THREE ESSAYS ON FOOD STAPLES SUFFICIENCY: BIOPHYSICAL ASSESSMENT, SOCIOECONOMIC ANALYSIS, AND POLICY EVALUATION OF THE RICE SECTOR IN CENTRAL LUZON, PHILIPPINES

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Dedication

When a woman is in labor,
she is in anguish because her hour has arrived;
but when she has given birth to a child,
she no longer remembers the pain because of her joy
that a child has been born into the world.

John 16:21

Ardy

…you are the most amazing and wonderful blessing of purest joy and truest love that I have ever received and experienced

…know that Mommy loves you unconditionally from infinity and beyond

…you are that one constant in my life and every inch of this work is for you

Train the young in the way they should go;
even when old, they will not swerve from it

John 16:21

Mama and Papa

…you have sacrificed so much and the inspiration, drive, and unfaltering support you are giving me made me the person that I am today

…day after day, you have been there for Ardy and me to make sure we lead a virtuous life

…the only thing better than having you for parents is Ardy having you as his grandparents

…words are not enough for me to let you know how much I love you both

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Abstract

The Philippines launched the Food Staples Sufficiency Program (FSSP) in 2012 with a target to increase rice staples from 15.77 million metric tons in 2010 to 22.73 million metric tons in 2016. To attain the target, the government promoted classical approaches of (1) expanding land and irrigation areas, (2) increasing productivity through cropping intensification and introduction of high yielding varieties, and (3) strengthening food system connectivity by reducing rice wastes. In support of rice expansion, this study conducted a geospatial multi-criteria assessment to estimate yield in current and potential areas with biophysical and environmental characteristics capable of supporting rice production. Cognizant of the relationship between production efficiency and achieving the target, this study carried out a stochastic production frontier analysis coupled with spatial dependence assessment. In further recognition that attaining rice self-sufficiency is subject not only to the level of biophysical expansion and efficiency enhancement but also on the ability of producers to utilize effectively all the resources or capital at its disposal, this study also examined the influence of the farmer's individual social capital on production and adoption of sustainable practices.

Results show that the Philippines has about 2.06 million hectares of land that can be allocated to rice expansion. With this potential, the target is attainable even if expansion is not maximized given that yield per hectare is set at the maximum historical yield of 3.89 metric tons. Given that average annual regional technical efficiency in Central Luzon is 0.827 and is representative of farm performance across the country, with adequate provision of agricultural water to farmers and training programs, it is possible to increase national yield above 3.89 metric tons per hectare. At this rate and with the amount of land devoted to rice in 2010, which is 4.3 million hectares, it is possible to surpass the target of 22.73 million metric tons. Findings also demonstrate the direct and indirect connection of social relations to building a farmer's social capital stock, which in turn was determined to help enhance farm-level efficiency and productivity.

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Preface

Rice is the most important staple food in the Philippines. Any Filipino meal would not be complete without some form of rice on the table. The average Filipino diet is based on this crop. It is thus not surprising that the per capita rice consumption in the Philippines rose to almost 8 percent, from 106 kilograms in 2000 to 114 kg in 2012. It is for this reason that rice accounts for almost a third of an average Filipino household's food expenditures and it provides almost half of the calorie requirements of Filipinos. Rice is therefore considered a socially- and politically-sensitive commodity, and securing supply at whatever cost is paramount.

In the last 20 years, rice demand in the Philippines is greater than the local supply making the Philippines one of the top five rice importing countries in the world. Because of this reliance on imports to sustain domestic rice demand, the Philippines has become vulnerable to high and volatile global rice prices particularly during the 2008 rice crisis. The brunt of the crisis brought panic buying and riots in many portions of the country.

In response to the rice crisis of 2008 and to sustain the country's agricultural growth as well as guarantee its food security, the Philippine government launched the Food Staples Sufficiency Program (FSSP) in 2012 with a target to increase rice staples from 15.77 million metric tons in 2010 to 22.73 million metric tons in 2016. To attain the target, the government promoted classical approaches of (1) expanding land and irrigation areas, (2) increasing productivity through cropping intensification and introduction of high yielding varieties, and (3) strengthening food system connectivity by reducing rice wastes. The government is very positive that the rice self-sufficiency is attainable even before the target date.

Agricultural experts and economists, however, do not see eye to eye with the government as historical trends in rice production speak otherwise. A recent review of data show that from 1994 to 2010, the average annual growth in rice production in the Philippines is only 3.2 percent and in a span of seven years, the government believes that through the FSSP it can double the annual production to 6.3 percent. The experts noted that the target is very ambitious and not possible within the program's timeframe.

With the opposing views on the FSSP, this dissertation seeks to shed some light on whether rice self-sufficiency target can actually be attained by 2016 and if so, at what costs. As such, following the historical paths of agricultural expansion, increased in productivity per hectare, and enhanced connectivity in the agricultural systems, this dissertation has five main chapters that primarily investigate food staple sufficiency in the Philippines. Chapter 1 introduces the reader to the concepts of food security and food self-sufficiency as well as the specific strategies under the Food Staples Sufficiency Program (FSSP). Chapter 2 presents the geospatial assessment of potentially suitable areas for rice expansion. Chapter 3 demonstrates the incorporation of geolocations in the estimation of production and technical efficiency levels of farmers in Central Luzon. Chapter 4 investigates the influence of social capital on rice production, efficiency levels, and adoption of sustainable management practices. The last section, Chapter 5, provides policy implications and recommendations in support of staple food self-sufficiency.

The second chapter focuses on geospatial multi-criteria assessment to identify current and potential areas with biophysical and environmental characteristics capable of supporting rice production. The land suitability analysis show that at the national scale, the Philippines has about 2.06 million hectares of land that can be allocated to rice expansion and with this potential, the rice self-sufficiency target is attainable even if expansion is not maximized given that yield per hectare is set at the maximum historical yield of 3.89 metric tons. With regard to opportunity cost, results show that not converting the areas to other nonagricultural uses yields a forgone value of Ph₱128 billion higher than using the land for rice production. The agricultural use of land for rice production, on the other hand, provides a higher return than allocating areas for corn production. In terms of spillover effects from expanding rice production, around 56,800 million cubic meters of water will be necessary to support the FSSP target. This suggests that with business-as-usual scenarios with water supply and withdrawal curves, about 93 percent of the water used for the agricultural sector will be devoted to rice production alone if the potential expansion continues. The rice by-products, at the maximum, can produce 279 megawatts of power, which can also be equivalent to 1,866 million liters of oil. From an applied standpoint, decision makers can use the land suitability results as a guide to channel investment plans and enhance rice expansion initiatives across the country.

Given that only 20 percent of the necessary increase in production can be expected from land expansion and the remaining 80 percent can be generated through increased productivity, Chapter 3 centers on stimulating an upward shift in the production function by increasing efficiency levels. Cognizant of the relationship between efficiency of rice production and achieving the FSSP target, stochastic production frontier analysis revealed that given that average annual regional technical efficiency in Central Luzon is 0.827 and is representative of farm performance across the country, with adequate provision of agricultural water to farmers and training programs, it is possible to increase national yield above 3.89 metric tons per hectare. At this rate and with the amount of land devoted to rice in 2010, which is 4.3 million hectares, it is possible to surpass the FSSP target of 22.73 million metric tons. This indicates that the FSSP target is achievable without expansion of land areas devoted to rice.

To design policies that address the specific and geographic production needs of rice farmers, Chapter 3 extends previous work that investigated productivity increases through technical efficiency enhancement by evaluating how geospatial attributes influence farmer production performance within the overall context of achieving the FSSP target. Results show significant clustering of best and worst performing farms, specifically in Tarlac City. The optimized hotspot analysis suggests that proximity to high performing farms influences yield per hectare and the level of technical efficiency. The villages of Sapang Maragul, Tibag, and Tibagan are the technical inefficiency hot spot locations in Tarlac City. These areas represent high incidence of low levels of technical efficiency.

The attainment of the FSSP target depends on the ability of the rice producers to increase farm technical efficiency. It is imperative that policy interventions prioritize productivity cold spot areas and hot spot zones for technical inefficiency. These are the locations where agricultural planners and policymakers can make greater impacts on rice yields. Relevant policies and initiatives, therefore, should take into account the appropriate geographical level to ensure the greatest contribution to the attainment of the FSSP target.

The achievability of rice self-sufficiency is subject not only to the level of biophysical expansion and production costs reduction or technical efficiency enhancement but also on the ability of producers to utilize effectively all the available resources or capital at its disposal. For this reason, to ensure that domestic staple food self-sufficiency remains viable, Chapter 4 examines the influence of social capital and network in improving productivity in support of the FSSP target. The fourth chapter investigates the level of influence of the farmer's individual social capital on the factors affecting the technical efficiency of farms. Through structural equation modeling, the Chapter assesses the role that social capital plays in the adoption of sustainable management practices in rice farming.

Chapter 4 demonstrates the direct and indirect connection of social relations to building a farmer's social capital stock, which in turn can help enhance efficiency and productivity. The models show that ego (personal) network of farmers positively influences the acquisition of social capital in the form of access to resources such as technology, information, financing, and production materials among others. Through intermediary variables such as training and adoption of technology, Chapter 4 shows that an increased in technical efficiency and productivity of rice farms is positively related to access to social capital assets and resources. In terms of adopting sustainable management practices, the infancy of the concept of by-product utilization for energy production probably influenced the insignificant effect of social capital. Nevertheless, social capital has an overall positive effect on adoption of water conservation practices.

The results of the analysis in Chapter 4 offers a different frame of reference for farmers and decision makers who are finding ways to make rice production sustainable and at the same time profitable. If the policy objective were to influence the level of efficiency and production at the farm level as well as sustainable rice farming, it would be partial not to take into consideration the role of social networks and social capital. Farmers and decision-makers should view social capital as a potential source of strategic farm-level enhancement in efficiency and production. If the conventional factors of production are leveraged with social capital assets and resources, there is a likelihood that rice self-sufficiency may be attainable.

The key findings included in this dissertation definitely shine some light on the achievability of rice self-sufficiency in the Philippines. Policy makers at the local and national levels as well as agricultural researchers and even extension workers will find the information in this dissertation useful in their decision-making process. They will gain insights on possible practical steps to move closer to attaining autarky in staple food production.

Rusyan Jill Mamiit
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Chapter 1. Introduction

The move to elevate and resolve problems on food security and food self-sufficiency at various levels has rapidly escalated in the last decade. Governmental organizations, small groups, and giant private entities around the world called to raise awareness and attract participation in assessing and inviting action to address issues confronting the dilemma on availability and access to staple foods. To understand the extent and the expanse by which measures have been undertaken to address food security and food self-sufficiency issues at macro and micro levels, this chapter explores the concepts of food security *vis-à-vis* food self-sufficiency, state of staple food supply and demand, and efforts to resolve staple food sufficiency problems, with a particular focus in the Philippines.

This chapter presents the rationale on the importance of assessing the breadth of physical resources necessary to support staple food self-sufficiency. Further, this chapter expounds on the *raison d'être* for assessing spatial technical efficiency of staple food production. Finally, this chapter illustrates the influence of social capital in the addressing staple food security and self-sufficiency problems.

Food Security and Autarky in Staple Food Production Defined

In the early 1960s, the Food and Agriculture Organization of the United Nations (FAO) launched the Freedom from Hunger Campaign (FFHC). Apart from being an awareness-raising movement, FFHC served as a catalyst for governments and peoples to recognize the extent and nature of hunger around the world. The Campaign, in particular, focused on revolutionizing subsistence agriculture to market economy and increasing productivity (Shaw, 2007) to address growing starvation, malnutrition, and deprivation to basic dietary needs.

With the Freedom from Hunger Campaign (FFHC) in place, countries all over the world were cognizantly realizing the need to combat hunger as manifested in the first World Food Congress in 1963. Action plans to reduce the rate of starvation through food surplus distribution and agricultural expansion were major outputs of the Congress. Simon (2012) noted that during the 1960s, the same period when FFHC commenced, world food production per capita increased by more than 20 percent.

The climatic conditions, political instability, and institutional unrest in many regions of the world in the early 1970s brought an abrupt change to the momentum accomplished by the FFHC.[1] Headey & Fan (2010 and 2008) and Shaw (2007) reported a 180 percent increase in wheat prices between 1970 and 1974. Price of rice rose to 225 percent on the same period and corn prices inflated by 80 percent between 1972 to 1974.

The global situation in the early 1970s radically contributed to an increase in hunger, malnutrition, and ultimately poverty in many countries. To address these growing concerns, the Food and Agriculture Organization of the United Nations (FAO) called for a World Food Conference in 1974, wherein participating governments asserted the right of "every man, woman, and child […] to be free from hunger and malnutrition in order to develop their physical and mental faculties" (Shaw, 2007). In this conference, governments committed to eradicate global hunger, malnutrition, and food insecurity within a decade (FAO, 2014). In addition, in this meeting, the concept of food security has evolved to encompass both availability and access to food commodities to satisfy basic physiological needs.

A decade after the World Food Conference, governments failed to meet the target set in 1974. Low rate of increase in food and agricultural production as well as severe drought in Africa beset the period. Low commodity prices of many agricultural products also continued to persist at that time (FAO, 1985).

To counterbalance the unrelenting presence of pervasive malnutrition and under-nutrition as well as the growing uncertainty on the capacity of agriculture to meet present and future needs of the rising global population, the Food and Agriculture Organization of the United Nations (FAO) called for a World Food Summit in 1996.[2] In the Summit, representatives from 185 nations renewed their pledge to achieve food security for all and attain the intermediate goal of "reducing the number of undernourished people to half their present[3] number no later than

[1] In Simon's (2012) historical account, cereal production dramatically decreased resulting to high prices of cereals at the world market. At the same time, the Organization of Petroleum Exporting Countries (OPEC) increased the price of petroleum to very steep level. This resulted in a ripple effect of high fertilizer and transportation costs for staple food commodities.

[2] Fukuda-Parr & Orr (2013) noted that despite the annual growth rate of 0.5% in the global per capita food supply between 1969 and 1990, global hunger persisted.

[3] Present here refers to the year 1996.

2015" (Meyers, 2001).[4] At various levels, governments and non-governmental organizations provided food aid, farming supplies, agricultural capacity building and training programs as well as increased funding for agricultural research to ensure that the global target will be reached by 2015 (Subramaniam & Bunka, 2013).

