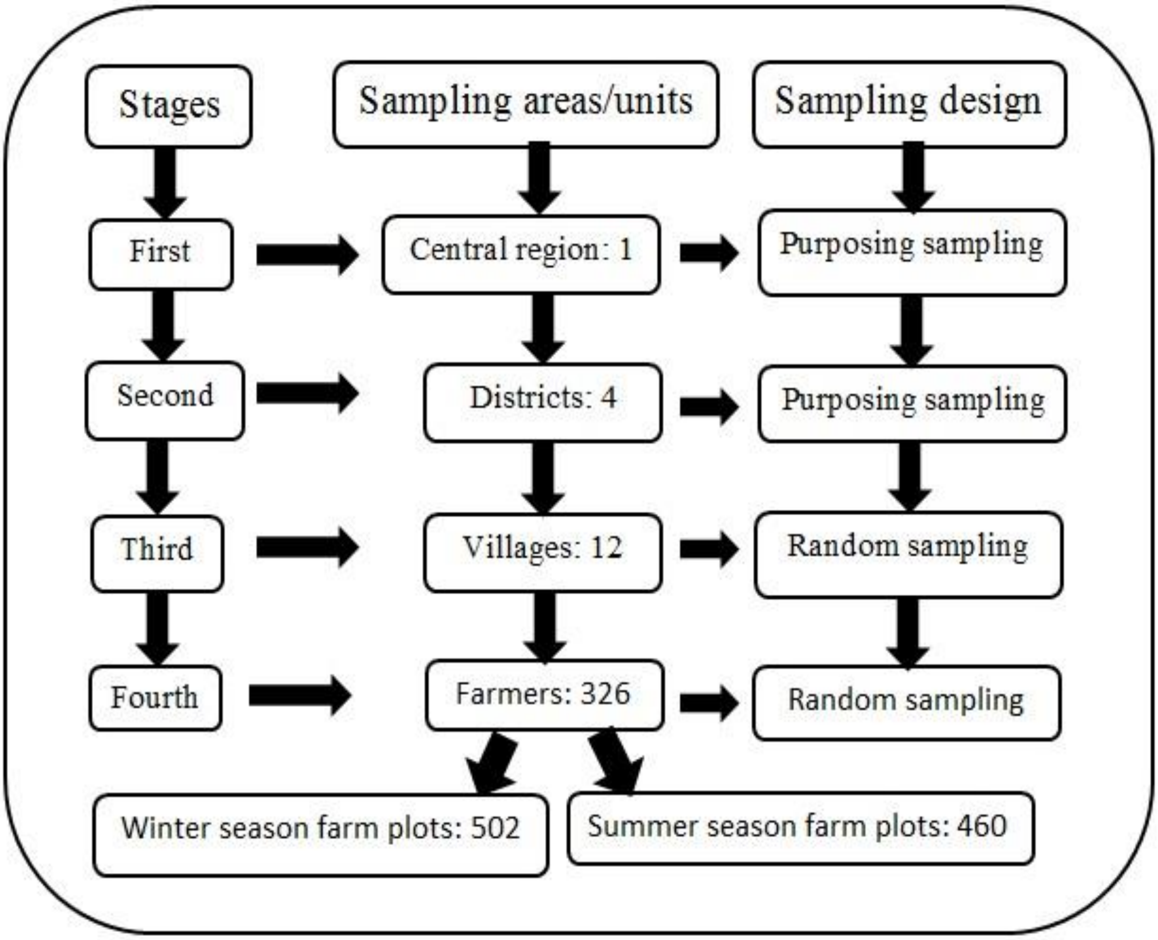


Figure 4. Sampling design of this study

The geographical focus of this study is the central region. This region was selected because it represents the largest region in terms of area covered by vegetable cultivation (38% of the total 0.25 million hectares) and contributes the largest vegetable production (40% of the total 3.3 million tonnes) in 2012 (Table 8).

Table 8. Area, production and productivity of vegetables by agroecological regions in Nepal, 2012/13

Regions	Area (Ha)	Production (Mt)	Productivity (Mt/Ha)
Eastern	69,250	945,040	13.65
Central	94,505	1,299,827	13.75
Western	34,009	468,662	13.78
Mid-western	27,775	340,168	12.25
Far-western	20,853	247,987	11.89
Nepal	246,392	3,301,684	13.40

Source: Statistical Information (MOAD, 2013)

In the central region, we selected four districts or this study such that they represent all three agro-ecological regions (mountain, hill, and terai) of the country (Figure 5). Dolakha disctrict represent the mountain region, Lalitpur and Dhading the hills, and Dhanusa for the terai. Two districts from the hilly region were selected because there were a larger number of districts in this region which grow vegetables that are linked with Kathmandu market. These districts were on the top in production among the districts in each agro-ecological zones; where Dhanusa produced 58,095 tonnes, followed by Dhading 75,005 tonnes, Lalitpur 53,114 tonnes, and Dolakha produced 8,790 tonnes in 2012 (MOAD, 2013).

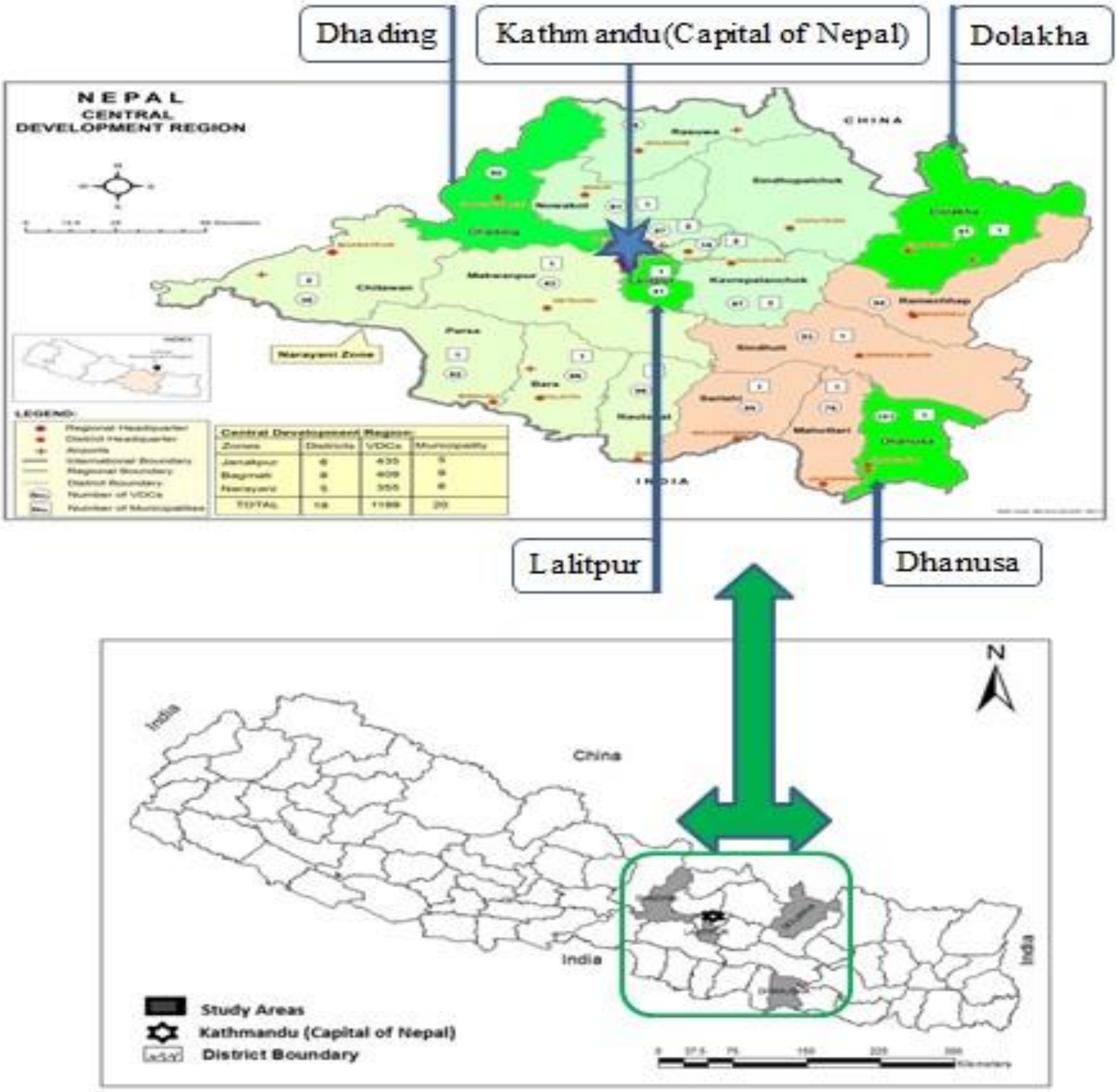


Figure 5. Map of Nepal showing study areas

For each of these four disticts, a list of major villages was prepared in consultation with District Agriculture Development Offices (DADO). Three villages in each district were randomly selected to be surveyed. The agro-climatic and socio-economic characteristics of the study are presented in Table 9.

Table 9. Study areas and their characteristics

District	Villages	Sample size	Geography
Dolakha	Boach Bhimeshowar Kavre	90	Mountain: Characterized by higher altitudes (2000m to 2600m), cold weather, steep land, lack of basic infrastructure (irrigation, roads and market facilities) and weak access to public services including extension services.
Lalitpur	Luvu, Jharuwarasi Devichor	88	Hills: Characterized by moderately cool weather with moderate altitude (1000 m to 1900 m), upland and valley with terraced land, and relatively better access to roads, market infrastructure, extension services, irrigation facilities, and education facilities.
Dhading	Jeevanpur Benighat Dhusa	165	
Dhanusa	Dhalkebar Bengadabar Digambarpur	159	Terai: Characterized by lower altitudes (250 m to 500 m), hot climate, mostly lowland, and with better access to roads, markets, irrigation facilities, and extension services.

Source: Author’s composition, 2015

Next, using the profile of each village obtained from DADO we randomly selected 326 farm households to be surveyed during July to August, 2013 from all farms which produce vegetables for sale after home consumption. The sample size represents 10.16% of the total population in the study areas (Table 10).

Table 10. Sample size in this study by districts

Districts	Total farmers	Sample farmers	% Representation
Dolakha	545	86	15.78
Lalitpur	750	75	10.00
Dhading	945	85	8.99
Dhanusa	970	80	8.25
Total	3210	326	10.16

In order to evaluate the efficiency of vegetable farms at plot levels, we disintegrated the vegetable farms into winter and summer season vegetable plots. The winter season vegetable farm plots 502 and summer season vegetable farm plots 460 were selected from the selected samples households to be included in the study. This study considered for winter season vegetables such as cauliflower, tomato, cabbage, radish, bean, cowpea, eggplant, and onion, while for summer season vegetable crops were gourds (bitter, bottle, pointed and sponge), pumpkin, cucumber, cowpea, tomato, cabbage, and eggplant. We did not include some crops (such as potato and asparagus) because such crops have higher ranges of economic activities that caused a heteroskedasticity problem in the data set. For example, farmer cultivate potato in large size of land which require larger quantity of input costs and the output is also high that made outlier in the data set. Similarly, we did not include asparagus which is grown by limited farmers in small scale while the market value of the product is very high that also made outlier in the data set.

A farm record and recall technique were adopted to collect data related on cost share of inputs in production process, quantity of production, farm gate price, and farm specific socio-economic information.

In addition, key informant interviews were conducted among the policymakers, local leaders, government officials, and farmers'/traders' organizations to collect information on problems, issues, and policies recommendations. The information collected from the key informants was used in the respective parts of this study.

The secondary sources of data were also collected from Central Bureau of Statistics (CBS), Ministry of Agricultural Development (MOAD), Department of Agriculture (DOA), Agribusiness Promotion and Marketing Development Directorate (ABPMDD), Ministry of Finance, and National Planning Commission, and etc.

3.2 Theoretical and analytical framework

3.2.1 Parametric production function

3.2.1.1 Stochastic frontier Cobb-Douglas production function

The stochastic frontier analysis (SFA) is a parametric approach that was adopted to estimate the technical efficiency and to determine the factors influencing inefficiency in vegetable production (equation 1) assuming a perfectly competitive market structure in this study. The parametric efficiency analysis is one of the most investigating areas in applied production economics that decomposes error terms into stochastic random error, and inefficiency due to technical inefficiency in production process (Sauer, 2006). This approach is the most suitable in efficiency analysis, particularly in farm level cross-section data that might have measurement error, missing variables, and weather (Coelli, 1995).

There are two approaches in stochastic frontier analysis: one-step or two-step. In one-step approach, the farm inputs and farm related socio-economic variables are analyzed in a single framework. While using a two-step approach, first estimate the technical efficiencies of individual farms, and second step regress the technical efficiency scores of individual farms by farm-specific characteristics and socio-economic factors. Wang and Schmidt (2002) argued that aone-step model specifies both stochastic frontier and one-sided half normal error can be estimated in a single step, while two steps procedure is biased.

Therefore, we adopted the stochastic frontier Cobb-Douglas production function with one-stage procedure in evaluating the technical efficiency of vegetable farms at household levels (study I). The outputs of vegetables were considered as a function of inputs and socio-economic factors (Battese and Coelli, 1995; Coelli et al., 2005).

$$ln(Y_i) = \ln(X_i)\beta + v_i - u_i \qquad \mathrm{i} = 1 \ldots \ldots \mathrm{n} \tag{1}$$

Where, Y_i is the vegetable production value of the ith farm, X_i is the inputs for ith farm, β is the unknown parameter to be estimated, ln is natural logarithm, and v_i is random variable assumed to be independently and identically distributed with $N(0, \sigma_v^2)$. While u_i is a non-negative random variable that account for technical inefficiency in production, which is assumed to be independently and identically distributed as truncations.

The inefficiency effect was defined as $u_i = z_i\delta$, where (z_i) stand for farm-specific characteristics and socio-economic explanatory variables that may influence the technical inefficiency of a vegetable farms and (δ) is unknown parameter to be estimated.

The maximum likelihood estimates of the parameters were estimated using computer program frontier version 4.1, developed by Coelli (1996b). The technical efficiency of vegetable farms is defined as the ratio of the observed output to the frontier output which could be produced by a fully efficient farm (equation 2) in which the inefficiency effect is zero. The technical efficiency of farms exists between zero and one, and is inversely related to the inefficiency effect (Coelli and Battese, 1996).

$$TE_i = \frac{\exp(X_i)\beta + v_i - u_i}{\exp(X_i)\,\beta + v_i} = \exp(-U_i\,) \tag{2}$$

The variance parameters, sigma squared (σ^2), and gamma (γ) were estimated using equations (3 and 4) (Battese and Corra, 1977).

$$\sigma_s^2 = \sigma_v^2 + \sigma_u^2 \tag{3}$$

$$\gamma = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2) \tag{4}$$

We hypothesized that vegetable farms were technically efficient ($\gamma = 0$) using likelihood ratio (LR) test statistics (equation 5). The LR test statistics have an approximately Chi-square distribution with the parameter equal to the number of parameters assumed to be zero in the null hypothesis (H_0), provided H_0 is true (Battese and Coelli, 1995).

$$LR = -2[\ln\{likelihood\ (H_0)\} - \ln\{likelihood\ (H_0)\}] \tag{5}$$

The cross-section data faces the heteroskedasticity problem (Hill et al., 2011). Therefore, we tested heteroskedasticity with the White's test, and the value was found to be 101.05, which was less than $\chi^2_{(0.90,102)} = 120.678$, and confirmed that the heteroskedasticity problem did not exist in the dataset.

3.2.1.2 Stochastic frontier translog production function

In applied production economics the stochastic frontier translog production function is commonly applied. Based on the results of likelihood ratio-type test (LR), we used stochastic frontier translog production function (Equation 6) to estimate productive efficiency of plot level vegetable farms in seasonal, agroecological, and gender perspectives (study II). In this study, we adopted the two-stage procedure: first step, we estimated inefficiency scores (1-efficiency score) of each farms; and second step, the technical inefficiency scores were regressed by farm-specific characteristics and socio-economic variables (Equation 8).Sharif and Dar (1996) and Wang et al. (1996) used the two-step approach and found consistent results. Battese and Coelli (1995) extended the stochastic production frontier model and argued that the inefficiency effects can be expressed as a linear function of explanatory socio-economic variables.

$$ln(Y_i) = \beta_0 + \sum_{j=1}^{7} \beta_j \, lnX_{ij} + \frac{1}{2}\sum_{j=1}^{7}\sum_{k=1}^{7} \beta_{jk} \, lnX_{ij} lnX_{ik} + \varepsilon_i, \mathrm{i} = 1 \ldots . \mathrm{n} \tag{6}$$

$$\varepsilon_i = v_i - u_i \tag{7}$$

Where, $Y_i$is the vegetable output of the ith farm; X_{ij} is the inputs for ith farm; ln is natural logarithm; v_i is random variable assumed to be independently and identically distributed with $N(0, \sigma_v^2)$; $u_i$is a non-negative random variable that accounts for the technical inefficiency in production, assumed to be independently and identically distributed $N(0, \sigma_u^2)$ as truncations.

$$u_i = \delta_0 + \sum_{l=1}^{6} \delta_l \, Z_l + \omega \tag{8}$$

Where, the farm-specific characteristics and socio-economic variables represented by Z_l that explain the technical inefficiency in vegetable farms; ω represents the truncated random variable; $\beta_{0,}$ $\beta_{j,}\beta_{jk,}\delta_{0,}$ and δ_l are unknown parameters to be estimated. We hypothesized that vegetable farms were technically efficient ($\gamma = 0$) using likelihood ratio-type test statistics (equation 5).

3.2.1.3 Stochastic frontier translog profit function

The stochastic profit frontier is the most suitable approach to estimate profit efficiency because it assumed that any errors in the production decision are translated into lower profit for the farmers (Ali et al., 1994). The profit frontier is theoretically consistent with the production technology to estimate production, revenue, and cost efficiency with cross-section data (Battese and

Coelli, 1992; Kumbhakar and Lovell, 2000). Therefore, we employed two-stage procedure of stochastic translog profit function to estimate the profit efficiency of vegetable farms at household levels (study III). In the first stage, we estimated the profit inefficiency scores (1-profit efficiency scores) of individual farms and in second stage regressed inefficiency scores by farm-specific characteristics and socio-economic variables associated with vegetable farming. According to Battese and Coelli (1995), the inefficiency effects can be expressed as a linear function of socio-economic explanatory variables in stochastic production frontier model. In this study, the stochastic profit function was defined as a function of variable input prices, fixed factors and error terms (Equation 9).

$$\pi_i = f\left(P_{i,} Z_i\right). \exp(\xi_i) \tag{9}$$

Where, π_i represents normalized restricted profit of ith farm; P_i represents vector of variable input price of ith farm; Z_i represents vector of fixed factor of ith farm; ξ_i is error term of ith farm ($\xi_i = v_i - u_i$). A two sided random variable (v_i) assumed to be independently and identically distributed $N(0, \delta_v^2)$, and a non-negative random variable (u_i) accounts for profit inefficiency in production process assumed to be independently distributed with mean, $\mu_i = \delta_0 + \sum_d \delta_d S_{di}$, and variance $N\left(\mu_{i,} \sigma_u^2\right)$. The S_{di} represent dth socio-economic variable that explain inefficiencies of ithfarm,δ_0 is intercept and δ_d is coefficient for unknown parameters to be estimated. The profit efficiency (PE) of ithfarm is presented in Equation 10.

$$PE_i = E[exp(-u_i)\backslash \xi_i] = E\left[\exp\ (-\delta_0 - \sum_{d=1}^{D} \delta_d S_{di})\backslash \xi_i\right] \tag{10}$$

The expected operator (E) can be achieved by obtaining the conditional expectation of u_i with the observed value of error term, ξ_i. The maximum likelihood estimate (MLE) of stochastic frontier translog profit function was applied to measure the unknown parameters using Frontier 4.1 (Coelli,1996b). The variance parameters, sigma-squared (σ^2) = $\sigma_v^2 + \sigma_u^2$, and gamma $(\gamma) = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$ were estimated (Battese and Coelli, 1995). The gamma (γ) value ranges 0 to 1; where $\gamma = 0,$ indicates that the farms were efficient, while $\gamma > 0,$ indicates that the farms were inefficient because of technical, allocative, and scale inefficiency.

Based on theoretical insight we developed empirical stochastic translog profit model (Equation 11) to estimate the profit efficiency dropping ith subscript in vegetable farms, and inefficiency effect model (Equation 12).

$$ln\pi' = \alpha_0 + \sum_{j=1}^{5} \alpha_j \ lnP'_j + \frac{1}{2}\sum_{j=1}^{5}\sum_{k=1}^{5} \beta_{jk} \ lnP'_j \ lnP'_k + \sum_{j=1}^{5}\sum_{l=1}^{2} \emptyset_{jl} \ lnP'_j \ lnZ_l + \sum_{l=1}^{2} \tau_l lnZ_l + \frac{1}{2}\sum_{l=1}^{2}\sum_{t=1}^{2} \emptyset_{lt} lnZ_l ln\, Z_t + v - u \tag{11}$$

$$u = \delta_0 + \sum_{d=1}^{7} \delta_d \ S_d + \omega \tag{12}$$

where π' represents the restricted profit, estimated with total revenue less total cost of variable inputs normalized by dividing with the price of vegetable outputs; P'_j represents the price of jth input normalized by dividing with output price, where j stands for labor, traction power, seed, fertilizer and pesticide; Z_l represents the quantity of fixed inputs, where l stands for area under vegetable cultivation and other variable cost, and ln is natural logarithm. The S_d represents for socio-economic variables to explain profit inefficiency of vegetable farms, where d stands for seed type, information index, contact of farmer with extension agent, credit access, experience, distance of farm to market and gender of farm manager; ω represents the truncated random variable; $\alpha_0, \alpha_j, \beta_{jk}, \emptyset_{jl}, \tau_l, \emptyset_{lt}, \delta_0, and\ \delta_d$ are unknown parameters to be estimated.

We hypothesized that vegetable farms were technically efficient ($\gamma = 0$) using likelihood ratio (LR) test statistics (equation 5). The heteroskedasticity problem was tested using White's test in the data set (Hill et al., 2011); the calculated value was found to be less than critical value [$25.03 < \chi^2_{(0.99,35)} = 57.342$], and confirmed that the heteroskedasticity problem was not existed.

3.2.2 Non-parametric production function

3.2.2.1 Input oriented data envelopment analysis (DEA)

The input oriented data envelopment analysis approach was adopted to estimate the efficiency (economic, technical, allocative, pure technical, and scale) of vegetable farms at plot levels (study IV). In this study, both constant returns to scale (CRS), as in Charnes et al. (1978), and variable returns to scale (VRS) as in Banker et al. (1984) were used. The constant returns to scale assumption proposed by Charnes et al. (1978) gives the overall technical efficiency score by solving Equation 13, which is the objective function of a linear programming model. Suppose n decision making units (DMUs), in this case vegetable farms, produce a single type of output by using different inputs, m. Here, Y_i is the output produced; X_i is the vector of inputs ($m \times 1$); Y is the vector of outputs ($1 \times n$), and X is the ($m \times n$) matrix of inputs of DMUs. Then the problem can be stated as follows:

$$\min_{\theta_i^{CRS}\,\lambda} \theta^{CRS} \tag{13}$$

$$\text{Subject to: } Y_i \leq Y\lambda$$

$$\theta_i^{CRS} X_i \geq X\lambda$$

$$\lambda \geq 0$$

Here, $\theta_i^{CRS}$is the technical efficiency score of the ith DMU under CRS and λ is $(n \times 1)$ vector of weights attached to each of the efficient DMUs. A separate linear programing problem is solved to obtain the technical efficiency score for each of the DMUs. For any DMU, if $\theta^{CRS} = 1,$ then the DMU is on the frontier and is technically efficient assuming CRS; and if $\theta^{CRS} < 1,$ the DMU lies below the frontier and is considered technically inefficient. The technically efficient cost of production of the ith DMU is given by $W_i'(\theta_i^{CRS} X_i)$ for the CRS model. Technical efficiency (TE) refers to the ability of a farm to either produce the optimum level of outputs from a given bundle of inputs, or to produce the given level of outputs from the minimum amount of inputs for a given technology. Allocative efficiency (AE), also called price efficiency, measures the degree to which the farm equates marginal value product with marginal cost.

An alternative approach developed by Banker et al. (1984) assumes variable returns to scale (VRS), which commonly exists in agriculture. Given this possibility, we analyzed the efficiency of Nepalese vegetable farms using both CRS and VRS DEA approaches. In order to derive overall economic efficiency (EE), we can solve the cost-minimizing DEA model (Equation 14) under CRS assumption, which is the objective function of a linear programming model (Fare et al., 1985, 1994).

$$\min_{x_i^*\lambda} W_i' X_i^* \tag{14}$$

$$\text{Subject to: } Y_i \leq Y\lambda$$

$$X_i^* \geq X\lambda$$

$$\lambda \geq 0$$

Where, the cost-minimizing or economically efficient input vector for the ith DMU is X_i^*, given its input price vector, $W_{i,}$ and the output level, $Y_{i.}$ The overall economic efficiency score for the ith farm was computed as the ratio of the minimum cost to the observed cost and is comparable to the economic efficiency score (Equation 15), where $EE = 1$ indicates economically efficient, and $EE < 1,$ indicates economically inefficient. The economic efficiency for a DMU can also be defined as the product of technical and allocative efficiency (Farrel, 1957).

$$EE_i = \frac{W_i' X_i^*}{W_i' X_i} \tag{15}$$

The allocative efficiency index is the ability of a farm to choose its inputs in a cost minimizing way (Equation 16).

$$AE_i = \frac{EE_i}{\theta_i^{CRS}} = \frac{W_i' X_i^*}{W_i'(\theta_i^{CRS} X_i)} \tag{16}$$

Where, $AE = 1,$ indicates that the farm is allocatively efficient, and $AE < 1,$ indicates the maximum proportion of cost that the technically efficient farm could save by behaving in a cost minimizing way (Chavas and Aliber, 1993).

The overall technical efficiency can be disaggregated into its components: pure technical efficiency (PTE) and scale efficiency (SE) by solving a VRS DEA model, which is obtained by imposing the additional constraint, $\sum_{j=1}^{n} \lambda_j = 1$ on the equation (13) (Banker et al., 1984). When separating the scale effect from the technical efficiency, the pure technical efficiency is obtained from VRS DEA. The scale efficiency is defined as the most efficient scale of operation in the sense of maximizing average productivity. Therefore, the technical efficiency score under VRS is denoted by θ_i^{VRS}, and the technically efficient cost of production of the ith DMU under VRS is equal to $W_i'\left(\theta_i^{VRS} X_i\right)$. The technical efficiency measure from VRS DEA, (θ_i^{VRS}), is equal to, or greater than the CRS measure (θ_i^{CRS}) for the ith DMU because the VRS analysis is more flexible and envelops the data in a tighter way than the CRS analysis. The scale efficiency was computed as the ratio of the overall technical efficiency measure under CRS (θ_i^{CRS}) of ith DMU to the corresponding measure under VRS (θ_i^{VRS} in Equation 17) (Chavas and Aliber, 1993).

$$SE_i = \frac{\theta_i^{CRS}}{\theta_i^{VRS}} \tag{17}$$

Where, $SE = 1$ indicates that the farm is operating at the efficient scale, and SE < 1 indicates scale inefficiency (i.e. that the farm could increase productivity by increasing or decreasing its scale). The potential for scale inefficiency exists due to the presence of either increasing or decreasing returns to scale, which can be estimated by solving non-increasing returns to scale (NIRS), $\sum_{j=1}^{n} \lambda_j \leq 1$, or non-decreasing returns (NDRS) , $\sum_{j=1}^{n} \lambda_j \geq 1$. We hypothesized that vegetable farms were technically efficient ($\gamma = 0$) using likelihood ratio-type test (LR) statistics (equation 5).

3.2.2.2 Output oriented data envelopment analysis (DEA)

We employed non-parametric deterministic mathematical linear programming approach developed by Farrell (1957)in women's labor contribution on the efficiency of vegetable farms in mountain region (study V). This approach attributes all the deviations from the frontier technology to the inefficiency. It does not require any specific functional forms and does not impose priori parametric restrictions on the underlying technology. Furthermore, this approach can be used to estimate the technical and scale efficiencies.

We used the output-oriented DEA model (Ali and Seiford, 1993) for a single output to estimate the technical and scale efficiencies of small scale vegetable farms. Decision making units (DMUs), n producing single output by using different inputs, m. The ith DMU uses x_{ki} units of the kth input in the production of y_i units of output. A separate linear programing (LP) problem can be solved for each DMU.

Based on the nature of data and returns to scale in the vegetable farms, the output-oriented DEA model with variable returns to scale (VRS) assumption for the ith DMU was developed (Equation 18), which is the objective function of linear programming model.