Five years after the World Food Summit, the member states of the United Nations re-affirmed its commitment to "eradicate [global] extreme poverty and hunger" through the Millennium Development Goals (MDG). As a supplement to the goal set at the World Food Summit, one of the targets under the first goal of the MDG is to decrease into half the proportion of people suffering from hunger by 2015 (United Nations, 2013).[5] In the MDG context, hunger is measured in terms of the number of people who are undernourished and the pervasiveness of children below five years of age who are underweight (Fanzo, et al., 2010).

International efforts to reach the World Food Summit and MDG targets expanded from east to west and north to south since the introduction of the MDGs in 2001. In the first several years, there was progress, particularly in halving the number of people that are undernourished and suffering from hunger. The FAO reported that an 11 percent reduction in global undernourishment has been observed between 1990 and 2007 (FAO, IFAD, & WFP, 2013) and the number of hungry people has fallen by 17 percent in 2013 compared to the 1990 benchmark (FAO, 2013).[6] The momentum gained at the global level, although remarkable, has been found sluggish and likely to result to the unattainability of the targets given the rate of achievement made thus far (Aborisade & Bach, 2014; Subramaniam & Bunka, 2013; FAO, 2013; FAO, 2010; Golay, 2010; Kracht, 2005).

Exacerbating the slack in curtailing undernourishment and hunger worldwide was the sudden instability in both the supply and price of basic food commodities between 2007 and 2008.[7] The volatility in world commodity prices took the world by surprise and caused 'panic

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[4] The FAO used the 1990-1992 figures as baseline for the target set at the Summit. FAO, IFAD, & WFP, (2013) reported that in 1990-1992, there were 1,015.3 million people who are undernourished.

[5] The United Nations Millennium Development Goals set 1990 as the baseline year of the targets.

[6] Table 1.1 from FAO, IFAD, & WFP, (2013) summarizes the progress made since 1990 in terms of addressing global undernourishment.

[7] Gonzalez (2010) recounted that the rise in world commodity prices between 2007 and 2008 "plunged an additional 115 million people into the ranks of the malnourished." Piesse & Thirtle (2009) compared the price commodity price increases of 2007and 2008 to that the 1972 to 1974 food crises.

hoarding' and 'panic buying' in different corners of the globe.[8] The extent of the repercussions from this abrupt episode brought the issue of food security from the sidelines to the "center of public debate" (Gonzalez, 2010) at various sectoral levels (Headey, 2013; Warr, 2012). The world's attention is once again focused on identifying and implementing measures, immediate and long-term, that can result in "sustainable and equitable food production and distribution systems" (Gonzalez, 2010).

Understanding Food Security through a Multi-Dimensional Lens

In 2008, global staple food price instability[9] swept the world. Nations, particularly those in the global south, scrambled to ensure adequate supply are available to support the basic dietary needs of the population. The price spike and food shortage in many regions of the world drew the attention not only of policy makers and news media but also of ordinary citizens to the concepts of food security and notions of food self-sufficiency.

Food security is a relatively young concept. As a concept, it started to gain prominence only in the mid-1970s during various fora on food supply problems – "of assuring the availability and to some degree the price stability" of basic food commodities – at the global and national levels (Clay, 2002; Maxwell & Smith, 1992). Despite its short history as a concept, food security has evolved as an important economic and development principle.[10]

From the simple and narrow definition of having adequate and enough food available for all at all times (Pinstrup-Andersen, 2009; Maxwell & Frankenberger, 1992), food security has been interpreted in various ways in the last four decades (Heidhues, et al., 2004; Clay, 2002; Maxwell, 1996; Maxwell & Smith, 1992) specifically when refering to scale – from households, to regional, national, and global levels (Lee, 2007).[11] Even if this has been the case, a large

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[8] McMichael (2009) reported that in the period 2007 and 2008, food riots occurred in various parts of Italy, Uzbekistan, Morocco, Guinea, Mauritania, Senegal, West Bengal, Indonesia, Zimbabwe, Burkina Faso, Cameroon, Yemen, Jordan, Saudi Arabia, Egypt, Mexico, Argentina, and Haiti. Barrett (2010) also noted the same incidents in more than two dozen countries.

[9] According to Byerlee, Jayne, & Myers (2006) "food price instability refers to any abrupt change in price, irrespective of its predictable."

[10] Figure 1.1 from Maxwell & Smith (1992) summarizes important initiatives related to food security from 1943 to 1990.

[11] Warr (2014) noted in his address to the Australian Agricultural and Resource Economics Society that global food security means "global supplies are sufficient to meet aggregate global requirements." Accordingly, he believes that national food security is "based on food security at the household level," and "if households are not food secure, it is hard to see how the nation could be." Household food security, on the other hand, "refers to having access to

amount of literature has defined food security in more or less, similar ways. The widely accepted definition, thus far, is the description adapted in the World Food Summit in 1996, which states that food security "exists when all people, at all times, have physical, [*social*], and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (Poppy, et al., 2014). The World Bank, together with United Nations agencies, development aid organizations such as the United States Agency for International Development (USAID) and the *Deutsche Gesellschaft für Internationale Zusammenarbeit* (GIZ) GmbH (German Federal Enterprise for International Cooperation) as well as organizations under the Consultative Group on International Agricultural Research (CGIAR), has accepted this multidimentional nature of food security which includes access, availability, stability, and utilization as part of the overall equation (Poppy, et al., 2014; Tweeten, 1999).

The conceptualization of food security, in general, is through the lenses of availability, accessibility, utilization, and stability (Barrett, 2010; Ericksen, 2008; Schmidhuber & Tubiello, 2007). Aborisade & Bach (2014) declared that to attain and sustain food security, particularly at the global level, a "multi-dimensional approach must be used in formulating and implementing an appropriate strategy." This suggests to take "geography, demography, disposable income, socio-economic status, urbanization, globalization, religion, culture, marketing, and consumer attitude" into consideration in solving the food security equation (Capone, El Bilali, Philipp, Gianluigi, & Driouech, 2014). Figure 1.1 illustrates the hierarchical[12] relationship between availability, accessibility, and utilization. It also shows the overarching role of stability in ensuring food security.

The concept of food security was intially viewed from the narrow production supply lens – that as long as there is enough food produced, food security can be attained. This is the availability dimension of food security, which relates to the ability of the agricultural production system to meet food demand at various sectoral level (i.e., there is adequate quantities of food

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adequate food at all times" but is more forward looking in a sense that it includes expectations of future circumstances and not just the present, which essentially means it accounts for uncertainties. At the individual level, food security is all about the allocation of available food to the members of the household.

[12] Barrett (2010) asserted that the different dimensions of food security are intrinsically hierarchical, "with availability necessary but not sufficient to ensure access, which is, in turn, necessary but not sufficient for effective utilization." Correspondingly, Pinstrup-Andersen (2009) also claimed that "availability does not assure access, and enough calories do not assure a healthy and nutritional diet."

available on a regular basis) (Capone, El Bilali, Philipp, Gianluigi, & Driouech, 2014; Schmidhuber & Tubiello, 2007). In addition to production, Capone, El Bilali, Philipp, Gianluigi, & Driouech (2014) named distribution and trade as the key factors that influence food availability. Lutz, Scherbov, Prskawetz, Dworak, & Feichtinger (2002) also identified "population, poverty, education and gender inequalities" as elements that can "reduce food production," which can result in a "decline in food availability and invariably resulting in food insecurity."

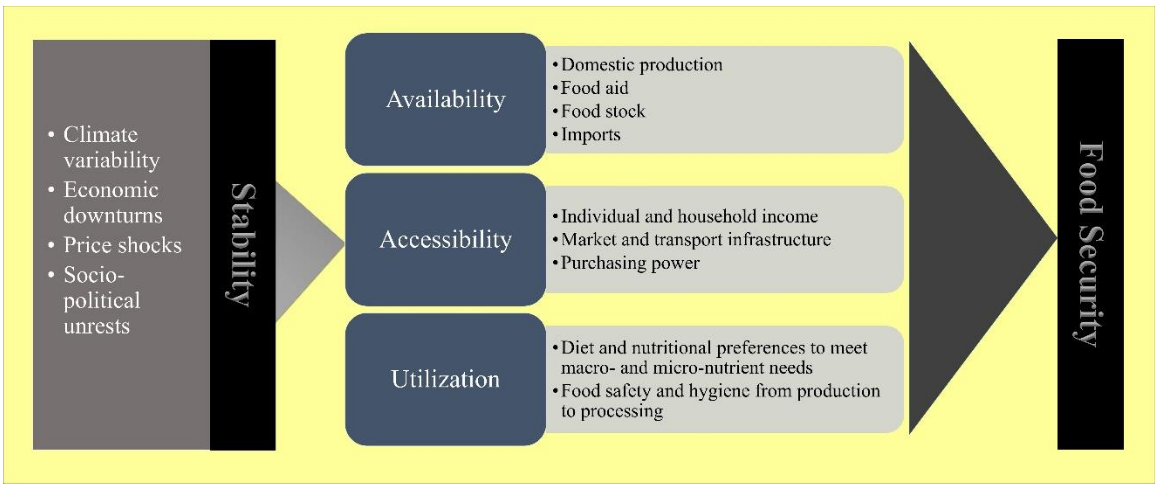

Figure 1.1: Author's schematic representation of the parameters that give multi-dimensionality to food security [with information from (UNICEF, 2014)].

Ericksen (2008) attributed the relevance of access to food as a critical factor of food security as opposed to availability alone according to Amartya Sen[13], who promoted the notion of entitlements and food access.[14] Access to food implies having sufficient means, resources, and entitlements[15] (i.e., purchasing power) to obtain appropriate foods for a nutritious diet (Capone,

[13] Sen brought to the forefront the accessibility issue because he observed in the food famine in Bengal in 1943 that there was enough food available but people suffered hunger because they lack purchasing power due to excessive price of available food and majority has no physical means (i.e., transportation or mode of transfer) to get to areas where food was made available.

[14] According to (Pinstrup-Andersen, 2009), having available food does not assure access and having sufficient "calories do not assure a healthy and nutritional diet."

[15] Entitlements in this context relate to the "purchasing power of consumers and the evolution of real incomes and food prices." Specifically, entitlements are "commodity bundles" that are not necessarily monetary in nature (i.e., traditional rights to share common resources) "over which a person can [use] given the legal, political, economic, and social arrangements of the community of which he or she is a member" (Schmidhuber & Tubiello, 2007).

El Bilali, Philipp, Gianluigi, & Driouech, 2014; Schmidhuber & Tubiello, 2007). Food is accessible if it is affordable[16] and equitably[17] distributed according to people's preferential[18] options (Capone, El Bilali, Philipp, Gianluigi, & Driouech, 2014).

Because of the emphasis of public health on nutritional outcomes, the concept of utilization was recently added into the multi-dimensional nature of food security (Ericksen, 2008). The utilization dimension relates to "appropriate use" of food based on "knowledge of basic nutrition" and sanitation across the food chain (Capone, El Bilali, Philipp, Gianluigi, & Driouech, 2014). As elucidated by Barrett (2010), "utilization reflects concerns about whether individuals and households make good use of the food to which they have access." This means it is not sufficient that an individual receives adequate amounts of food because if the person is unable to use the food for reasons such as illness, for instance, food becomes under-utilized (Schmidhuber & Tubiello, 2007). Food safety as well as nutritional[19] and social values is, therefore, key elements in the aspect of food utilization (Capone, El Bilali, Philipp, Gianluigi, & Driouech, 2014).

The stability parameter refers to the resilient condition of the agricultural, environmental, social, economic, cultural, institutional, and political systems to assure that access, availability, and utilization of sufficient, safe, nutritious, and affordable food is possible (Poppy, et al., 2014; Schmidhuber & Tubiello, 2007).[20] Ecker & Breisinger (2012) asserted the achievability of the stability dimension at both the macro and micro levels, with macro referring to external or

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[16] Food prices play an important role in determining access to food. Godfray, et al. (2010) examined the correlation between global food prices and food availability. The authors found that "poor transport and market infrastructure raise the prices of inputs, such as fertilizers and water," and this resulted in increased costs in production, which in turn influence food price accessibility.

[17] Choudhary & Parthasarathy (2007) articulated that "individual food security depends on various visible and invisible intra-household factors such as gender and age" and household food security does not ensure individual food security since, more often than not, "food available to a household is not equally accessible to the men, women and children of the household."

[18] These preferences are options that are "socially and culturally acceptable and consistent with religious and ethical values" (Pinstrup-Andersen, 2009).

[19] As stated in Farre, Twyman, Zhu,, Capell, & Christou (2011), "food security depends not only on the availability of food but also its nutritional quality."

[20] An important cause of instability in terms of access to food is climate variability. Schmidhuber & Tubiello (2007) described that "landless agricultural laborers, who […] depend on agricultural wages in a region of erratic rainfall and have few savings" are at higher risk of losing access to food. The authors further noted that the same might occur in communities where there is no climate variability. For instance, illness may prevent individuals to earn daily wage that can result in the lack of access to food especially if these individuals "cannot take out insurance against illnesses."

internal balances of a country to ensure aggregate food security. The micro level refers to securing incomes for vulnerable populations so they are financially equipped during regular, seasonal, or sudden food price shocks. Environmental disruption such as disasters and calamities as well as climatic changes that cause extreme weather events can incite food supply, access, and utilization instability in the macro or micro scales.

While food security is undeniably a very important and pressing socioeconomic issue, the concept of food self-sufficiency has recently surfaced up the policy platform of many nations because of the most recent food crisis. Self-sufficiency as reported by Palazzi (1996) is a necessary condition to achieve food security on the aggregate level. Cognizant of the relationship between food security and food self-sufficiency, countries such as the Philippines, Indonesia, Bhutan, Bangladesh, and even the United Kingdom have jumped on board the food self-sufficiency policy agenda.[21]

Autarky

The apparent and potential risks of food shortage at various sectoral levels have set off many governments to adopt autarkic agricultural policies. Studies revealed that these types of policy platforms are commonly taken up in response to food supply volatility, mainly at the global and national scales (Anderson & Strutt, 2014; Chaifetz & Jagger, 2014; Bah, 2013; Ito & Ni, 2013; Aslam, 2009; Amid, 2007; Hassan, Faki, & Byerlee, 2000). Based on these grounds and given the food crisis of 2007 and 2008, policies aimed at food autarky have been recently regarded as the most viable course of action to take.