In equation 18, $\emptyset_i$ is the proportional increase in output for the ith DMU; s is the output slack; e_k is the kth input slack; and λ_j is the weight of jth DMU. The output-oriented constant returns to scale (CRS) model is obtained by eliminating the constraint$\sum_{j=1}^{n} \lambda_j = 1$ in equation (18).

$$\max_{\emptyset_i \lambda_i} \emptyset_i \tag{18}$$

Subject to:

$$\sum_{j=1}^{n} \lambda_j y_j - \emptyset_i y_i - s = 0$$

$$\sum_{j=1}^{n} \lambda_j x_{kj} + e_k = x_{ki} \qquad k = 1, \ldots., m \; inputs;$$

$$\sum_{j=1}^{n} \lambda_j = 1 \qquad j = 1, \ldots, n \; DMUs;$$

$$\lambda_j \geq 0; s \geq 0; \; e_k \geq 0$$

The single output-oriented DEA model seeks to maximize the proportional increase in output within the production possibility set when output slack, s, becomes zero. If the value of $\emptyset$ in equation (18) is 1, $\lambda_i = 1$, and $\lambda_j = 0$ for $j \neq i$, the ith DMU lies on the frontier and is efficient. For the inefficient units, if $\emptyset > 1$, $\lambda_i = 0$, and $\lambda_j \neq 0$ for $j \neq i$. The frontier production level for the ith DMU is denoted by $\widehat{y_i}$ (Equation 19).

$$\widehat{y_i} = \sum_{j=1}^{n} \lambda_j y_j = \emptyset_i y_i \tag{19}$$

The output-oriented technical efficiency of the ith DMU, denoted by TE_i, can be computed by Equation (20), which is consistent with the technical efficiency can be obtained under the stochastic production frontier.

$$TE_i = \frac{y_i}{\hat{y}_i} = \frac{1}{\emptyset_i} \tag{20}$$

The technical efficiency score of the ith DMU in the CRS ($TE_{i,CRS}$) is less than or equal to that in the VRS ($TE_{i,VRS}$) because VRS is more flexible and envelops the data in a tighter way than the CRS frontier. The scale efficiency, SE_i, is defined as the ratio of technical efficiency from CRS to the technical efficiency from VRS DEA assumption (Equation 21) of the ith DMU (Favero and Papi, 1995; Bjurek et al., 1990).

$$SE_i = \frac{TE_{i,CRS}}{TE_{i,VRS}} \tag{21}$$

Where, $SE_i = 1$ indicates the scale efficiency and $SE_i < 1$ indicates the scale inefficiency of the ith DMU. The scale inefficiency exists due to either increasing or decreasing returns to scale, which can be determined by the sum of weights, $\sum_{j=1}^{n} \lambda_j$, under the CRS assumption (Banker, 1984). If $\sum_{j=1}^{n} \lambda_j = 1$, shows the constant returns to scale (optimal scale), if $\sum_{j=1}^{n} \lambda_j < 1$, indicates the increasing returns to scale (sub-optimal scale), and if $\sum_{j=1}^{n} \lambda_j > 1$ that indicates decreasing returns to scale (super-optimal scale) (Førsund and Hernaes, 1994; Lothgren and Tambour, 1996).

3.2.3 Tobit analysis

We adopted a two-limit Tobit model (Maddala, 1985) to determine the effects of explanatory variables on vegetable farm efficiencies. The dependent variable, efficiency score, is censored distribution rather than normal distribution because their efficiency scores are bounded between zero and unity. Using such censored samples in ordinary least square (OLS) estimates gives inconsistent estimation; thus, we used Tobit regression model (Equation 22) using the maximum likelihood approach (Tobin, 1958).

$$EE_i^* = \beta_0 + \sum_{m=1}^{M} \beta_m W_{im} + \varepsilon_{i,} \qquad \varepsilon_i \sim ind(0, \sigma^2) \tag{22}$$

$$EE_i = 1 \; if \; EE_i^* \geq 1$$

$$EE_i = y_i^* \; if \; 0 \leq EE_i^* \leq 1$$

$$EE_i = 0 \; if \; EE_i^* \leq 0$$

Where, EE_i^* is a latent variable represents the efficiency index for the ith farm that expressed in terms of the observed variable EE_i (efficiency score estimated from DEA); $\beta_0\ and\ \beta_m$ are unknown parameters to be estimated; W_{im} are explanatory variables associated with vegetable farms; and $\varepsilon_{i,}$ is an error term that is independently and normally distributed with zero mean and constant variance $(0, \sigma^2)$.

Usually cross-section data is suffered with heteroskedasticity problem (Hill et al., 2011); thus we tested heteroskedasticity with White's test in the data set. The estimated value was found to be less than critical value $[56.20 < \chi^2_{(0.99,35)} = 57.342]$, and confirmed that there is no heteroskedasticity problem in the data set.

3.3 Variables specification

The variables specifications in this study are presented in Table 11. The vegetable production was considered as the function of land, labour, traction power, seeds, organic matters, chemical fertilizers, and other variable costs. The vegetable output (Kg) was considered as a dependent variable in order to estimate economic, technical, allocative, and scale efficiency. The vegetable output in the farm was calculated by adding farm use as seeds, household consumptions, sales, and gifts. In estimating the efficiency at household levels, the productions in all plots were added as a single unit. While in estimating the efficiency at plot levels, the output produced in a plot was considered as a sample unit. In order to estimate the profit efficiency, we considered normalized restricted profit (US$) as a dependent variable in this study.

This study adopted eight variable inputs such as land, labor, traction power, seeds, organic matter (compost), chemical fertilizers, pesticides, and other variable cost as independent input variables. The land was considered as the area covered by vegetable crops estimated in hectares. The labour in man-days (family and hired), and traction power in pair bullocks (animal or and tractor) used for plowing vegetable farms, and organic matter (compost) used for plant nutrients either purchased or homemade (Kg), seed (US$), chemical fertilizer (US$), and pesticide (US$). The other variable cost was depreciated cost (US$) incurred for temporary bamboo-plastic tunnel, thatch, and simple equipment. In estimating the economic and allocative efficiency using input oriented DEA model, land charge was estimated assuming 20 % of vegetable output value; labor, traction power, and organic matter (US$); and seed, fertilizer (kg),and pesticide (Kg).

To determine the underlying causes if there were possible factors affecting the inefficiency of vegetable farms, we introduced 20 explanatory variables related to technology, support services, farm-specific characteristics, and socio-economic factors. These variables were age of farm manager, farmers' association, experiences of farmers in vegetable farming, seed types, education levels of farm manager, training of farm manager, extension contact, credit access, market access, distance of markets from the farms, information index, index for underdevelopment of infrastructure, external support index, gender of farm manager, and women participation index. In addition, we introduced some explanatory variables related to women labor contribution in vegetable farming activities such as women participation on land preparation, vegetable plantation, crop management, harvesting-marketing, and decision-making.

The age of farm manager was considered in years, hypothesized that the younger farmers perform more efficiently than the elders. Tauer (1995) reported that middle age (35-44 years) farmers are more efficient than younger and elder farmers. However, the older farmers are more likely to have had more farming experience; they are also likely to be more conservative and thus they are less willing to adopt new practices (Coelli and Battese, 1996).

Farmers' association, in terms of farmers' group or farmers' cooperative, is a main approach in Nepalese agriculture development process for more than four decades; however, all the farmers are not involved in association. Nonetheless, in the recent years, farmers have been more involved in working with farmers' cooperatives. Therefore, farmers working in groups or in cooperatives was defined as "farmers' association dummy", considered as 1 if the farmer worked in association and 0 otherwise.

The experience of farmers was adopted as the number of years working in vegetable farming. It was hypothesized that longer the experiences of the farmers higher the levels of efficiency in vegetable production.

The vegetable farmers are using both improved and local varieties of seeds. Improved seed varieties were believed to be more resistant to disease, insect and pest and that give the higher levels of productive efficiency than those that of local one. Therefore, in this study, the seed type dummy was assumed to be 1 if producer used improved varieties and 0 otherwise. In order to identify whether the seed used by sample farmers was improved or local, we used seed classification profile prepared by the Ministry of Agricultural Development, Nepal.

The years of education of farm manager believed to positively influence on the levels of efficiency in vegetable production since educated manager can grasp knowledge and adopt technologies relatively faster than non-educated one. We considered the number of academic years of education of farm managers to assess its effect on vegetable production efficiency.

An extension service refers to trainings, extension contacts, exhibition materials, and publication materials (leaflets, booklets, newspapers, for example). It is a powerful tool in disseminating improved farming technologies to the farmers that has positive impact on the efficiency. In this study we introduced two types of main extension services separately such as number of training received by farm manager and number of farmer's contact with extension agents. The farmer' training is one of the key extension activities to disseminate improved farming technologies to the farmers. The total number of trainings received by farm manager (either from government/private/any institutions) with regards to vegetable farming was considered to determine its impact on the efficiency in vegetable production. The number of contacts of farmers with extension agents during a cropping period was used to analyze its effect on profit efficiency.

The vegetable farmers are embarrassed with limited financial resources, and also charged higher interest rate by informal financial sources (moneylenders, relatives and friends). Ferrari et al. (2007) reported that about 72 % of the farm households borrow credit from informal sectors despite the much higher interest rates up to 42 %, while banks charges 8 to10 % annually because of lack of formal financial institutions in the rural areas. This situation limits the accessibility of required credit that reduces the use of inputs in vegetable farming, which adversely affects the outputs (Kumar et al., 2013). Therefore, we co-opted credit access dummy considering 1 if the farmer availed credit and 0 otherwise.

The smallholder vegetable farmers are constrained with market access, particularly in the developing countries. It is one of the key concerns for vegetable farmers, which plays a vital role in profitability of the farmers and overall development of vegetable sector. To assess the effects of market access on the efficiency, we introduced two types of market related explanatory variables such as market access dummy and distance of farms to the markets. The market access was considered 1 if farmers were satisfied with accessed to markets and 0 otherwise. The distance of farm to the markets (in kilometer) was used to measure the effects of location of markets(near or far) on profit efficiency in vegetable farming, assuming that longer the distance lower the profit efficiency.

Nepalese vegetable farmers are handicapped with ineffective information services that adversely affected farmers to get lower levels of outputs. This study introduced new variable, information index, comprising of five information components: i) input marketing, ii) improved farming technologies, iii) output marketing of the vegetable products, iv) demand and supply situation of vegetables in the markets, and v) price movement of products in the markets. The cost of access approach was adopted where each of these components indexed from 1 to 5 in each farm; thus, the total index of the farm ranges from 5 (minimum) to 25 (maximum). It was hypothesized that higher the index, better the information accessed to the farmers, and leading to be higher level of profit efficiency.

Infrastructure is one of the key components in vegetable sector development, which is very weak in developing countries including Nepal where resources are very limited. In this study, the index for underdevelopment of infrastructures was adopted, which was estimated by aggregating six infrastructure elements: i) agriculture road network, ii) irrigation, iii) electricity, iv) agriculture service center (ASC), v) financial institution, and vi) location of school near the vegetable farms. We used the cost of access approach where each of these elements were indexed from 1 to 5; thereby aggregated index ranges from 6 (minimum) to 30 (maximum). We hypothesized that the index has a negative relationship with efficiency in vegetable production: higher the index, less the infrastructure development, and lower the efficiency. Rahman (2003) reported that underdevelopment in infrastructure significantly influenced the profit inefficiency in Bangladeshi rice farms. This variable was newly introduced in stochastic Cobb-Douglas production function to analyze the influence of underdevelopment of infrastructures on Nepalese vegetable farms.

The government of Nepal, in collaboration with donor partners, has been investing a huge amount of resources, especially since 1990s in vegetable production and marketing. To analyze the effects of these support services on farm efficiency we introduced an external support index consisting of seven components: i) fertilizers, ii) irrigation, iii) seeds, iv) pesticides, v) production material (plowing, digging, sprayer material), vi) extension material (leaflets, posters and mass communication from newspaper, radio and television) and vii) post-harvest material (packaging, harvesting, weighing, drying material). Each of these components were indexed from zero to one; one if the farmer was satisfied with the support and zero otherwise. Thus, the total index of each farm household ranged from zero to seven.

Vegetable farming is labour-intensive, and women are typically the major sources of labour forces in vegetable production and food systems (ILO, 2008). While they are less likely to have access to education, credit, market and extension supports(Spieldoch, 2011) that led vegetable farms to be inefficient. The gender inequality limits economic growth and diminishes the effectiveness of poverty reduction programs and policies. Most of the previous researches used labour as an explanatory factor but these studies ignored to disaggregate labour force into men or women such accounts makes faulty decision to be successful in agriculture. However in the recent years, it has been realized that without incorporating gender analysis, policy directions towards the productive efficiency in agriculture are unlikely to succeed (Bozoğlu and Ceyhan, 2007). Indeed, gender perspective analysis in resource use efficiency is important frontage in sustainable agriculture development. Thus we introduced two gender related indicators in our model. The first was gender of the farm manager, measured 1 if the farm manager was a male and 0 otherwise. The second was a women participation index, which captures five types of contributions: i) land preparation, ii) plantation, iii) crop management (irrigation, insect-pest management, fertilization and weeding), iv) harvesting and marketing, and v) decision-making with regard to vegetable farming. Each of these five contributions was scored from one (minimal participation of women in vegetable farming) to five (maximum participation of women in vegetable farming). Thus, the aggregated index ranged from 5 (minimum) to 25 (maximum) for each farm households.

Most of the studies used gender of household head as an explanatory variable, which is inadequate to represent the contribution of women and men in vegetable farming activities. For instance, although the household head is male, most of the farming activities have done by women and vice versa; thus that lead misleading in policy formulation. Therefore we regressed the inefficiency scores (TE from CRS DEA) of each farms by women related explanatory variables associated with vegetable farming. The major activities where women have been involved in vegetable farming such as women participation in land preparation, women participation in vegetable plantation, women participation in crop management (irrigation, insect-pest management, fertilization and weeding), women participation in harvesting and marketing, and women participation in decision-making. Each of these five components were indexed from one (minimal participation of women) to five (the highest participation) in each DMU in our Tobit regression model.

Table 11. Variables specification in the efficiency analysis of vegetable farms

SN	Variables	Unit	Variables specification	Exp. sign	Study applied*
Dependent variables					
1	Output quantity	Kg/farm	Quantity of vegetable output		I, II, IV, V
2	Restricted profit	US$/farm	Normalized restricted profit		III
2	Inefficiency	Score	Subtract efficiency score from one		I, II, III, IV, V
Independent input variables					
1	Land	Hectare	Area of land covered by vegetables	+ or -	I, II, III, IV, V
2	Labor	Man-day/farm	Labor (family and hired) used in farms	+ or -	I, II, III, IV, V
3	Traction power	Pair bullock/farm	Pair of traction bullock used in farms	+ or -	I, II, III, IV, V
4	Seeds	US$/farm	Cost expenses for vegetable seeds	+ or -	I, II, III, IV, V
5	Organic matter	Kg/farm	Compost used in farms	+ or -	I, II, IV, V
6	Chemical fertilizers	US$/farm	Chemical fertilizers used in farms	+ or -	I, II, III, IV, V
7	Pesticides	US$/farm	Chemical pesticides used in farms	+ or -	I, III, V
8	Other variable costs	US$/farm	Cost expenses for bamboo-plastic tunnel, thatch, and simple equipment	+ or -	I,II,III,IV

Table 11. Continue….

SN	Variables	Unit	Variables specification	Exp. sign	Study applied*
Explanatory farm-specific and socio-economic variables					
1	Age of farm manager	Years	Member of household who handle farms	-	I
2	Farmers' association	Dummy	1 if farmer involved in farmers' group or cooperative, 0 otherwise	+	I
3	Experience of farmers	Years	Total years of farmers working in vegetable farming	+	III
4	Seed types	Dummy	1 if used improved seed, and 0 otherwise	+	III, IV
5	Education of manager	Years	Academic years of schooling of manager	+	II, V
6	Training of farm manager	Number	Number of trainings received by manager in a cropping period	+	I, II, IV, V
7	Extension contact	Number	Number of contacts of farmer with extension agents (GO, NGOs, and private sector) in a cropping period	+	III
8	Credit access	Dummy	1 if farmers availed credit, and 0 otherwise	+ or -	II, III, IV
9	Market access	Dummy	1 if manager satisfied with access to market, and 0 otherwise	+	I, II, IV

Table 11. Continue….

SN	Variables	Unit	Variables specification	Exp. sign	Study applied*
10	Distance of farm to markets	Km.	Distance of farms to markets estimated in kilometer	-	III, V
11	Information index	Index (1-5)	Components: Input marketing, improved farming technologies, output marketing, demand and supply of products, and price situation of products	+	III
12	Index for underdevelopment of infrastructure	Index (1-5)	Components: Road network, irrigation, electricity, agriculture service center, financial institution, and school's location	-	I
13	External support index	Index (0-1)	Components: Fertilizers, irrigation, seeds, pesticides, production material, extension material (leaflets, posters, radio and television), post-harvest (packaging, harvesting, weighing, drying)	+	IV
14	Gender of farm manager	Dummy	1 if the farm manager was male, and 0 otherwise	+ or -	II, III, IV, V

Table 11. Continue….

SN	Variables	Unit	Variables specification	Exp. sign	Study applied*
15	Women participation index	Index(1-5)	Components: Land preparation, plantation, crop management (irrigation, insect-pest management, weeding), harvesting-marketing, and decision-making	+ or -	II, IV
16	Women participation inland preparation	Index(1-5)	1 for minimum participation, and 5 for highest participation		V
17	Women participation in vegetable plantation	Index(1-5)	1 for minimum participation, and 5 for highest participation		V
18	Women participation in crop management	Index(1-5)	1 for minimum participation, and 5 for highest participation		V
19	Women participation in harvesting- marketing	Index(1-5)	1 for minimum participation, and 5 for highest participation		V
20	Women participation in decision-making	Index(1-5)	1 for minimum participation, and 5 for highest participation		V

Note: * I,II,III,IV,V stand for study I, study II, study III, study IV, and study V.

3.4 Hypothesis of the study

This study formulated the following hypothesis:

1. Smallholder vegetable farms in the study area are efficient in economic, technical, allocative, and scale efficiency;
2. Vegetable farms are profit efficient;
3. Summer season vegetable farms are more efficient than winter season vegetable farms;
4. Women farmers are more efficient than men in vegetable farming;
5. Agriculture inputs such as land, labor, traction power, seed, organic matter, fertilizer, pesticides, and other inputs significantly determine the vegetable outputs;
6. The efficient farms perform higher level of output and less output–loss, and higher level of profit and less profit-loss in vegetable farming relative to less efficient farms;
7. The explanatory variables related to technologies, farm-specific characteristics, and socio-economic factors (Table 11) significantly influence the inefficiencies in vegetable production.

3.5 Conceptual framework

The main objective of this study is to evaluate the efficiency of vegetable farms and to derive the policies in improving rural household income of smallholder farmers in Nepal using cross-sectional data collected during July-August, 2013. We adopted parametric and non-parametric approaches to estimate the economic, technical, allocative, scale and profit efficiency of vegetable farms in seasonal, agroecological, and gender perspectives. The whole study of vegetable farm efficiency analysis was conducted into five separate studies in terms of farm levels (household and plot), seasons (winter and summer), agroecologies (mountain, hills and terai), and approaches (parametric and non-parametric). These separate studies are as follows (Figure 6):

Study I. The technical efficiency of vegetable farms at household levels was estimated using stochastic frontier Cobb-Douglas production frontier.

Study II. The technical efficiency of vegetable farms at plot levels was evaluated, and compared the efficiency performances between seasonal, agroecological, and gender perspectives adopting stochastic translog production function.

Study III. The profit efficiency of vegetable farms at household levels was measured employing stochastic frontier translog profit function.

Study IV. The input oriented non-parametric approach of data envelopment analysis was applied to estimate the efficiency (economic, technical, allocative, pure technical, and scale) of vegetable farms at plot levels for winter and summer season.

Study V. The output oriented non-parametric approach of data envelopment analysis was used to estimate the efficiency (technical and scale) of vegetable farms at plot levels in winter season as a case study. This study is more focused on women's labor contribution on the efficiency of vegetable farms in mountain region as a case study.

In order to analyze the factors affecting inefficiency in vegetable farms in study IV and study V, we adopted a two-limit Tobit model (Maddala, 1985) because the dependent variable, the inefficiency score, is bounded between zero and unity.

In this study, we used dependent variable, vegetable output (Kg) in estimating the production efficiency, and restricted normalized profit to estimate the profit efficiency (US$). The independent input variables were:

land, labor, traction power, seeds, organic matter, chemical fertilizers, pesticides, and other input costs to estimate the efficiencies.

In order to determine the underlying causes of inefficiencies in vegetable production, some major explanatory variables related to technologies, farm-specific characteristics, and socio-economic factors were introduced in this study. These explanatory variables were: age of farm manager, farmers' association, experiences, seed types, education, training, extension contacts, credit access, and market access, distance of markets from the farms, information index, index for underdevelopment of infrastructures, external support, gender of farm manager, and women participation index. To determine the women's labor contribution on vegetable production efficiency, women participation in land preparation, vegetable plantation, crop management, harvesting-marketing, and decision-making activities were introduced.

Based on the empirical analysis, some important factors were identified that influenced the inefficiencies in vegetable production of smallholder farmers. This study suggests some policies interventions to enhance vegetable production and increase income that improve the household economy, and eventually reduce the poverty of smallholder farmers in Nepal. The conceptual framework of this study is presented in Figure 6.

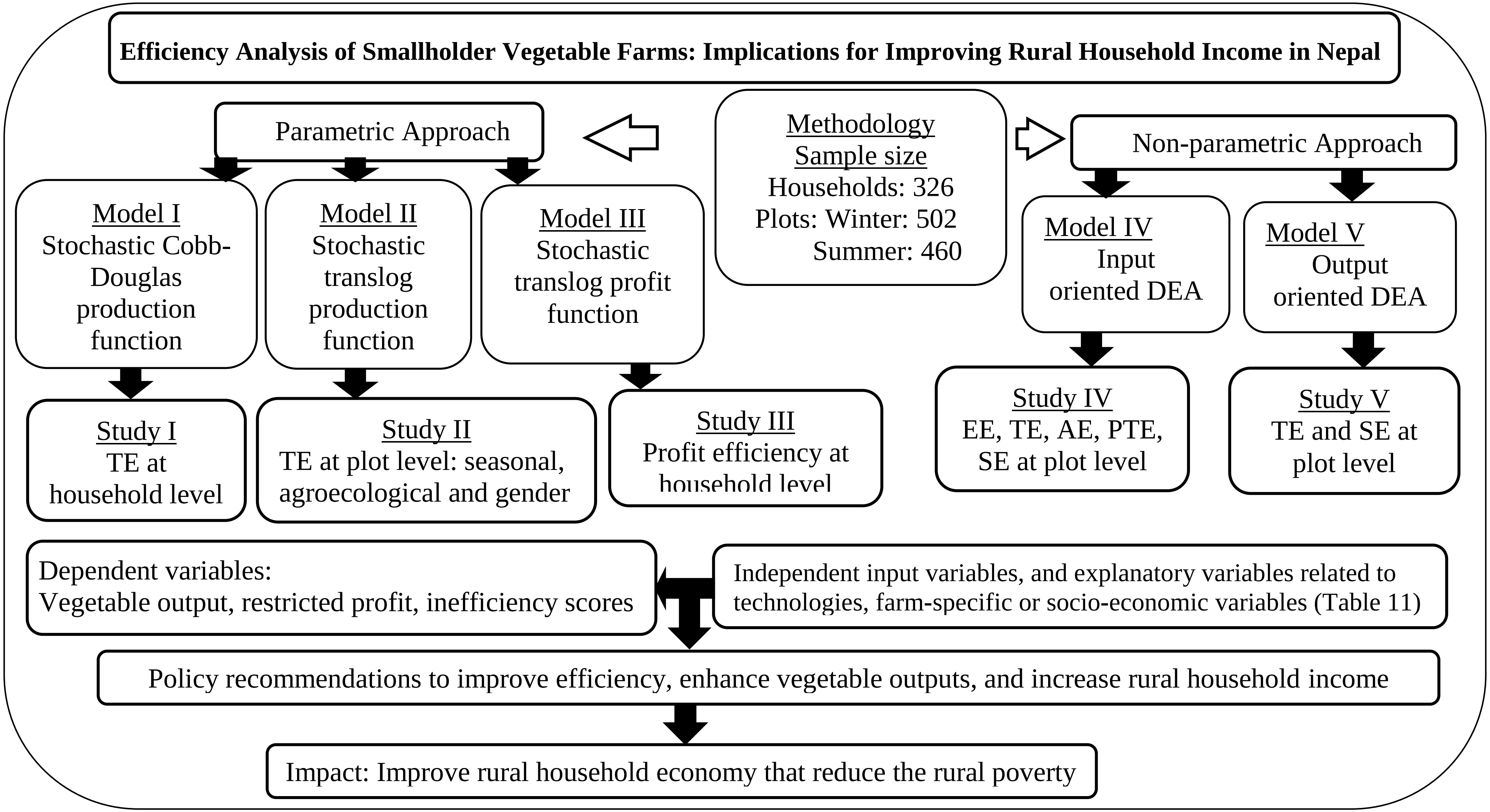


Figure 6: Conceptual framework for the analysis of efficiency of smallholder vegetable farms, Nepal.

Chapter 4

Results and Discussion

4.1 Descriptive statistics

The descriptive statistics of the variables used in this study are presented in Table 12 for household level farms (study I and study III), Table 13 for plot level farms (study II and study IV), and Table 14 for plot level farms in mountain district (study V).

In Table 12, the average size of vegetable farms was quite small (0.40 ha), the mean of output value of vegetable farms US$ 1139.69, and net profit US$ 421.59. The variable cost used in vegetable farming was estimated to be higher in labor cost, followed by organic matter (compost), traction power, chemical fertilizers, pesticides, and seeds.

The average age of farm manager was estimated to be 42.5 years, which is economically active age group and more productive for vegetable farming. The majority of the farmers (71%) were involved in farmers' groups or cooperatives. The majority of farmers (75%) used improved seeds, and the average number of trainings received by the farm manager was 1.52. Less than 30 % of the farmer availed credit, majority of the farmers (71%) access market facilities; they sell their products at the farms (to commission agents or traders), local markets (daily or weekly markets), cooperative markets, or wholesale markets. The mean of information index was found to be 15.75 out of 25, indicated that vegetable farmers utilized more than 50% information, particularly on input marketing and farming technologies. Furthermore, the average index for the underdevelopment of infrastructure was 18 (60% of the total index 30) indicating that farmers relying on poor infrastructure conditions. The majority of vegetable farms (77%) were managed by male farmers in the study areas.

Table 12. Descriptive statistics of variables at household level farms

Variable	Mean	Standard deviation
Input and output variables		
Land (ha)	0.40	0.31
Output value (US$)	1139.69	923.48
Profit (US$/farm)	421.59	403.06
Labor (man-days)/ farm	94.06	75.80
Labor cost (US$/farm)	297.86	253.86
Traction power (US$)	133.35	124.06
Seed cost (US$)	105.01	84.29
Chemical fertilizer cost (US$)	129.77	105.68
Organic matter (US$)	141.74	96.76
Pesticide (US$)	108.17	89.55
Other variable cost (US$)	116.34	85.99
Explanatory variables		
Age of manager (years)	42.51	9.21
Farmers' association (dummy)	0.71	0.46
Experience of farmers (year)	12.31	8.79
Seed types (dummy)	0.75	0.43
Trainings of manager (No.)	1.52	2.05
Extension contact (No.)	1.88	1.90
Credit access (dummy)	0.29	0.45
Market access (dummy)	0.71	0.46
Distance of farm to market (Km.)	25.17	38.35
Information index (No.)	15.75	4.6
Index for underdevelopment of infrastructure (No.)	18.00	4.33
Gender of manager (dummy)	0.77	0.42

Table 13 presents the descriptive statistics of variables used in study II and IV with regard to plot level vegetable farms in winter and summer seasons. The mean value of output and all the input variables except seed cost were higher in winter season farms than those that in summer season. For the farm-specific explanatory variables, all the variables except seed types and women participation index were higher in winter season vegetable farms. The women participation index was found to be more than 15 out of 25 in both seasons; indicated that there was a significant contribution of women labour force in vegetable farming.

Table 13. Descriptive statistics of variables at plot level farms by seasons

Variable	Winter season		Summer season	
	Mean	Std. dev.	Mean	Std. dev.
Input and output variables				
Output (Kg,00)	23.82	21.87	15.81	10.03
Land (Ha)	0.13	0.09	0.10	0.08
Labor cost (US$)	114.91	89.36	72.60	28.00
Traction power cost (US$)	34.61	29.09	30.86	27.03
Seed cost (US$)	29.28	31.23	33.69	30.43
Organic matter (Kg/farm)	283.71	183.41	244.49	129.41
Chemical fertilizer cost (US$)	38.02	30.67	32.71	20.93
Other variable cost (US$)	63.94	34.32	41.95	221.01
Seed type (dummy)	0.23	0.42	0.76	0.42
Explanatory variables				
Education of manager (year)	6.76	3.48	6.24	3.88
Training of manager (No.)	1.52	1.73	1.06	1.66
Credit access (dummy)	0.29	0.47	0.26	0.46
Market access (dummy)	0.71	0.42	0.69	0.42
External support index (No.)	5.28	1.48	3.72	1.41
Women participation index (No.)	15.72	3.91	16.58	4.28

Table 14 presents the descriptive statistics of study V with regards to plot level vegetable farms in mountain district. The composition of costs share was higher in other variable cost, organic matter and seeds cost. The women participation index in all farming activities such as land preparation, vegetable plantation, crop management, harvesting and marketing, and decision making were found to be more than 68%. This index indicates that there was considerable level of women involvement in each vegetable farming activity.