Autarky is the state of being self-sufficient. In the agricultural context, autarky refers to self-sufficiency in domestic food production without relying on external support. As stated in Palazzi (1996), autarky pertains to the domestic "capacity of a system to produce, independently and without need for external inputs, the quantity of food needed for the physical and social sustenance of all the people belonging to the system." Autarky is domestic food self-sufficiency with zero-import objective (Chaifetz & Jagger, 2014), whereas food security is the capability of a

[21] See Bishwajit, et al., (2013), Warr (2011), Peljor & Minot (2010), Deb, Hossain, & Jones (2009), and Barling, Sharpe, & Lang (2008) for more information.

system to cater the same amount of food to all the members of the system by whatever means i.e., through local production or imports.

Increasing self-sufficiency with respect to food has been regarded as a critical factor in attaining agricultural sustainability i.e., if a country increases its level of self-sufficiency, it will translate to an increase in food security (van Dartel & Nigten, 2014; Bah, 2013; Thomson & Metz, 1998). Studies, however, claim that though the intents of a self-sufficient food policy are similar to the motives behind food security agenda, food security is not necessarily synonymous to agricultural autarky (Anderson & Strutt, 2014; Timmer, 2012; Warr, 2011). Schmidhuber & Tubiello (2007) asserted that self-sufficiency, which is based on the proportion of domestic food produced to the total food consumed locally,[22] is "neither necessary nor sufficient to guarantee food security."[23] Some research, in fact, has shown that food self-sufficiency is economically desirable only for certain crops (Chaifetz & Jagger, 2014).

As a development policy by itself, agricultural autarky or food self-sufficiency has been criticized to be ineffective to address food security concerns. Ito & Ni (2013) and Thomson & Metz (1998) stressed that food self-sufficiency policies have certain degree of autonomy that is very "auto-centric" and such policy strategy places greater emphasis on the need for self-reliance and does not take into consideration the concept of comparative advantage. Anderson & Strutt (2014) and Warr (2011), for instance, expressed that import-restrictive measures under a food self-sufficiency regime may boost domestic farm outputs due to reduced import competition, but at the same time it can lead to high commodity prices, which can translate to a decline in the range of food available for domestic consumption.[24] For these reasons, food self-sufficiency has been on the periphery of the agricultural policy regimes until recently when food staples with very thin markets[25] such as rice, maize, and wheat experienced commodity price shocks.

[22] This refers to self-sufficiency ratio (SSR) and it excludes stock changes (Thomson & Metz, 1998).
[23] The authors argued that although agriculture is non-existent in countries like Singapore and Hong Kong, citizens are food secure. In India, self-sufficiency in agriculture is very much possible, however, millions of people remain food insecure. Anderson & Strutt (2014) observed that self-sufficiency of certain staples in China has not hampered food insecurity of a large portion of its population.
[24] More often than not, this is the case according to Hassan, Faki, & Byerlee (2000) because under a food self-sufficiency policy, food crop expansion is favored over cash crop production, which then leads to inefficient allocation of productive agricultural resources due to non-comformity to a nation's agricultural comparative advantage.
[25] Thin markets pertain to food staples not being traded internationally in great amounts, which in the case of the 2007 and 2008 food crisis, "pushed prices up and created difficulties for all importers" due to "increased demand from more than one major importer" (Thomson & Metz, 1998).

To minimize the risks associated with unreliable food supply and fluctuating prices, many countries, of late, have adopted autarky or self-sufficiency as the national agricultural policy banner. Several countries have historically experimented with food self-sufficiency. In the 1980s, several African nations have food self-sufficiency as part of their core agricultural policies as reflected in the Lagos Plan of Action (Hassan, Faki, & Byerlee, 2000). Zimbabwe explicitly made maize self-sufficiency as its agricultural policy. Sudan also attempted self-sufficiency in wheat (Chaifetz & Jagger, 2014; Siddig & Mubarak, 2013). More recently, Sierra Leone aimed for rice self-sufficiency with the target of increasing yield to two metric tons per hectare (Bah, 2013).

In Asia and the Pacific region, China, Indonesia, Iran, and the Philippines are among the handful of countries that advocated agricultural autarky at various points in history (Anderson & Strutt, 2014; Chaifetz & Jagger, 2014; Ito & Ni, 2013; Warr, 2011). In the 1980s, Iran ventured in the wheat self-sufficiency business. Despite consistent growth, the country failed to achieve self-sufficiency two decades later (Chaifetz & Jagger, 2014).

China reiterated its commitment to self-sufficiency in food staples in 2008 (Ito & Ni, 2013). The Chinese government has managed to keep its food self-sufficiency policy until recently when the share of its farm products to its total imports has declined. Part of the success of the food self-sufficiency program in China is attributed to the the country's substantial investment towards agricultural research and development, which in 2008 accounted for 0.50 percent of China's agricultural gross domestic product (GDP) (Anderson & Strutt, 2014).

Bah (2013) construed that a wide array of physical, biological, cultural, socioeconomic, political, institutional, and technical elements inhibit engagement to agricultural autarky. These challenges associated with implementing a food self-sufficiency program, however, did not deter countries to make it the heart of their agricultural agenda given the aftershocks of the 2007 and 2008 food price and supply crisis. In Southeast Asia, Indonesia and the Philippines favored rice self-sufficiency. Even prior to the volatility of agricultural commodity prices in 2007 and 2008, Indonesia has already advocated for rice self-sufficiency in 2004 by imposing very stiff tariffs on rice imports (Warr, 2011).

In 2012, the Government of the Philippines promoted rice self-sufficiency through its Food Staples Sufficiency Program (FSSP). The Program aims to increase rice staples from 15.77

million metric tons in 2010 to 22.73 million metric tons in 2016. To attain this target, the Philippine government advocated a classical approach through "improvement in physical and institutional infrastructure such as irrigation and research extension systems" (Chaifetz & Jagger, 2014). Further, cognizant that one of the most effective measures to secure self-sufficiency is to "regulate the conversion of farmland for other uses and then enhance land productivity" (Ito & Ni, 2013), the Philippine government proposed expansion of rice plantation and irrigation areas to complement introduction of high yielding varieties and widespread mechanization of the rice industry.

Food self-sufficiency continues to be an appealing agricultural policy option for many countries. Even if this policy strategy has an elusive success rate and doubts have been cast over its feasibility, the Philippines remains optimistic that food self-sufficiency is a viable goal. With the confidence placed over this food policy, it is imperative to focus the spotlight on the plausibility of the Food Staples Sufficiency Program (FSSP) in the Philippines.

Strategic Efforts to Confront Staple Food Production Issues

Rice, maize, and wheat are considered as the world's three most essential staple[26] food according to the Food and Agriculture Organization of the United Nations (FAO). The significance of these crops is far-reaching as they provide 60 percent of the food energy intake of more than 4 billion people (FAO, 1995).[27] On that account, the provision of adequate staple food has been an economically important and politically sensitive issue in both developed and developing nations.

At times when ration of staple food is threatened by price volatility and supply instability such as the precarious agricultural dilemma of 2007 and 2008 as well as certain periods in 2011 and 2012 (von Braun, Algieri, & Kalkuhl, 2014), governments step in to formulate and implement agricultural policies and programs to address unprecedented effects that staple food price shocks may bring. The World Bank (2008) has classified common policy interventions into: (1) interventions that strengthen targeted safety nets to ensure household food security, (2)

[26] A food is considered staple if it "is eaten regularly and in such quantities as to constitute the dominant part of the diet and supply a major proportion of energy and nutrient needs" of the population according to the FAO (1995).
[27] Approximately, an individual spends 70 percent of the income on staple food commodities (von Braun, Algieri, & Kalkuhl, 2014).

domestic food price interventions through short-run trade policy measures or administrative action, and (3) interventions to enhance longer-term food supply.[28] These categories are akin to the food policy measures examined by Adelman & Berck (1989)−agricultural commodity price stabilization policy, food import bill insurance, food aid, food price subsidy intervention, and food self-sufficiency policy through productivity-enhancing agricultural investments.

Because of the gravity of the impacts brought by the recent crash in staple food prices, governments formulated short-, medium-, and long-term policy strategies to influence the sphere of decision-making at the producer and consumer levels. Cash transfer for vulnerable groups as well as food-for-work programs and food aid distributions were the immediate policy schemes applied to address the food dilemma. To foster agricultural growth, the World Bank noted in a review that the typical policy response of governments to the staple food price shocks was to stimulate domestic production, which explicitly or implicitly involves subsidies for agricultural inputs (Independent Evaluation Group, 2013). Some countries used buffer stocks, levied hefty tariffs on food imports, and imposed export bans and restrictions to increase domestic production, to guarantee supply and to raise agricultural revenue and affordability of staples.

The Governments in Sub-Saharan Africa, for instance, have put into effect price control strategies, import tariffs, export restrictions, and input subsidies among others. Staatz, Dembélé, Kelly, & Adjao (2008) recognized how Niger, Burkina Faso, Mali, Senegal, Cameroon, and Nigeria implemented tariff relief policies as part of its larger food security agenda. Correspondingly, increases in public-sector wages and food subsidies were the favored food policy measures in the Middle East (IFPRI, 2013).

Brazil, Mexico, Honduras, and Madagascar in the Latin American region have implemented cash transfers, school feeding, and food-for-work programs as part of the policy options to address rising staple food prices (World Bank, 2008). In more industrialized countries such as Norway, the utilization of buffer stocks has been central to its food security policy (Torres, Rojas, & Torres, 2007). In the European Union, the Common Agricultural Policy according to Peters & Pierre (2014) has been providing substantial subsidies to the farmers to secure the Union's food supply stability.

[28] For more information on the implementation of the policies in different countries, see World Bank (2008).

In Asia and the Pacific region, the Government of Nepal doubled its fertilizer subsidy in 2013 from US$35 million to approximately US$63 million (IFPRI, 2013). India and Viet Nam, on the other hand, introduced rice export bans in 2007 and 2008 to protect its domestic market from the transmission of increasing international food prices (Pinstrup-Andersen, 2014). To assure adequate domestic food production, China has been raising its public investments on agricultural research and development at a rate greater than India and Brazil (IFPRI, 2013).

Following the dramatic swings in staple food prices in 2007 and 2008, the island nations of Indonesia and the Philippines in Southeast Asia advocated food self-sufficiency policy interventions through investments in productivity-enhancing programs. The Indonesian Government adopted the "Food Self-Sufficient Villages" policy measure, which advocates food self-sufficiency at the lowest level of the society through diversification in food consumption (Salim, 2010). The Philippines, on the other hand, launched the "Food Staples Sufficiency Program" (FSSP) in 2012. The FSSP includes short- and long-term investments on agricultural research and development as well as extension systems and agricultural infrastructure such as roads, irrigation, and market places.

The autarkic policy measures implemented in Indonesia and the Philippines aim to mitigate the effects of the sudden price surges on staple foods in 2007, 2008, and certain periods in 2011 and 2012. With the food self-sufficiency policy, the Indonesian and Philippine Governments hope to build agricultural resilience in the longer-term. In recognition of the role that the food self-sufficiency interventions play in the future of the agricultural sectors in these countries, particularly, the Philippines, the need to examine staple food self-sufficiency strategies is imperative.

Staple Food Production and Consumption in the Philippines

Rice constitutes the dominant part of the Filipino diet and as such, it is the most important food crop staple in the Philippines. With an average staple food production proportion of greater than 50 percent from 2002 through 2013, rice has consistently dominated the total volume of crop staples domestically produced in the Philippines in the last decade (Figure 1.2). Compared to other staples consumed locally such as white corn, banana (*saba*), and root crops such as cassava (*kamoteng kahoy*) and sweet potato (*kamote*) with single digit rate increase in area harvested, rice production area increased by 17 percent in the same period (BAS, 2014a). Data from the Bureau of Agricultural Statistics (BAS) showed that the area expansion translated to a moderate increase of 18 percent in yield per hectare, whereas in the same span of time, yield per hectare for corn, banana, cassava, and sweet potato increased by 60, 21, 39, and 24 percent, respectively (BAS, 2014a; BAS, 2014b).

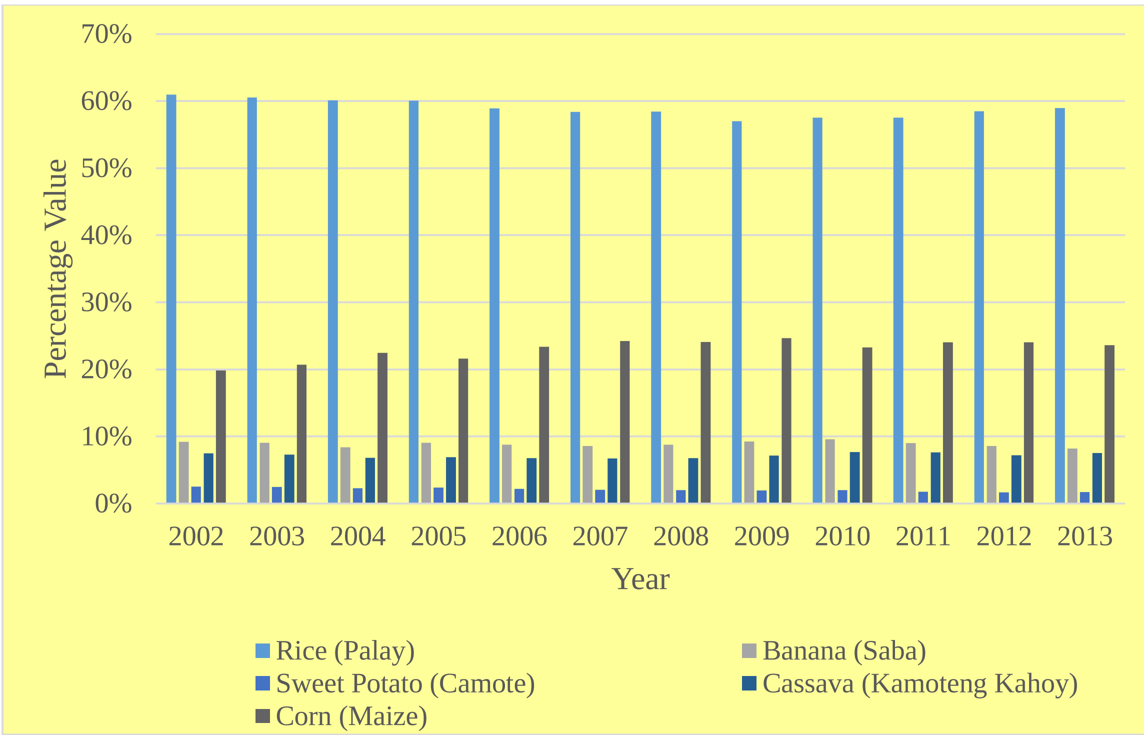

Figure 1.2: Percentage volume share of food staples in the Philippines (2002-2013).
Note: Author's estimates based on data from the Bureau of Agricultural Statistics (BAS, 2014b).