Table 14. Descriptive statistics of variables at plot level farms in mountain region

Variables	Mean	Standard deviation
Input and output variables		
Output (Kg,00)	20.40	11.11
Land (Ha/farm)	0.12	0.07
Labor (Man-days/farm)	24.04	12.09
Traction power cost (US$/farm)	21.30	10.33
Seed cost (US$/farm)	24.21	12.78
Organic matter (Kg/farm)	274.14	137.41
Chemical fertilizer cost (US$/farm)	22.23	11.73
Other variable cost (US$/farm)	42.76	13.22
Explanatory variables		
Gender of farm manager (dummy)	0.43	0.49
Land preparation (Index 1-5)	3.44	1.02
Planting vegetable (Index 1-5)	3.50	0.77
Crop management (Index 1-5)	3.79	0.99
Harvesting and marketing (Index 1-5)	3.70	1.12
Decision making (Index 1-5)	3.38	1.29
Education levels of farm manager (year)	5.57	3.23
Training of farm manager (No.)	2.71	2.81
Distance of farms to market (Km.)	19.47	8.66

4.2 Study I. Technical efficiency of vegetable farms at household levels: A parametric approach

This study evaluated the technical efficiency of smallholder vegetable farms at household levels using 326 household cross-sectional data collected during July and August, 2013.We adopted stochastic frontier Cobb-Douglas production function (equation 1) to estimate the technical efficiency of vegetable farms. We considered output of vegetables as the dependent variable, while eight inputs such as land, labor, traction power, seeds, chemical fertilizers, organic matter (compost), pesticides, and other variable input costs were used as independent variables. In order to identify the underlying causes that influenced the inefficiency in vegetable production, we adopted five different types of explanatory variables related to farm-specific characteristics, support services, and socio-economic variables with regard to vegetable farming. These variables were age of farm manager, farmers' association, number of trainings received by farm manager, farmer's access to markets, and index for underdevelopment of infrastructure.

In this study we discuss the maximum likelihood estimates of stochastic frontier Cobb-Douglas production function; sources of inefficiencies in vegetable farms; technical efficiency distribution in vegetable farms; technical efficiency, actual output, optimum potential output, and output-loss in vegetable farms; and conclusions and policy implications.

4.2.1 Maximum likelihood estimates of stochastic Cobb-Douglas production function

The results of maximum likelihood estimates (MLE)of stochastic Cobb-Douglas production frontier are presented in Table 15. The variance parameters were found to be highly significant, which indicated that inefficiency existed in vegetable farming. The coefficient of gamma (γ) was found to be much higher (0.73), and significant at 1% level, which revealed that about 73% of the inefficiency in vegetable production was attributed by technical inefficiency, and small portions (27%) by random error accounted for weather, draught, storm, typhoon and other different natural calamities. We tested the null hypothesis of technically efficient ($\gamma = 0$) using the likelihood-ratio test. The null hypothesis was strongly rejected at 1% level (LR statistics $9.095 > \mathrm{X}^2_{(1,0.99)} = 7.879$), which also confirmed that inefficiency existed in vegetable farming.

All the input variables except seed were highly significant, and consistent in expected signs. The sum of the elasticity found to be more than one (1.118) confirmed that there was increasing returns to scale; implying that as increases in inputs increases the outputs in vegetable farming. The elasticity was much higher for labor, followed by land, compost, other variable cost, animal power, pesticide, and fertilizer, and indicated that these variables have a major effect in vegetable production.

Table 15. MLE of stochastic Cobb-Douglas production function at household level farms

Independent variable	Coefficient	Standard error	t-value
Constant	0.169	0.599	2.820***
lnLand	0.196	0.075	2.631***
lnLabor	0.316	0.072	4.373***
lnTranction power	0.112	0.041	2.744***
lnSeed	0.015	0.038	0.390
lnFertilizer	0.087	0.032	2.756***
lnOrganic matter (compost)	0.163	0.047	3.450***
lnPesticide	0.103	0.036	2.834***
lnOther variable cost	0.126	0.031	4.105***
Sum of elasticity of inputs	1.118		
Variance parameters			
Sigma-squared (δ^2)	0.167	0.025	6.767***
Gamma (γ)	0.733	0.088	8.315***
Likelihood Ratio (LR) test	9.095***		

Table 15. Continue….

Independent variable	Coefficient	Standard error	t-value
Inefficiency effects model			
Age of farm manager	0.003	0.002	1.878**
Farmers' association	-0.026	0.039	-0.672
Training of farm manager	-0.014	0.009	-1.565*
Market access	-0.072	0.039	-1.871**
Index for underdevelopment of infrastructure	0.015	0.004	3.529***

Note: Superscript ***, **, * indicate significant at 1 %, 5 %, and 10 % levels, respectively

4.2.2 Sources of inefficiencies in vegetable farms

In inefficiency effect model, all the socio-economic variables except farmers' association were significant, and consistent in the expected signs of the coefficients (Table 15). The positive effect of age supported the hypothesis that younger farmers are more efficient. This result was not different from the past studies (Bozoğlu and Ceyhan, 2007; Hussain et al., 2012). However, it had an important implication for the Nepalese context that younger people could be involved in vegetable farming instead of migrating to foreign countries seeking employment. In fact, a large number of younger Nepali workers (annually about 350 thousand) have been migrating abroad for employment (CBS, 2010) even if the salary is relatively lower than the amount that could be earned from vegetable farming because of demotivation in agriculture farming occupation. This trend of out-migrating of younger people from the country can profoundly damage for sustainable economic development in the country. As the younger farmers are productive, dynamic, and updated in information, they can promptly grasp and adopt improved technologies that helps to reduce cost per unit, eventually enhancing efficiency. Therefore, young farmers need to be encouraged with composite package of intensive training with regard to vegetable farming, credit access with minimum operating costs, and market access to the farmers.

Farmers' association, farmers' training, and market access were negatively affected on inefficiency and consistent as expected. The negative estimation of training of household head was significant, and implying that providing training to the farmers could help to reduce inefficiency. The result was consistent with the finding of Ojo et al. (2009) and Enwerem and Ohajianya (2013). Training and extension programs disseminate improved technologies on farming practices that help to enhance production efficiency and significantly increase net farm income (Akobundu et al., 2004). In particular, farmers' field school of agriculture extension has been instrumental in developing technical competencies of the farmers to improve their efficiency and agricultural productivity (Joshi and Karki, 2010).

The government extension system in Nepal is weak and ineffective to disseminate improved technologies to the farmers in rural areas. Agriculture extension services with pluralistic approach consisting of NGOs/INGOs, cooperatives, and foreign agriculture development agencies are crucial in developing skills of extension workers and disseminate improved farming technologies to the farmers. There are mainly two kinds of problems encountered in agriculture training and extension systems in Nepal: first, the ratio of the number of technicians to the number of farm households is very low (one technician covers 1500-2000 farm households); second, the technicians available in the country are not well trained. Therefore, this study recommends policy to coordinate and align with foreign technical assistance team for developing capacity of technical trainers and extension workers. In addition, the capacity building programs should also be given to the leading farmers focused to younger and women that would have multiplier impact through farmers-farmers extension approach.

The statistically significant coefficient of market access confirmed the hypothesis of positive relationship of market with efficiency in vegetable farming. Market access to farmers would create opportunities in getting reasonable price for their products in competitive condition, and eventually improve efficiency. Group marketing or cooperative marketing are common in agricultural markets in supporting smallholder commercialization and marketing performance, especially for the fresh-products (Bernard and Spielman, 2009; Lemeilleur and Codron, 2011). Nepalese vegetable farmers are handicapped on market access in two ways: first, limited market infrastructure facilities nearby the production areas; second, the government rules and regulations restrict farmers from getting entry into the markets to sell their products. The government rule as of Agriculture Market Regulation Directives 1996 provides market space to the traders rather than the producers for conducting their business. The market environment needs to be farmers-friendly to ensure that the producers have access to the market where government role is imperative.

The index for underdevelopment of infrastructure was statistically significant and consistent with the hypothesis of positive relationship with inefficiency, which implies that improving infrastructures would help to enhance vegetable production efficiency. Among six infrastructure elements, the overall index was higher in agriculture service center (ASC), followed by agriculture road network, financial institution, school, irrigation, and electricity (Table 16). The higher index in ASC indicates that institutions assigned for providing extension services were poorly developed; thus farmers were unable to get enough extension facilities, and consequently affected on inefficiency in vegetable production.

Table16.Index for underdevelopment of infrastructures

Agroecological region	Agri. road	Irrigation	Electricity	ASC	Financial institutions	School location
Mountain	3.47	2.59	2.13	3.66	2.73	2.64
Hill	3.23	2.53	2.19	3.56	3.03	2.20
Terai	4.05	2.45	3.11	3.76	4.13	3.90
Mean	3.58	2.52	2.48	3.66	3.30	2.91
Rank	2	5	6	1	3	4

Note: Higher index represents less development. ASC stands for agriculture service center (government extension service system at field level).

Garrett (2001) argued that a larger number of extension institutions provide educational services at a lower cost that contribute to increase efficiency. We suggest policymakers to establish ASC adjacent to vegetable farming areas and disseminate improved technologies on vegetable farming practices and provide technical assistance to the farmers. The underdevelopment of road network adversely affected farmers in delivering the inputs and outputs required from and to the markets that made the product more expensive and inefficient. Rudimentary rural road network not only adds to the cost of the product but also increases the marketing losses. Adequate agriculture road network is essential for vegetable sector development.

The existence of inadequate number of financial institutions in rural areas compelled farmers to avail credit from informal financial sources (local moneylenders, traders, relatives, and friends). About 72% of the households borrow credit from the informal sectors despite the much higher interest rates up to 42% while banks charge 8 to10% annually, because borrowers prefer faster lending process even if the interest rate is higher (Ferrari et al., 2007). This situation limits the accessibility of the required credit, reduces the inputs use by the farmers that adversely affects vegetable production (Kumar et al., 2013). Thus, establishment of financial institutions in rural areas and disbursement of credit to the farmers with competitive interest rate can help to access financial resources and can contribute in improving efficiency in vegetable production.

4.2.3 Technical efficiency distribution in vegetable farms

The technical efficiency score of vegetable farms ranged from 0.30 to 0.94 and the mean score was 0.77 (Figure 7). It showed that a wide range and great extent of inefficiency was found in Nepalese vegetable farms, indicating that there is considerable potential to increase outputs by improving farm management practices at the frontier level. About 97% of the farms exhibited below the highest level of benchmarking implying considerable scope for improving efficiency by learning from the best allocation decisions from efficient farms. The frequency distribution of efficiency showed that 23% of the farms exhibited less than 0.70 score, majority of the farms (74%) had a range of 0.71 - 0.90 score, and only 3% farms exhibited more than 0.90 score.

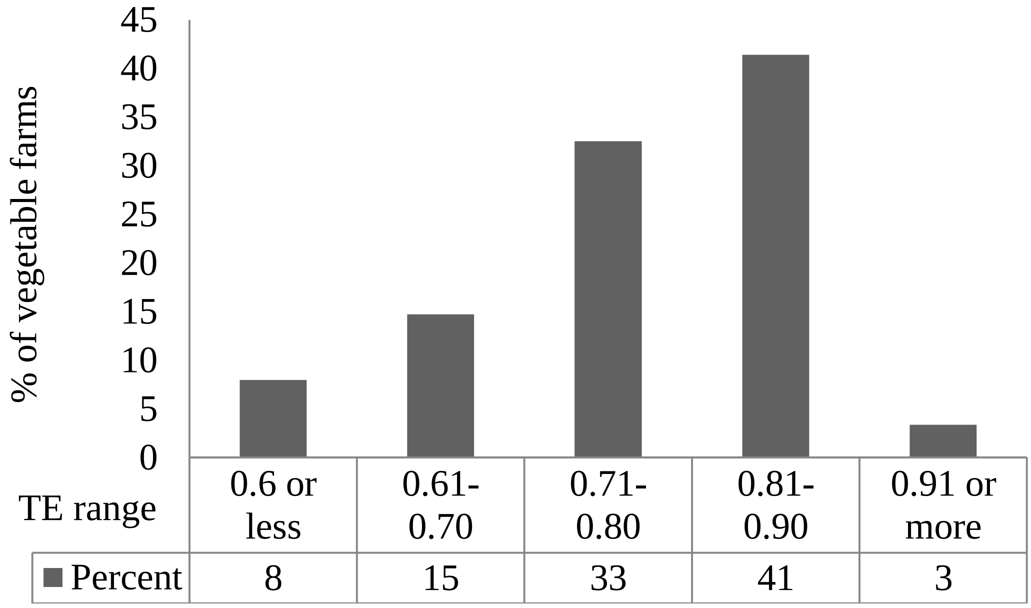


Figure 7. Technical efficiency distribution at household level farms

4.2.3.1Technical efficiency in vegetable farms by farm size

The vegetable farms were categorized into two groups: large (≥0.40 ha), and small (<0.40ha). The technical efficiency was found to be quite high in large farms compared to small farms (Table 17). This result support the principle of economics of scale; larger the farm size, lower the cost, and higher the efficiency. This finding was consistent with the results of Ogundari and Ojo (2007) and Nyagaka et al. (2010), and contradictory to Bielik, and Rajčániová (2004), Enwerem and Ohajianya (2013), and Altieri et al. (2011).

Table 17. Technical efficiency of vegetable farms at household levels by farm size

Farm size	TE	Std. dev.	Minimum	Maximum
Small farms (< 0.40 ha)[1]	0.77	0.105	0.420	0.940
Large farms (≥ 0.40 ha)	0.78	0.105	0.300	0.930

Note: [1]The mean of farm size is 0.40 hectares

4.2.3.2 Technical efficiency in vegetable farms by agroecological regions

Agroecology perspective analysis is crucial for ecology-based agricultural development that would have a meaningful impact on the livelihood and food security of smallholder farmers. The results revealed that vegetable farming in terai region was more efficient than in the hills and mountain regions, and hill farming was more efficient than that in the mountain (Table 18).

Table 18.Technical efficiency in vegetable farms at household levels by agroecological regions

Agroecological region	Mean TE	Std. dev.	Minimum	Maximum
Mountain	0.75	0.098	0.425	0.888
Hill	0.78	0.111	0.300	0.941
Terai	0.78	0.096	0.524	0.932
All locations	0.77	0.105	0.300	0.940

The higher efficiency in terai vegetable farming could be explained by fairly more productive land, more access to infrastructures, and effective extension service. The efficiency gap was much higher in hill vegetable farms than in the terai and mountain. Vegetable production could considerably increase in all the agroecological regions, and more specifically in the mountain and the hill region by increasing technical efficiency operating the farms at the frontier level.

4.2.4 Technical efficiency, actual output, optimum output and output-loss in vegetable farms

The study showed rigorous empirical evidence of inefficiencies in Nepalese vegetable farms. The average technical efficiency level, actual output, optimum potential output and output-loss of vegetable farms (per farm) are presented in Table 19.

The maximum (optimum) vegetable output is achieved by operating the farms at the frontier level, which was estimated by dividing the actual output by the technical efficiency scores of individual farms. The output-loss is the amount that have been lost due to the inefficiencies in vegetable production given prices and fixed factor endowments, which was calculated by multiplying the maximum outputs with the technical inefficiency scores.

As the Table 19 demonstrated that the vegetable farmers have been lost outputs about 25 % (US$932.00 per farm)in vegetable farming because of inefficiencies. If the farms had been operated with best practices at the frontier levels, the farmers would have increased the outputs by 25 % using the existing quantity of inputs, and that additional amount outputs would be used for rural economic development activities.

The technical efficiency was positively correlated with output levels; as higher the efficiency, higher the outputs, and lower the losses. The larger farms had higher efficiencies with lower output-losses than small-size farms. The younger farmers had higher levels of efficiencies, and lower output-losses than those that of elder farmers. The mean of outputs was higher to the farms operated by the farmers who were associated with farmers association. The numbers of trainings to the farmers did not show significant effects on efficiency and output levels.

Those farms, accessed with markets and more infrastructure facilities, performed the higher levels of outputs. Hence, the larger farms, farms managed by younger farm manager, farmers associated with farmers' association, farms accessed with markets, and farms associated with well-developed infrastructure, performed the higher levels of technical efficiencies and higher levels of vegetable outputs.

Table 19. Technical efficiency, actual output, optimum output, and output-loss at household level vegetable farms

Variables	Mean TE	Actual output (US$)	Optimum-output (US$)	Output-loss (US$)	Output-loss (%)
Output-loss by technical efficiency					
Lower TE (<0.77)[1]	0.67	2741.61	4126.80	1385.20	33.57
Higher TE (≥ 0.77)	0.84	3215.44	3818.35	602.90	15.79
t-ratio (lower vs. higher TE)	-23.538***	-3.955***	1.908**	11.889***	
Output -loss by farm size					
Small-size (< 0.40 ha)[2]	0.77	3174.78	4158.19	983.41	23.65
Large-size (≥ 0.40 ha)	0.78	2744.65	3579.70	835.053	23.33
t-value (very small vs. small)	-0.721	3.487***	3.541***	1.846**	
Output-loss by age of manager					
Younger farmer (>42.51 years)[3]	0.78	3083.43	4006.24	922.814	23.03
Elder farmer(≥42.51 years)	0.77	2957.52	3892.69	935.17	24.02
t-value (younger vs. elder)	0.469	1.042	0.708	-0.158	
Output-loss by farmers' association					
Non-member	0.78	2985.86	3911.06	925.196	23.66
Member	0.77	3030.89	3961.82	930.93	23.50
t-value (non-member vs. member)	0.302	-0.34	-0.28	-0.07	

Table 19. Continue……

Variables	Mean TE	Actual output (US$)	Optimum-output (US$)	Output-loss (US$)	Output-loss (%)
Output-loss by number of trainings					
Less training	0.77	2834.12	3712.35	878.23	23.83
More training	0.77	3305.54	4314.75	1009.22	23.44
t-value (less vs. more)	0.150	-3.88***	-3.74***	-1.65**	
Output-loss by market access					
Market not access	0.77	2603.69	3418.45	814.76	23.83
Market access	0.77	3190.60	4167.65	977.05	23.44
t-value (not access vs. access)	-0.071	-4.56***	-4.38***	-1.91**	
Output-loss by infrastructure index					
Less infrastructure (<18 index)[4]	0.77	2786.62	3654.60	867.98	23.75
More infrastructure (≥ 18 index)	0.77	3217.22	4199.35	982.13	23.39
t-value (less vs. more infrastructure)	0.090	-3.62***	-3.45***	-1.47*	
Average		2,991.00	3,923.00	932.00	23.71

Note: [1]Mean of technical efficiency 0.77; [2]mean of farm size 0.40 ha; [3]mean of age of farmers 42.51 years; [4]mean of index for under development of infrastructure 18.00.

4.2.5 Conclusions and policy implications

This study estimated the technical efficiency and determined factors that influenced the inefficiency of vegetable farms at household level using stochastic frontier Cobb-Douglas production frontier with cross-section data collected during July to August, 2013. Based on the results, the mean of technical efficiency score was found to be 0.77, revealed that there was substantial scope to increase vegetable outputs with the existing technologies. On average, each vegetable farm household lost their outputs about 25 % equivalent to 932 US$ in vegetable farming that could be improved by improving the technologies and operating the vegetable farms at the frontier levels. The farmers could have same quantities of products if they had reduced 25 % of the input resources; thus the resources could be used in alternative economic activities to generate extra income for the farm families.

The productive input variables such as land, labor, traction power, chemical fertilizers, composts, pesticides, and other variable costs were seen as important factors that influenced the total value production differential. This implied that policymakers should focus on increasing farm size and making land more productive, developing efficient and skillful labor, upholding traction power making it more productive, promoting composts for plant nutrients, and making more accessible and affordable fertilizers, pesticides, and other variable costs to the farmers.

The age of farm manager, training to farmers, market access, and infrastructure development were confirmed to be important factors in determining inefficiency in vegetable farming. The positive relationship of younger farmers with technical efficiency implied that policies should encourage younger farmers with adequate incentive packages incorporating extension services, training programs, and financial access that help to enhance efficiency. Different types and levels of training program focus on crops management, insect-pest control, inputs management, and market management need to be implemented.

In addition, market access to the farmers reduces the inefficiency in vegetable farms. Policies should give priority in greater access of markets to the farmers that would require government support for providing adequate resources in establishing market infrastructures, and endorse farmer-friendly rules and regulations instead of the traders.

The development in infrastructures such as establishment of agriculture service centers at the field level, agriculture road networks, and financial institutions were seen to be the key infrastructure components in enhancing efficiency in vegetable production. Policymakers need to pay serious attention to formulate policies and programs prioritizing these specific infrastructure components. But such infrastructures require huge budgetary resources, which could be a major problem for a resource-poor country like Nepal. Therefore, exploring the local resources and its utilization through participatory development approach, aligned with the international funding sources could be one of the best alternatives for necessary resource management and developing infrastructures.

Finally, we recommend the following policies: i) encourage younger farmers in vegetable farming; ii) increase the number of trainings and extension programs integrating them with younger farmers' participation; iii) provide greater access to markets to the farmers; and iv) develop infrastructures, especially focus on the establishment of agriculture service centers in the vegetable production areas, construction of agriculture road networks between the production areas and markets, and establishment of financial institutions in the rural areas.

4.3 Study II. Technical efficiency of vegetable farms at plot levels in seasonal, agroecological, and gender perspectives: A parametric approach

The main purpose of this study was to estimate the technical efficiency of plot level vegetable farms with closer scrutiny into seasonal (winter and summer), agroecological (mountain, hills, and terai), and gender perspectives adopting stochastic frontier translog production function (Equation 6) with two-step procedure using the data collected during July and August 2013. The micro-level efficiency analysis describes more practical based implications to utilize the best available technology and to allocate resources productively (Chavas et al., 2005).The quantity of vegetable output was considered as the dependent variable, while land, labor, traction power, seeds, organic matter, chemical fertilizers, and other variable costs were independent variables. In order to determine the underlying causes if there were explanatory factors influenced the inefficiency in vegetable farms, we regressed inefficiency scores using ordinary least square estimation by explanatory variables such as education of farm managers, number of trainings received by farm managers, credit access, market access, gender of farm managers, and women participation index with regard to vegetable farming.

In this study we discuss on maximum likelihood estimates of stochastic translog production function; factors affecting technical inefficiency in vegetable farms; technical efficiency scores distribution in vegetable farms; technical efficiency, actual output, optimum potential output, and output-loss in vegetable farms; and conclusions and policy implications.

4.3.1 Maximum likelihood estimates of stochastic translog production function

The results of maximum likelihood estimates (MLE) of the parameters using stochastic translog production function(STPF)are presented in Table 20. The variance parameters in both seasons were found to be highly significant.

The coefficient of gamma (γ) was much higher in winter season (0.64) than that of summer (0.54), revealed that more than half of the inefficiencies in vegetable farms were attributed by the technical inefficiency, and rest of the inefficiencies existed because of random error accounted for climate, drought, and other natural calamities. The null hypothesis of technically efficient ($\gamma = 0$) was tested using the LR test. We rejected the null hypothesis at 10 % level for winter season vegetable farms (LR statistics $3.523 > X^2_{(0.90,1)} = 2.706$) , and summerseason vegetable farms (LR statistics $2.791 > X^2_{(0.90,1)} = 2.706$), and confirmed that the inefficiencies existed in vegetable farms.

In the winter season vegetable farms, the coefficients of inputs such as labour, organic matters, chemical fertilizers, and other variable costs showed significant positive, while land, traction power, and seeds were insignificant effects on vegetable outputs using STPF (Table 20). In long-rung, traction power (traction power square) and organic matter (organic matter square) showed significant positive effects, while seeds (seed square) had significant negative effect on vegetable outputs. The sum of elasticities of parameters was found to be more than unity (1.263) revealed that there was increasing returns to scale; implied that an increase in the use of inputs also increases the outputs more than proportionality in vegetable farming. Using ordinary least square (OLS) estimates of these seven input variables, the output elasticities in decreasing order were found for labour, other variable cost, land, chemical fertilizers, organic matter, and traction power (Table 21). The standardize coefficients (beta value) of the parameters, labor, other variable costs, chemical fertilizers, land and organic matters are the five inputs with greater effects on vegetable outputs.

Table 20. MLE of stochastic translog production function at plot level farms

Variables	Winter season	Summer season
	Coefficients	Coefficients
Constant	1.817 (0.181)***	7.923 (0.199)***
lnL	-0.029 (0.317)	0.232 (0.270)
lnW	0.517 (0.204)***	-0.333 (0.254)*
lnP	0.055 (0.167)	0.288 (0.157)**
lnS	-0.066 (0.105)	-0.119 (0.092)*
lnO	0.213 (0.137)*	0.410 (0.138)***
lnF	0.208 (0.112)**	0.089 (0.118)
lnC	0.365 (0.138)***	-0.020 (0.118)
lnL×lnW	0.149 (0.188)	-0.403 (0.173)***
lnL×lnP	-0.078 (0.139)	-0.016 (0.099)
lnL×lnS	-0.018 (0.088)	-0.126 (0.065)**
lnL×lnO	0.104 (0.119)	0.240 (0.109)**
lnL×lnF	-0.056 (0.100)	0.011 (0.081)
lnL×lnC	0.036 (0.120)	-0.298 (0.079)***
1/2 (lnL× lnL)	-0.194 (0.279)	0.033 (0.092)
lnW×lnP	-0.113 (0.129)	0.194(0.129)*
lnW×lnS	0.044 (0.079)	0.096 (0.075)*
lnW×lnO	0.015 (0.105)	-0.107 (0.135)
lnW×lnF	0.042 (0.086)	-0.047 (0.105)
lnW×lnC	-0.077 (0.114)	-0.102 (0.112)
1/2 (lnW×lnW)	-0.140 (0.174)	0.093 (0.134)
lnP×lnS	-0.030 (0.065)	0.001 (0.043)
lnP×lnO	-0.026 (0.096)	-0.051 (0.087)
lnP×lnF	-0.012 (0.081)	-0.057 (0.065)
lnP×lnC	0.023 (0.088)	0.132 (0.063)**
1/2 (lnP×lnP)	0.137 (0.073)**	0.094 (0.059)*

Table 20. Continue….

Variables	Winter season	Summer season
	Coefficients	Coefficient
lnS×lnO	0.048 (0.064)	-0.031 (0.052)
lnS×lnF	-0.014 (0.046)	0.034 (0.043)
lnS×lnC	0.027(0.055)	0.047 (0.042)
1/2 (lnS×lnS)	-0.111 (0.065)**	0.036 (0.021)**
lnO×lnF	-0.186 (0.060)***	0.028 (0.062)
lnO×lnC	-0.121 (0.079)*	-0.151 (0.072)**
1/2 (lnO×lnO)	0.235 (0.109)**	0.021 (0.053)
lnF×nC	0.038 (0.063)	0.002 (0.051)
1/2 (lnF×lnF)	-0.005 (0.036)	0.042 (0.043)
1/2 (lnC×lnC)	0.055 (0.101)	0.153 (0.041)***
Variance parameters		
Sigma-squared (σ^2)	0.220 (0.048)***	0.308 (0.053)***
Gamma (γ)	0.636 (0.132)***	0.543 (0.153)***
Log likelihood	-269.088	-283.286
Likelihood Ratio (LR) test	3.522*	2.791*

Note: Land: L; labor wage: W; traction power: P; seed: S; organic matter: O; chemical fertilizer: F; other variable cost: C. ***, **,* indicate significant at 1%, 5%, and 10% levels, respectively. Parenthesis is standard error.

Table 21.OLS estimates and standardized coefficients of input variables at plot level farms in winter season

Variables	Coefficient	Std. error	SC*
lnConstant	7.959***	0.069	
lnLand	0.192***	0.059	0.163
lnLabour	0.368***	0.050	0.308
lnTraction power	0.088**	0.046	0.081
lnSeed	-0.004	0.029	-0.004
lnOrganic matter	0.126***	0.040	0.103
lnChemical fertilizer	0.159***	0.031	0.164
lnOther variable cost	0.298***	0.039	0.236

Note: superscript * stands for standardized coefficient.

In summer season vegetable farms, the input variables such as traction power and organic matters showed significant positive effects, while labor and seeds exhibited significant negative effects on vegetable outputs using STPF model (Table 20). In long-run, traction power (traction power square), seed (seed square), and other variable cost (other variable cost square) showed highly significant positive effects, implied that further increase on these inputs increases the outputs. The sum of the elasticities was found to be less than unity (0.549) indicated that there was decreasing return to scale. In the OLS model, the estimated coefficients of inputs in decreasing order were found for other variable cost, traction power, land, labor, and organic matter (Table 22). The standardize coefficients for the parameters were found in decreasing order such as other variable cost, traction power, land, and labor implied that these variables are the most effective factors to determine the summer season vegetable production (Table 22).

Table 22.OLS estimates and standardized coefficients of input variables at plot level farms in summer seasons

Variables	Coefficient	Std. error	SC*
lnConstant	7.821***	0.081	
lnLand	0.282***	0.056	0.240
lnLabour	0.231***	0.069	0.126
lnTraction power	0.297***	0.044	0.273
lnSeed	0.002	0.027	0.003
lnOrganic matter	0.099***	0.046	0.085
lnChemical fertilizer	0.022	0.037	0.022
lnOther variable cost	0.301***	0.036	0.289

Note: superscript * stands for standardized coefficient.

4.3.2 Factors affecting technical inefficiency in vegetable farms

In order to determine if there were underlining causes (support services and socio-economic variables) for the inefficiencies in vegetable farms, various explanatory variables were regressed on the inefficiency scores of each vegetable farms. There are interesting empirical evidences on the relationship of explanatory variables and inefficiencies in vegetable production. Results showed that all the explanatory variables in both seasons, except credit access in summer season, were statistically significant with consistent signs (Table 23). Statistically significant negative effect of education of farm manager on the inefficiency of vegetable production for both seasons indicated that higher levels of academic education of farmers help to improve the productive efficiency in vegetable farms. This result was consistent with the past studies of Abdulai and Eberlin (2001), and Bozoğlu and Ceyhan (2007). Educated farmers are more proactive in adopting latest technologies, dynamic in nature, and update information help to reduce cost per unit, and eventually enhance the efficiency in vegetable production.