Despite modest growth in production, rice remains the main staple of nearly 100 million Filipinos. Majority of the population derive a considerable proportion of their energy and nutrient needs from rice. In 2009, rice provided 47 percent of the caloric intake of Filipinos (Figure 1.3). The Bureau of Agricultural Statistics (BAS) reported that, on average, a Filipino consumed 114.27 kilograms of rice in 2012.[29] This food consumption share of rice has been steady at 45 percent or more from 1999 through 2012 (Table 1.1).

[29] Since 2005, the Philippines has been consistently ranked as one of the top ten countries with per capita rice consumption over 100 kilograms per year across income groups in both urban and rural areas (IRRI, 2014).

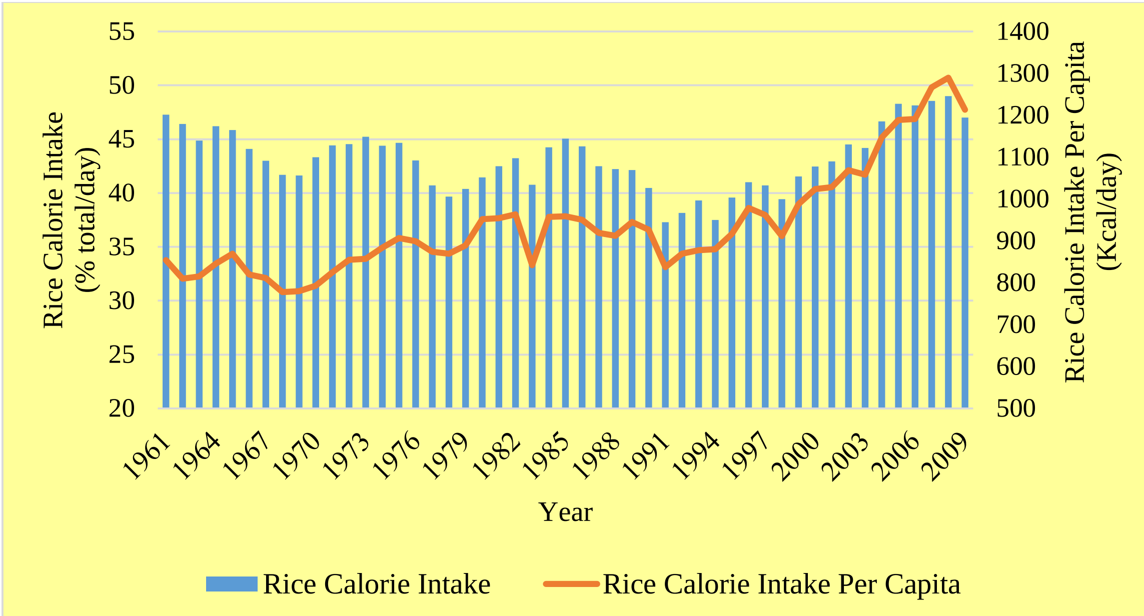

Figure 1.3: Rice calorie intake of Filipinos as a percentage of total daily supply.
Note: Author's computation based on data from IRRI (2013).

Table 1.1: Annual per capita consumption of agricultural commodities in the Philippines (1999-2000, 2008-2009, 2012).

Commodity Consumed *(in kilograms/capita)*	**2012**	**2008-2009**	**1999-2000**
Total: Rice Consumed	114.27	119.08	105.77
Total: ALL Other Food Consumed[30]	129.13	108.00	170.51

Note: Calculations are from data available from the Bureau of Agricultural Statistics (BAS, 2013a).

The Family Income and Expenditure Survey (FIES) conducted by the National Statistics Office every three years revealed that rice and other cereal-based products have the largest share of expenditure to total food expenditure. In 2012, food accounted for 42.8 percent of the total family expenditure (National Statistics Office, 2013). Of this proportion, allocation to rice and other cereal-based products is approximately less than 30 percent.

With an average population growth rate of about two percent in the last two decades (National Statistics Coordination Board, 2014), demand for rice is projected to intensify. In light

[30] All other food includes food crops such as bananas, potatoes, cassavas. Livestock and dairy products as well as fish and seafood products are also included in the "ALL other food" category.

of this forecast and cognizant of the importance of rice to Filipinos, the Government of the Philippines has been formulating policy options and specific interventions to ensure supply and affordability of the resource. Of late, the "Food Staples Sufficiency Program" (FSSP) has been the flagship program of the current administration to boost agricultural productivity of food staples, particularly rice, and to make Filipino farmers globally competitive (Department of Agriculture, 2012).

Food Staples Sufficiency Program (FSSP) in the Philippines

In pursuit of developing an enabling environment for inclusive growth which refers to "sustained growth that creates jobs, draws the majority of the population into economic and social mainstream, and reduces mass poverty" (NEDA, 2011), the Government of the Philippines formulated the Philippine Development Plan (PDP) for 2011-2016. The PDP provides the broad strokes of direction, priorities, and strategies that the country should carry on and enforce. The plan embodies the current administration's (President Benigno Simeon Aquino III's Administration) 16-point agenda or social contract with Filipinos, which includes food security[31], infrastructure development, and sustainable use of natural resource endowments.

To achieve the goals of the food security agenda, the Government of the Philippines launched the "Food Staples Sufficiency Program" (FSSP) in 2012. The FSSP aims to bring equitable economic growth in farming communities by improving agricultural productivity. The Program recognizes that "food insecurity and mass poverty in agriculture cannot be solved within the sector alone" and that the dynamic linkages between agriculture and other related sectors must be taken into consideration in formulating feasible solutions (Department of Agriculture, 2012).

The FSSP targets to substantially reduce rice imports and increase the country's crop staple self-sufficiency ratio to 100 percent. Data show that among the major domestic crop staples, rice has the lowest self-sufficiency ratio (Figure 1.4). To narrow and eventually eliminate this gap, the FSSP aims to increase rice staple production from 15.77 million metric tons in 2010 to 22.73 million metric tons in 2016. To achieve this target, production must grow by six percent

[31] The 7th agenda: "From treating the rural economy as just a source of problems to recognizing farms and rural enterprises as vital to achieving food security and more equitable economic growth, worthy of re-investment for sustained productivity."

per year (Department of Agriculture, 2012).[32] This implies that area harvested must grow by 15 percent in 2016 and irrigation service area must expand from 1.5 to 1.7 million hectares between 2011 and 2016. Accordingly, within the span of less than a decade, rice production should increase by 44 percent and yield per hectare by 25 percent.

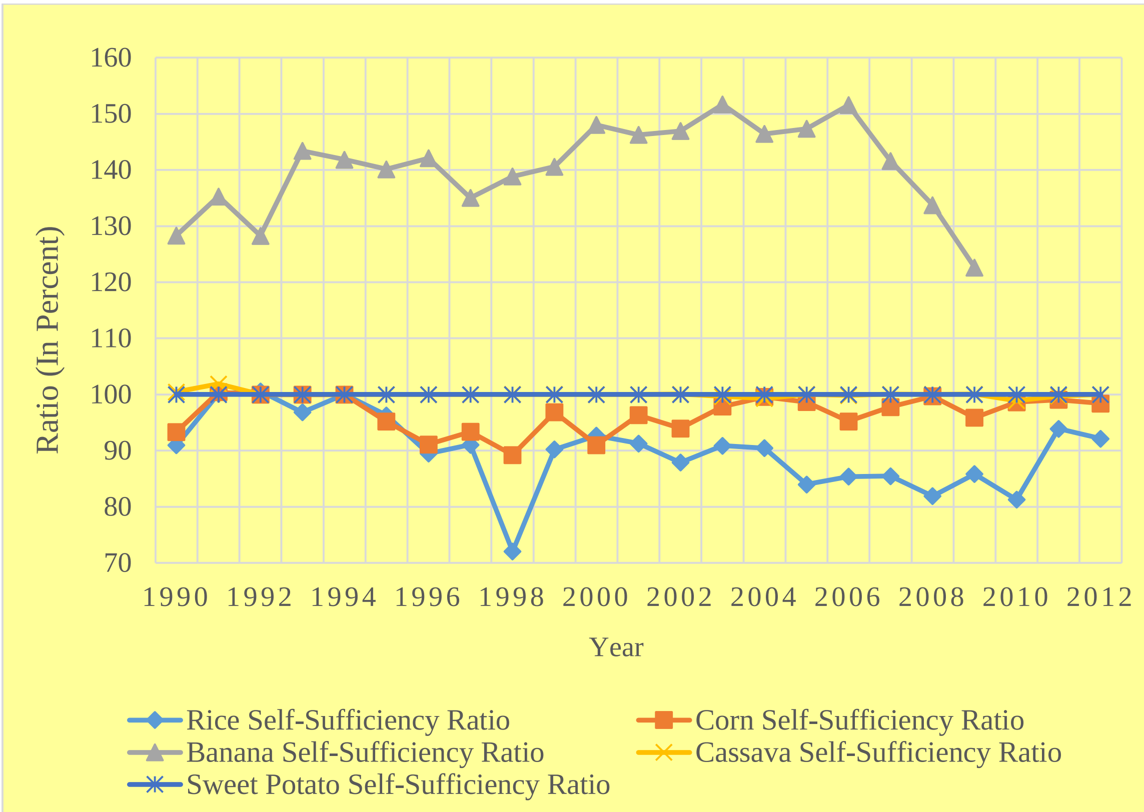

Figure 1.4: Food crop staple self-sufficiency ratio (1990 to 2012).
Note: Chart derived using data from the Bureau of Agricultural Statistics (BAS, 2013b).

Although the FSSP targets may seem aggressive, the policy measure, in general, is actually conservative since it "prioritizes traditional crops with production targets designed to close the domestic supply and demand gap" (Briones, 2013). The Department of Agriculture (2012) recognizes that when attained, the FSSP targets serve as an insurance for the country

[32] This suggests that harvest area needs to expand by at least two percent annually and yield should grow by four percent per year at the minimum (Department of Agriculture, 2012).

against world trade shocks and unprecedented social and political unrest as well as environmental disasters in key rice exporting nations.[33] The ultimate realization of the FSSP goals lies on the successful implementation of strategies and innovations incorporated in the program, which range from import reduction, increased public investment in agricultural infrastructure, equipment, and irrigation as well as substantial funding for research and extension.

Strategies and Interventions

To achieve the food staple sufficiency targets, the Philippine Government has formulated three main suites of strategies. These strategies include: (1) raising productivity and competitiveness, (2) enhancing economic incentives and enabling mechanisms to increase and sustain improvement in production, farm mechanization and post-harvest technologies, and (3) managing demand. Under each of these strategies, the Government of the Philippines has identified specific interventions or activities that would help attain the target (Table 1.2).

With approximately 75 percent of the rice produced in the Philippines are generated from irrigated ecosystems (BAS, 2014b), expansion of irrigation services is a priority intervention to raise productivity and competitiveness. By boosting investments in large- and small-scale irrigation projects, the Food Staples Sufficiency Program (FSSP) targets to increase irrigated harvest area by more than 800,000 hectares in 2016 or approximately 36 percent larger than the 2011 area harvested (Department of Agriculture, 2012). Improvement in cropping intensity by prioritizing irrigation development in areas that have potential for two or more cropping per year complements the wide-scale irrigation program.

To further enhance rice productivity and competitiveness in the country, the Philippine Government targets to widen the adoption of high quality in-bred and hybrid seeds that is projected to increase average yield to 5-6.5 metric tons per hectare (Department of Agriculture, 2012). Enhancement in research and development as well as delivery of extension services is

[33] According to the Department of Agriculture, 84 percent of global rice exports are controlled by only five countries—Viet Nam, Thailand, India, Pakistan, and the United States. This suggests an unofficial rice trade oligopoly making trade transactions subject to political decisions of only a handful of nations. Any social, political, economic, environmental, and agricultural turmoil in any of these countries may cause serious impacts on global rice trade.

another key intervention that can help promote the acquisition and utilization of farm machineries and equipment to boost efficiency and reduce production costs. Further, extending the rice productivity and competitiveness interventions to high elevation and upland ecosystems is projected to significantly raise awareness and production in upland communities where traditional farming system is widely practiced.

Table 1.2: Strategies, interventions, and activities under the Philippines' Food Staples Sufficiency Program (FSSP).

Strategy	Specific Interventions and Activities
Raise Productivity and Competitiveness	
Accelerate expansion of irrigation services.	• Prioritize rehabilitation and restoration of existing facilities and construct new irrigation systems. • Improve efficiency of irrigation systems through system modernization and integrated water resource management. • Frontload investments from 2011 to 2013 to accelerate area expansion and realize the benefits within the plan period. • Improve cropping intensity. • Invest in small-scale irrigation systems to serve areas that are not reached by large-scale facilities.
Ensure (i) adoption of suitable high quality seeds and (ii) increased used of fertilizers and other integrated crop management practices.	• Develop effective crop production systems and strengthen seed linkages and networks. • Strengthen seed certification activities through improvement and upgrading of national, regional, and satellite seed testing facilities. • Work with private seed growers to raise production capacity and improve distribution of high quality seeds. • Maintain buffer seeds stocks equivalent to ten percent of planting requirement in the wet season and five percent in the dry season in all regions and provinces to ensure availability of quality seeds during calamities and crop failure. • In partnership with local government units (LGUs), private seed growers, and farmers' organizations, establish community seed banks to maintain the required buffer seed stock and promote an informal system of seed exchange in areas that are not adequately served by the private markets. • Reduce the gap between optimal and actual rates of nitrogen use by enhancing farmers' access to credit and insurance. • Maximize the utilization of farm wastes and locally available biomass including non-burning of rice straws. • Promote supplementary irrigation in rainfed areas to optimize timing and rates of fertilizer application. • Conduct soil analysis and soil fertility maps for all rice producing areas. • Conduct effective surveillance and monitoring of pests and diseases at the local level.

Strategy	Specific Interventions and Activities
	• Conduct training and provide technical assistance by government extension workers and selected farmer-leaders.
Sustain research and development in new varieties and crop management.	• Develop location-specific technologies to accelerate adoption of new technologies suited to local conditions. • Develop technologies to break the low rice yield barriers in rainfed, upland, and other adverse environments. • Develop technologies to surpass the dry season irrigated lowland rice yield plateau. • Develop natural products and value-adding systems for rice. • Conduct impact evaluation, policy research, and advocacy.
Promote mechanization of on-farm and post-harvest operations.	• Promote the acquisition of appropriate farm machinery to bolster efficiency, ensure timeliness of farm operations, and lower unit costs. • Provide appropriate drying facilities to reduce farmers' dependence on conventional drying methods (e.g., drying *palay* on highway) that result in loss of *palay*.[34] • Modernize the rice milling industry to increase milling rates. • Provide affordable access to appropriate farm machinery through distribution to qualified beneficiaries, establishment of service centers, and pooling of equipment.
Enhance the effectiveness and strengthen the delivery of extension services.	• Adapt the *Farmer Field Schools* and other extension modalities to fit the priority technology and information needs of farmers in locality. • Upgrade technical and facilitation skills of extension workers at the farm level. • Organize farmers, and strengthen existing cooperatives and organizations. • Strengthen monitoring and evaluation of rice extension programs.
Boost yield growth in rainfall areas.	• Promote supplemental irrigation such as small farm reservoir (SFR), shallow tube wells (STWs), and pump irrigation system from open sources (PISOS). • Encourage use of high-quality seeds of appropriate varieties of rice and other crops. • Promote nutrient management appropriate to rainfall areas. • Provide extension services and training on *Palayamanan*.[35] • Extend credit and insurance for rice and other crops.
Harness the potential of high-elevation and upland rice ecosystems.	• Promote sustainable farming systems and practices in upland communities, thereby increasing farmers' income. • Establish a seed propagation program and production protocols for traditional and modern rice varieties suitable to specific areas.
Enhance Economic Incentives and Enabling Mechanisms	
Market reforms.	• Strengthen price support and procurement policy. • Allow market forces greater role in setting retail prices.

[34] *Palay* refers to unmilled rice.

[35] *Palayamanan* is an integrated rice-based diversified farming system developed and established by the Philippine Rice Research Institute (PhilRice) that synergistically combines farming ventures such as rice, onion, poultry, livestock, and aquaculture (Corales, et al., 2004).

Strategy	Specific Interventions and Activities
	• Implement reforms to enable the National Food Authority (NFA) to perform effective price support and procurement functions.
Strengthen credit provision to small farmers through credit sector reforms, improved credit guarantee programs, and innovations in credit delivery.	
Expand insurance coverage by strengthening institutional capacity and developing innovative products that address farmers' needs.	
Manage Food Staples Consumption	
Diversify food staples consumption by intensifying production of other staples including white corn (maize), cassava (*kamoteng kahoy*), sweet potato (*kamote*), and banana (*saba*).	
Encourage the consumption of unpolished or brown rice.	
Reduce food wastage.	

Note: Tabulated information are copied from a document from the Department of Agriculture (2012).

The Food Staples Sufficiency Program (FSSP) also offers economic incentives to farmers to catalyze enhanced production. One of the primary stimuli is setting support prices that would gurantee reasonable returns to farmers. Enhancement in credit delivery and insurance coverage, in cooperation with the Land Bank of the Philippines (LBP) and the Philippine Crop Insurance Corporation (PCIC), is one of the basic FSSP enabling mechanisms to provide opportunities to farmers who do not readily have access to loans and crop insurance services.

The majority of the preceding FSSP activities are measures that address the supply side of rice production. To address the demand side, the FSSP includes mechanisms that manage food staple consumption. For one, FSSP promotes the consumption of unpolished rice such as brown rice since they have a higher milling recovery rate. In addition, to divert high reliance on rice as the main food crop staple, the FSSP includes diversification of food staples by including corn, cassava, sweet potato, and banana as part of the daily diet of Filipinos. A campaign to reduce rice wastage, which was estimated at an annual rate of 300,000 metric tons in 2008 (Department of Agriculture, 2012), is also a vital intervention to manage rice demand.

As a wide-ranging program that seeks to cover both the supply and demand side of rice production, the FSSP is coming on strong to attain staple food self-sufficiency in the Philippines. Since its commencement, the Philippine Government has made certain milestones in attaining the FSSP targets. The Department of Agriculture (DA) recently reported that the government is on track in achieving the FSSP objectives.

Program Achievements Thus Far

Three years since the Philippine Government set its focus on the ambitious goal of achieving staple food self-sufficiency as early as 2013[36], the FSSP has made significant progress towards such goal. To meet the specific Program targets, the national government has substantially increased budget allocation to the Department of Agriculture (DA). From Ph₱ 86 billion in 2010, the agricultural budget increased by 29 percent to Ph₱ 111 billion in 2013 (Department of Budget and Management, 2014). The growth in agricultural expenditures is a testament to the government's commitment to reform the country's agricultural sector and pave the way to achieve staple food self-sufficiency.

In terms of specific FSSP accomplishments, DA has largely focused on the supply-side interventions. More specifically, the efforts have largely centralized on raising productivity and competitiveness of staple food crops, particularly rice. For one, DA infused massive infrastructural investments to accelerate expansion of irrigation services.[37] In the span of three years, DA has also widened the adoption of climate-resilient and heirloom rice varieties across the country. Credit sector and insurance reforms have been implemented through the *Sikat Saka Program* (SSP).

<u>Expansion of Irrigation Services</u>. The National Irrigation Administration (NIA) (2014) has estimated that there are 3.01 million hectares of potentially irrigable areas around the country. Of these, approximately 1.54 million hectares were irrigated in 2010 either under the national irrigation systems (NIS), communal irrigation systems (CIS), or under private irrigation systems (PIS). With budget infusion from DA, NIA has increased irrigation service areas to 1.68 million hectares in 2013 (Department of Agriculture, 2014). The Autonomous Region of Muslim Mindanao (ARMM) had the highest percentage increase of irrigated areas at 90 percent. From only 23,870 hectares of irrigated areas in 2010, ARMM has 45, 306 hectares of irrigable areas at the end of 2013. The regions of Cagayan Valley and Western Visayas also had substantial gain

[36] The President of the Philippines declared 2013 as the National Year of the Rice.
[37] Since 2011, the National Irrigation Administration accounts for 40 percent of the total budget allocated to the Department of Agriculture (Department of Agriculture, 2014).

in irrigable areas in 2013 with 31 percent and 44 percent increase, respectively (National Irrigation Administration, 2014).[38]

Development and Adoption of High Quality Seeds. In collaboration with the Food and Agriculture Organization of the United Nations (FAO), the Department of Agriculture has been developing and testing stress-tolerant and climate-resilient rice varieties known as the Green Super Rice (GSR). At present, six lines of the GSR are being tested across regions in the country. The average yield per hectare for GSR lines adopted in 35 drought-prone sites is 4.72 metric tons, which is 21 percent greater than the best recorded yield per hectare in 2013 (Department of Agriculture, 2014).

To complement the development of new high quality seeds, DA in partnership with the International Rice Research Institute (IRRI) launched the Heirloom Rice Project (HRP). The goal of the project is to enhance the productivity and enrich legacy of traditional or heirloom rice varieties mainly produced in Philippine uplands. DA and IRRI have been holding training to preserve heirloom rice varieties in the Cordillera Autonomous Region (CAR) and certain areas of Mindanao such as the Arakan Valley Complex and Lake Sebu in Cotabato, where traditional rice varieties dominate rice production of local farmers (IRRI, 2015).

On-Farm and Post-Harvest Investments and Mechanization. With regard to on-farm production-related mechanization, the FSSP has surpassed most of its targets. DA reported that it has provided two percent more transplanters, four percent more reapers, and 43 percent more sprayers to farmers in the last three years than originally targeted. Progress in post-harvest mechanization has also been attained in 2013. The Department has reached 74 percent and 58 percent of its goal of providing threshers and multi-purpose drying facility, respectively (Department of Agriculture, 2014). On top of exceeding some of the mechanization targets, approximately 2,361 kilometers of farm-to-market roads have been constructed since the implementation of the FSSP (Department of Public Works and Highways, 2014).

[38] As of 2013, NIA manages 237 NIS nationwide with a total service area of .80 million hectares and firmed-up service area (FUSA) of .72 million hectares. In the 2012-2013 cropping seasons, the total irrigated area was 1.8 million hectares: .55 million hectares during the dry season (November 2012 to April 2013), .58 million hectares during the wet season (May 2013 to October 2013), and .05 million hectares for the third crop. In 2013, the country attained an irrigation cropping intensity of 146.5% based on the service area or 163% based on FUSA (National Irrigation Administration, 2014).

Enhancement of Extension Services. Under a collaborative agreement with IRRI, the Philippine government through the Philippine Rice Research Institute (PhilRice) is implementing the adoption of computer-based decision support tools to help farmers in managing nutrient supply as well as pest and insect infestations. Rice Crop Manager and the Fertilizer Requirement Calculator are two of the tools that extension workers are using to help farmers determine the quantity of nutrients to use and timing of application. If used accordingly, these decision-support tools can possibly help farmers reduce their nutrient expenditures and increase their incomes to as much as Ph₱ 4,500 per hectare per cropping. Patent for the Fertilizer Requirement Calculator is currently pending (Department of Agriculture, 2014).

Strengthened Credit Provision and Crop Insurance Coverage. As part of the FSSP, DA teamed-up with the Land Bank of the Philippines (LBP) to launch the *Sikat Saka Program* (SSP), a lending program that gives farmers direct access to credit through their respective irrigator's associations. At present, SSP is available at 25 major rice-producing provinces in the country (Land Bank of the Philippines, n.d.). Since it commenced in 2012, SSP has released Ph₱ 464 million of loans to 5,833 small farmers nationwide (Department of Agriculture, 2014). In addition to loans at affordable interest rates, the SSP also has a crop insurance component, which makes the loan program not only a credit instrument but a vital risk-management tool at the event of natural calamities, pest infestations, and disease outbreaks. The SSP, together with the National Irrigation Administration's Early Cropping (Crop Insurance) Program and the Weather-Adverse Rice Areas (Crop Insurance) as well as the DA's regular insurance program (Rice Insurance Program), has dramatically increased enrollment in crop insurance programs by 139 percent in 2013 with more than 855,000 farmers insured (Department of Agriculture, 2014).

With the above interventions in place, the Philippines has achieved 96 percent rice self-sufficiency ratio at the end of 2013 compared to only 81 percent in 2010 (BAS, 2013b). The 15 percent rise in the ratio is remarkable since many of the large rice-producing regions in the country were under severe natural and climatic disasters in the last three years.[39] From 2010 to

[39] On an annual basis, an average of 20 typhoons, tropical storms, and tropical depression pass by the Philippine Area of Responsibility (PAR). Some of the strongest and most destructive typhoons in history hit the Philippines in 2011 (local names: *Pedring* and *Sendong*), 2012 (local name: *Pablo*), and 2013 (local names *Santi* and *Yolanda*). The damage sustained by agricultural sector from these disasters amounted to Ph₱ 87 billion (Department of Agriculture, 2014).

2013, the country has also reached its national best productivity in the rice sector with 18.44 million metric tons of domestically produced rice (BAS, 2014b). This production rate translates to an all-time high average yield per hectare of 3.89 metric tons in 2013 in contrast with 3.62 in 2010 (Department of Agriculture, 2014).

Along with the historical domestic productivity achievements in the rice sector, the Philippines has also drastically reduced reliance on rice imports in the last three years. In 2013, the country has reduced its rice imports by almost 89 percent from 2.36 million metric tons in 2010 to merely 272,000 metric tons at the end of 2013 (Department of Agriculture, 2014). Since FSSP commenced, the rate of rice importation has not only declined but has been consistently lower than the nationally authorized import quantity.

Future Prospects for the FSSP

The Department of Agriculture (DA) remains committed to achieving 100 percent rice self-sufficiency before 2016. DA aspires to maintain the continued success of the interventions implemented. At the same time, the Department seeks to sustain inflation of agricultural commodities at 3.5 to 4.5 percent, particularly staple food. To do this, the Department, through the FSSP, aims to add to 210,000 hectares more of irrigated agricultural lands so that by 2016 there will be a total of 1.89 million hectares with irrigation services (Department of Agriculture, 2014). DA also plans to upscale the adoption of the different lines of Green Super Rice to help farmers increase their incomes.

With the upcoming implementation of the ASEAN Economic Community at the end of 2015[40], DA is gearing itself in providing enabling mechanisms to local farmers to be at par and competitive with their counterparts from other member states. Since import and export tariffs are eliminated under the AEC, DA is providing capacity building support to local farmers and growers so that domestic agricultural produce will meet regional quality standards. If rice self-sufficiency is achieved before the AEC commences, the Department intends to capitalize on its

[40] The Philippines is a member state of the Association of Southeast Asian Nations (ASEAN). Together with Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Singapore, Thailand, and Viet Nam, the Philippines by the end of 2015 will embark into the ASEAN Economic Community (AEC). As one regional community, there will be free movement of capital, goods, investments, services, and skilled labor between and among the ten nations.

infant yet niche export market of organic red and black rice, which is already cultivated in various parts of the country and is currently in demand in the Middle East and in North America (Anonymous, 2015; Anonymous, 2014). Overall, DA plans to increase agricultural exports, including rice, by 9.5 to 10.5 percent by 2016. Given all these prospects, DA projects that agricultural labor productivity should see a two to five percent improvement by 2016 (Department of Agriculture, 2014).

Achieving the FSSP Target through Biophysical Expansion of Rice Production

One of the approaches to address food supply concerns is to spur factor accumulation in the agricultural sector. As a system of devoting additional stocks of fixed and variable production inputs, factor accumulation, also known as agricultural extensification, is the conventional practice of inciting agricultural production mainly by bringing more land for cultivation (Godfray & Garnett, 2014; Springer & Duchin, 2014). This strategy is only plausible if land, the primary platform for any agricultural activity, is an unlimited resource. However, since land, particularly agricultural areas, is becoming a scarce resource, it is imperative that lands are allocated to crops that they are more suitable to.

Making decisions on the use of scarce resources is more often than not complex and multifaceted since it involves resource allocation options. Agricultural land extensification, therefore, asserts the need to examine how attributes of a particular area when combined with land utilization properties influence the determination of intended use. In support of staple food self-sufficiency, agricultural extensification requires an assessment of a wide range of sites based on a set of criteria that are defined by a variety of agronomic, environmental, physical, and socioeconomic factors (Qiu, Chastain, Zhou, Zhang, & Sridharan, 2014). To do such assessment and, therefore, maximize the agricultural production potential, land suitability analysis allows matching crop requirements with the different aspects of terrestrial resources (Elaalem, 2012; Driessen & Konijn, 1992).