Table 23.Factors affecting technical inefficiency at plot level farms by seasons

Variables	Winter season	Summer season
	Coefficients	Coefficient
Inefficiency effect model		
Constant	0.369 (0.020)***	0.314(0.018)***
Education of farm manager	-0.003 (0.001)***	-0.002(0.001) **
Training of farm manager	-0.011 (0.003)***	-0.004 (0.002)**
Credit access	-0.019 (0.009) **	-0.004 (0.009)
Market access	-0.039 (0.010)***	-0.022 (0.009)***
Gender of farm manager	0.015 (0.009)**	0.019 (0.009)**
Women participation index	-0.002 (0.001) **	-0.002 (0.001)*

Note: Superscript ***, **,* indicate significant at 1%, 5%, and 10% levels, respectively. Parenthesis is standard error.

The negative effect of training of farm manager on the inefficiency in both seasons supported the hypothesis that larger number of trainings increases the levels of the efficiencies in vegetable outputs. This result was consistent with the findings of Bhatta et al. (2008), Ojo et al. (2009), and Enwerem and Ohajianya (2013). Trainings programmes disseminate technologies on improved farming practices that increase the ability of farmers in decision-making process (Akobundu et al., 2004). Farmers' field school of agriculture extension has been instrumental in developing technical competencies of farmers to improve their productive efficiency (Joshi and Karki, 2010). In addition, community integrated pest management (CIPM) programme is the best approach for insect-pest management since CIPM minimizes the use of toxic chemical pesticides, improve the health of producers and consumers, and consequently contribute in socio-economic processes (Atreya, 2007).

The credit access was statistically significant negative effect on the inefficiency in winter season vegetable farms suggest that farmers' access to credit tend to increase the levels of the efficiencies. Most of the farmers avail credit for winter season vegetable farming, and that resource are used as seed money for summer vegetable farming. Although, improved cultivars are more profitable and have a great impact on overcoming the poverty, poor farmers cannot afford such types of seeds (Dias, 2010). Therefore, access to financial resources through rural agriculture credit programmes could help poor farmers to overcome the financial constraints, especially to purchase seeds, fertilizers, equipment, hiring labour, and marketing activities with regard to vegetable farming and that attribute to improve the productive efficiency.

Market access was highly significant negative effects on inefficiency in both seasons, implied that effective marketing facilities to farmers tend to improve the levels of the efficiencies in vegetable farming. In developing countries, small-scale farmers are frequently constrained by weak market access because of lack of market infrastructure facilities and ineffective marketing regulations (Minten et al., 2010). Adequate marketing infrastructures and farmer-friendly market regulations help farmers sell their products, increase their income and contribute to improve rural economy. Cooperative marketing approach could increase the income of smallholder farmers by increasing the economics of scale and reducing the marketing margin (Bernard and Spielman, 2009; Lemeilleur and Codron, 2011; Jia et al., 2012; Kim et al., 2014). Farmers' group (one of the major agricultural development approaches in Nepal) could play a potential role in both service provisions (inputs delivery and output marketing services), while such groups are ineffective (MOAD, 2014a); thus, national policies should support and strengthen farmers' groups not only to enhance the efficiency in vegetable production but also to improve the rural economy.

The coefficient for gender of farm manager was statistically significant positive effect on inefficiency in both seasons, implied that women farm managers were more productive and efficient than that of male counterpart in vegetable farming. The previous results of Rahman (2010) and Olagunju et al.

(2013) found that women farmers were more efficient than men and significantly contribute to agriculture production. The coefficient of women participation index was significant negative effect on the inefficiency of vegetable production in both seasons, which was consistent with the result of Bozoğlu and Ceyhan (2007), implied that increased levels of women involvement in vegetable farming would improve the productive efficiency. The women participation index was found 60 %, which was almost similar result with the finding of FAO (2000, 2011) where women labor shared 60 to 80 % of the total labour forces in agriculture. The average index was higher in vegetable plantation, followed by crop management, harvesting-marketing, land preparation, and decision-making activity (Table 24).

Table 24. Women participation index in vegetable farming at plot level farms by seasons

Variable	Winter season		Summer season	
	Average index	Rank	Average index	Rank
Land preparation	2.98	4	3.17	4
Planting of seedling	3.45	1	3.64	1
Crop management	3.35	2	3.51	2
Harvesting and marketing	3.29	3	3.46	3
Decision-making	2.66	5	2.80	5
Total index	15.72		16.59	

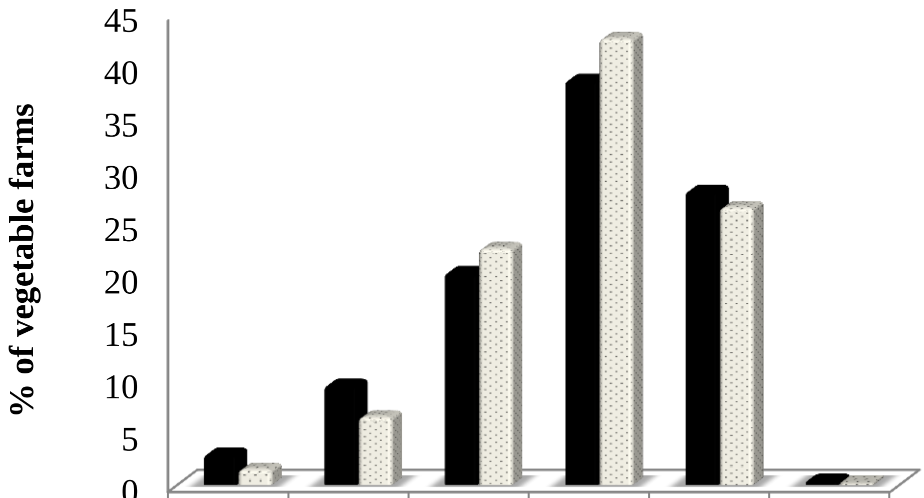
Note: Index one (minimum participation), five (maximum participation) for each component in the farms.

The composition of the index indicated that the women participation in decision-making activity was the lowest in both seasons; this could be one of the reasons to be reduced levels of efficiency in vegetable farms. Indeed, in achieving sustainable agricultural development goal, involvement of women in decision-making levels is imperative.

4.3.3Technical efficiency distribution in vegetable farms

4.3.3.1 Technical efficiency distribution in vegetable farms by seasons

The technical efficiency of vegetable farms in winter and summer season is presented in Figure 8. The average technical efficiency score in summer season vegetable farms showed higher at 0.74, ranged from 0.35 to 0.92, as compared to winter season at 0.73, ranged from 0.30 to 0.91. This score indicated that a wider ranges and greater extent of inefficiencies exists in both seasons, implied that substantial improvements (more than 25 %) in vegetable production could be achieved by operating the farms at the frontier level without use of extra inputs.



TE range	0.5 or less	0.51-0.60	0.61-0.70	0.71-0.80	0.81-0.90	0.91 or more
Winter farms (percent)	2.99	9.56	20.32	38.65	28.09	0.40
Summer farms (percent)	1.52	6.52	22.61	42.61	26.52	0.22

Figure 8. Technical efficiency distribution at plot levels farms by seasons

The vegetable farmers in this study using different technologies, most of which are inefficient. To reduce the inefficiencies and achieve higher levels of efficiencies in vegetable production many of the farmers would have to adopt superior technologies.

The majority of the vegetable farms (92 % in the summer and 87 % in winter season) performed 0.61 to 0.90 efficiency scores. Limited vegetable farms (10 %) exhibited less than 0.60 scores, and very limited farms (less than 0.5 %) showed efficiency score more than 0.91 in both seasons. About 99 % of the farms exhibited the efficiency scores below the highest level of benchmarking in both seasons, implying that 99 % farms could improve efficiency and substantial increase outputs by learning the best inputs allocation decisions from the highest level of the efficient farms.

4.3.3.2Technical efficiency distribution in vegetable farms by agroecological regions

Nepalese agriculture is extreme heterogeneous because of its diverse geographical, agroecological and seasonal conditions. Diversities in agroecology and associated climate could be the potential endowments for explaining vegetable outputs differential. The technical efficiency scores of vegetable farms in agroecological regions (Table 25) suggest that substantial potential increase in vegetable outputs could be achieved in all the regions given the existing technology and inputs costs.

In winter season, the mean of the technical efficiency score was found to be higher in terai, followed by hill and mountain regions. While in summer season, it was higher in terai followed by hill and mountain. The mean was significant at 1 % level for mountain region while it was not significant for hill and terai in both seasons. This suggests that vegetable farmers would gain more outputs in hills and mountain during winter and terai in summer season vegetable farming. The condition if farmers have operated the farms at the frontier level, they could have increased wide ranges of vegetable outputs: terai (winter 11-60 %, summer 9-43 %); temperate (winter 8-65 %, summer 11-60 %); and mountain region (winter 12-64 %, summer 13-70 %).

Table 25. Technical efficiency at plot level farms by agroecological regions

Season	Mean	Std. dev.	Minimum	Maximum	t-test
Winter season					
Mountain	0.72	0.0946	0.36	0.88	-3.091***
Hill	0.75	0.1037	0.35	0.92	-0.785
Terai	0.72	0.1142	0.40	0.89	-0.352
Mean/total	0.73				
Summer season					
Mountain	0.73	0.0978	0.30	0.87	-2.444***
Hill	0.74	0.0898	0.40	0.89	-0.981
Terai	0.75	0.0842	0.57	0.91	0.299
Mean/total	0.74				

4.3.3.3Technical efficiency distribution in vegetable farms by gender

Rural women are less likely to have access to financial services, technology, education and markets that rendered them on up-scaling outputs and increasing net returns (Spieldoch, 2011). The mean of the technical efficiency score was higher for the farms which were managed by women than that of men in both seasons (Table 26)revealed that women farm managers were more productive and efficient. This result was consistent with previous study of Oladeebo and Fajuyigbe (2007), while contradictory with finding of Nisrane et al. (2011).

The levels of inefficiencies in vegetable farms would improve by encouraging and empowering women farmers providing them greater opportunities, access to resources and capacity building programmes. Therefore, women farmers should be empowered to reach them at decision-making levels that enhance the efficiency in vegetable production and contribute to sustainable rural economy.

Table 26.Technical efficiency distribution at plot level farms by gender

Season	Mean	Std. dev.	Minimum	Maximum	t-test
Winter season					
Female	0.74	0.1033	0.39	0.92	-0.774
Male	0.72	0.1114	0.35	0.92	0.471
Summer season					
Female	0.75	0.0897	0.30	0.91	-0.824
Male	0.73	0.0908	0.45	0.90	0.231

4.3.4 Technical efficiency, actual output, optimum output, and output-loss in vegetable farms

The study showed surprisingly rigorous empirical evidence of inefficiency in Nepalese vegetable farms. Better understanding of the costs composition and different farm-specific and socio-economic factors with regards to vegetable farming are crucial for developing effective policies to enhance efficiency in vegetable production. The technical efficiency, actual output, optimum output, and output-loss in vegetable farms are presented in Table 27(winter season) and Table 28 (summer season).

The average actual output as presented in Table 27 and 28 represent the observed levels of outputs produced in vegetable farms. The optimum vegetable output is achieved by operating the farms at the frontier level, which was estimated by dividing the actual output by the technical efficiency scores of individual farms. The output-loss is the amount that have been lost due to the inefficiencies in vegetable production given prices and fixed factor endowments, which was calculated by multiplying the optimum outputs with the technical inefficiency scores.

The technical efficiency was higher in summer season vegetable farms (0.74) as compared with winter season vegetable farms (0.73). Because of higher inefficiencies in winter season vegetable farms, the average output-loss was also much higher estimated at 766.8 kg (24.36%) per farm in this season as compared to summer season estimated at 525 kg (23.24%) per farm.

On average about 25 % of the outputs has been lost because of inefficiencies in vegetable farms that can be improved by operating the farms at the frontier levels. Operating the vegetable farms with more efficient way would increase about 25 % of outputs within the existing technologies and the amount of input resources. If farmers had decreased about 25 % of input resources, still they could have produced the same quantity of outputs; thus this quantity of overused input resources could have utilized in other income generating or in rural economic development activities.

In winter season, the average technical efficiency and outputs (actual outputs and optimum outputs) levels were found to be higher in the vegetable farms which were operated by the farmers with higher levels of education (Table 27). The farm manager, who received larger number of trainings, performed significantly higher levels of actual outputs, optimum potential outputs, and higher levels of technical efficiencies. Those farmers, who availed credit in vegetable farming, showed higher levels of vegetable outputs than the farmers who did not. The farmers, who accessed to markets, showed higher levels of outputs, higher levels of efficiencies, and lower levels of output-loss. Similarly, the vegetable farms managed by women farmers, performed higher levels of outputs and higher levels of efficiencies as compared with the farms managed by the men farmers.

Table 27. Technical efficiency, actual output, optimum output, and output-loss at plot level farms in winter season

Variables	TE	Actual output (kg)	Optimumoutput[1] (kg)	Output-loss[2] (kg)	Output-loss (%)
Output-loss by education of manager					
Less educated (<6.76 years)[3]	0.70	1972	2698	726	26.91
More educated (≥6.76 years)	0.75	2733	3530	797	22.58
t-ratio (less vs. more educated)	-5.374***	-3.938***	-3.517***	-1.281*	
Output-loss by training of manager					
Less number of trainings (< 1.52)[4]	0.70	2189	2982	793	26.59
More number of trainings (≥ 1.52)	0.77	2690	3409	719	21.09
t-ratio (Less vs. more training)	-6.802***	-2.511***	-1.747**	1.300*	
Output-loss by credit access					
Credit not availed	0.72	2268	3007	739	24.58
Credit availed	0.74	2615	3430	815	23.76
t-ratio (Not availed vs. availed)	-1.989**	-1.678**	-1.675**	-1.291*	
Output-loss by market access					
Market not access	0.69	2065	2868	803	28.00
Market access	0.75	2514	3263	748	22.92
t-ratio (Not access vs. access)	-5.294***	-2.100**	-1.508*	0.893	

Table 27. Continue…..

Variables	TE	Actual output (kg)	Optimum output (kg)	Output-loss (kg)	Output-loss (%)
Output-loss by gender of farm manager					
Women manager	0.74	2394	3158	765	24.22
Men manager	0.72	2364	3127	763	24.40
t-ratio (Women vs. men manager)	1.181	0.145	0.124	0.024	
Output-loss by women partic. index					
Less women participation (< 15.72)[5]	.73	2562.95	3411.07	848.12	24.86
More women participation(≥ 15.72)	.74	2159.63	2819.82	660.19	23.41
t-ratio (Less vs. more participation)	-0.880	2.060**	2.478***	3.404***	
Average	0.73	2383	3147	764	24.28

Note: [1]Estimation of optimum output by dividing the actual output by technical efficiency score. [2]Output-loss was calculated by multiplying optimum output with technical inefficiency score. [3]Mean of education levels of farm manager 6.76 years; less than mean is regarded as less educated and equal or more than mean is more educated. [4]Mean of number of training 1.52; less than mean is regarded as less number of training and equal or more than mean is large number of training. [5]Mean of women participation index 15.72.

In summer season vegetable farms, the mean of technical efficiency and outputs (actual outputs and optimum outputs) levels were found to be higher in the vegetable farms operated by educated farmers (Table 28). Similarly, the average efficiency level and output were higher in the farms which were operated by the farmers who received larger number of trainings. In this season, there was no significant difference in efficiency levels because of agriculture credit availed; however the output levels had higher in the farms that availed credits. The vegetable farms that accessed to markets showed significantly higher levels of efficiencies and outputs, and lower levels of output losses. Table 28 clearly indicated that the women farmers performed significantly higher levels of efficiencies and outputs, and lower levels of output-losses in vegetable farming than the men counterpart.

Therefore, the vegetable farms managed by the farm managers, who had higher levels of educations, managers who received larger number of trainings, farmers who availed credits, farms who accessed to markets, and farms managed by women, performed higher levels of efficiencies and higher level of outputs.

Table 28. Technical efficiency, actual output, optimum output, and output-loss at plot level farms in summer season

Variables	TE	Actual output (kg)	Optimum output (kg)	Output-loss (kg)	Output-loss (%)
Output-loss by education of manager					
Less educated (< 6.24 years)[6]	0.74	1580	2078	498	23.97
More educated (≥ 6.24 years)	0.75	1907	2461	554	22.51
t-ratio (Less vs. more education)	1.482 *	-2.229**	-2.121**	-1.429*	
Output-loss by training of manager					
Less number (< 1.06 times)[7]	0.74	1688	2202	514	23.34
More number (≥ 1.06 times)	0.75	1807	2348	540	23.00
t-ratio (Less vs. more training)	-1.256	-0.799	-0.794	-0.670	
Output-loss by credit access					
Credit not availed	0.74	1690	2205	515	23.36
Credit availed	0.74	1844	2392	547	22.87
t-ratio (Not availed vs. availed)	-0.318	-0.968	-0.954	-0.771	
Output-loss by market access					
Market not access	0.72	1649	2176	527	24.22
Market access	0.75	1776	2300	523	22.74
t-ratio (Not access vs. access)	-2.976***	-0.799	-0.631	0.092	

Table 28. Continue……

Variables	TE	Actual output (kg)	Optimum output (kg)	Output- loss (kg)	Output-loss (%)
Output-loss by gender of manager					
Female manager	0.75	1780	2314	534	23.08
Male manager	0.73	1607	2104	498	23.67
t-ratio (Female vs. male)	1.447*	1.018	1.001	0.800	
Output-loss by women participation index					
Less women participation (<16.58)[8]	0.74	1819	2358	539	22.86
More women participation (≥16.58)	0.74	1636	2142	506	23.62
t-ratio (Less vs. more participation)	0.134	1.232	1.186	0.849	
Average	0.74	1732.8	2258	525	23.25

Note: [6]Mean of education levels of farm manager 6.24 years; less than mean is regarded as less educated and equal or more than mean is more educated. [7]Mean of number of training 1.06; less than mean is regarded as less number of training and equal or more than mean is large number of training. [8] mean of women participation index 16.58

4.3.5 Conclusions and policy implications

This study evaluated the technical efficiency of plot level vegetable farms with closer scrutiny into seasonal, agroecological, and gender perspectives using stochastic frontier translog production function with the data obtained from survey during July to August, 2013. The technical efficiency in vegetable farms was found to be higher in terai and mountain regions during summer season, whereas the efficiency was higher in temperate hill region during winter season. The wider range and greater extent of inefficiencies existed in the vegetable farms in both seasons and in all the regions. The vegetable farms had huge output-lost (winter: 767 kg/plot, and summer: 525 kg/plot) because of inefficiencies, which is the great lost for resource poor rural farmers. On average, about 25 % outputs could increase by operating the farms at the efficient levels.

The input variables such as land, labour, traction power, seed, organic matter, chemical fertilizers, and other variable cost determined the levels of vegetable outputs. In addition to the policies suggested by MOAD (2014), the policymakers should focus on making labour force more productive and efficient by providing them adequate trainings programs, increasing productivity of traction power (animal and tractor for plowing), encouraging farmers to use organic manures, and making easy access of fertilizers to the farmers.

The productive efficiency in vegetable farms would improve with increased levels of education to farmers, larger number of farmers' trainings, and access to agriculture credits and markets. The trainings and extension programmes should incorporate crop management, inputs allocation, market management, integrated pest management, cross-cutting issues of vegetable production, income, poverty reduction, gender, and economic development. Pluralistic extension approach consisting of government sector, non-governmental organizations, and private sectors could be the best extension strategy to provide effective training and extension services to the rural vegetable farmers.

Financial institutions and cooperatives need to be encouraged to implement the rural agriculture micro-credit programmes with minimum administrative operation costs for resource poor farmers in vegetable farming that help to increase the use of inputs at lower costs and improve the productive efficiency. Market access to farmers increases the efficiency by improving backward and forward linkages of vegetable production and establishing vegetable markets nearby production areas. Strong government support is required to allocate adequate resources, and endorse farmer-friendly rules and regulations be sure that farmer’s access to markets. Market infrastructures development requires more resources; thereby, a strategic cooperation and alignment with private sectors, farmers’ group, cooperatives, and funding agencies is imperative. Farmers’ cooperatives marketing approach would increase the economics of scale and reduce the cost per unit that increases income of the farmers.

The gender related explanatory variables (women farm manager and women participation index) are asserted to be important factors explaining efficiency in vegetable farming. Policies should encourage and empower women farmers in vegetable farming with composite incentive package consisting of education programs, training and extension services, agriculture credit programs, and market facilities. Such policies (discussed above) would certainly enhance the efficiency levels in vegetable production that increase the farmers’ income and eventually improve the rural economy.

4.4 Study III. Profit efficiency of vegetable farms at household levels: A parametric approach

The main objective of this study is to measure the profit efficiency and to derive policies to improve the level of efficiency in vegetable farms. This study adopted stochastic translog profit function(Equation 11 and 12) with a two-stage procedure. To measure the profit efficiency, restricted normalized profit was considered as a dependent variable. For the independent variables, this study used input variables: land, labor cost (hired and family), traction power cost (animal and tractor), seeds cost, fertilizers cost, pesticides cost, and other variable costs. In order to determine if there were underlying causes in influencing the profit inefficiency, seven explanatory factors (related to technology, support services, farm-specific characteristics and socio-economic variables) were regressed on the profit inefficiency using ordinary least square estimation. These explanatory variables were seed types, information index, extension contact, credit access, experience of farmers, distance of farm to markets, and gender of farm manager.

In this study we discuss on the maximum likelihood estimates of stochastic translog profit function; determinants of the profit inefficiencies in vegetable farms; profit efficiency distribution in vegetable farms; profit efficiency, actual profit, optimum profit, and profit-loss in vegetable farms; and conclusions and policy implications.

4.4.1 Maximum likelihood estimates of stochastic translog profit function

The results of maximum likelihood estimates (MLE) of stochastic translog profit function and inefficiency effect model are presented in Table 29. The null hypothesis of profit efficiency ($\gamma = 0$) was tested using LR; the null hypothesis was strongly rejected at 1% level (LR statistics $8.36 > X^2_{(1,0.99)}$ = 6.63), and revealed that profit inefficiency existed in vegetable farms. The variance parameter, gamma (γ),was found to be 0.63, which was statistically significant at 1% level, and proved that 63% of the inefficiency in vegetable farms was because of the technical, allocative and scale inefficiency. About 37% of the profit inefficiency was attributed by random error accounted for weather, climate or other natural calamities. The coefficients of variable inputs such as labor, seed, fertilizer, and pesticide were significantly different from zero. The negative sign of the coefficient of labor indicated that 1% increase in labor wage will decrease profit by 2.43%, and the negative effect of seed price on profit implied that 1% increase in seed price will decrease profit by 3.73%. The coefficients of fertilizer and pesticide showed positive relationship with profit indicated that further increases the use of these inputs will increase the profit to the farmers. The fixed factors, land and other variable cost were statistically significant at 1% level. Profit increases sharply with increase in land size in vegetable farming. Profit elasticity with respect to land was estimated 7.7, indicated that 1% increase in area under vegetable cultivation will increase profit by 7.7%. In contrarily, the statistically significant coefficient of other variable cost showed that 1% increase in farm other variable costs will decrease profit by 3.94%.

Table 29. MLE of stochastic translog profit function at household level farms

Variable	Parameter	Coefficient	t-value
Constant	α_0	30.265	3.045***
lnP'_W	α_W	-2.426	-1.538*
lnP'_A	α_A	1.286	0.954*
lnP'_S	α_S	-3.726	-2.823***
lnP'_F	α_F	2.027	2.754***
lnP'_P	α_P	1.619	1.915**
$\frac{1}{2}(\ln P'_W \times \ln P'_W)$	β_{WW}	-0.127	-0.660
$\frac{1}{2}(\ln P'_A \times \ln P'_A)$	β_{AA}	-0.216	-1.760**

Table 29. Continue…

Variable	Parameter	Coefficient	t-value
$\frac{1}{2}(\ln P'_S \times \ln P'_S)$	β_{SS}	0.031	0.294
$\frac{1}{2}(\ln P'_F \times \ln P'_F)$	β_{FF}	0.065	2.734***
$\frac{1}{2}(\ln P'_P \times \ln P'_P)$	β_{PP}	0.076	2.467***
$\ln P'_W \times \ln P'_A$	β_{WA}	0.307	2.294***
$\ln P'_W \times \ln P'_S$	β_{WS}	0.012	0.087
$\ln P'_W \times \ln P'_F$	β_{WF}	-0.098	-1.139
$\ln P'_W \times \ln P'_P$	β_{WP}	-0.093	-1.138
$\ln P'_A \times \ln P'_S$	β_{AS}	0.095	0.718
$\ln P'_A \times \ln P'_F$	β_{AF}	-0.066	-0.863
$\ln P'_A \times \ln P'_P$	β_{AP}	-0.152	-1.318*
$\ln P'_S \times \ln P'_F$	β_{SF}	0.065	1.241
$\ln P'_S \times \ln P'_P$	β_{SP}	0.065	1.259
$\ln P'_F \times \ln P'_P$	β_{FP}	-0.097	-1.626*
$\ln P'_W \times \ln P'_L$	$\emptyset_{WL}$	-0.588	-2.854***
$\ln P'_W \times \ln P'_C$	$\emptyset_{WC}$	0.227	1.767**
$\ln P'_A \times \ln P'_L$	$\emptyset_{AL}$	0.153	0.793
$\ln P'_A \times \ln P'_C$	$\emptyset_{AC}$	-0.136	-1.149
$\ln P'_S \times \ln P'_L$	$\emptyset_{SL}$	-0.357	-1.979**
$\ln P'_S \times \ln P'_C$	$\emptyset_{SC}$	0.197	2.535***
$\ln P'_F \times \ln P'_L$	$\emptyset_{FL}$	0.226	2.297***
$\ln P'_F \times \ln P'_C$	$\emptyset_{FC}$	-0.078	-1.829**
$\ln P'_P \times \ln P'_L$	$\emptyset_{PL}$	0.255	1.806**
$\ln P'_P \times \ln P'_C$	$\emptyset_{PC}$	0.016	0.390

Table 29. Continue…

Variable	Parameter	Coefficient	t-value
$\ln Z_L$	τ_L	7.701	3.428***
$\ln Z_C$	τ_C	-3.943	-3.328***
$\frac{1}{2}(\ln Z_L \times \ln Z_L)$	$\emptyset_{LL}$	1.039	3.770***
$\frac{1}{2}(\ln Z_C \times \ln Z_C)$	$\emptyset_{CC}$	0.264	2.475***
$\ln Z_L \times \ln Z_C$	$\emptyset_{LC}$	-0.461	-3.221***
<u>Variance parameters</u>			
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	σ^2	0.338	6.613***
$\gamma = \sigma_u^2 / (\delta_u^2 + \delta_v^2)$	γ	0.634	5.759***
Log likelihood		-198.361	
Log Likelihood Ratio	LR	8.363***	

Note: Labor wage: W; traction power: A; seed: S; fertilizer: F; pesticide: P; land: L; other variable cost: C. ***, **, * indicates significance at 1%, 5%, and 10% level, respectively. Figures in parenthesis are standard error.

4.4.2 Determinants of the profit inefficiency in vegetable farms

The results of explanatory factors explaining the profit inefficiencies in vegetable farms are presented at the lower part of Table 30. All the explanatory variables related to farm-specific characteristics, support services and socio-economic factors included in the model were statistically significant. The negative effect of seed type on the profit inefficiency indicated that using improved seed varieties could improve the profit efficiency. Improved varieties are used as risk aversion strategy for weather risk tolerance, disease-pest tolerance and high yielding that contribute to enhance efficiency, and provide more profit to the farmers. The government support is crucial to formulate policies in developing human resources, allocate sufficient budget and conduct researches for varietal development. Farmers should also be encouraged to adopt improved varieties of seeds that reduce cost per unit, and increase profit efficiency.

Table 30.Determinants of profit inefficiency at household level farms

Variable	Parameter	Coefficient	t-value
Constant	δ_0	0.354	14.950***
Seeds type	δ_1	-0.076	-5.940***
Information index	δ_2	-0.002	-1.410*
Extension contact	δ_3	-0.005	-1.520*
Credit access	δ_4	0.023	1.930**
Experience of farmers	δ_5	-0.001	-1.380*
Distance of farm to market	δ_6	0.001	2.630***
Gender of farm manager	δ_7	0.019	1.550*

Note: ***, **, * indicates significance at 1%, 5%, and 10% level, respectively. Figures in parenthesis are standard error.

Statistically significant coefficient of information index showed negative effect on inefficiency, indicated that farmers' access to information on farming technology, inputs marketing and outputs marketing could help them to earn higher profit in vegetable farming. An average information index was higher in input marketing, followed by farming technologies, output marketing, demand-supply situation of vegetables, and price movement of products in the markets. This index indicated that the farmers utilized information mainly on input marketing and farming technology rather than output marketing. Indeed, the farmers cannot improve profit efficiency and earn higher profit from vegetable farming unless they are access to output marketing information appropriately. Better information access to the farmers on output marketing helps them in decision making to select crop varieties and appropriate season to be cultivated, purchase inputs from markets, sell outputs in markets, and leading to be higher profit. Effective market information service also helps farmers to minimize market losses during storage, transportation, packaging and handling of products. Information services could be effective by encouraging private sector to be involved in information dissemination using media, publications, extension materials, and training and visit programs.