Matching Crop Requirements with Land Attributes

The two central premises of any agricultural land suitability assessment include the understanding of the characteristics of the potential area for cultivation and the recognition of the constraints and minimum requirements of the possible crop or crops of choice for production (Walke, Obi Reddy, Maji, & Thayalan, 2012; Prakash, 2003; Tan, Shibasaki, & Rajan, 2000; Driessen & Konijn, 1992). To ensure productivity, workability, and sustainability of a particular form of land utilization[41], Baja, Chapman, & Dragovich (2014) articulated that "the systems of land use should be well matched with the inherent characteristics of the land." By virtue of this matching process, the potential and limitations of the land for cultivation is predicted.

In most agricultural land suitability assessment, regardless of the crop under consideration, the common land attributes examined include soil, vegetation, topography, water sources, and climate (Ya`u, Manasseh, & Sharifai, 2014; Elsheikh, et al., 2013; Walke, Obi Reddy, Maji, & Thayalan, 2012; Keshavarzi, Sarmadian, & Ahmadi, 2011; Mustafa, et al., 2011; Ashraf, 2010; Baniya, 2008; Prakash, 2003; Ahamed, Rao, & Murthy, 2000; Bell, Seng, Schoknecht, Vance, & Hin, n.d.). Since each crop has specific growth requirements, the essential land suitability prerequisites vary.[42] More often than not, however, hydrological, environmental, and edaphic growth factors are the typical crop requirement attributes considered for the matching procedure (Clement, 2013; Jones, et al., 2013; Ashraf, 2010; Verheye, Koohafkan, & Nachtergaele, 2008; Manrique & Uehara, 1984).

When soil is considered as part of the suitability assessment, the typical attributes included are texture, drainage, depth, and acidity. Depending on the objective of the suitability analysis, others such as Elsheikh, et al. (2013) and Pereira, Dias, & Alves (2010) included soil nutrient availability, nutrient retention, rooting conditions, soil workability and oxygen soil drainage as key edaphic factors in the soil-crop matching process. Further, chemical properties

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[41] As explained in Baja, Chapman, & Dragovich (2014), productivity refers to increasing yields. Workability, according to the authors, means that cultivating the land is not deterred by topography or land forms, for instance. Sustainability, on the other hand, has something to do with the capability of the land to sustain a particular use for an extended period of time.

Caution, however, should be observed when interpreting productivity, workability, and sustainability. It does not necessarily mean that a productive, workable, and sustainable land exhibit the highest suitability for a particular crop use. Since land, according to Baniya (2008), is always productive to specific crops with defined set of inputs and where crop selection is made considering minimum inputs are applied. Increasing yields may be attributed to the intensity of using inputs such as fertilizers and irrigation and not to its suitability, per se. In terms of workability, an unsuitable land with very steep slopes and with high rubble content, for instance, may still be workable at a relatively high cost.

[42] Driessen & Konijn (1992), Manrique & Uehara (1984), Sys & Riquier (1980) and Doorenbos & Pruitt, (1977) have summarized the growth requirements of selected crops such as cotton, maize, wheat, rice, groundnut, sugarcane, and potato.

such as the cation exchange capacity of the soil, percentage of exchangeable sodium, and edaphic electrical conductivity have also been examined as part of suitability assessment (Khan & Khan, 2014; Pratibha & Sudhakar, 2014; Reshmidevi, Eldho, & Jana, 2009).

The amount of rainfall and distance to surface water sources are the hydrological attributes mostly included in a suitability analysis. Certain assessments, however, consider ground water quality as part of the analysis. Waqar, Rehman, & Ikram (2013) examined ground water quality as part of the land suitability assessment for rice cultivation in the Sheikhupura and Nankana Sahib Districts of Punjab in Pakistan. In addition, since rainfall variability is often related to changes in temperature, a number of studies that included hydrological characteristics in the suitability assessment have also included temperature (Pratibha & Sudhakar, 2014; Waqar, Rehman, & Ikram, 2013; Reshmidevi, Eldho, & Jana, 2009).

Although it is not a standard practice in the matching process of land attributes and crop requirements, socioeconomic factors have been sparsely included in various land suitability assessments. Bell, Seng, Schoknecht, Vance, & Hin (n.d.), for instance, took into account market access factors, population pressure, and poverty indicators in Cambodia as socioeconomic input to land suitability assessment. In Iran, Maddahi, Jalalian, Zarkesh, & Honarjo (2014) examined the following socioeconomic and geographic attributes to assess rice land suitability: distance from main road, distance from rice milling plant, distance from population centers, working population, proximity to the rural cooperative, and proximity to agricultural service centers. Heumann, Walsh, & McDaniel (2011) emphasized the significance of incorporating socioeconomic variables such as market prices and labor availability in their agricultural crop suitability mapping study in rural Thailand.

Rice Land Suitability Assessment

Making decisions on the use of scarce resources is more often than not complex and multifaceted that it involves both policy and resource allocation options. Rice production expansion requires a resource allocation decision since it is focused over the “direct use of resources” such as land “to achieve a particular goal” of producing higher yields (Eastman, 2005). In light of the wide array of possibilities and the competing land use objectives, several biophysical and environmental factors need to be taken into consideration. With the intricate inter-relationships among relevant decision criteria, land suitability assessment may not be simply addressed through conventional evaluation methods (Yang, et al., 2008; Malczewski, 2004). It is for this reason that the application of multi-criteria evaluation (MCE) methods with geographic information system (GIS) has emerged as an analytical and rational decision support system to address the complexities of considering one or more measurable attributes of the alternatives being considered in a land suitability analysis (Stratigea & Grammatikogiannis, 2012; Khoi & Murayama, 2010; Chen, Yu, & Shahbaz, 2009).

Land suitability assessment fundamentally involves an overlay procedure of geographically defined datasets and their related thematic attributes (Malczewski, 2006; Ceballos-Silva & Lopez-Blanco, 2003; Barredo & Bosque-Sendra, n.d.). Due to its “easy-to-understand outputs and intuitively appealing results,” superimposed spatial data generated through geographic information systems have been a a popular choice when conducting a land suitability analysis (Malczewski, 2004). Despite the wide acceptance of using overlay mapping methods, the robustness of the approach as applied to land suitability assessment has been questioned. Kihoro, Bosco, & Murage (2013), Khoi & Murayama (2010), Eastman (2005), and Malczewski (2004) are few among a number of researchers who recently highlighted difficiencies in the overlay method. These researchers reckoned that the overlay technique in GIS can provide more viable results when combined with evaluation methods that take into account the uniqueness and dependence of various criteria.

On the basis of the abovementioned research, this study identifies sets of edaphic and environmental criteria that influence rice throughout its growing period. With respect to the Food Staples Sufficiency Program (FSSP) targets, this study estimates the range of additional hectares of suitable land that are potentially available to contribute to the national food staple sufficiency target. The study also evaluates the level of productivity per hectare as well as the amount of water supply that potentially suitable rice regions may require.

Enhancing Technical Efficiency for Rice Self-Sufficiency

The historical paths in agriculture include the era of expansion, the age of productivity, and the emerging epoch of connectivity. To increase domestic rice production and enable the Philippines to be rice self-sufficient by 2016, the Department of Agriculture espoused the classical approaches of (1) expanding land area under rice production, (2) increasing productivity per unit area through intensification of two or more cropping per year and introducing high yielding varieties to narrow yield gaps, and (3) strengthening connectivity of food systems to minimize farm-to-plate rice wastes (Laborte, et al., 2012; Pearson, 2012). Given that only a portion of increased production can be expected from land expansion, it is imperative to stimulate an upward shift in the production function by increasing efficiency levels.

Farm-Level Efficiency and Shifts in the Rice Production Function

For decades, farming systems around the world have depended on economic analyses to investigate ways to improve rates of production (Quilty, McKinley, Pede, & Buresh, 2014). Technical efficiency is a widely used criterion to assess how well a farmer performs. Much of the analyses trace its roots from the seminal work of Farrell (1957) on production efficiency, which examined a firm's ability to produce maximum output given a set of inputs and technology.

Farrell (1957) decomposed a firm's efficiency into technical, allocative, and economic efficiencies. In his groundbreaking article, he described technical efficiency from an input-oriented (IO) perspective and an output-oriented (OO) view. The IO perspective measures how to minimize input utilization given a certain level of output. The OO view assesses potential increase in output given some level of inputs. Allocative efficiency takes into account optimal input use and increase in potential returns given certain level of prices. Economic efficiency is the sum of the technical and the allocative efficiencies of the firm.

Among the major food staples in the Philippines, which include white corn, banana (*saba*), and root crops such as cassava (*kamoteng kahoy*) and sweet potato (*kamote*), rice has received relatively more attention in terms of the assessment of the technical efficiency of its production sector. Pate & Tan-Cruz (2007), Villano & Fleming (2006), Villano & Fleming (2004), and Coelli (1995) provided a chronological review of technical efficiency of rice farms in various parts of the Philippines since the 1980s. The historical documentation highlights the considerable methodological and geographical efforts devoted to assessing efficiency of rice farmers.

Cognizant of the potential impact of enhanced efficiency in rice production, this study investigates the current level of efficiency of farmers in the Philippines. If room for improvement is determined, the study also examines the factors that could possibly increase the farm-level efficiency. The study also estimates the potential increase in yield per hecatre if technical efficiency of farmers are enhanced.

Distance, Space, and Rice Production

The last few decades witnessed the increasing interest in illustrating the unequivocal stance that location plays in efficient agricultural production. The notion of how location factors influence agricultural production has its roots from the agricultural location theory that started with the classical work of von Thunen (1826) and Tobler's (1970) first law of geography stating that in crop production at the farm-level, "everything is related to everything else, but near things are more related than distant things". As elaborated by Griffith (1992), this means that "what belongs in a given areal unit somehow migrates to adjacent areal units" such as the use of fertilizer in farm plots that rain can wash portions of the chemicals to neighboring plots causing a positive spillover.

Spatial dependence demonstrates how values or attributes observed at one location depend on the values or attributes present at neighboring or nearby locations (Fusco & Vidoli, 2013; LeSage & Pace, 2009; Anselin, 1988). Since rice production is a dynamic process that takes place in areas with varying fertility, soil types, and production resource endowments such as water, this study contends that productive, efficient, and even inefficient farms cluster according to their physical distance to other best or worst performing farms. Following the complementarity argument made by Porter (2000, 1998, 1990) on industrial clustering that the performance of a firm in a cluster affects the performance of the other cluster members, this study assumes that increased productivity at the farm level would be similar to that of the agglomerated industries since transmission of information as well as access to specialized inputs and labor are more fluid in neighboring farms or dwellings than those distant from one another.

In contribution to the growing spatio-economic literature on agricultural production, this study investigates spatial productivity and efficiency patterns as well as geographic variability in rice production in the Philippines. Combining spatial information to agricultural economic production data has serious implications on agricultural policies and farm management strategies as Areal, Balcombe, & Tiffin (2010), Barrios & Lavado (2010), and Weiss (1996) asserted. This spatio-economic exercise is, therefore, particularly relevant to the Philippine government's campaign on staple food self-sufficiency as this may help in the implementation of site-specific development interventions to optimize agricultural efficiency and improve economic returns.

Social Connections, Resource Acquisition, and Farm-Level Efficiency

The achievability of the rice self-sufficiency target is subject not only to the level of biophysical expansion and production costs reduction or technical efficiency enhancement but also on the ability of producers to utilize effectively all the available resources or capital at its disposal. In the rice production system, there are several forms of capital that when employed in the production process, they produce definite flows of income or streams of benefits. The capital can be in the form of financial resources (e.g., cash or credit to buy seeds or other inputs), physical assets (e.g., land, machinery, equipment), natural endowments (e.g., river for irrigation), and human resources (e.g., skilled laborers).[43] One capital that is accumulated by and among actors (Esser, 2008) and manifested in the form of relationships of farmers to fellow farmers or other non-farming members of the community is not inherently considered as part of the core capital that support the rice production system. This latter form of capital is known as the social capital.

In the analysis of economic activities such as crop production, Woolcock (2002) suggested that social capital is an under-appreciated factor of production. Empirical evidence has shown that failing to account social capital in agricultural production has the propensity to undermine productivity. In many instances, well established social capital has been touted as an important prerequisite in the adoption of agricultural innovations and technologies as well as sustainable production and climate adaptation practices that can affect levels of production in either the short- or long-run.[44]

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[43] See Barrera-Mosquera, de los Rios-Carmenado, Cruz-Collaguazo, & Coronel-Becerra (2010) for extended definition of each kind of capital. This study only presents five forms of capital. However, Barrera-Mosquera, de los Rios-Carmenado, Cruz-Collaguazo, & Coronel-Becerra (2010) included seven forms of capital. The other two types of capital not presented in this essay are cultural and political capital.

[44] For example, see Pretty, Toulmin, & Williams (2011), van Rijn & Bulte (2011), Njuki, Mapila, Zingore, & Delve (2008), and Heemskerk & Wennink, (2004).

To ensure that domestic staple food self-sufficiency remains viable, it is equally essential to examine not only the financial, natural, physical, and human capital employed in the rice production process but also the influence of social capital and network in improving productivity in support of the FSSP target. In this regard, this study examines the individual or personal social networks of farmers in the Philippines. In particular, the study investigates the level of influence of the farmer's individual social capital on the factors affecting the technical efficiency of farms.

Social Networks and Social Capital Accumulation

The intimate linkage of social network and social capital theories is fairly a recent phenomenon that started to take off in the late 1990s. Borgatti, Jones, & Everett (1998) and Lin (2001, 1999) are among those who early on recognized close connection in these two schools of thought in the social sciences. Social networks are commonly associated to the number of friends, colleagues, or associates that one is connected to. As such, the typical way of assessing it is by simply counting the individual social connections one has. In an assessment of social network measures that formalize the notion of social capital, Borgatti, Jones, & Everett (1998) identified that the more social relationships one has, the higher the chances that at least one of those connections has useful asset or resource leading to more social capital.

Consistent with the work of Coleman (1988) and Burt (1992) on the social network theory, Adler & Kwon (2002) noted in a comprehensive review of the concept of social capital that the social network theory strongly influences social capital research. They argued that the accumulation of social capital lies in the structure and composition of an individual's social relations. More often than not social network yields positive externalities or benefits that lead to an aggregation of social capital resources (Glaeser, Laibson, & Sacerdote, 2002).