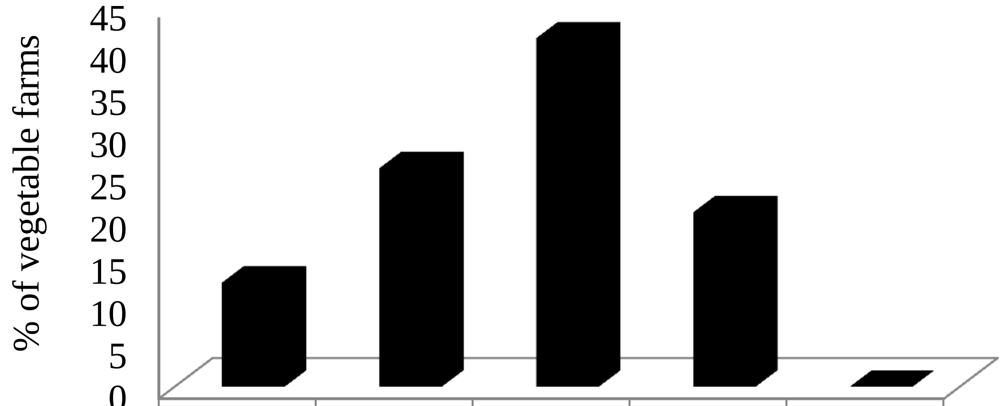
The negative effect of extension contact on the profit inefficiency indicated that increasing the number of contacts of farmer with extension agents can increase the profit efficiency. Dinar (1996) argued that extension system need to be more diversified, and provide different packages of extension services to different targeted group of farmers. Extension service can be effective with the pluralistic extension mechanism that incorporates farmers' group, private sector, and NGO, particularly in the areas where public extension service is inadequate. The coefficient of credit was positively related with inefficiency, revealed that farmers, who availed credit, reduced their profit efficiency because of high cost of credit. Farmers' friendly credit programs improve productive efficiency (Jensen, 2000).Ferrari et al. (2007) reported that 72% households borrowed credit from informal sector (moneylender, relatives and friends) despite its higher interest rates up to 42%, while banks charged 8 to10% per year because of inaccessibility of credit service in rural areas. As a result, farmers compelled to avail required credit from informal sources at a higher interest rate that affected vegetable farms to be inefficient. Therefore, policies should encourage formal financial institutions, micro-credit programs, and cooperative credit programs to provide financial resources to farmers with subsidized rate in vegetable farming. The coefficient of experience of farmers was significantly different from zero and consistent expected sign. Experiences help farmers to allocate resources appropriately, better farm management, explore and utilize alternative markets for inputs and outputs, and consequently that improve efficiency performance.

The distance of farm to market was statistically significant and consistent with expected sign. Farms, closer to market could have greater opportunities to sell their products in competitive price that help farmers to earn higher level of profit. Nepalese vegetable farmers are handicapped on the government rules and regulations, which limit farmers for getting entry in markets to sell their products. Additionally, market infrastructures development (collection center, cooperative, wholesale or retail market) nearby vegetable production areas, and rural road networks that link the production areas to the markets need to be established. These infrastructures development require strong government support to allocate resources, and set-up the rules be ensured that farmers accessed to the market facilities. Farmers also need to be encouraged for vegetable farming in the areas across the road-corridor, or nearby markets. Farmers' or cooperative marketing could be an appropriate strategy for smallholder vegetable farmers that improve profit efficiency.

Gender perspective analysis in profit efficiency is useful discipline in formulating policies for vegetable farming. The coefficient of gender of farm manager was significant and positively related with the profit inefficiency, implied that female farmer had better profit performance than that of male counterpart. Although, women are relatively less access to resources and opportunities in extension services, they are more sincere in resource allocation and economic planning that led them more efficient in vegetable farming. Therefore, policymakers should give more attention to encourage women in vegetable farming with incentive packages integrating extension services, training programs and credit facilities.

4.4.3 Profit efficiency distribution in vegetable farms

The mean of profit efficiency of vegetable farms was found to be 0.72 ranged from 0.12 to 0.90 (Figure 9), implied that average profit could increase by 28% if the vegetable farms operated at the frontier levels. The majority of the farms (61.8%) exhibited more than the average score, limited farms (12.3%) showed equal or less than 0.60 score, whereas none of the farms performed higher than 0.90 score. The results of wider and higher extent of profit efficiency score revealed that there is a broader scope to increase vegetable output and earn higher profit to the farmers by improving the technical, allocative and scale efficiency.



PE ranges	0.6 or less	0.61-0.70	0.71-0.80	0.81-0.90	0.91-more
■ Percent	12.3	25.8	41.2	20.6	0

Figure 9. Profit efficiency distribution in vegetable farms at household levels

4.4.4 Profit efficiency, actual profit, optimum profit and profit-loss in vegetable farms

The profit-loss is the amount that have been lost due to inefficiency in production given prices and fixed factor endowments (Rahman, 2003). The average profit efficiency, actual profit, optimum profit, and profit-loss (US$/Ha) are presented in Table 31.At the last row of Table 31 show that the average actual profit was 1251.91 US$/hectare and optimum profit was1685.52 US$/hectare. There were higher levels of inefficiencies (28 %), and higher amount of profit-loss estimated at 433.61 US$/ha (26 % of the optimum profits). If the farms had operated at the best frontier level, the farmers could have earned much higher levels of profits that have been lost.

The profit efficiency, actual profit, and optimum profit were significantly higher in the vegetable farms which used improved seed varieties than that of local varieties. The farmers who used local seeds had higher amount of profit-loss estimated at 33 % of the optimum profit, while farmers who used improved seed varieties had relatively less amount of loss estimated at 24 %.The farmer, who used better information, performed significantly of profit efficiency, higher level of actual profit, and higher level of optimum profit. Those farmers who adopted better information had less amount of profit loss as compared to farmers who used less information. The number of farmers' contact with extension agents equal or more than 1.88 times in a cropping period, considered as more extension contact, earned significantly higher level of actual profits, operated the farm at higher efficiency, and less profit-loss as compared with less extension contacts.

Those farmers, who did not receive credit for vegetable farming, had higher level of actual profit, optimum profit, and less percentage of profit-loss than that those of credit availed. Similarly, the farmers, who had equal or more than 12.31 years of experiences in vegetable farming, performed higher level of actual profit, and higher level of profit efficiency, higher level of optimum profit, and less percentage of profit-loss per hectares than those of less experiences. Those vegetable farms, which were located near the markets (< 25.49 km), earned higher level of actual profit, higher level of optimum profit, and operated the farm at higher level of efficiency, and less percentage of profit-loss than those of farms which were located far from the markets. Similarly, the vegetable farms, operated by women, had higher level of actual profit, higher level of optimum profit, and higher level of profit efficiency as compared with the farms operated by the male farmers.

Table 31. Profit efficiency (PE), actual profit, optimum profit and profit-loss at household level farms

Variables	PE	Actual profit (US$/ha)	Optimum[1] profit (US$/ha)	Profit-loss[2] (US$/ha)	Profit-loss %)
Profit- loss by seeds type					
Local seed	0.65	883.83	1309.82	425.98	32.52
Improved seed	0.74	1374.09	1810.23	436.14	24.09
t-ratio (local vs. improved)	-6.950***	-3.212***	-2.498***	-0.185	
Profit-loss by information index[3]					
Less information ($< 15.75\ inde$)	0.70	984.85	1363.56	378.70	27.77
Better information ($\geq 15.75\ inde$)	0.74	1504.56	1990.12	485.55	24.40
t-ratio (less vs. better information)	-3.630***	-3.966***	-3.653***	-2.270***	
Profit-loss by extension contact[4]					
Less contacts ($< 1.88\ times$)	0.70	1018.31	1403.55	385.24	27.45
More contacts ($\geq 1.88\ times$)	0.74	1475.64	1955.58	479.93	24.54
t-ratio (less vs. more contacts)	-3.929***	-3.471***	-3.204***	-2.008***	
Profit-loss by credit availed					
Credit not availed	0.72	1261.98	1689.22	427.24	25.29
Credit availed	0.71	1227.13	1676.40	449.26	26.80
t-ratio (not availed vs. availed)	0.523	0.235	0.066	-0.421	

Table 31. Continue….

Variables	PE	Actual profit (US$/ha)	Max. profit (US$/ha)	Profit-loss (US$/ha)	Profit-loss %)
Profit-loss by experience[5]					
Less experience ($< 12.31\ years$)	0.69	1033.47	1450.21	416.74	28.74
More experience ($\geq 12.31\ years$)	0.75	1523.05	1977.61	454.55	22.98
t-ratio (less vs. more experience)	-4.868***	-3.704***	-3.039***	-0.793	
Profit-loss by distance of market[6]					
Farms near market ($< 25.17\ km$)	0.73	1354.89	1811.80	456.90	25.22
Farms far-market ($\geq 25.17 km$)	0.68	941.65	1305.10	363.45	27.85
t-ratio (near vs. far-farms)	3.486***	2.695***	2.530***	1.712**	
Profit-loss by gender of manager					
Female manager	0.73	1393.83	1867.60	473.76	25.37
Male manager	0.72	1209.32	1630.89	421.56	25.85
t-ratio (female vs. male manager)	0.734	1.161	1.142	0.928	
Average	0.72	1251.91	1685.52	433.61	25.73

[1] Optimum profit was calculated by dividing the actual profit per hectares of individual farm by its efficiency score. [2]Estimate of profit-loss by multiplying optimum profit with profit inefficiency score. [3] Mean of information index 15.75; [4]Mean of extension contact 1.88; [5]Mean of experience 12.31 years; [6] Mean of distance from farm to market 25.17km.

4.4.5 Conclusions and policy implications

Enhancing profitability and profit efficiency in vegetable farming increase the level of income and improve livelihood of vegetable farmers. This study measured the profit efficiency of vegetable farms and determined the factors affecting inefficiency at household level using stochastic frontier translog profit function with a total of 325 randomly selected cross-section data spread over 12 villages.

The mean profit efficiency was found to be 0.72, indicated that 28% inefficiencies were found in vegetable farms that could be recovered by improving the technical, allocative, and scale efficiency in vegetable farming. Because of inefficiencies in vegetable farms, farmers had huge amount of profit-lost (US$ 433.61/ha). The input variables labor, seeds, fertilizers, pesticides, land and other variable costs were proved to be significant factors to determine profitability in vegetable farming. The policymakers should focus policy formulation to educate farmers in allocating resources at the optimum proportion to achieve the frontier level of profit.

The explanatory variables such as improved seed varieties, better information, higher number of contacts with extension workers, long years of experience in vegetable farming, farms near to the markets, and women farmers were demonstrated better performance in profit efficiency. Therefore, policy implications are made to promote improve vegetables seed varieties, provide effective information services to the farmers, deliver effective extension services, provide financial access to the farmers, develop markets linking with production areas, and encourage women in vegetable farming with adequate incentive packages to enhance profit efficiency.

4.5 Study IV. Economic, technical, allocative, and scale efficiency of vegetable farms at plot levels: Anon-parametric approach

Poverty and hunger reduction are intertwined challenges and enduring issues in the world, particularly in developing countries and more pronounced in Nepal. Improvements in efficiency in vegetable farming help farmers increase per capita income that improves the household economy of rural smallholder farmers. In this study, we estimated the economic, technical, allocative, and scale efficiency of vegetable farms at plot levels using input oriented DEA (Equation 13) and cost minimizing DEA (Equation 14) approaches with cross-sectional data from 502 plots for winter season and 450 plots for summer season. This study considered vegetable output (Kg) as the dependent variable to estimate the efficiencies, while the independent input variables were land, labor, traction power, seeds, organic matters, fertilizers, and other variable input costs. In order to determine the factors affecting inefficiencies in vegetable production, some explanatory variables such as seed types, training of farm manager, credit access, market access, external support index, gender of farm manager, and women participation index were regressed on the inefficiencies (economic, technical, allocative, pure technical, and scale) using Tobit model.

This study consists of the ordinary least square estimation; economic, technical, allocative and scale efficiency distribution in vegetable farms; factors affecting inefficiencies in vegetable production; economic efficiency, actual cost, minimum cost, and potential costs reduction in vegetable production; and conclusions and policy implications.

4.5.1 Ordinary least square estimation

4.5.1.1Ordinary least square estimation for winter season farms

The results of ordinary least square estimation (OLS) and standardization of coefficients of the variables used in winter season vegetable farms are reported in Table 32. All the variables, except other variable input costs were found to be significant in determining vegetable outputs. The sum of coefficients, 1.049, is almost unity which indicates that there are near constant returns to scale in vegetable production. The output elasticities, in decreasing order were for labor, organic matter, chemical fertilizer, land, power and seed. With regard to the standardized coefficients (Table 32), labor, chemical fertilizer and organic matter are the three inputs with greater effect on vegetable outputs.

Table 32.OLSestimation and standardized coefficients for winter season plot level farms

Variables	Ordinary least square		Standardized coefficient	
	Coefficient	Std. error	SC*	Rank
Constant	2.733***	0.653		
lnLand	0.159***	0.060	0.153	4
lnLabor	0.286***	0.067	0.243	1
lnPower	0.104**	0.045	0.091	5
lnSeed	0.059**	0.033	0.056	6
lnOrganic matter	0.257***	0.042	0.214	3
lnChemical fertilizer	0.200***	0.030	0.239	2
lnOther variable input cost	-0.016	0.038	-0.012	7
Sum of elasticities	1.049	-		

Note: SC stands for standardized coefficient. Superscript ***, **, * indicate significant at 1, 5 and 10 % levels, respectively.

4.5.1.2 Ordinary least square estimation for summer season farms

Table 33 shows the results of ordinary least square estimation (OLS) and standardization of coefficients of the variables used in summer season vegetable farms. All the variables, except for the traction power were found to be statistically significant in determining vegetable outputs. The sum of elasticities of the parameters is 1.005 (almost unity), indicates that there are near constant returns to scale in vegetable production. The output elasticities and standardized coefficients are in decreasing order for labor, other input costs, seeds, land, organic matter, and chemical fertilizer. This indicated that these inputs are the most effective factors determining vegetable outputs for summer season.

Table 33.OLS estimation and standardized coefficients for summer season plot level farms

Variables	Ordinary least square		Standardized coefficient	
	Coefficient	Std. error	SC	Rank
Constant	2.727^{***}	0.643		
lnLand	0.093^{**}	0.048	0.117	4
lnLabor	0.416^{***}	0.071	0.348	1
lnTraction power	0.023	0.040	0.022	7
lnSeed	0.108^{***}	0.035	0.129	3
lnOrganic matter	0.083^{**}	0.043	0.078	5
lnChemical fertilizer	0.067^{**}	0.038	0.073	6
lnOther variable input cost	0.215^{***}	0.042	0.191	2
Sum of elasticities	1.005			

Note: SC stands for standardized coefficient. Superscript ***, **, * indicate significant at 1, 5 and 10 % levels, respectively.

4.5.2 Economic, technical, allocative and scale efficiency distribution for vegetable farms

The average economic, technical, allocative, and scale efficiency scores in winter and summer season vegetable production were estimated using the DEAP 2.1 program (Coelli, 1996a). Results show that there is a big gap between observed and frontier efficiency scores under both approaches. The farmers in the study are using a number of different technologies, most of which are inefficient. To reduce the inefficiencies many of the farmers would have to adopt superior technologies.

4.5.2.1 Economic, technical, allocative and scale efficiency for winter season farms

The average economic, technical and allocative efficiency scores were found to be higher under VRS than CRS assumption (Table 34), which was consistent with previous findings of Sharma et al. (1999), Dhungana et al. (2004), and Murthy et al. (2009). The mean of EE was found to be 0.30 under CRS and 0.39 under VRS assumptions, which is far from the frontier efficiency level. This indicates that there is a great deal of inefficiency in Nepalese vegetable farms and that substantial reductions in cost of variable inputs are possible without reducing production. Few vegetable farms (less than 1 %) had efficiency scores more than 0.91, while a majority of the farms (92 % under CRS, and 82 % under VRS) had efficiency scores equal to, or less than, 0.50. The mean TE score were found to be 0.62 under CRS and 0.73 under VRS; less than 15 % of farms under CRS and 26 % farms under VRS exhibited efficiency scores more than 0.91. A majority of the farms (more than 53 %) showed efficiency scores between 0.51 and 0.90 under both approaches, whereas less than 32 % had efficiency scores equal to, or less than, 0.50. The mean of AE scores were 0.50 and 0.55 under CRS and VRS, respectively, while very few vegetable farms (around 1 %) achieved efficiency scores more than 0.91 under either approach. Forty-six % of farms under CRS and 58 % under VRS exhibited AE scores between 0.51 and 0.90, and 53 % of farms under CRS and 41 % under VRS scored equal to, or less than, 0.50. The average SE was found to be 0.85, indicating that 15 % of the costs the vegetable farms could be eliminated by changing the scale of farms under existing technology. Most of the farms (56 %) exhibited scale efficiency scores of more than 0.91, about 35 % farms had scale efficiency scores between 0.51 and 0.90, and less than 10 % of farms scored less than 0.50 on scale efficiency.

Table 34. Economic, technical, allocative, and scale efficiency for winter season plot level farms (CRS and VRS DEA)

Efficiency score	EE	TE	AE	SE
≤ 0.40	78.29 (60.96)	20.32 (6.97)	28.69 (21.51)	3.98
0.41-0.50	13.35 (20.92)	11.75 (7.37)	24.70 (19.52)	4.58
0.51-0.60	5.38 (8.57)	18.13 (16.33)	20.72 (21.51)	5.18
0.61-0.70	1.79 (4.78)	12.55 (17.73)	16.33 (18.73)	6.97
0.71-0.80	0.80 (2.19)	9.96 (12.15)	6.37 (12.15)	8.96
0.81-0.90	0.20 (1.58)	12.35 (13.55)	2.79 (5.38)	13.94
> 0.91	0.20 (1.00)	14.35 (25.9)	0.40 (1.20)	56.37
Mean efficiency	0.30 (0.39)	0.62 (0.73)	0.50 (0.55)	0.85

Notes: Economic efficiency: EE, technical efficiency: TE; allocative efficiency: AE; scale efficiency: SC. Figures in parenthesis are under VRS.

4.5.2.2 Economic, technical, allocative and scale efficiency for summer season farms

Table 35 shows that the mean of economic, technical, allocative, and scale efficiency scores for summer season vegetable production. In summer season vegetable farms, there were higher levels of inefficiencies under both approaches (CRS and VRS), indicates that the farmers are adopting a number of inefficient technologies. In order to reduce the inefficiencies in vegetable farms many of the farmers would have to adopt improved technologies. All the efficiencies (economic, technical and allocative) were higher under VRS than CRS assumption.

In summer season, the mean of economic efficiency was found to be 0.44 under CRS and 0.47 under VRS DEA assumptions. The majority of the farms (66 % under CRS and 0.61 % under VRS) performed efficiency score less than 0.50 indicates that there is a great deal of inefficiency and that substantial cost reductions in variable inputs are possible without reducing production. While, less than 2 % farms under CRS and only 4 % farms under VRS had economic efficiency scores more than 0.80. The mean TE was found to be 0.68 under CRS and 0.74 under VRS DEA in vegetable farms; and majority of the farms operated between 0.51-0.90 scores. Similarly, the mean of AE scores were 0.66 under CRS and 0.65 under VRS, and most of the vegetable farms (90 %) achieved efficiency scores between 0.40-0.90. The lower level of economic efficiency could improve by changing the superior technologies and reallocation of resources in vegetable farming. The mean of scale efficiency was found to be 0.92, which is quite high indicating that 8 % of the costs the vegetable farms could be eliminated by changing the scale of farms. Most of the farms (70 %) performed scale efficiency more than 0.91, about 30 % farms had between 0.51 and 0.90.

Table 35. Economic, technical, allocative, and scale efficiency for summer season plot level farms (CRS and VRS DEA)

Efficiency score	Summer season (% of farms)			
	EE	TE	AE	SE
≤ 0.40	47.33 (40.44)	9.78 (4.44)	12.67 (12.22)	0.22
0.41-0.50	18.44 (20.44)	12.00 (10.22)	10.89 (12.89)	0.00
0.51-0.60	17.11 (18.89)	14.00 (12.22)	15.11 (15.11)	1.11
0.61-0.70	10.00 (9.56)	16.44 (16.67)	16.89 (18.44)	2.67
0.71-0.80	5.33 (6.44)	16.00 (15.11)	17.78 (15.56)	7.33
0.81-0.90	1.11 (2.67)	14.67 (15.11)	17.78 (18.89)	18.89
> 0.91	0.67 (1.56)	17.11 (26.22)	8.89 (6.89)	69.78
Mean efficiency	0.44 (0.47)	0.68 (0.74)	0.66 (0.65)	0.92

Note: Economic efficiency: EE, overall technical efficiency: TE; allocative efficiency: AE; scale efficiency: SC. Figure in parenthesis is under VRS.

In general, the estimated levels of economic and technical inefficiencies suggest that significant reductions in variable input costs can be achieved in vegetable farming. While adjustments in scale of farms offer limited opportunities for increased efficiencies, significant cost savings could be achieved by moving the farms towards the frontier isoquant through more efficient use of inputs (technical efficiency) and reallocation of inputs (allocative efficiency). As table 33 and 34 indicates, technical inefficiency and allocative inefficiency contribute about equally to overall economic inefficiency especially when the scale effects are used to adjust technical inefficiency.

4.5.3 Factors affecting inefficiencies (Economic, technical, allocative, pure technical, and scale) in vegetable farms

In order to determine if there were any underlying causes (like technology, and support services including extension, training or infrastructure services) for the inefficiencies of vegetable farms, various explanatory factors were regressed on the inefficiency of economic, technical, allocative, pure technical, and scale using a two-limit censored Tobit model. The coefficients of parameters used in the model are presented in Table 36 for winter season and Table 37 for summer season. As the last row of Table 36and 37indicates, we are able to reject the null hypothesis of no relationship between the explanatory variables and economic efficiency, technical efficiency, allocative efficiency, pure technical efficiency, and scale efficiency in vegetable production. We conclude therefore that there is evidence that the inefficiencies are at least partially related to the explanatory variables.

Table 36. Factors affecting economic, technical, allocative, pure technical and scale inefficiency for winter season plot level farms

Variables	EIE	TIE	AIE	PTIE	SIE
Constant	0.783 (0.049) ***	0.542 (0.087)***	0.483 (0.055) ***	0.237 (0.008)***	0.128(0.057)**
Seed type	-0.021 (0.015)*	0.024 (0.027)	-0.046 (0.017)***	0.031 (0.026)	0.008 (0.004)
Training of manager	-0.004 (0.004)	0.001 (0.006)	-0.003 (0.004)	-0.007 (0.006)	0.008 (0.005)**
Credit access	-0.020 (0.013)*	0.029 (0.024)	-0.044 (0.015)***	0.002 (0.023)	0.035 (0.017)**
Market access	-0.021 (0.016)*	0.009 (0.028)	-0.028 (0.018)*	0.017 (0.028)	-0.019 (0.021)
External support index	-0.010 (0.005)**	-0.019 (0.008)***	0.003 (0.005)	-0.016 (0.008)**	-0.011 (0.006)**
Gender of manager	0.036 (0.019)**	0.056 (0.034)**	0.004 (0.021)	-0.017 (0.033)	0.097 (0.025)***
Women partic. index	-0.002 (0.002)*	-0.008 (0.003)***	0.002 (0.002)	-0.010 (0.003)***	-0.001 (0.002)
Sigma	0.136 (0.004)	0.245 (0.008)	0.153 (0.005)	0.237 (0.085)	0.182 (0.006)
Log likelihood	284.861	24.96	226.517	-90.663	140.805
LR	23.51***	-53.768***	18.14***	16.30**	37.31***

Note: Economic inefficiency: EIE, technical inefficiency: TIE, allocative inefficiency: AIE, pure technical inefficiency: PTIE and scale inefficiency: SIE. Values in parentheses are asymptotic standard errors. Superscripts ***, **, * indicate significant at 1, 5 and 10 % levels, respectively.

Table 37. Factors affecting economic, technical, allocative, pure technical, and scale inefficiency for summer season plot level farms

Variables	EIE	TIE	AIE	PTIE	SIE
Constant	0.726 (0.312)***	0.411 (0.049)***	0.419 (0.043)***	0.326 (0.056)***	0.897 (0.022)***
Seed type	-0.382 (0.150)***	-0.029 (0.023)	-0.019 (0.021)	-0.026 (0.027)	-0.010 (0.010)
Training of manager	-0.023 (0.034)	-0.016 (0.005)***	0.006 (0.005)	-0.012 (0.006)**	-0.009 (0.003)***
Credit access	-0.220 (0.137)*	0.003 (0.021)	-0.050 (0.019)***	0.001 (0.025)	-0.005 (0.009)
Market access	-0.319 (0.175)**	-0.015 (0.028)	-0.053 (0.024)**	-0.009 (0.032)	-0.003 (0.012)
External support index	-0.023(0.054)	0.004 (0.008)	-0.006 (0.007)	0.002 (0.009)	-0.001 (0.003)
Gender of manager	0.204 (0.156)*	-0.002 (0.025)	0.047 (0.021)**	0.006 (0.028)	0.011 (0.011)
Women partic. index	-0.024 (0.015)*	-0.004 (0.002)*	-0.001 (0.002)	-0.004 (0.003)	-0.001 (0.001)*
Sigma	1.322 (0.044)	0.208 (0.007)	0.181 (0.006)	0.233 (0.009)	0.090 (0.003)
Log likelihood	-764.4377	27.869	129.390	-82.210	440.438
LR	22.97***	13.81*	28.71***	7.35	16.73**

Note: Economic inefficiency: EIE, technical inefficiency: TIE, allocative inefficiency: AIE, pure technical inefficiency: PTIE, and scale inefficiency: SIE. Values in parentheses are asymptotic standard errors. Superscripts ***, **, * indicate significant at 1, 5 and 10 percent levels, respectively.

There are a number of interesting significant relationships identified in Table 36 and 37.The seed type used by farmer was significant and negative in the EIE and AIE equations for winter seasons and EIE for summer season. It implies that improved seed varieties increase the economic and allocative efficiency in winter season and economic efficiency in summer season vegetable farming. Improved varieties can potentially be technically more efficient and that plays an important role in overcoming the poverty and food insecurity for the smallholder poor farmers (Fuwa, 2007; Dias, 2010). The number of trainings taken by the farm manager was significant and positive effects on SIE for winter vegetable production. The number of training was negative significant on TIE, PTIE, and SIE. It implies that training activities reduce the inefficiencies in vegetable farming. Extension and training programs help farmers in decision-making, particularly for varietal selection, farming practices, and marketing activities (Akobundu et al., 2004). In recent years, farmers' field schools have been established to develop farmers' competencies in crop management practices focusing on integrated pest management (IPM) (Joshi and Karki, 2010). Since the IPM approach focused on encouraging farmers to appropriate use of inputs and minimizing the use of toxic chemicals that helps to improve health of producers and consumers (Atreya, 2007).

Credit access had significant negative effects on EIE, AIE and SIE in winter season, negative significant on EIE and AIE for summer season which suggests that having access to credit allowed farmers to get the inputs necessary to be more productive. This result was consistent with the finding of previous studies (Khan and Ali, 2013; Gbigbi, 2011). The positive relationship between access to credit and scale inefficiency for winter season vegetable production, may simply mean that farmers operating at a more efficient scale were less likely to need outside other variable cost. The coefficient on market access was statistically significant with negative effects on EIE and AIE for both seasons, which implies that providing market access to the farmers would improve economic and allocative efficiency. In developing countries, small-scale vegetable farmers are frequently constrained by poor market access because of lack of market facilities and inappropriate or ineffective marketing regulations (Minten et al., 2010). Adequate market structures and farmer-friendly market regulations help farmers sell their products and ultimately reduce rural poverty. Direct marketing or cooperative marketing approaches could improve the efficiency of smallholder farmers (Bernard and Spielman, 2009; Lemeilleur and Codron, 2011; Jia et al., 2012; Kim et al., 2014).

The significant and negative effect of external support on EIE, TIE, and SIE in winter season but not in summer season farms, indicates that supports from government, non-governmental organizations (NGOs) or donor partners reduce the inefficiencies. The composition of external support index showed that the support services were more focused on chemical fertilizers, followed by extension services, post-harvest materials, production materials, and seeds (Table 38). The policy need to be focused on irrigation, production materials including seeds, and extension services.

Table 38. External support index in vegetable farming

Components	Winter season		Summer season	
	Average index	Rank	Average index	Rank
Fertilizer	0.75	1	0.69	1
Irrigation	0.09	6	0.21	6
Seed	0.20	5	0.35	4
Pesticide	0.05	7	0.09	7
Production material	0.23	4	0.32	5
Extension service	0.60	2	0.57	2
Post- harvest material	0.52	3	0.43	3

Note: Index one (supported), zero (not supported) in each component.