To examine if the theoretical view of having established social network helps in the build up of one's social capital, this study investigates the social relationships among farmers. Further, the direct and indirect connection of social networks and social capital are assessed. This study believes that having access to resources and assets that build up social capital provide a fertile foundation for a deeper understanding of how the acquisition of such capital results in enhanced productivity and efficiency at the farm-level.

Social Capital, Yield, and Technical Efficiency

Social capital has three distinct dimensions—structural, relational, and cognitive (Nahapiet & Ghoshal, 1998). Structural mainly pertains to the pattern of connections and relationship between and among the farmers and the social network. The relational dimension relates to the type and degree of social connections farmers have established through time. The cognitive facet of social capital refers to various social components shared within the network, which can include shared interpretation and representation.

The role of social capital in the agricultural sector has been well recognized particularly in rural communities in developing countries (Winters, Crissman, & Espinosa, 2004). In those parts of the world, the majority of the cases linking social capital to crop production and farm-level technical efficiency measure such type of capital through participation or membership in community organizations (see Solıs, Bravo-Ureta, & Quiroga, 2009; Katungi, Smale, Machethe, & Tushemereirwe, 2007; Binam, Tonye, Wandji, Nyambi, & Akoa, 2004; and Gorton & Davidova, 2004 among others). It is apparent that the perception of social capital as an abstract concept makes it challenging to account quantitatively for its totality. Cognizant of this difficulty in measurement, Van der Gaag & Webber (2008) suggested that to quantify an individual's social capital, one must know the types of resources a person gets access to because of the social relations established.

Rice farming is one of the key sectors where the influence of social capital on production and technical efficiency can be empirically observed. As such, this study examines how social capital can directly and indirectly affect production and technical efficiency through intermediary variables such as adoption of new technologies and support towards sustainable management practices. By determining these linkages, it may be possible to design policies that foster concurrent enhancement of social capital and production as well as efficiency levels.

Dissertation Scope and Objectives

In support of the unifying theme of food staple self-sufficiency, the goal of this dissertation is to shed more light on the achievability of rice self-sufficiency in the Philippines. In particular, under the umbrella of food staple self-sufficiency, this dissertation seeks to assess the viability of biophysical resources in supporting rice self-sufficiency. This dissertation also examines the production and technical efficiency levels of farmers in the Philippines as represented by those from Central Luzon. The factors that may influence the improvement in production and efficiency are also assessed. This dissertation also recognizes the role that social capital plays in the rice farming systems in the Philippines and as such, it investigates the linkages between the farmers' personal social networks, social capital acquisition, and level of production as well as technical efficiency.

More specifically, the objectives of the biophysical assessment presented in Chapter 2 are as follows:

1. identify current and potential regions with biophysical and environmental characteristics capable of supporting rice production,
2. estimate the range of additional hectares of suitable land that are potentially available to contribute to the national food staple sufficiency target, and
3. assess the amount of water supply that potentially suitable rice regions may require as well as the possible by-products that can be generated from the suitable rice areas.

In terms of assessing the potential improvement on yield per hectare based on technical efficiency enhancement as demonstrated in Chapter 3, the specific aims include:

1. assessment of farm-level parameters of stochastic production frontier for two cropping seasons in Central Luzon, Philippines,
2. examination of the factors that influence technical efficiency at the farm level, and
3. evaluation of how geospatial attributes affect production performance of farmers within the overall context of achieving the rice self-sufficiency target.

To determine the role of social capital in the production process as well as adoption of sustainable management practices, Chapter 4 of this dissertation seeks to:

1. examine the individual or ego (personal) social networks of farmers in Central Luzon,
2. investigate the level of influence of the farmer's individual social capital on the factors affecting the technical efficiency of farms in Central Luzon, and
3. assess the role that social capital plays in the adoption of sustainable management practices in rice farming.

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Chapter 2. A Suitability Assessment of Edaphic and Environmental Factors Influencing the Achievability of the Food Staples Sufficiency Program (FSSP) Target in the Philippines

Abstract

In 2012, the Philippines launched the Food Staples Sufficiency Program (FSSP) with a target to increase rice staples from 15.77 million metric tons in 2010 to 22.73 million metric tons in 2016. To increase rice production and enable the country to be rice self-sufficient by 2016, the Philippine Department of Agriculture espoused to increase the areas devoted to rice and irrigation complementing introduction of high yielding varieties and widespread mechanization of the rice industry. In support of the plan to expand rice cultivation and irrigation service areas under the FSSP, this study conducted a land suitability assessment to identify current and potential areas with biophysical and environmental characteristics capable of supporting rice production. To complement the suitability assessment, this study also estimated the range of production yield that potentially suitable rice land can sustain to support the FSSP targets. The study also assessed the amount of water supply that potentially suitable rice areas may require and the possible by-products the suitable lands can generate.

Based on the combination of multi-criteria evaluation (MCE) methods with geographic information system (GIS), the suitability analysis showed that at the national scale, the Philippines has about 2.06 million hectares of land that can be allocated to rice expansion. At a region-specific level, Central Luzon can still accommodate expanded rice production to about 94,085 hectares of land in the region. With this potential for expansion, the necessary yield per hectare to attain the FSSP target is between 3.54 to 4.53 metric tons.

As with any land use decision, the allocation of any parcel of land to a particular use commonly comes with a price known as opportunity cost. Assessed against two most viable alternatives, results show that the opportunity cost of not converting the areas to other non-agricultural uses amounts to as much as PhP 128 billion. The agricultural use of land for rice production, on the other hand, provides a higher return than allocating areas for corn production.

In terms of spillover effects from expanding rice production, around 56,800 million cubic meters of water will be necessary to support the FSSP target. This suggests that if business as

usual (BAU) scenarios with water supply and withdrawal curves remain, about 93 percent of the water used for the agricultural sector will be devoted to rice production alone if the potential expansion continues. The rice husks by-products, at the maximum, can produce 279 megawatts of power, which can also be equivalent to 1,1866 million liters of oil.

The results clearly emphasize the spatial extent of suitable areas as well as the potential costs of the planned expansion. From an applied standpoint, decision-makers can use the land suitability results as a guide to channel investment plans and enhance rice expansion initiatives across the country. Further, since the intimate link between energy resources, food self-sufficiency, and water security is seldom thought of together in the food self-sufficiency equation, it may be necessary to tie the FSSP initiative with the water and energy security programs at various scales of planning.

Introduction

To minimize the risks associated with unreliable food supply and fluctuating prices, many countries have adopted autarky or self-sufficiency as the national agricultural policy banner. Self-sufficiency with respect to staple food has been regarded as a critical factor in attaining agricultural sustainability. Accordingly, van Dartel & Nigten (2014), Bah (2013) and Thomson & Metz (1998) asserted that if a country increases its level of self-sufficiency, it would translate to an increase in food security.

In 2012, the Government of the Philippines promoted rice self-sufficiency through its Food Staples Sufficiency Program (FSSP). The FSSP targets to substantially reduce rice imports and increase the country's crop staple self-sufficiency ratio[1] to 100 percent. Data show that among the major domestic crop staples, rice has the lowest self-sufficiency ratio (Figure 2.1).

To narrow and eventually eliminate the self-sufficiency ratio gap, the FSSP aims to increase rice staple production from 15.77 million metric tons in 2010 to 22.73 million metric tons in 2016. To achieve this target, on average, production must grow by six percent per year (Department of Agriculture, 2012).[2] This implies that area harvested must grow by 15 percent in

[1] Schmidhuber & Tubiello (2007) noted that self-sufficiency is assessed based on the proportion of domestic food produced to the total food consumed locally.
[2] This suggests that harvest area needs to expand by at least two percent annually and yield should grow by four percent per year at the minimum (Department of Agriculture, 2012).

2016 and irrigation service area must expand from 1.5 to 1.7 million hectares between 2011 and 2016. Accordingly, within the span of less than a decade, rice production should increase by 44 percent and yield per hectare by 25 percent.

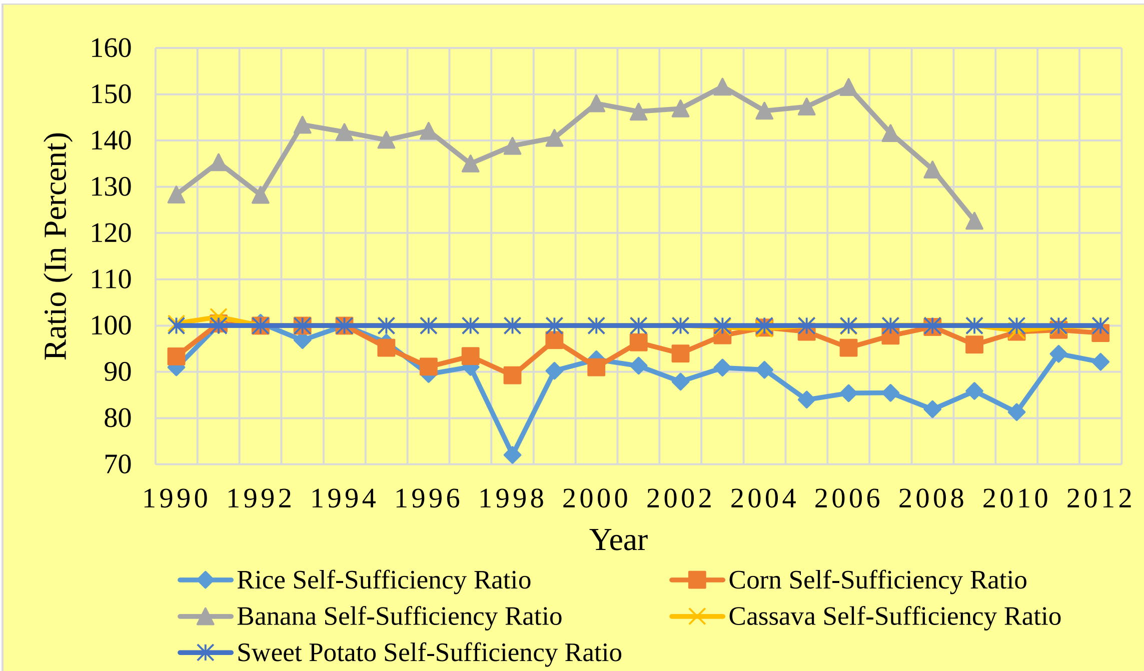

Figure 2.1: Food crop staple self-sufficiency ratio (1990 to 2012).
Note: Chart derived using data from the Bureau of Agricultural Statistics (BAS, 2013a).

Cognizant that one of the most effective measures to secure food self-sufficiency is to "regulate the conversion of farmland for other uses and then enhance land productivity" (Ito & Ni, 2013), the Philippine government proposed expansion of rice plantation and irrigation areas to complement introduction of high yielding varieties and widespread mechanization of the rice industry. Keeping in mind the confidence placed over the achievability of the target under a food staple autarky regime in the Philippines, it is imperative to focus the spotlight on the plausibility of biophysical expansion of rice production in the country. It is, therefore, important to assess the extent of potentially suitable areas for expansion that can help obtain the FSSP target.

In support of the plan to expand rice cultivation and irrigation service areas under the Food Staples Sufficiency Program, this study carries out a land suitability analysis to identify current and potential regions with biophysical and environmental characteristics capable of supporting rice production. As a decision-making assessment tool that examines how attributes of a particular land area when combined with land utilization properties influence the determination of intended use, land suitability analysis is a relevant approach to match crop requirements with the different aspects of terrestrial resources (Elaalem, 2012; Driessen & Konijn, 1992). By considering a multitude of edaphic and environmental criteria, this paper estimates the range of additional hectares of suitable land that are potentially available to contribute to the national food staple sufficiency target. The level of productivity per hectare is also evaluated based on the results of the suitability analysis. The amount of water supply that potentially suitable rice regions may require is also assessed, as well as the possible by-products that can be generated from the suitable rice areas.

Materials and Methods

Study Area

Rice constitutes the dominant part of the Filipino diet and as such it is considered the most important food crop staple in the Philippines. The majority of the population derives a considerable proportion of their energy and nutrient needs from rice. In 2009, rice provided 47 percent of the caloric intake of Filipinos. The Bureau of Agricultural Statistics (BAS) reported that the average Filipino consumed 114.27 kilograms of rice in 2012.[3] The consumption percentage share for rice has been steady at 45 percent or more from 1999 through 2012 (Table 2.1).

Future production must heed the Filipinos growing demand for rice. A commonly used approach to address this issue is to allocate more land for production. This strategy is plausible if land, the primary platform for any agricultural activity, is an unlimited resource.[4] To achieve rice self-sufficiency through spatial expansion, it is important to have an understanding of the way land is utilized and the how it is appropriated to different uses. It is equally critical to recognize crop requirements *vis-à-vis* associated land characteristics. The combination of crop

[3] Since 2005, the Philippines has been consistently ranked as one of the top ten countries with per capita rice consumption over 100 kilograms per year across income groups in both urban and rural areas (IRRI, 2014).
[4] Although the Philippines has a total land area of 30 million hectares, only a little more than 14 million hectares are considered alienable and disposable lands. The rest are classified as forestlands. Of the alienable and disposable lands, approximately 30 percent are currently used for rice production (Navata & Turingan, 2013).

requirements criteria and physical land attributes forms the basis for suitability of regions that can support additional rice production.

Table 2.1: Annual per capita consumption of agricultural commodities in the Philippines (1999-2000, 2008-2009, 2012).

Commodity Consumed *(in kilograms/capita)*	**2012**	**2008-2009**	**1999-2000**
Total: Rice Consumed	114.27	119.08	105.77
Total: ALL Other Food Consumed[5]	129.13	108.00	170.51

Note: Calculated values are from data available from the Bureau of Agricultural Statistics (BAS, 2013b).

Under the current circumstances, it is imperative to assess the extent of potential rice production expansion across the Philippines. It is for this reason that one part of this study examines land suitability at the national scale and another at a region-specific scope. More specifically, the study focuses in the Central Luzon region (Figure 2.2).