The gender of the farm manager had a statistically significant positive effect on EIE, TIE and SIE for winter season, and positive significant effect on EIE and AIE for summer season vegetable production, implying that women managers are more effective than their male counterparts. This result was consistent with the findings of other researchers (Rahman, 2000; Gbigbi, 2011). The statistically significant negative effect of the women participation index on EIE, TIE and PTIE for winter season, and EIE, TIE, SIE for summer season in vegetable farming implies that greater involvement of women in vegetable farming activities improves efficiency in vegetable production. The women contribution on vegetable production was more than 60 % which was consistent with the results of a FAO (2011) study where women labor accounted for between 60 and 80 % in agricultural labor in developing countries. The women participation index indicate that the higher index was found in vegetable plantations, followed by crop management, land preparation, harvesting-marketing, and decision-making activity in the whole vegetable production process. On average, women were more involved in vegetable cultivation activities than in decision-making, which could explain some of the inefficiency in vegetable farming in Nepal. IFAP (2010) argued that women farmers are indispensable in building the world’s sustainable future through their contribution to food security and poverty reduction, whereas they are often barely visible in the decision-making processes. Therefore, reaching women at the decision-making levels, and access to resources and opportunities is very important in vegetable sector development in developing economies.

The results of standardized coefficients of explanatory variables are presented in Table 39. In winter season vegetable production, the coefficient was higher for external support index, followed by gender of farm manager, women participation index, credit and market access, seed type, and training of farm manager in decreasing order, indicating that these variables are the most effective factors for improving economic efficiency in vegetable production. For the summer season, the standardized coefficients in decreasing order were found for seed types, followed by market access, women participation index, credit access, gender of farm manager, training of farm manager, and eternal support index, indicating that these variables are the important to be addressed for enhancing vegetable production efficiency. The negative sign of coefficients indicates that these variables reduce the inefficiency in vegetable farms.

Table 39. Standardized coefficients of explanatory variables on economic inefficiency in vegetable production

Variables	Winter season		Summer season	
	SC*	Rank	SC*	Rank
Seed type	-0.062	6	-0.119	1
Training of farm manager	-0.057	7	-0.034	6
Credit access	-0.067	4	-0.074	4
Market access	-0.063	5	-0.099	2
External support index	-0.102	1	-0.026	7
Gender of farm manager	0.099	2	0.065	5
Women participation index	-0.068	3	-0.075	3

Note: Superscript * stands for standardized coefficient.

4.5.4 Economic efficiency, actual cost, minimum cost and potential cost reduction in vegetable production

The study produced surprisingly rigorous empirical evidence of inefficiency in vegetable farms. Effective information and better understanding of the cost composition are crucial for developing effective policy for enhancing efficiency in vegetable production. Average economic efficiency, actual cost, minimum cost or economically efficient cost, and potential cost reduction in vegetable farms are presented in Table 40 for winter season and Table 41 for summer season. The minimum level of cost is the amount that the farms could have spent if the farms have operated at the frontier level given price and fixed factor endowments, which was estimated by multiplying the actual costs by economic efficiency scores of individual farms. Potential costs reduction is the amount that have been lost due to the technical and allocative inefficiencies in vegetable farming given price and fixed factor endowments, which was computed by multiplying actual costs by inefficiency indexes.

We found that sample vegetable farmers would be able to reduce their actual costs by 75 % in winter season, and 60 % in summer season by operating the vegetable farms at the full technical and allocative efficiency. The vegetable farms which used improved seed varieties, showed higher level of economic efficiency and lower levels of potential cost reduction in winter season, while the result was opposite for the summer season.

Economic efficiencies were not affected by the number of trainings (less versus large numbers) received by farm manager in winter season vegetable farms. For the summer season vegetable farms, the economic efficiency was positively affected by the number of trainings; larger the number of training higher the levels of efficiency. Those farmers, who availed credit in vegetable farming, showed higher levels of efficiency than the farmers who did not in both seasons, which indicated that credit programs can have a positive impact on vegetable farming.

Vegetable farmers, with better access to markets, performed at a significantly higher level of efficiency and lower level of potential cost reduction in both seasons. Vegetable farms, which used less external support, showed a higher level of efficiency than those that used more support for winter season vegetable farms. In contrast to the summer season, more external support vegetable farms performed higher levels of economic efficiencies and lower level of potential cost reduction.

Vegetable farms managed by women farmers, performed at a significantly higher level of economic efficiency and lower level of potential cost reduction as compared with the farms managed by male farmers in both seasons. This result was consistent with a previous study by Oladeebo and Fajuyigbe (2007), but contradicted the findings of Nisrane et al. (2011). Our finding showed that those farms with higher levels of women participation in vegetable farming activities, showed significantly higher levels of economic efficiency and lower levels of potential cost reduction in both seasons, suggest that the efficiency of vegetable farming could increase by policies designed to empower women farmers. Women can be empowered by providing higher levels of education and with capacity building programs (Yousefy and Baratali, 2011; Guinée, 2014) and by increasing their access to assets, resources and opportunities (Wiig, 2013).

Table 40. Economic efficiency, actual cost, minimum cost and potential cost reduction at plot level farm in winter season

Variables	Mean EE	Actual cost (US$)	Minimum cost (US$)	Potential cost reduction (US$)	Potential cost reduction (%)
Cost minimization by seed types					
Local variety	0.29	429.75	103.96	325.78	75.81
Improved variety	0.32	394.84	104.53	290.30	73.52
t-value (local vs. improved)	-1.645**	1.370*	-0.176	1.443*	
Cost minimization by number of trainings					
Less number of trainings (< 1.52)[1]	0.30	401.20	102.05	299.15	74.56
Large number of trainings (≥ 1.52)	0.30	469.98	108.89	361.08	76.83
t-value (less vs. large number)	0.350	-2.959***	-2.333***	-2.758***	
Cost minimization by credit access					
Credit not availed	0.29	409.41	101.60	307.81	75.18
Credit availed	0.31	446.52	109.11	337.41	75.56
t-value (Not availed vs. availed)	-1.045	-1.634*	-2.641***	-1.349*	
Cost minimization by market access					
Market not access	0.29	439.37	104.83	334.54	76.14
Market access	0.32	361.78	101.59	260.19	71.92
t-value (Not access vs. access)	-1.714**	3.058***	1.007	3.036***	

Table 40. Continue…

Variables	Mean EE	Actual cost (US$)	Minimum cost (US$)	Potential cost reduction (US$)	Potential cost reduction (%)
Cost minimization by external support					
Less support (<5.28 index)[2]	0.31	383.57	101.49	282.07	73.54
More support (≥5.28 index)	0.29	461.81	106.82	354.98	76.87
t-value (less vs. more supports)	1.616*	-3.694***	-1.981**	-3.564***	
Cost minimization by gender of manager					
Female manager	0.34	341.10	99.75	241.35	70.76
Male manager	0.29	439.61	105.06	334.55	76.10
t-value (female vs. male manager)	3.173***	-3.582***	-1.519*	-3.510***	
Cost minimization by women participation index					
Less participation (<15.72 index)[3]	0.29	445.25	104.74	340.51	76.48
More participation (≥15.72 index)	0.31	392.83	103.30	289.52	73.70
t-value (less vs. more particip.)	-2.191**	2.444***	0.528	2.463***	
Average potential cost reduction		421.76	104.10	317.66	74.73%

Note: [1] Mean of number of training in winter season 1.52; [2] mean of external support in winter 5.28; [3]mean of women participation index in summer 15.72.

Table 41. Economic efficiency, actual cost, minimum cost and potential cost reduction at plot level farms in summer season

Variables	Mean EE	Actual cost levels (US$)	Minimum cost levels (US$)	Potential cost reduction (US$)	Potential cost reduction (%)
Cost minimization by seed types					
Local variety	0.47	355.20	154.09	201.09	56.62
Improved variety	0.43	380.94	150.28	230.65	60.55
t-value (local vs. improved)	-2.232**	-1.704**	0.755	-1.982**	
Cost minimization by trainings					
Less trainings (<1.06)[4]	0.43	387.86	153.17	234.67	60.51
Large trainings (≥1.06)	0.46	341.13	146.00	195.14	57.20
t-value (less vs. large number)	1.389*	3.294***	1.502*	2.810***	
Cost minimization by credit access					
Credit not availed	0.431	370.49	147.50	222.96	60.18
Credit availed	0.461	384.69	159.39	225.31	58.57
t-value (Not availed vs. availed)	-1.807**	-1.021	-2.581***	-0.170	
Cost minimization by market access					
Market not access	0.38	387.63	135.69	251.89	64.99
Market access	0.46	371.09	155.77	215.32	58.02
t-value (Not access vs. access)	-4.172***	1.081	-4.005***	2.433***	

Table 41. Continue….

Variables	Mean EE	Actual cost levels (US$)	Minimum cost levels (US$)	Potential cost reduction (US$)	Potential cost reduction (%)
Cost minimization by external support					
Less support (<3.72 index)[5]	.42	384.64	149.06	235.53	61.24
More support (≥3.72 index)	.46	365.29	153.25	212.06	58.05
t-value (less vs. more support)	2.460***	1.508*	-0.980	1.853**	
Cost minimization by gender of farm manager					
Women manager	0.45	371.54	153.45	218.08	58.70
Men manager	0.41	384.82	144.40	240.41	62.47
t-value (women vs. men)	2.240**	-0.896	1.836**	-1.527*	
Cost minimization by women participation index					
Less particip. (<16.58 index)[6]	0.43	382.25	150.60	231.63	60.60
More particip. (≥16.58 index)	0.45	365.74	151.89	213.85	58.47
t-value (less vs. more particip.)	-1.477*	1.279	-0.297	1.394*	
Average potential cost reduction		374.88	151.18	224.00	59.68

Note: [4]Mean of number of training in winter season 1.06; [5] mean of external support in winter 3.72; [6]mean of women participation index in summer 16.58.

4.5.5 Conclusions and policy implications

This study analyzed the efficiency of vegetable production in winter and summer season. We fit an input oriented Data Envelopment Analysis (DEA) model to estimate alternative measures of farm efficiency using cross-sectional data collected from 502 farm plots for winter season and 450 for summer season. Our measure of farm output is volume of vegetable produced at the farm level. We consider seven different inputs in our DEA model to estimate the efficiency of the small-scale vegetable farms. The efficiency values were then regressed on a set of explanatory variables (including technology, socio-economic and agriculture support service related variables) to identity the policy and programmatic interventions that would do most to boost farm level efficiency.

The DEA results showed that a majority of the farms are operating very inefficiently relative to the most efficient farms. The average technical and allocative efficiency were estimated as 0.62 and 0.50 for winter season, and 0.68 and 0.66 for summer season respectively suggesting that there is a potential to increase both technical as well as allocative efficiency for majority of the farms when compared with best practice farms. The average potential for cost reduction is 75% for winter season, and 60 % for summer season vegetable farms and such cost reduction comes by adopting the best technology practices of the efficient farms through the optimal resource allocation.

The results from Tobit model suggest that technical efficiency and allocative efficiency of vegetable farms are affected by a number of explanatory variables related to types of external support index (combination of seven different input related services like seed, fertilizer, pesticide, irrigation etc.), gender of household head, women participation (combination of five different activities like land preparation, vegetable plantation, crop management, harvesting and marketing, and decision making), access to credit, access to market, and type of seed for winter season vegetable production. In this season, the external support and gender related factors (participation of women in vegetable production activities and gender of household head) are negative and significant for TIE but not AIE. This suggests that these variables are important to augment output. Credit access, market access and improved seed on the other hand are statistically significant for AIE but not for TIE. This suggests that policies that create better access to credit, market and improved seed lead to cost efficiency of the farm households.

For the summer season, the technical efficiency was negatively affected by number of trainings but not AIE. Most of the explanatory variables such as credit access, market access, and gender of farm manager affected the AIE, not TIE. This suggests that create better access to credit and market, and women manager lead to technical efficiency for the summer season vegetable production.

Improved seed with better germination and greater tolerance against weather (heat or cold), disease and pest susceptibility would increase efficiency and yield for any given level of inputs. Increased yield augments income for farmers subsequently reducing poverty. Policymakers should therefore consider promoting agriculture research and varietal trails for development of improved vegetable seeds. Given the fact that women's role in vegetable production is very important, policies that promote women capabilities (like training, support to women farmer's groups, targeted programs for households headed by women) are suggested. Credit programs are also shown to be important for small farmers and we suggest policymakers develop programs that make production credit more accessible to small farmers, particularly through cooperatives, micro-finance institutions or other means that are more cost effective for administering small loans.

The findings of this study reinforce some of the current agriculture sector policies and priorities (MOAD, 2014) but we also suggest these policies to be streamlined with sectors like rural infrastructure, banking and social programs (such as gender equality and women empowerment). In this study we provide an analysis and assessment of vegetable farm performance (efficiency), and identify factors that can positively impact farm efficiency. Finally, we make some policy recommendations for improved farm efficiency and increased farm household income which, when sustained over time, can contribute to the national poverty reduction goal. Given the fact that our sample constitutes farm households randomly selected from all three agro-ecological regions of the country, our findings and policy prescriptions can be generalized to the national level.

The study suggest future research to isolate the characteristics of farms (technology employed, level of support services availed, and women's contribution, for example) for efficient versus inefficient farms, based on specific vegetables grown and specific agro-ecological regions of the country. Such research would not only supplement the contribution of this study but also determine if there is need for crop and region-specific priorities for increased efficiency. On-going research of this type will lead to policies that enhance the income of small scale vegetable farmers allow them to better contribute in the national goal of poverty reduction.

4.6 Study V. Women's labor contribution on the efficiency of vegetable farms in mountain region: A non-parametric approach

The role of women is dominating in vegetable production and food systems in the developing countries. However, there is an enduring debatable issue on women's labor discrimination in farming and rural household economic activities. Indeed, the rural women farmers are discriminated to have access to technology, education, financial services and markets (Spieldoch, 2011). Such discrimination limits the agriculture production, economic growth and diminishes the effectiveness of poverty reduction policies (Bozoğlu and Ceyhan, 2007). Gender perspective planning would have greater impacts on agriculture production economy. Therefore, this study covers a mountain district (Dolakha) as a case study to analyze the contribution of women labor forces and related socio-economic factors on the efficiency of vegetable production. The technical efficiency of vegetable farms was estimated employing the output oriented DEA model (Equation 18), and scale efficiency (Equation 21). The vegetable output (Kg) was considered as the dependent variable in estimating the efficiency of vegetable farms, while seven independent input variables such as land, labor, traction power, seed, organic matter, chemical fertilizer, and other input costs were introduced. In the second step, the technical inefficiency scores were regressed using Tobit model by gender of farm manager, women labor in land preparation, women labor in plantation, women labor in crop management, women labor in harvesting-marketing, women labor in decision-making, education levels of farm manager, training received by farm manager, and distance of farm to market.

This study discuss on ordinary least square estimation; technical and scale efficiency in vegetable farms; factors affecting technical inefficiency in vegetable production; and conclusions and policy implications.

4.6.1 Ordinary least square estimation

All the variables for the exception for land and traction power were found to be significant in determining vegetable outputs using ordinary least square estimates (OLS) (Table 42). The output elasticities of parameters were higher and positive for labor, other variable cost, organic matter, and seed, and negative for chemical fertilizer. The sum of elasticities was found to be 0.69, which was less than unity, indicated that there was decreasing returns to scale in vegetable farming. We also tested standardized coefficients of the parameters to identify the major factors that effect on vegetable outputs. The coefficients showed that the inputs like labor, organic matter, seed, other variable input costs, and chemical fertilizer had greater effect on vegetable outputs (Table 42).

Table 42.OLSestimation and standardize coefficients at plot level farms

	OLS		Standardize coefficient	
Variables	Coefficient	Std. error	Coefficient	Rank
Constant	3.523***	1.616	-	-
lnLand	-0.056	0.116	-0.092	6
lnLabor	0.340**	0.167	0.403	1
lnTraction power	-0.057	0.110	-0.068	7
lnSeed	0.186***	0.077	0.232	3
lnOrganic matter	0.205**	0.103	0.242	2
lnChemical fertilizer	-0.134*	0.085	-0.157	5
lnOther variable input	0.207**	0.112	0.172	4
Sum of elasticities	0.691	-	-	-

Note: ***, **, * indicate significant at 1, 5 and 10 % levels, respectively.

4.6.2 Technical and scale efficiency in vegetable farms

The efficiency scores distribution in vegetable farms assuming CRS and VRS approach using the DEAP 2.1 program (Coelli, 1996a) is presented in Table 43. Efficiency scores showed that there was higher extent of inefficiency in vegetable farms that can be recovered using existing technology operating the vegetable farms at the optimum level. Inefficient farmers could substantial increase their vegetable output by adopting improved technologies.

The technical efficiency score was higher under VRS as compared to CRS assumption, and consistent with the previous findings of Dhungana et al. (2004), and Murthy et al. (2009). The mean of the technical efficiency was found to be 0.65 under CRS DEA assumption, which is far below the frontier efficiency level, indicates that there is a higher levels of inefficiencies in vegetable farms, implied that vegetable farms could increase 35% of outputs using the same cost levels. Twenty one % of the farms exhibited the technical efficiency scores more than 0.81; less number of farms (15 %) showed efficiency score between 0.51 to 0.80, and 25 % farms had efficiency score less than 0.50. The average technical efficiency score under VRS assumption was found to be 0.77; more than 50% farms exhibited efficiency score more than 0.81, about 30 % farm showed efficiency score between 0.51 to 0.80, and less number of farms (18 %) performed efficiency score less than 0.50.

The mean of scale efficiency was found to be 0.86; majority of the farms (71%) exhibited efficiency scores more than 0.81, about 26% farms showed efficiency scores between 0.51 to 0.80, and very less farms (2 %) had efficiency scores less than 0.50. This efficiency index indicated that there is limited scope to increase vegetable outputs by changing the scale of operation of the farms.

Table 43.Technical and scale efficiency at plot level farms in mountain region

Efficiency score	Technical efficiency (CRS)		Technical efficiency (VRS)		Scale efficiency	
	No. of farms	%	No. of farms	%	No. of farms	%
≤ 0.40	14	16	8	9	0	0
0.41-0.50	11	12	8	9	2	2
0.51-0.60	12	13	13	14	3	3
0.61-0.70	17	19	9	10	9	10
0.71-0.80	16	18	5	6	12	13
0.81-0.90	6	7	3	3	20	22
> 0.91	14	16	44	49	44	49
Mean efficiency	0.65	-	0.77	-	0.86	-

4.6.3Factors affecting technical inefficiency in vegetable production

The explanatory variables were regressed on the technical inefficiency scores of each DMU under CRS approach to determine if there was underlying effects of factors related on women labor and socio-economic variables on vegetable production efficiency (Table 44). The null hypothesis of technically efficient in vegetable farms was strongly rejected with the LR statistics ($71.52_{(0.99,9)} > 18.548$), confirmed that there was inefficiency existed in vegetable farming.

The variables such as gender of farm manager, women participation in crop management, women participation in harvesting and marketing, women participation in decision-making, and training for farm manager were significant with consistent sign. The gender of farm manager was statistically significant positive effect on the inefficiency, implied that women farmers were more efficient and productive than that of male counterpart, and was consistent result of Udry et al. (1995), and Shrestha et al. (2014b). FAO (2009) reported that investment in empowering rural women is not only for moral imperative but also to be a promising strategy in fighting against poverty and hunger. Thus, encouraging and empowering women farmers in vegetable farming would improve overall socio-economic condition in the rural community.

The coefficient of women participation in crop management was significant negative effect on the inefficiency, implied that women involvement in crop management activities in vegetable farming, particularly on irrigation system management, insect-pest management, fertilizer application, and weed control management reduce the inefficiency, and women farmers were more efficient and productive than that of male farmers. The capacity building of women farmers by providing trainings programs on irrigation management, integrated pest management (IPM), composting, fertilizer application methods, weed management, and effects of chemical used on human health would help to improve the efficiency levels in vegetable farming, and eventually contribute to safe health of producers and consumers.

The coefficient of women participation in harvesting and marketing was statistically significant negative effect on inefficiency, implied that the contribution of women labor on harvesting and marketing activities reduce the inefficiency in vegetable production. FFTC (2015) reported that the largest portion of vegetable losses during post-harvest and marketing stages estimated at 20-50% of the total outputs in developing countries. The main reason could be poor infrastructure, lack of marketing facilities, poor handling and transportation, and loading and unloading. Shrestha et al. (2014a) argued that vegetable farmers are greatly affected to be hurt and discouraged because of negative price shock at the market hubs. The policies on empowering women farmers through training programs in harvesting and marketing activities would reduce marketing losses and increase farmers' income.

The negative coefficient of women participation in decision-making indicates that the involvement of women in decision-making process significantly contribute to reduce the inefficiency in vegetable production. Therefore, empowerment of women to reach them up to decision-making position is crucial not only to increase vegetable production but also to improve socio-economic condition of rural communities.

Table 44.Factors affecting technical inefficiency (CRS) and Standardized coefficients of plot level farms in mountain region

Variables	Coefficient	Std. error	Standardized coefficient	Rank
Constant	0.789***	0.141	-	-
Gender of farm manager	0.073*	0.050	0.169	4
Women labor in land preparation	-0.013	0.020	-0.059	7
,, vegetable plantation	0.034	0.027	0.111	6
,, crop management	-0.049***	0.019	-0.213	2
,, harvesting- marketing	-0.061***	0.018	-0.296	1
,, decision-making	-0.025*	0.017	-0.138	5
Education level of farm manager	-0.002	0.005	-0.025	8
Training received by manager	-0.013**	0.007	-0.188	3
Distance of farm to market	-0.001	0.002	-0.010	9
Sigma	0.151	.012	-	-
Log likelihood	27.51	-	-	-
LR statistics	71.52***	-	-	-

Note: ***, **, * indicate significant at 1, 5 and 10 % levels, respectively.

The coefficient of education of farm manager was not significant but still consistent sign, implied that higher levels of education facilities improve the efficiency in vegetable production. Wu (1977) reported that medium levels of education (6 years) significantly contributed in agriculture production where production is typically carried out by small family farms in

Taiwan. The women's education has strong contribution in agriculture production(Stefanou and Saxena, 1988), while women are discriminated to access education and technical supports (Trauger et al., 2008). Education is found to have higher payoff to productivity in a modernizing environment than in traditional agriculture (Pudasaini, 1983).

The number of trainings received by farm manager had negative significant effects on the inefficiency of vegetable production. Farmers' training and extension programmes help to disseminate technologies on improved crop management practices that increase the productivity and efficiency of vegetable farms. Such training programs should include farmer's field school on integrated pest management, cultivation and management practices, cost-benefit analysis, harvesting and marking, and cross-cutting issues of vegetable productions with health hazard, income and nutrition security.

The standardized coefficients of explanatory variables (Table 44) showed that the elasticities in decreasing order were higher in women participation in vegetable harvesting-marketing, followed by crop management, training received by farm manager, gender of farm manager, and women participation in decision-making. Therefore, these are the most effective components in decreasing order to increase vegetable outputs and enhance the efficiency in vegetable production.

4.6.4 Conclusions and policy implications

This study estimated the efficiencies (technical and scale) for vegetable farms and assessed the contribution of women related socio-economic factors on the efficiency of vegetable production. We adopted output oriented DEA model using survey data collected from vegetable farmers during July-August 2013 in mountain region of Nepal. Considering seven input variables in the DEA model, the mean of the technical efficiency was found to be 0.65, indicates that large extents of inefficiencies exist in smallholders vegetable farms that can be improved by operating the vegetable farms at the frontier levels. The scale efficiency was 0.86, indicates that there was limited opportunities to increase additional vegetable outputs by rescaling the size of farms.

Based on the results of Tobit model, some important policy suggestions can be derived to improve the efficiency in vegetable production. Being a women as a farm manager play an paramount role in vegetable farming, and thus the policies should be derived to promote women empowerment by providing training, strengthening women farmer's groups, targeted programs to women, and different women focused programs. The training programs to the women farmers should include improved technologies on plantation techniques, IPM and farmer's field schools, crop management practices, harvesting and marketing practices, and cross-cutting issues of gender and development. Women can be empowered by the synergetic efforts of education, gender-sensitive planning and development programs, and encourage women to be involved in vegetable farming.

Finally, we recommend policies on empowering women farmers with adequate incentive packages in vegetable farming that would certainly increase household income, reduce poverty, and eventually improve rural livelihoods. Future research need to be focused in the areas that represent hills and terai to analyze the effects of women labor and related socio-economic factors on the efficiency in vegetable production.

Chapter 5

Conclusions and Policy Recommendations

Based on the empirical results and discussion in this study, following conclusions and policy recommendations are derived to enhance the efficiency in vegetable production, improve household economy, and reduce the rural poverty in Nepal.

5.1 Conclusions of the study

This study analyzed the efficiency of smallholders vegetable farms adopting parametric and non-parametric approaches with cross-sectional data obtained from household survey during July to August, 2013. We focused our study to analyze the efficiency of vegetable farms with closure scrutiny into farm levels (household and plot level farms), methodological (parametric and non-parametric approaches), seasonal (winter and summer), agroecological (mountain, hill, and terai), and gender (men and women farm manager).The variance parameters (sigma-square, gamma, and likelihood ratio) were statistically significant in all the models and revealed that there was a wider range and greater extents of inefficiencies existed in vegetable farms that could be improved by operating the farms at the best frontier practices. The summary of results of this study is presented in Appendix 3 and 4. The major conclusions of this study are as follows:

1. Technical efficiency at household level farms: The mean of the technical efficiency at household level farms was found to be 0.77 adopting stochastic Cobb-Douglas production functions indicating that about 23 % of additional vegetable outputs can be increased with existing technologies using the same quantity of inputs.
2. Technical efficiency at plot level farms: The mean of the technical efficiency at plot level farms for summer season was

found to be higher (0.74) than those that for winter season (0.73) using stochastic translog productions function. The efficiency was higher in terai than in hill and mountain regions during summer season, whereas it was higher in the hills than in mountain and terai regions during winter season.

3. Profit efficiency at household level farms: The mean of profit efficiency at household level farms was 0.72, indicate that there was 28% inefficiencies existed in the vegetable farms because of technical, allocative, and scale inefficiency.
4. Economic, technical, allocative, and scale efficiency: In using input oriented DEA (CRS) model, the efficiency level at plot level farms in summer season was higher than in winter season. In summer season, the mean of economic efficiency was 0.44, technical efficiency 0.68, allocative efficiency 0.66, and scale efficiency 0.92. While in winter season, the average of economic efficiency was 0.30, technical efficiency 0.62, allocative efficiency 0.50, and scale efficiency 0.85.
5. Output-loss, profit-loss, and cost-reduction: The average output-loss at household level farms was 25 % (US$ 932/farm) and the average profit-loss 26 % (US$434/ha). Additionally, the average potential cost reduction in summer season was lower estimated at US$ 224/farm (60%) than in winter season at US$318/farm (75%), and such cost reduction comes by adopting the best technology practices of the efficient farms through the optimal resource allocation.
6. Important input variables: On the basis of standardized coefficient values in decreasing order, the major input variables are labor, organic matter, and chemical fertilizer in determining vegetable outputs.
7. Technology related factors: Improved seed varieties potentially improve the level of efficiency in vegetable production. In

addition, farmer's training and extension services proved to be the important factors to increase the efficiency in vegetable farming.

8. Socio-economic factors: The most important socio-economic factor in improving efficiency is gender of farm manager. The women manager proved to be a significant factor in improving efficiency in vegetable farming. Further, women participation, particularly in crop management, harvesting-marketing, and decision-making improve the level of efficiency in vegetable production.
9. Support services: Market access, credit access, and information service(mainly output marketing and improved farming technologies)are proved to be key factors to improve the level of efficiency in vegetable production.
10. The development of infrastructures (particularly in agriculture service center at the field level, irrigation facilities, agriculture road network, and financial institution) are proved to be important components, which improve the efficiency in vegetable farming. The support services from external agencies (GOs, NGOs, cooperatives, for example) in terms of irrigation facilities, distribution of production including improved seeds, and extension materials would improve the efficiency levels in vegetable farming.

5.2 Policies Recommendations

The policies recommendations on the basis of coefficients or standardized coefficient values of parameters are derived for enhancing the efficiency in vegetable farms, and improving the household income of rural farmers in Nepal. The policy recommendations for improved farm efficiency and increased farm household income which, when sustained over time, can contribute to the national poverty reduction goal. The important policies of this study are derived as follows:

1. The efficiency in vegetable outputs can be improved by developing labor force more skillful and productive providing adequate number of trainings and extension services, encouraging farmers to use organic matters for plant nutrients, and making fertilizers more accessible and affordable to the farmers.
2. Improved seed with better germination and greater tolerance against weather (heat or cold), disease and pest susceptibility would increase efficiency and yield for any given level of inputs. Increased yield augments income for farmers subsequently reducing poverty. Policymakers should therefore consider promoting agriculture research and varietal trails for development of improved vegetable seeds.
3. Farmer’s trainings and extension programs improve the level efficiency in vegetable production. Training activities should incorporate improved farming techniques, IPM farmer’s field schools, crop management (irrigation, insect-pest management, fertilization, weeding), harvesting and marketing technologies, cost-benefit analysis, and cross-cutting issues on gender in vegetable farming, women empowerment, income generation and poverty reduction. Pluralistic extension approach (consisting of government sector, non-governmental organizations, and private sectors) should be the best extension strategy for effective dissemination of technologies and extension services to the rural farmers.
4. Policies should promote women empowerment through composite incentive package consisting of education programs, training and extension services, agriculture credit programs,

market facilities, support to women farmer's groups, and targeted programs for households headed by women.

5. Farmers' access to market improves the backward and forward linkages in vegetable production. Strong government support is required to allocate adequate resources, and endorse farmer-friendly rules and regulations be ensure that farmer's access to markets. Market infrastructures development (construction of vegetable collection centers, wholesale markets, cold storage, for example) requires more resources; thereby, a strategic cooperation and alignment with private sectors, farmers' group, cooperatives, and funding agencies is imperative. Farmers' direct marketing or cooperatives marketing approach would increase the economics of scale and reduce the cost per unit that increases income of the farmers.
6. Agriculture credit programs should be accessible with minimum administrative operation cost to small-scale farmers. To this ends, the policy should encourage commercial banks, rural development banks, cooperatives, and micro-credit programs. Such minimum administrating costs for resource poor farmers help increase the use of inputs at lower costs and that increase the productive efficiency and the profit efficiency.
7. Effective and efficient information services help farmers to improve efficiency in vegetable production. Information services should focus on output marketing (market price, demand and supply situation, and consumer's preferences), farming technologies, and inputs marketing. Encourage private sector to be involved in information dissemination using media, publications, extension materials, and training and visit programs.
8. Policymakers need to pay serious attention to formulate policies and programs in prioritizing infrastructures development,

particularly establish agriculture service centers at the field level, agriculture road networks, and financial institutions. As such types of infrastructures entail huge budgetary resources; the resource poor countries like Nepal should utilize local resources, and align with international funding agencies.

9. Provide support services from external agencies (GOs, NGOs, cooperatives, for example) in irrigation facilities, distribution of production materials including improved seeds, and extension materials would improve the efficiency levels in vegetable farming.
10. The government should coordinate with foreign agricultural development partners for providing foreign technical assistance team in prioritized areas such as agriculture research and technology development, capacity building of agriculture extension workers, and vegetable market management and development activities.

The findings of this study reinforce some of the current agriculture sector policies and priorities (MOAD, 2014) but this study also suggest these policies to be streamlined with sectors like technology development and dissemination, rural infrastructure, banking and social programs (such as gender equality and women empowerment).

5.3 Recommendation for future research

The efficiency analysis in agriculture is always paramount in developing countries to maximize the outputs with minimum use of inputs, when the resources are limited, extension services are weak, input and output markets are inefficient, and policies are not effective in addressing the socio-economic factors. In order to increase the income of rural household and reduce the poverty, the future studies on the efficiency of vegetable farms should focus to isolate the characteristics of farms (technology employed, level of support services availed, and women's contribution, for example) for efficient versus inefficient farms, based on specific vegetables grown and specific agro-ecological regions of the country. Such research would not only supplement the contribution of this study but also determine if there is need for crop and region-specific priorities for increased efficiency.

In the recent years, the issue of food and nutrition security has been more focused with the organic vegetable production. It would be more worthy to conduct empirical studies on efficiency analysis of conventional versus organic vegetable farming and its contribution on food and nutrition systems. Such types of studies would also be more useful to reduce the poverty of rural households.

One of the major concerns on enhancing vegetable production is marketing efficiency and value chain analysis that need to be conducted in the future studies.

One of the major policies in agricultural development is to increase the total factor productivity (TFP) in agriculture (MOAD, 2014a). There is sluggish technology development in developing countries like in Nepal. Such types of studies on technology change and total factor productivity in agriculture would infer policies for improving overall economy in the country.

References

Abdulai, A., and R. Eberlin. 2001. Technical Efficiency During Economic Reform in Nicaragua: Evidence from Farm Household Survey Data. *Economic Systems* 25:113-125.

Adhikari, C. B., and T. Bjørndal. 2009. *Measuring the Extent of Technical Inefficiency in Nepalese Agriculture Using SDF and DEA Models.* World Bank, Kathmandu, Nepal.

Aigner, D., C. A. K. Lovell, and P. Schmidt. 1977. Formulation and Estimation of Stochastic Frontier Production Function Models. *Journal of Econometrics* 6:21-37.

Akobundu, E., J. Alwang, A. Essel, G. W. Norton, and A. Tegene. 2004. Does Extension Work? Impacts of A Program to Assist Limited-Resource Farmers in Virginia.*Review of Agricultural Economics* 26: 361–372.

Ali, F., A. Parikh, and M. K. Shah. 1994. Measurement of Profit Efficiency Using Behavioral and Stochastic Frontier Approaches. *Applied Economics* 26: 181–188.

Ali, F., A. Parikh, and M. K. Shah. 1996. Measurement of Economic Efficiency Using the Behavioral and Stochastic Cost Frontier Approach. *Journal of Policy Modeling*18(3): 271-277.

Ali, A. I., and L. M. Seiford. 1993. *The Mathmetical Programming Approach to Efficiency.* Oxford University Press, United Kingdom.

Ali, M., and J. C. Flinn. 1989. Profit Efficiency Among Basmati Rice Producers in Pakistan Punjab. *Americal Journal of Agricultural Economics*71(2) 303-310.

Alkire, S., A. Peterman, A. Quisumbing, and G. Seymour. 2013. The Women’s Empowerment in Agriculture Index. *World Development* 52:71–91.

Allendorf, K. 2007. Do Women's Land Rights Promote Empowerment and Child Health in Nepal? World Development 35(11) 1975-1988.

Altieri, M. A., F. R. Funes-Monzote, and P. Petersen. 2011. Agroecologically Efficient Agricultural Systems for Smallholder Farmers: Contributions to Food Sovereignty. *Agronomy for Sustainable Development* 32(1):1-13. doi 10.1007/s13593-011-0065-6.

Amores, A. F., and Thijs ten Raa. 2014. Firm efficiency, industry performance and the economy: three-way decomposition with an application to Andalusia. *Journal of Productivity Analysis*,42:25–34.

Aryal, K., P. Chaudhary, S. Pandit, and G. Sharma. 2009. Consumers’ Willingness to Pay for Organic Products: A Case From Kathmandu Valley. *The Journal of Agriculture and Environment*10(1):12-22.

Atreya, K. 2007. Farmers’ Willingness to Pay for Community Integrated Pest Management Training in Nepal. *Agriculture and Human Values* 24 (3): 399-409. doi: 10.1007/s10460-007-9063-3.

Atreya, K., F. H. Johnsen, and B. K. Sitaula. 2012. Health and Environmental Costs of Pesticide Use in Vegetable Farming in Nepal. *Environment, Develoment and Sustainability* 14:477–493. doi: 10.1007/s10668-011-9334-4.

AVRDC. 2010. Prosperity for the Poor and Health for All: Strategic Plan 2011-2025. AVRDC- The World Vegetable Center, Taiwan. Retrived on Feb 5, 2015, from the World Wide Web: http://avrdc.org/wpfb-file/avrdc-strategic-plan-2011-2025_final2-pdf/.

Banker, R. D., A. Charnes, W. W. Cooper. 1984: Models for the Estimation of Technical and Scale Inefficiencies in DEA. *Management Science* 30:1078–1092.

Battese, G. E., and G. S. Corra. 1977. Estimation of a Production Frontier Model: With Application to the Postal Zone of Eastern Australia. *Australian Journal of Agricultural Economics* 21(3):161-179.

Battese G. E., and T. J. Coelli. 1992. Frontier Production Functions, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India. *The Journal of Productivity Analysis* 3:153-169.

Battese, G. E., and T. J. Coelli. 1995. A Model for Technical Inefficiency Effects in A Stochastic Frontier Production Function for Panel Data. *Empirical Economics* 20:325-332.

Bernard, T., and D. J. Spielman. 2009. Reaching the Rural Poor Through Rural Producer Organizations? A Study of Agricultural Marketing Cooperatives in Ethiopia. *Food Policy* 34:60-69.

Bhatta, K. P., A. Ishida, K. Taniguchi, and R. Sharma. 2008. Whose Extension Matters? Role of Governmental and Non-Governmental Agricultural Extension on the Technical Efficiency of Rural Nepalese Farms. *Journal of South Asian Development* 3(2):269-295.

Bielik, P., and M. Rajčániová. 2004. Scale Efficiency of Agricultural Enterprises in Slovakia. *Agricultural Economics (AGRICECON–Czech)* 50(8): 331–335.

Binswanger, H. P., and J. B. Quizon. 1986. *What Can Agriculture Do for the Poorest Rural Groups?* The World Bank, Washington DC, United States of America.

Bjurek, H., L. Hjalmarsson, and F. R. Førsund. 1990. Deterministic Parametric and Nonparametric Estimation in Service Production. *Journal of Econometrics* 46: 213–227.

Bogale, T., and A. Bogale. 2005. Technical Efficiency of Resource Use in the Production of Irrigated Potato: A Study of Farmers Using Modern and Traditional Irrigation Schemes in Awi Zone, Ethiopia. *Journal of Agriculture and Rural Development in the Tropics and Subtropics* 106 (1):59–70.

Bozoğlu, M., and V. Ceyhan. 2007. Measuring the Technical Efficiency and Exploring the Inefficiency Determinants of Vegetable Farms in Samsun Province, Turkey. *Agricultural Systems* 94(3): 649-656.

CBS. 2010. *Nepal Vegetable Crops Survey: A Statistical Report.* Central Bureau of Statistics, National Planning Commission, Kathmandu, Nepal.

CBS. 2011. *Nepal Living Standards Survey: Statistical Report (Volume Two):* Central Bureau of Statistics, National Planning Commision, Kathmandu, Nepal.

CBS. 2013. *Statistical Year Book of Nepal.* Central Bureau of Statistics, National Planning commission, Kathmandu, Nepal.

Charnes, A., W. W. Cooper, and E. Rhodes. 1978. Measuring the Efficiency of Decision Making Units. *European Journal of Operational Research* 2: 429-444.

Chavas, Jean-Paul, and M. Aliber. 1993. An Analysis of Economic Efficiency in Agriculture: A Nonparametric Approach. *Journal of Agricultural and Resource Economics* 18(1):1-16.

Chavas, Jean-Paul, R. Petrie, and A. Roth. 2005. Farm Household Production Efficiency: Evidence from the Gambia. *American Journal of Agricultural Economics* 87(1): 160–179.

Coelli, T. J. 1995. Recent Developments in Frontier Modeling and Efficiency Measurement. *Australian Journal of Agricultural Economics* 39:219-245.

Coelli, T. J. 1996a. *A Guide to DEAP Version 2.1: A Data Envelopment Analysis (Computer Program)*. CEPA Working Paper 96/08, Department of Econometrics, University of New England, Armidale, Australia.

Coelli, T. J. 1996b. *A Guide to Frontier Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation.* CEPA Working Paper 7/96, Department of Econometrics, University of New England, Australia.

Coelli, T. J., D. S. P. Rao, C. J. O'Donnell, G. E. Battese. 2005. *An Introduction to Efficiency and Productivity Analysis (Second Edition).*Springer, United States of America.

Coelli, T. J., and G. E. Battese. 1996. Identification of Factors Which Influence the Technical Inefficiency of Indian Farmers. *Australian Journal of Agricultural Economics* 40(2):103-128.

Coelli, T. J. and S. Perelman. 1999. A Comparison of Parametric and Non-Parametric Distance Functions: With Application to European Railways. *European Journal of Operation Research* 117:326-339.

Cooper, W. W., L. M. Seiford, and J. Z. Editors. 2011. *Handbook on Data Envelopment Analysis (Second Edition)*. Springer, New York, Dordrecht Heidelberg London.

Dhungana, B. R., P. L. Nuthal, and G. V. Nartea. 2004. Measuring the Economic Inefficiency of Nepalese Rice Farms Using Data Envelopment Analysis. *The Australian Journal of Agricultural and Resource Economics* 48(2): 347-369.

Dias, J. C. da Silva. 2010. Impact of Improved Vegetable Cultivars in Overcoming Food Insecurity. *Euphytica* 176(1):125-136.

Dillon, A., M. Sharma, X. Zhang. 2011. Estimating the Impact of Rural Investments in Nepal. *Food Policy* 36, 250–258.

Dinar, A. 1996. Extension Commercialization: How Much to Charge for Extension Services. *American Journal of Agricultural Economics* 78: 13-20.

Drake, L., and T. G. Weyman-Jones. 1996. *Productive and Allocative Inefficiencies in UK Building Societies: A Comparison of Nonparametric and Stochastic Frontier Techniques.* The Manchester School 64, 22-37.

Enwerem, V. A., and D. O. Ohajianya. 2013. Farm Size and Technical Efficiency of Rice Farmers in Imo State, Nigeria. *Greener Journal of Agricultural Sciences* 3:128-136.

FAO. 2000. *Gender and IPM in Nepal.* The FAO Program for Community IPM in Asia, Food and Agriculture Organization, Kathmandu, Nepal.

FAO. 2009. *Women and Rural Employment: Fighting Poverty by RedefiningGender Roles*. Food and Agriculture Organization of the United Nations, Viale delle Terme di Caracalla, Rome, Italy.

FAO. 2011. *The Role of Women in Agriculture.* Food and Agriculture Organization, Kathmandu, Nepal.

FAO. 2013. *FAO Statistical Year Book.* Food and Agriculture Organization of the United Nations, Rome.Retrived on April 3, 2015, from the World Wide Web:http://www.fao.org/docrep/018/i3107e/i3107e00.htm.

Fare, R., S. Grosskopf, and C. A. K. Lovell. 1985. *The Measurement of Efficiency of Production*. Kluwer-Nijhoff Publishing.

Fare, R., S. Grosskopf, and C. A. K. Lovell. 1994. Production Frontiers. *The Economic Journal* 105 (430):738-740.

Farrell, M. J. 1957. The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society* 120(3): 253-290.

Favero, C.A., and L. Papi. 1995. Technical Efficiency and Scale Efficacy in the Italian Banking Sector: A Non-Parametric Approach. *Applied Economics* 27: 385–395.

Ferrari, A., G. Jaffrin, and S. R. Shrestha. 2007. *Access to Financial Services in Nepal*. The World Bank, Washington, United States of America.

Ferrier, G. D., and C. A. K. Lovell, 1990. Measuring Cost Efficiency in Banking: Econometric and Linear Programming Evidence. *Journal of Econometrics* 46:229-245.

FFTC. 2015. *Postharvest Losses of Fruit and Vegetables in Asia*. Food and Fertilizer Technology Center, Asia and Pacific Region. Retrived on April 13, 2015, from the World Wide Web: https://www.agriskmanagementforum.org/doc/postharvest-losses-fruit-and-vegetables-asia.

Fletschner, D. 2008. Women's Access to Credit: Does It Matter for Household Efficiency? *American Journal of Agricultural Economics* 90(3): 669-683. doi: 10.1111/j.1467-8276.2008.01143.x.

Førsund, F. R., and E. Hernaes. 1994. *A Comparative Analysis of Ferry Transport in Norway.*Kluwer Academic Publishers.

Fuwa, N., C. Edmonds, and P. Banik.2007.Are Small-Scale Rice Farmers in Eastern India Really Inefficient? Examining the Effects of Micro-Topography on Technical Efficiency Estimates. *Agricultural Economics* 36 (3): 335–346.

Garrett, T. A. 2001. Economies of Scale and Inefficiency in County Extension Councils: A Case for Consolidation. *American Journal of Agricultural Ecnomics* 83:811-825.

Gautam, D. M., and D. R. Bhattarai. 2006. *Post-harvest Horticulture*. Public Printing Press. Kathmandu, Nepal.

Gbigbi, M. T. 2011. Economic Efficiency of Smallholder Sweet Potato Producers in Delta State, Nigeria: A Case Study of Ughelli South Local Government Area. *Research Journal of Agriculture and Biological Sciences* 7(2): 163-168.

Guinée, N. 2014. Empowering Women through Education: Experiences from Dalit Women in Nepal. *International Journal of Educational Development* 39:173-180.

Hazell, P., P., Poulton, S. Wiggins, and D. Andrew. 2010. The Future of Small Farms: Trajectories and Policy Priorities. World Development 38(10): 1349-1361.

Heath, R. 2014. Women's Access to Labor Market Opportunities, Control of Household Resources, and Domestic Violence: Evidence from Bangladesh. *World Development* 57:32-46.

Hill, R. C., W. E. Griffiths, and G. C. Lim. 2011.*Principle of Econometrics (Sixth Edition).*John Wiley and Son, United States of America.

Hjalmarsson, L., S. C. Kumbhakar, and A. Heshmati. 1996. DEA, DFA and SFA: A Comparison. *Journal of Productivity Analysis* 7:303-327.

Huong, P. T. T., A.P. Everaarts. J.J. Neetesonc, and P.C. Struik. 2013. Vegetable production in the Red River Delta of Vietnam II: Profitability, labour requirement and pesticide. *NJAS - Wageningen Journal of Life Sciences* 67:27– 36.

Hussain, A., A. Saboor, M. A. Khan, A. Q. Mohsin, and F. Hassan. 2012. Technical Efficiency of Wheat Production in Rain-Fed Areas: A Casse Study of Punjab, Pakistan. *Pakistan Journal of Agricultural Sciences* 49:411-417.

IFAP. 2010. *Cooperative Enterprise Empowers Women*. International Federation of Agricultural Producers, Paris, France. Retrive on Feb 15, 2015, from the World Wide Web: http://www.copac.coop/idc/2010/2010-ifap-en.pdf.

ILO. 2008. *Promotion of Rural Employment for Poverty Reduction*. International Labor Organication, Geneva.

Jensen, F. E. 2000. The Farm Credit System As a Government-Sponsored Enterprise. *Review of Agricultural Economics* 22(2):326–335.

Jia, X., J. Huang, and Z. Xu. 2012. Marketing of Farmer Professional Cooperatives in the Wave of Transformed Agrofood Market in China. *China Economic Review* 23 (3):665-674. doi: http://dx.doi.org/10.1016/j.chieco.2010.07.001.

Joachim, N. B., T. Jean, W. Njankoua, N. Gwendoline, and A. Mireille. 2004. Factors Affecting the Technical Efficiency among Smallholder Farmers in the Slash and Burn Agriculture Zone of Cameroon. *Food Policy* 29(5): 531-545.

Joshi, N. N., and R. Karki. 2010. *Small-Scale Commercial Vegetable Production to Promote Livelihood and Food Security in the Rural Hills of Nepal*. Rural Reconstruction Nepal, Kathmandu.

Kafle, B. 2011.Factors Affecting Adoption of Organic Vegetable Farming in Chitwan District, Nepal. *World Journal of Agricultural Sciences* 7(5):604-606.

Kalaitzandonakes, N. G., and E. G. Dunn. 1995. Technical Efficiency, Managerial Ability and Farmer Education in Guatemalan Com Production: A Latent Variable Analysis. *Agricultural and Resource Economics Review* 24:36-46.

KFVMDB. 2013. *Annual Report: Fruit and Vegetable Transaction*. Kalimati Fruit and Vegetable Market Development Board, Kathmandu, Nepal.

Khan, H., and F. Ali. 2013. Measurement of Productive Efficiency of Tomato Growers in Peshawar, Pakistan. *Agricultural Economics (AGRICECON–Czech)* 59(8): 381–388.

Kim, Man-Keun, K. R. Curtis, and I. Yeager. 2014. An Assessment of Market Strategies for Small-Scale Produce Growers. *International Food and Agribusiness Management Review* 17(3):187-204.

Kumar, C. S., C. G. Turvey, and J. D. Kropp. 2013. The Impact of Credit Constraints on Farm Households: Survey Results from India and China. *Applied Economic Perspectives and Policy* 35(3):508-527. doi: 10.1093/aepp/ppt002.

Kumbhakar, S. C. 1987. The Specification of Technical and Allocative Inefficiency in Stochastic Production and Profit Frontiers. *Journal of Econometrics* 34:335–348.

Khumbhakar, S. C. 1996.Efficiency Measurement with Multiple Outputs and Multiple Inputs. *The Journal of Productivity Analysis* 7:225-255.

Kumbhakar, S. C. 2001. Estimation of Profit Functions When Profit Is Not Maximum. *American Journal of Agricultural Economics* 83(1): 1-19.

Kumbhakar, S. C., and A. Bhattacharya. 1992. Price Distortions and Resource-Use Efficiency in Indian Agriculture: A Restricted Profit Function Approach. *The Review of Economics and Statistics* 74(2):231-239.

Kumbhakar, S. C., B. Biswas, and B. D. Bailey. 1989. A Study of Economic Efficiency of Utah Dairy Farmers: A System Approach. *The Review of Economics and Statistics* 71(4): 595-604.

Khumbhakar, S. C., and C. Lovell. 2000. *Stochastic Frontier Analysis.* Cambridge Unniversity Press.

Lamb, R. L. 2002. A Market-Forces Policy for the New Farm Economy?*Review of Agricultural Economics* 24(1):15–30.

Lemeilleur, S., and Jean-Marie, Codron. 2011. Marketing Cooperative vs. Commission Agent: The Turkish Dilemma on the Modern Fresh Fruit and Vegetable Market. *Food Policy* 36:272-279.

Lothgren, M., and M. Tambour. 1996. *Alternative Approaches to Estimate Returns to Scale in DEA-Models.* Working Paper No. 90. The Economic Research Institute, Stockholm School of Economics, Stockholm, Sweden.

Maddala, G. S. 1985. *Limited-Dependent and Qualitative Variables in Econometrics*. Cambridge University Press, United Kingdom.

Mehta, A. K., and A. Shah. 2003. Chronic Poverty in India: Incidence, Causes and Policies. *World Development* 31:491-511.

Midmore, D.J.and H.G.P. Jansen. 2003. Supplying Vegetables to Asian Cities: Is There a Case for Peri-urban Production? *Food Policy* 28:13–27.

Minten, B., A. Vandeplas, Y. Ghorpade, and J. F. M. Swinnen. 2010. Horticulture Wholesale Trade and Governance in India: Evidence from Uttarakhand. *Journal of South Asian Development* 5:113-136.

Mishra, R., and A. Kumar. 2005. The Spatial Integration of Vegetable Markets in Nepal. *Asian Journal of Agriculture and Development* 8(1):101-114.

MOAD. 1996. *Directives on Agriculture Produce Market Management*. Agribusiness Promotion and Marketing Management Directorate, Ministry of Agricultural Development, Kathmandu, Nepal.

MOAD. 2004. *National Agricultural Policy*. Ministry of Agriculture and Cooperatives, Kathmandu, Nepal.

MOAD. 2005. *Agribusiness Promotion Policy*. Ministry of Agriculture and Cooperatives. Kathmandu, Nepal.

MOAD. 2013. *Statistical Information on Nepalese Agriculture*. Ministry of Agricultural Development, Kathmandu, Nepal.

MOAD.2014a. *Agriculture Development Strategy*. Ministry of Agricultural Development, Kathmandu, Nepal.

MOAD.2014 b. *Food and Nutrition Security Plan of Action of Nepal*. Ministry of Agricultural Development, Kathmandu, Nepal.

Murillo-Zamorano, L. R. 2004. Economic Efficiency and Frontier Techniques. *Journal of Economic Survey* 18(1):33-77.

Murthy, D. S., M. Sudha, M. R. Hegde, and V. Dakshinamoorthy. 2009. Technical Efficiency and Its Determinants in Tomato Production in Karnataka, India: Data Envelopment Analysis (DEA) Approach. *Agricultural Economics Research Review* 22: 215-224.

NARC. 2010. *NARC's Strategic Vision for Agricultural Research 2011-2030*. Nepal Agricultural Research Council, Kathmandu, Nepal.

Naz, M., I. A. Khan, and B. Shahbaz. 2014. Role of Rural Women in Agriculture and Household Food Security in Faisalabad District. Pakistan Journal of Agricultural Sciences 51(3):759-763.

Nazir, S., I. A. Khan, B. Shahbaz, and F. Anjum. 2013. Rural Women's Participation and Constraints in Agricultural Activities: A Case Study of District Nankana Sahib, Punjab. Pakistan Journal of Agricultural Sciences 50(2): 317-322.

Nepal, R., and G. B. Thapa. 2009. Determinants of Agricultural Commercialization and Mechanization in the Hinterland of a City in Nepal. *Applied Geography* 29:377–389.

Nicholson, W. 2005.*Microeconomic Theory: Basic Principles and Extensions (Ninth Edition)*. South-Western, Thomson Learning.

Nisrane, F., G. Berhane, S. Asrat, G. Getachew, A. S. Taffesse, and J. Hoddinott. 2011. *Sources of Inefficiency and Growth in Agricultural Output in Subsistence Agriculture: A Stochastic Frontier Analysis.* International Food Policy Research Institute and Ethiopian Development Research Institute, Addis Ababa, Ethiopia.

NPC. 1995. *Nepal Agriculture Perspective Plan:* Natinal Planning Commision, Kathmandu, Nepal.

NPC. 2014. *Thirteenth Interim Development Plan 2014-2016*. National Planning Comission, Kathmandu, Nepal.

Nyagaka, D. O., G. A. Obare, J. M. Omiti, and W. Nguyo. 2010. Technical Efficiency in Resource Use: Evidence from Smallholder Irish Potato Farmers in Nyandarua North District, Kenya. *African Journal of Agricultural Research* 5:1179-1186.

Obare, G. A., D. O. Nyagaka., W. Nguyo, and S. M. Mwakubo. 2010. Are Kenyan Smallholders Allocatively Efficient? Evidence from Irish Potato Producers in Nyandarua North District. *Journal of Development and Agricultural Economics* 2(3): 078-085.

Ogundari, K., and S. O. Ojo. 2007. An Examination of Technical, Economic and Allocative Efficiency of Small Farms: The Case Study of Cassava Farmers in Osun State of Nigeria. *Bulgarian Journal of Agricultural Science* 13:185-195.

Ogunniyi, L. T. 2008. Profit Efficiency among Cocoyam Producers in Osun State, Nigeria. *International Journal of Agricultural Economics and Rural Development* 1(1):38-46.

Ojo, M. A., U. S. Mohammed, A. O. Ojo, and R. S. Olaleye. 2009. Return to Scale and Determinants of Farm Level Technical Inefficiency Among Small Scale Yam Based Farmers in Niger State, Nigeria: Implications for Food Security. *International Journal of Agricultural Economics and Rural Development* 2(1):43-51.

Oladeebo, J. O., and A. A. Fajuyigbe. 2007. Technical Efficiency of Men and Women Upland Rice Farmers in Osun State, Nigeria. *Journal of Human Ecology* 22(2): 93-100.

Olagunju, F. I., S. B. Fakayode, R. O. Babatunde, and F. Ogunwole-Olapade. 2013. Gender Analysis of Sweet Potato Production in Osun State, Nigeria. *Asian Journal of Agricultural Extension, Economics and Sociology* 2(1):1-13.

Parikh, A., F. Ali, and M. K. Shah. 1995. Measurement of Economic Efficiency in Pakistani Agriculture. *American Journal of Agricultural Economics* 77 (3): 675-685.

Paudel, P., and A. Matsuoka. 2009. Cost Efficiency Estimates of Maize Production in Nepal: A Case Study of the Chitwan District. *Agricultural Economics-Czech* 55(3):139-148.

Piya, S., A. Kiminami, and H. Yagi. 2012. Comparing the Technical Efficiency of Rice Farms in Urban and Rural Areas: A Case Study from Nepal. *Trends in Agricultural Economics* 5(2):48-60.

Pokhrel, D. M. 2010. Comparison of Farm Production and Marketing Cost and Benefit among Selected Vegetable Pockets in Nepal. *The Journal of Agriculture and Environment*11(1):10-25.

Poulton, C., D. Andrew, and K. Jonathan. 2010. The Future of Small Farms: New Directions for Services, Institutions, and Intermediation. *World Development* 38(10): 1413-1428.

Pudasaini, S. P. 1983. The Effects of Education in Agriculture: Evidence from Nepal. *American Journal of Agricultural Economics* 65(3): 509-515.

Pudasaini, S. P. 1984. *Production and Price Rsponse of Crops in Nepal*. Government of Nepal, Kathmandu, Nepal.

Rahman, S. 2000. Women's Employment in Bangladesh Agriculture: Composition, Determinants and Scope. *Journal of Rural Studies* 16: 497-507.

Rahman, S. 2003. Profit Efficiency among Bangladeshi Rice Farmers. *Food Policy*28(5): 487-503.

Rahman, S. 2010. Women's Labour Contribution to Productivity and Efficiency in Agriculture: Empirical Evidence from Bangladesh. *Journal of Agricultural Economics* 61(2):318–342. doi: 10.1111/j.1477-9552.2010.00243.x.

Ralevil, P. S. G. Patil, and G. Vanloon. 2010. Integrated Agriculture Production Systems for Meeting Household Food, Fodder and Fuel Security. *Journal of Sustainable Agriculture* 34:878–906.

Roberts, D., E. Majewski, and P. Sulewski. 2013. Farm Household Interactions with Local Economies: A Comparison of Two EU Case Study Areas. *Land Use Policy* 31:156–165

SAARC. 2014. *Best Practices in Poverty Alleviation and SDGs in South Asia: A Compendoum SAARC 2014*. South Asian Association for Regional Cooperation, Kathmandu, Nepal.

Sapkota, K. 2004. *Gender Perspectives on Peri-urban Agriculture in Nepal.*Tribalhuwan University, Kathmandu Nepal. Retrived on June 27, 2014, from the World Wide Web:http://www.ruaf.org/gender-perspectives-periurban-agriculture-nepal.

Sauer, J. 2006. Economic Theory and Econometric Practice: Parametric Efficiency Analysis. Empirical Economics 31:1061-1087.

Sharif, N. R., Dar, A., 1996. An Empirical Study of the Patterns and Sources of Technical Inefficiency in Traditional and HYV Rice Cultivation in Bangladesh. *Journal of Development Studies* 32: 612–629.

Sharma, K. R., P. S. Leung, and H. M. Zaleski. 1997. Productive Efficiency of Swine Industry in Hawaii: Stochastic Frontier Vs. Data Envelopment Analysis. *Journal of Productivity Analysis* 8:447-459.

Sharma K. R., P. Leung, and H. M. Zaleski. 1999. Technical, Allocative and Economic Efficiencies in Swine Production in Hawaii: A Comparison of Parametric and Nonparametric Approach. *Agricultural Economics*20:23-35.

Shrestha, R. B., and P. Sushil. 2010. Rice Marketing Practices and Constraints in Nepal. *Nepalese Journal of Agricultural Economics* 1 (1): 66-77.

Shrestha, R. B., Wen-Chi, Huang, and R. Ghimire. (2014a). Market Price Cointegration of Tomato: Effects to Nepalese Farmers. *International Journal of Food and Agricultural Economics* 2(2):87-96.

Shrestha, R. B., Wen-Chi, Huang, and R. Ghimire. 2014b. Production Efficiency of Smallholder Vegetable Farms in Ilam District, Eastern Hill, Nepal. *American-Eurasian Journal of Agriculture and Environmental Science* 14(2): 150-154.

Shrestha, R. B., Wen-Chi, Huang, and U. Pradhan.2014. Resource Use Efficiency in Vegetable Production in the High Hills of Eastern Nepal. *Nepalese Journal of Agricultural Economics* 2(1): 65-72.

Slam, N. 2008. *Reduction Povrtity and Hunger in Asia Focus: The Role of Agricultural and Rural Development*. Internaational Food Policy Research Institute, Washington, USA, and Asian Development Bank, Manila, Philippines.

Spieldoch, A. 2011. *Key Role of Rural Women in Achieving Food Security.* European Forum on Rural Development, Palencia, Spain.

Stefanou, S. E., and S. Saxena. 1988. Education, Experience, and AIlocative Efficiency: A Dual Approach. *American Journal of Agricultural Economics* 7692: 338-345.

Tauer, L. 1995. Age and Farmer Productivity. *Review of Agricultural Economics* 17:63-69.

Thapa, G., and R. Gaiha. 2011. *Smallholder Farming in Asia and the Pacific: Challenges and Opportunities.* International Fund for Agriculture Development, Rome.

Tiwari, K. R., I. L. P. Nyborg, B. K. Sitaula, and G. S. Paudel. 2008. Analysis of the Sustainability of Upland Farming Systems in the Middle Mountains Region of Nepal. *International Journal of Agricultural Sustainability* 6(4):289-306.

Tobin, J. 1958. Estimation of Relationships for Limited Dependent Variables. *Econometrica* 26(1): 24-36.

Tonsor, G. T., and A. M. Featherstone. 2009. Production Efficiency of Specialized Swine Producers. *Review of Agricultural Economics* 31(3):493–510.

Trauger, A., C. Sachs, M. Barbercheck, N. E. Kiernan, K. Brasier, and J. Findeis. 2008. Agricultural Education: Gender Identity and Knowledge Exchange. *Journal of Rural Studies* 24:432–439.

Udry, C., J. Hoddinott, and H. Alderman. 1995. Gender Differentials in Farm Productivity: Implications for Household Efficiency and Agricultural Policy. *Food Policy* 20(5): 407-423.

Ukpong, I. G., and I. C. Idiong. 2013. Maximum Likelihood Estimates and Determinants of Technical Efficiency of Leafy Vegetable Producers in Akwa Ibom State, Nigeria. *Journal of Agricultural Science* 5(3). doi: 10.5539/jas.v5n3p139.

UN, ITC, and IFAD. 2012. *Rural Women and the Millennium Development Goals*. United Nations, International Training Center, International Fund for Agricultural Development.

USAID. 2011. *Value Chain-Market Analysis of the Off-Season Vegetable Sub-Sector in Nepal.* United States of America for International Development, Kathmandu, Nepal.

Varian, H. R. 1984. The Nonparametric Approach to Production Analysis. *Econometrica* 52(3):579-597.

Varian, H. R. 1992.*Micro Economic Analysis (Third Edition).* W. W. Norton and Company, Inc. United States of America.

Wadud, I. K. M. M., and H. A. Rashid. 2011. *Profit Efficiency and Farm Characteristics: Evidence from the Rice Farmers in Bangladesh*. Paper Presented at the Barcelona European Academic Conference, Barcelona, Spain.

Wang, H. J., and P. Schmidt. 2002. One-Step and Two-Step Estimation of the Effects of Exogenous Variables on Technical Efficiency Levels. *Journal of Productivity Analysis* 18:129-144.

Wang, J., E. J. Wailes, and G. L. Cramer. 1996. A Shadow-Price Frontier Measurement of Profit Efficiency in Chinese Agriculture. *American Journal of Agricultural Economics* 78: 146-156.

Wang, J., G. L. Cramer, and E. J. Wailes. 1996. Production Efficiency of Chinese Agriculture: Evidence from Rural Household Survey Data. *Agricultural Economics* 15:17–28.

Warth, L., and M. Koparanova. 2012. *Empowering Women for Sustainable Development.* Discussion Paper Series. United Nations Economic Commission for Europe, Geneva, Switzerland.

Watkins, K. B., T. Hristovska, R. Mazzanti, C. E. Wilson, and L. Schmidt. 2014. Measurement of Technical, Allocative, Economic, and Scale Efficiency of Rice Production in Arkansas Using Data Envelopment Analysis. *Journal of Agricultural and Applied Economics* 46(1): 89-106.

Weinberger, K., and T. Lumpkin. 2007. Diversification into Horticulture and Poverty Reduction: A Research Agenda. *World Development* 35(8): 1464–1480.

Wiig, H. 2013. Joint Titling in Rural Peru: Impact on Women's Participation in Household Decision-Making. *World Development* 52:104-119.

World Bank. 2003. *Reaching the Rural Poor: A Renewed Strategy for Rural Development*. The World Bank, Wasington D. C., United States of America.

World Bank. 2014. *World Development Indicators 2014*. The World Bank, Washington D. C., United States of America.

Wu, C. C. 1977. Education in Farm Production: The Case of Taiwan. *American Journal of Agricultural Economics 59(4)699-709*.

Yousefy, A., and M. Baratali. 2011. Women, Employment and Higher Education Schoolings. *Procedia-Social and Behavioral Sciences* 15:3861-3869.

Appendices

Appendix 1. Vegetable production trends in Nepal (1993/94-2012/13)

Year	Area (,000Ha)	Production (,000Mt)	Area growth (%)	Productivity growth (Mt/Ha)	Production growth (%)
1993/94	140.50	1197.49	-	8.52	-
1994/95	140.50	1211.51	0.00	8.62	1.16
1995/96	144.37	1327.29	2.68	9.19	8.72
1996/97	146.50	1357.44	1.46	9.27	2.22
1997/98	149.98	1449.47	2.32	9.66	6.35
1998/99	140.18	1342.57	-6.99	9.58	-7.96
1999/00	149.03	1489.67	5.94	10.00	9.87
2000/01	157.16	1652.98	5.17	10.52	9.88
2001/02	161.05	1738.09	2.41	10.79	4.90
2002/03	165.99	1799.98	2.98	10.84	3.44
2003/04	172.59	1890.10	3.82	10.95	4.77
2004/05	180.82	2065.19	4.56	11.42	8.48
2005/06	189.83	2190.10	4.75	11.54	5.70
2006/07	191.92	2298.69	1.09	11.98	4.72
2007/08	208.11	2538.90	7.78	12.20	9.46
2008/09	225.15	2754.41	7.57	12.23	7.82
2009/10	235.09	3003.82	4.23	12.78	8.30
2010/11	244.10	3203.56	3.69	13.12	6.23
2011/12	245.04	3298.82	0.38	13.46	2.89
2012/13	246.39	3301.68	0.55	13.40	0.09

Appendix 2.Constraints in vegetable production

Constraints	Dolakha	Lalitpur	Dhading	Dhanusa	All	Rank
Inputs availability	3.64	3.75	4.24	3.62	3.81	V
Labor availability	2.39	2.61	2.98	4.03	3.00	VI
Irrigation facilities	3.91	3.93	4.82	6.78	4.86	I
Transport services	3.49	3.65	1.87	2.05	2.77	VII
Technical supports	4.78	4.40	4.18	4.27	4.40	III
Information services	4.55	4.19	4.33	3.30	4.09	IV
Market access	5.24	5.48	4.81	3.75	4.82	II

Note: The index ranges from 1-7; one (less degree of constraint), and seven (highest degree of constraint).

Appendix 3. Summary results of input variables and efficiency analysis in vegetable production

Variables	TE at household levels (SFA)	TE at plot levels (SFA)		Profit efficiency at household levels (SFA)	Economic Efficiency (Input oriented DEA)		Women contribution (Output oriented DEA)
		Winter	Summer		Winter	Summer	
Dependent/ independent variables	Output (Kg)	Output (Kg)	Output (Kg)	Restricted profit (US$)	Output (Kg)	Output (Kg)	Output (Kg)
Land	0.196***	-0.029	0.232	7.701***	0.159***	0.093**	-0.056
Labor	0.316***	0.517***	-0.333*	-2.426*	0.286***	0.416***	0.340**
Traction power	0.112***	0.055	0.288*	1.286	0.104**	0.023	-0.057
Seed	0.015	-0.065	-0.119*	-3.726***	0.059**	0.108***	0.186***
Organic matter	0.163***	0.213*	0.410***		0.257***	0.083**	0.205**
Chemical fertilizer	0.087***	0.208**	0.089	2.027***	0.200***	0.067**	-0.134*
Pesticide	0.103***			1.619**		-	0.207**
Other variable inputs	0.126***	0.365***	-0.020	-3.943***	-0.016	0.215***	
<u>Variance parameters</u>							
Sigma-squared (δ^2)	0.167***	0.220***	0.308***	0.338***			
Gamma (γ)	0.733***	0.636***	0.543***	0.634***			
Likelihood Ratio (LR)	9.095***	3.523*	2.791*	8.363***			
Average efficiency	0.77	0.73	0.74	0.72	0.30	0.44	

Appendix 4.Summary results on factors affecting inefficiencies in vegetable production

Variables	TE at household levels (SFA)	TE at plot levels (SFA)		PE at household levels (SFA)	Economic Efficiency (Input oriented DEA)		Women contribution (Output oriented DEA)
		Winter	Summer		Winter	Summer	
Dependent variables	TIE	TIE	TIE	PIE	EIE (CRS)	EIE (CRS)	TIE (VRS)
Age of farm manager	0.003**	-	-	-	-		-
Farmers' association	-0.026	-	-	-	-		-
Experience of farmers	-	-	-	-0.001*	-		-
Seeds type	-	-	-	-0.076***	-0.021*	-0.382 ***	
Education of farm manager	-	-0.003***	-0.002***	-	-		-0.008**
Training of farm manager	-0.01*	-0.011***	-0.004**	-	-0.004	-0.023	-0.018***
Extension contact	-	-	-	-0.005*	-		-
Credit access	-	-0.019**	-0.004	0.023**	-0.020*	-0.220 *	-
Market access	-0.072**	-0.039***	-0.022***	-	-0.021*	-0.319 **	-
Distance of farm to market	-	-	-	0.001***	-		0.003
Information index	-	-	-	-0.002*	-		-

Table 4. Continue….

Variables	TE at household levels (SFA)	TE at plot levels (SFA)		PE at household levels (SFA)	Economic Efficiency (Input oriented DEA)		Women contribution (Output oriented DEA)
		Winter	Summer		Winter	Summer	
Dependent variables	TIE	TIE	TIE	PIE	EIE (CRS)	EIE (CRS)	TIE (VRS)
Index for underdevelopment of infrastructure	0.015***	-	-	-	-		-
External support index	-	-	-	-	-0.010**	-0.023	-
Gender of farm manager	-	0.015**	0.019**	0.019*	0.0204*	-0.204 *	0.107***
Women participation index	-	-0.002**	-0.002*	-	-0.024*	-0.024 *	-
Women participation in land preparation		-	-	-		-	0.008
Women participation in vegetable plantation		-	-	-		-	0.029
Women participation in crop management		-	-	-		-	-0.045***
Women parti. in harvesting- marketing		-	-	-		-	-0.042***
Women participation in decision-making		-	-	-		-	-0.045***

Note: TIE: Technical efficiency; TIE: technical inefficiency; PIE: profit inefficiency; EIE: economic inefficiency

Appendix5:Questionnaire set for vegetable farmer respondents, Nepal, 2013

Efficiency Analysis of Smallholder Vegetable Farms: Implications for Improving Rural Household Economy in Nepal

Name of enumerator: Date of interviewer:

1. Preliminary information

1.1 District:

1.2 Municipal/VDC/Ward No:

1.3 Name of farm manager (Mr. /Miss):

1.4 Contact Phone:

1.5 Age of farm manager: …years.

1.6 Schooling of manager (years.):…

1.7 Family size:…persons.

1.8 What are the major crops do you grow?

2.0 Farm related information

2.1 When did you start your commercial vegetable farming? ……years.

2.2 Why did you choose vegetable farming?

i) higher earning, ii) irrigation facility, iii) market accessed, iv) Others

2.3 Land ownership: Own/rented. If rented, proportion of rented area?........%

2.4 Farming approach: IPM / Non-IPM

2.5 How many times you grow vegetables in the same piece of land in a year? One/two/three crops/others

2.6 What types of varieties (improved or local) of vegetables did you use?

(i) Cauliflower: Improved/local, (ii) Cabbage: Improved/local

(iii) Tomato: Improved/local, (iv) Guards: Improved/local

(iv) Others:

2.7 Are you a member in any association (farmers' group/cooperatives)?

Yes / No; If yes, what types of benefit you got from the association?

Technical/credit/marketing/others

3. Did you have contact with extension agents (DADO, or NGOs) for technical support? Yes/No

If yes, how many times in a cropping season? ……..times.

4. Did you receive training on vegetable farming and marketing? Yes/No

If yes, how many trainings did you receive?.......numbers.

5. Did you avail credit (loan) from any of the sources? Yes / No

If yes, nature of financial institution: bank/cooperatives/traders/relative/others

6. Did you receive supports from external agencies (government/NGOs) for vegetable production? Yes/No; if yes, what types of supports?

6.1 Fertilizer? Yes/No; 6.2 Irrigation? Yes/No;

6.3 Seed? Yes/No; 6.4 Pesticides? Yes/No;

6.5 Production materials (plowing, digging, sprayer material);

6.6 Extension material (leaflets, posters and mass communication from newspaper, radio and television)? Yes/No;

6.7 Post-harvest material (packaging, harvesting, weighing, drying material)? Yes/No;

6.8 Others services? Yes/No;

6.9 What support do you expect from eternal agencies for vegetable farming?

7. Area, production and farm price of vegetables (winter and summer)

SN	Season/crops	Area (Ha)	Production (kg): A	Sold (kg)	Avg. Rate (Rs/kg): B	A + B (Rs, 000)*
7.1	Winter season vegetable					
i	Cauliflower					
ii	Cabbage					
iii	Tomato					
iv	Guards					
v	Others crops					
	Total					
7.2	Summer season vegetable					
i	Cauliflower					
ii	Cabbage					
iii	Tomato					
iv	Guards					
v	Others crops					
	Total					

* Gross value = (home consumption + seed used + sales + gift)-farm losses

8. Marketing Activities

8.1 Is there market access for your products? Yes/No

8.2. How far (km) is the markets from your production area? …….km.

8.3 Do you have marketing linkage with wholesaler/main traders? Yes /No

If yes, which market?...............,What is the name of traders?...............

8.4 Do you have any agreement with traders? Yes/No. If yes, what agreements?

9. Labors used for vegetables farming?

9.1 Gender based wage rate: male ….Rs/day, and female…….Rs/day

9.2 Why discrimination in wage rate?

10. Human and animal labor used in vegetable farming

SN	Season/crops	Human labor (family and hired)			Tractor/animal power*		
		No.	Wage rate (Rs/person)	Total cost (Rs, 000)	No.	Wage (Rs/set)	Total cost (Rs,000)
A	Winter season						
i	Cauliflower						
ii	Cabbage						
iii	Tomato						
iv	Guards						
v	Others crops						
	Total						
B	Summer season						
i	Cauliflower						
ii	Cabbage						
iii	Tomato						
iv	Guards						
v	Others crops						
	Total						

* Tractor is in terms of Rupees per hour

11. How much spent for seed, fertilizer, pesticide, other variable costs (Rs 000)?

SN	Season/crops	Seed (Rs)	Fertilizers Qt. (kg)	Fertilizers Cos (C)	(D) Compost (Rs ,000)	Fertilizer (C)×(D) (Rs.000)	Pesticide (Rs)	Other variable cost (Rs)
A	Winter season							
i	Cauliflower							
ii	Cabbage							
iii	Tomato							
iv	Guards							
v	Other crops							
	Total							
B	Summer season							
i	Cauliflower							
ii	Cabbage							
iii	Tomato							
iv	Guards							
v	Other crops							
	Total							

12. Women participation index in vegetable farming

SN	Activities	Index				
		1	2	3	4	5
i	Land preparation					
ii	Vegetable plantation					
iii	Crop management (irrigation, insect-pest management, fertilization, and weeding)					
iv	Harvesting and marketing					
v	Decision making					
	Total					

Note: Index one for less women participation and 5 for high participation.

13. Information score in vegetable production

SN	Activities/score	Information score				
		1	2	3	4	5
i	Input marketing					
ii	Improved farming technologies					
iii	Output marketing of the products					
iv	Demand and supply of the vegetables in markets					
v	Price movement of products in markets					
	Total					

Note: Index one for less information and 5 for high information received by farmers.

14. Index for underdevelopment of infrastructure

SN	Activities	Index				
		1	2	3	4	5
i	Road network					
ii	Irrigation					
iii	Electricity					
iv	Agri. Service center					
v	Financial institutions					
v	School or college					
	Total					

Note: Index five for less infrastructure development and one for high development.

15. What are the major constraints in vegetable production? (1 for less problem, 7 for big problem)

SN	Problems/Constraints	Rank (1-7)	Suggestive Measures
i	Inputs not available (improved seed, pesticide, fertilizer, etc.)		
ii	Lack of labor resource		
iii	Irrigation problem		
iv	Transportation (means and Road)		
v	Ineffective extension service		
vi	Ineffective market information		
vii	Market inaccessibility for the products		
viii	Others		

Bio Sketch of Author

Name:	Rudra Bahadur Shrestha
Gender	Male
Nationality:	Nepali (Passport No.: 0058856; ARC: TC00491313)
Date of Birth:	17th March, 1972
Place of birth:	Khandawari-12, Sankhuwasabha, Koshi, Nepal
Contact Address:	DTAIC, NPUST, No. 1, Shuefu Rd., Neipu, Pingtung 91201, Taiwan (Phone: +886-988849070)
Email address:	shrestha_rud1998@yahoo.com, rudra.b.shrestha@gmail.com

Research Interest

1) Efficiency analysis in agriculture production and marketing;
2) Cross-cutting issues of agriculture with food and nutrition security, economic development, and poverty reduction.

Software competency: Frontier 4.1, DEAP 2.1, STATA, Eviews, SPSS.

Educational background

Degree	Major	Date	Institution
Doctoral studies	Agricultural Economics	09/2012-07/2015	National Pingtung University of Science and Technology, Taiwan
Master of Science	Agricultural Economics	60/2007-04/2009	University of the Philippines Los Banos (UPLB), Philippines
Master Degree	Sociology	2001-2003	Trichandra College, Tribhuwan University, Nepal

Master Degree	Economics	1997 - 1999	Central Department of Economics, Tribhuwan University, Nepal
Bachelor of Science	Agricultural Economics	1992 - 1994	Institute of Agriculture and Animal Science (IAAS), Tribhuwan University, Nepal
Intermediate of Science	Agriculture	1989 - 1991	,,
SLC	General	1988	HSS, Khandawari, Shankhuwasabha, Nepal.

Thesis/Dissertations

1. Ph.D.: Efficiency Analysis of Smallholder Vegetable Farms: Implications for Improving Rural Household Income in Nepal (2015). Ph. D. thesis for Agricultural Economics. National Pingtung University of Science and Technology, Taiwan;
2. Master Degree: Farm-Retail Price Spread of Rice in Nepal (2009). M. S. thesis for Agricultural Economics. Graduate School, University of the Philippines Los Banos, Philippines;
3. Master Degree: Socio-economic Analysis of Women Traders in Kalimati Fruit and Vegetable Wholesale Market, Kathmandu, Nepal (2006). Master Degree thesis for Sociology. Trichandra Multiple College, Tribhuwan University, Nepal.
4. Master degree: A Diagnostic Study on Sweet Orange Marketing in Ramechhap District (1999). Master Degree Thesis in Economics, Central Department of Economics, Tribhuwan University, Nepal.

Professional Experiences

Executive Director, Kalimati Fruit and Vegetable Market Development Board (KFVMDB), Ministry of Agriculture and Cooperatives, Nepal (October, 2010-August, 2011 and May, 2012-Sept., 2012).

Senior Agricultural Economist, Agribusiness Promotion and Marketing Development Directorate, Ministry of Agriculture and Cooperatives, Nepal (May, 2010-Oct, 2010 and July, 2011-May, 2012).

Agricultural Economist, Agricultural Commodities Export Promotion Program, Ministry of Agriculture and Cooperatives, Nepal (Jan, 2005-March, 2007).

Agricultural Marketing Economist, Agribusiness Promotion and Marketing Development Directorate, Ministry of Agriculture and Cooperatives, Nepal (Sept., 2003-Dec., 2004).

Agriculture Planning Officer, District Agriculture Development Office, Ramechhap district, Government of Nepal (July, 1999-Sept., 2003).

Program Officer, Local Governance Program (LGP), District Development Committee (DDC) Morang, Ministry of Local Development/UNDP, Nepal (Feb., 1998-July, 1999).

Project Coordinator, Flood Disaster Control Program Morang-Jhapa, Rural Reconstruction Nepal (Jan, 1996- Jan, 1998).

Teaching Profession

Visiting Faculty, College of Development Studies, Purbanchal University, Nepal. Course: MS course on Agrarian Structure and Development(Jan, 2010-Sept, 2012).

Visiting Faculty, Himalayan College of Agricultural Science and Technology, Purbanchal University, Nepal. Course: Agricultural economics for B.Sc. Ag., and B. V. Sc. & A. H. (Sept., 2010-Sept., 2012).

Visiting Faculty, Mahendrodaya Multiple Campus, Ramechhap, Purbanchal University, Nepal.Bachelor program in economics.(2002-2003).

Publications

Shrestha, R. B., Wen-Chi Huang, S. Gautam, and T. G. Johnson. 2015. Efficiency of small scale vegetable farms: policy implications for rural poverty reduction in Nepal. *Agricultural Economics (AGRICECON-Czech)* 61(7).

Shrestha, R. B., Wen-Chi Huang, and U. Pradhan. 2015. Women's Labor Contribution on the Efficiency of Smallholder Vegetable Farms: Evidence from Mountain Region of Nepal. *International Journal of Research* 2(5): 167-179.

Ghimire, R., Wen-Chi Huang, and R. B. Shrestha. 2015. Factors Affecting Adoption of Improved Rice Varieties among Rural Farm Households in Central Nepal. *Rice Science* 22(1):35-43.

Shrestha, R. B., Wen-Chi Huang, and R. Ghimire. 2014. Production Efficiency of Smallholder Vegetable Farms in Ilam District, Eastern Hill, Nepal. *American-Eurasian Journal of Agricultural and Environmental Sciences* 14(2): 150-154, 2014.

Shrestha, R. B., Wen-Chi Huang, and R. Ghimire. 2014. Market Price Cointegration of Tomato: Effects to Nepali Farmers. *International Journal of Food and Agricultural Economics*2(2):87-96.

Shrestha, R. B., Wen-Chi Huang, and U. Pradhan. 2014. Resource Use Efficiency and Factors Influencing Inefficiency in Vegetable

Production in Eastern High-hill, Nepal. *Nepalese Journal of Agricultural Economics 2(1):65-70.*

Ghimire, R., Wen-Chi Huang, and R. B. Shrestha. 2014. Factors Affecting Nonfarm Income Diversification among Rural Farm Households in Central Nepal. *International Journal of Agricultural Management and Development* 4(2): 123-132.

Shrestha, R. B. 2012. Factors Affecting Farm-Retail Price Spread of Rice in Nepal. *The Journal of Agriculture and Environment*13(1):47-52.

Shrestha, R. B. and S. Pandey. 2011. Rice Marketing Practices and Constraints in Nepal. *The Nepalese Journal of Agricultural Economics 1(1):66-77*.

Khatri Chetri, D. B. and R. B. Shrestha. 2011. Farmers' Participation in Groundwater Markets in Terai Nepal. *The Nepalese Journal of Agricultural Economics*1(1)37:51.

Shrestha, R. B. and U. Pradhan. 20011. *Food and Nutrition Security Policies in Nepal.* Special Issues on Fruit and Vegetable in Nepal. Federation of Fruit and Vegetable Entrepreneurs, Nepal.

Shrestha, R. B. 2006. *Import Substitution versus Export Promotion of Cardamom and Coffee: Opportunities and Challenges*. Fourth National Marketing Conference. Kathmandu, Nepal.

Shrestha, R. B. 2002. Problem and Prospects of Agriculture Development in Ramechhap District. *Ramechhap Awaj.* Karmachari Milan Kendra Ramechhap, Nepal.

Shrestha, R. B. 2001. Periodic District Development Plan and Prospects of Agricultural Development in Ramechhap District. *Ramechhap Awaj*. Ramechhap, Nepal.

Shrestha, R. B. 2000. Agricultural Perspective Plan and Prioritized Pocket Package Strategy in Ramechhap district, Nepal. *Ramechhap Awaj*, Nepal.

Shrestha et al. 2000.*Periodic District Development Plan (FY 2000/2001-2007/2008)*. District Development Committee Ramechhap, Ministry of Local Development, National Planning Commission, Kathmandu, Nepal.

Shrestha, R. B., S. B. Gurung, and D. Poudel. 1995. A Comparison on the Use of External Inputs in Agriculture between Tribal and Migrant People in Western Chitwan. *Institute of Agriculture and Animal Science*. Chitwan, Nepal.

Awards, appreciations and recognitions

The Best Award of Articles: Technical Efficiency of Nepalese Vegetable Farms: Policy Implications for Reducing Inefficiency of Smallholder Farmers. Conference of Rural Economics Society of Taiwan (REST), Taipei, Taiwan (06/12, 2014).

Awarded “Sung-Ching Hsieh” Scholarship, academic year 2012/2013, DTAIC, NPUST, 2013.

NPUST scholarship for pursuing Ph. D. in Agricultural Economics at National Pingtung University of Science and Technology, Taiwan (Sept., 2012-June, 2015).

Letter of Appreciation: Significant Contribution in Agricultural Market Development, awarded by Dharan Agriculture Market, Nepal (10/02/2013).

Certificate of Appreciation: Commendable Leadership and Outstanding Services, awarded by Kalimati Fruit and Vegetable Market Development Board, Nepal (12/07/2011).

Certificate of Appreciation: Significant Contribution for Market Development, awarded by Institute of Kalimati Vegetable and Fruit Entrepreneurs, Nepal (22/07/2011).

Certificate of Appreciation: Significant Contribution for Market Development, awarded by Progressive Women Saving and Credit Cooperative, Nepal (22/07/2011).

Recognition of President for International Student Association (ISA), awarded by the University of the Philippines Los Banos, Philippines (11/12/2008).

IRRI, Asian Development Bank-Japan Scholarship (ADB/JSP) for pursuing MS degree in Agricultural Economics in University of the Philippines Los Banos (UPLB), Philippines (2007-2009).

Nuffic Scholarship, awarded for Pursuing International Agriculture in Larenstein University, The Netherland (2006/07).

The Best Personality Award – 2001/2002, awarded by District Development Committee Ramechhap, Nepal (29/04/2002).

Competitive Small Research Grant, awarded by Winrock International Nepal in Institute of Agriculture and Animal Science (IAAS), Nepal (1993).

Trainings

Training Course on Statistical/Econometric Analysis Using Stata, Social Science Division, International Rice Research Institute, Philippines (5-9/ 05/2008).

Summer Program in Economics Consisting Micro-economics, Macro-economics, Mathematical Economics and Econometrics. College of Economics and Management, University of the Philippines Los Banos, Philippines (1/04/2007-31/05/2007).

International Agriculture, organized by Larenstein University, the Netherland (1/10/2006-30/03/2006).

Application of GIS to Infrastructure and Resources Planning, Development and Management. National Society for GIS and South Asian Institute for Technology, Nepal (11/01/2003-16/02/2003).

Professional Involvement

Director (Information, Publication and Public Relation): Nepal Agricultural Economics Society (07/2005-12/2006 and 08/2009-09, 2012).

Member Secretary-Editorial Board, Nepalese Journal of Agricultural Economics (2011-2012).

President, International Student Association (ISA) - 2008, University of the Philippines Los Banos (UPLB), Philippines (1/1/2008-30/12/2008).

Alumni, Asian Development Bank – Japan scholars (since 2007).

Alumni, AFSTRI, IRRI, Philippines (since 2007).

Secretary-General, Karmachari Milan Kendra Ramechhap, Nepal (2000/2003)

Member, Ramechhap Awaj (annual publication), Nepal (2000-2003).

Member, Periodic District Development Plan, (FY 2000/2001- 2007/2008), Ramechhap District, Nepal (2000).

President, All Nepal Free Student Union, Chitwan District, Nepal (1991-1993).

References

Dr. Wen-Chi Huang, Associate Professor, Department of Agribusiness Management, National Pingtung University of Science and Technology, Taiwan. E-mail: wenchi@mail.npust.edu.tw

Dr. Yam Bahadur Thapa, President, Nepal Agricultural Economics Society. Email: yb.thapa@ntc.net.np