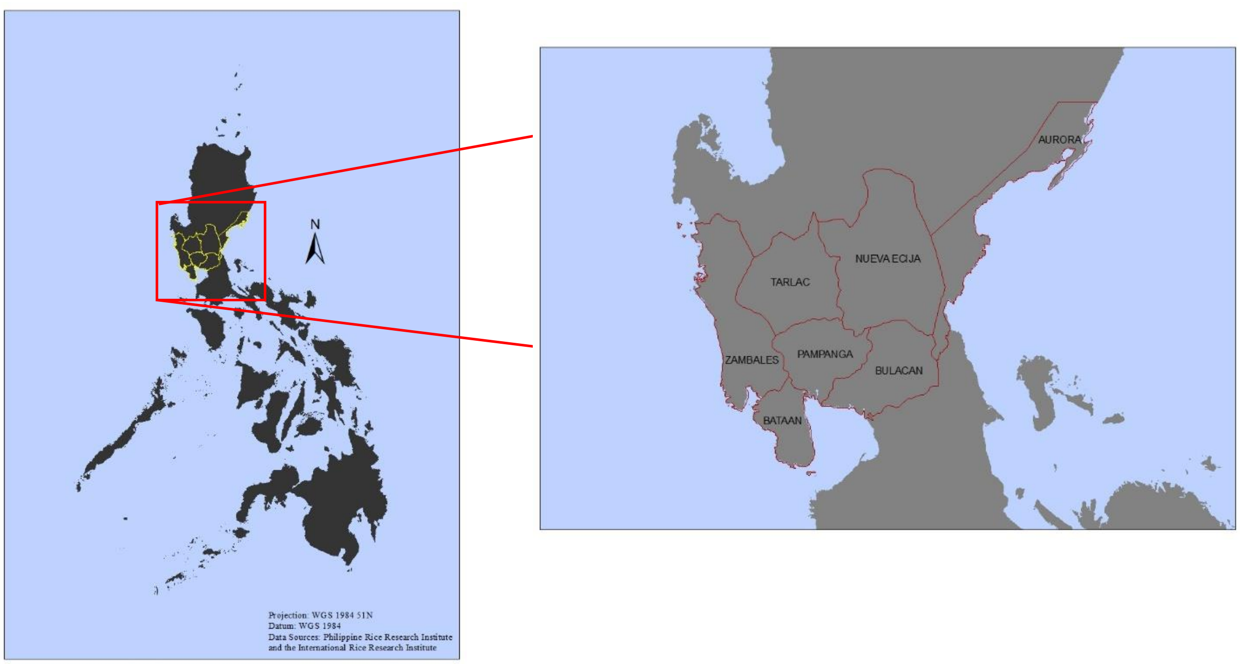

Figure 2.2: Study area location for potential rice production expansion under the FSSP.

[5] All other food includes food crops such as bananas, potatoes, cassavas. Livestock and dairy products as well as fish and seafood products are also included in the "ALL other food" category.

Central Luzon or Region III is particularly selected as a case study area for the land suitability assessment due to its contribution to rice production in the Philippines. The region lies at the heart of the main island of Luzon, 66 kilometers away from Manila, the National Capital Region. There are 12 cities and 118 municipalities from the seven provinces of Central Luzon namely, Aurora, Bataan, Bulacan, Nueva Ecija, Pampanga, Tarlac, and Zambales (DENR, 2014; Lugos, 2009).

The 2.2 million hectares of land area in Central Luzon is endowed with a balanced mix of natural resources and environmental assets such as mountain forests and surface water. The region is surrounded by three mountain ranges –Sierra Madre on the east, Caraballo on the north, and Zambales mountains on the west (Lugos, 2009). Approximately 45 percent of the region's land areas are classified as forest lands, protected areas composed of watersheds and forest reserves, national parks, games refuge, bird sanctuary and wildlife (DENR, 2014). The remaining 55 percent are largely composed of agricultural plains and mixed industrial, commercial, and residential areas (BAS, 2014a; DENR, 2014).

Having the longest contiguous area of agricultural lowlands, Central Luzon produces about one-third of the country's total irrigated and rainfed rice (BAS, 2014a; BAS, 2014b) making the region as the staple food granary of the Philippines. The region is also the third largest aquaculture producer in the Philippines (DENR, 2014). This makes the region not only the top producer of rice but also of tiger prawns and tilapia. Consequently, agriculture, fishery, and the forestry sectors account for almost 20 percent of Central Luzon's regional economy.

Multi-Criteria Spatial Assessment

Making decisions on the use of scarce resources is more often than not complex and multifaceted that it involves both policy and resource allocation options. The planned rice production expansion under the Food Staples Sufficiency Program (FSSP) requires a resource allocation decision since it is focused over the "direct use of resources" such as land "to achieve a particular goal" (Eastman, 2005). In light of the wide array of possibilities and the competing land use objectives, several biophysical and environmental factors need to be taken into consideration with respect to the FSSP target. With the intricate inter-relationships among relevant decision criteria, land suitability assessment may not be simply addressed through conventional evaluation methods (Yang, et al., 2008; Malczewski, 2004). It is for this reason that the application of multi-criteria evaluation (MCE) methods with geographic information system (GIS) has emerged as an analytical and rational decision support system to address the complexities of considering one or more measurable attributes of the alternatives being considered in a land suitability analysis (Stratigea & Grammatikogiannis, 2012; Khoi & Murayama, 2010; Chen, Yu, & Shahbaz, 2009).

Land suitability assessment fundamentally involves an overlay procedure of geographically defined datasets and their related thematic attributes (Malczewski, 2006; Ceballos-Silva & Lopez-Blanco, 2003; Barredo & Bosque-Sendra, n.d.). Due to its “easy-to-understand outputs and intuitively appealing results,” superimposed spatial data generated through geographic information systems have been a a popular choice when conducting a land suitability analysis (Malczewski, 2004). Despite the wide acceptance of using overlay mapping methods, the robustness of the approach as applied to land suitability assessment has been questioned. Kihoro, Bosco, & Murage (2013), Khoi & Murayama (2010), Eastman (2005), and Malczewski (2004) are few among a number of researchers who recently highlighted difficiencies in the overlay method. These researchers reckoned that the overlay technique in GIS can provide more viable results when combined with evaluation methods that take into account the uniqueness and dependence of various criteria.

As a spatial resource allocation problem, land suitability is inherently a multi-criteria problem, which is generally described as $S = f(x_1, x_2, x_3 \ldots x_n)$, where S is the suitability measure and x_i represent the factors affecting the suitability of the land (Mendoza, 1997). Central to the suitability assessment is the examination, in both qualitative and quantitative terms, of the individual and cummulative effects of the different attributes under consideration. This process requires the implementation of multi-criteria evaluation (MCE) techniques, which involve the selection and combination of related and, at times, remotely associated attributes to arrive at the most socially acceptable and technically feasible outcome. Through simple rating systems, multi-criteria evaluation can establish a compatible land use and crop growth requirement framework to simplify the process of determining the relative importance of a set of factors on the optimal crop yield possible (Kihoro, Bosco, & Murage, 2013; Elaalem, 2012).

Multi-criteria evaluation methods comprise a large family of different techniques (Malczewski, 2004; Nijkamp, Rietveld, & Voogt, 1990) and over the last two decades, one or a combination of these techniques has been integrated in the GIS environment. Some of the commonly integrated MCE methods into GIS include the analytical hierarchy process (AHP) (Kihoro, Bosco, & Murage, 2013; Store & Kangas, 2001), Boolean overlay operations (Malczewski, 2004; Jiang & Eastman, 2000), concordance analysis (Malczewski, 2004; Joerin, Theriault, & Musy, 2001; Carver, 1991), ideal point methods (Malczewski, 2004; Pereira & Duckstein, 1993; Jankowski, 1995), ordered weighted averaging (Chen & Paydar, 2012; Malczewski, 2006), and weighted linear combinations (Nzeyimana, Hartemink, & Geissen, 2014; Ashraf, 2010; Ceballos-Silva & Lopez-Blanco, 2003; Eastman, 1997; Carver, 1991). Among these methods, the weighted linear combinations and the Boolean overlay operations of intersection and union have been widely favored due to its simplicity and ease of application (Malczewski, 2006). An extensive literary review of the integration of these various techniques into GIS is beyond the scope of this paper.[6] The application of Boolean overlay operations to land suitability assessment, however, is further explored and implemented in this research.

Land Suitability Assessment Framework

Spatial decision-making processes such as the identification of areas capable of supporting additional rice production in support of staple food self-sufficiency target requires an assessment of a wide range of sites based on a set of criteria that are defined by a variety of agronomic, environmental, physical, and socioeconomic factors (Qiu, Chastain, Zhou, Zhang, & Sridharan, 2014). The initial step in the process entails the examination of the actual farm conditions required in rice production. These conditions are subject to review of secondary information, expert opinions, and primary farm observations. Desirable factors are then identified and compared against current and existing conditions (Eastman, 2005). From this comparative exercise, relevant factors to support the proposed rice production expansion are identified and evaluation criteria are defined. The rest of the process flow for the land suitabilty assessment is illustrated in Figure 2.3.

[6] A review of the historical development of some of the MCE methods and their applications into GIS is available from Malczewski (2004) and Collins, Steiner, & Rushman (2001).

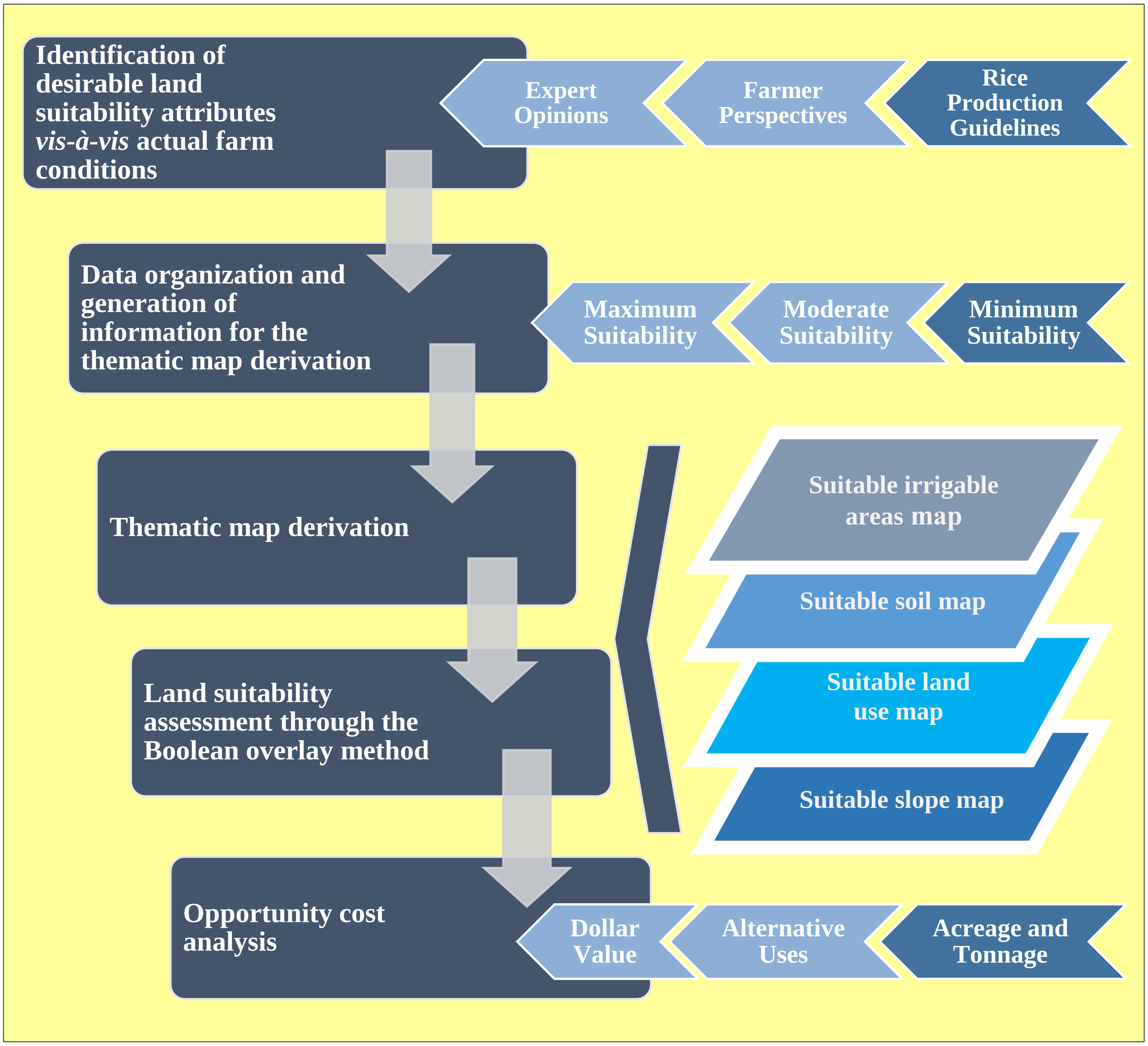

Figure 2.3: Framework of the land suitability assessment methods and processes.

On the basis of prudent review of literature as well as existing guidelines on rice production established by local agricultural agencies and rice research institutes, edaphic and environmental attributes that influence rice throughout its growing period have been hierarchically organized according to their degree of importance to rice production. With respect to the Food Staples Sufficiency Program (FSSP) target under consideration, inputs from discussion with subject matter experts and conversation with farmers during household surveys in the provinces of Nueva Ecija and Tarlac in December 2013 and January 2014, respectively, were also taken into cosideration in assessing the extent of influence of the attributes. The primary set of must-have attributes deemed to satisfy conditions towards the desired level of production under the FSSP include locational access to reliable water resource, soil characteristics, and land use designation. Of auxiliary importance but nonetheless necessary to consider is land terrain. Each of the attributes is characterized into various suitability scales. Table 2.2 summarizes the rationale for the range of suitability evaluation criteria considered.

Table 2.2: Assessment criteria used to assess scales of land use suitability *vis-a-vis* the FSSP target.

Suitability Constraints	Scales of Suitability		
	Maximum Size of Suitable Land Area	Moderate Size of Suitable Land Area	Minimum Size of Suitable Land Area
Priority Criteria			
Distance to existing communal irrigation systems	5 kilometers		
Distance to existing national irrigation systems	10 kilometers		
Distance to existing integrated irrigation systems	60 kilometers		
Distance to major river basins	10 kilometers		
Soil texture	Clay, loam, silt, clay-loam, silt-loam, silty-clay-loam		
Land use designation	Prime rice, prime agricultural, non-prime agricultural, and undesignated alienable and disposable land areas		
Auxiliary Criteria			
Land gradient	Alienable and disposable land areas with 0-8 percent slope	Alienable and disposable land areas with 0-5 percent slope	Alienable and disposable land areas with 0-3 percent slope

Water Resources. Satisfying FSSP target depends, in part, on the improvement in cropping intensity in areas that have potential for two or more croppings per year. [7]A single

[7] Rice production in the Philippines is currently divided into two cropping seasons: wet (rainy) season and dry season. Typically, rice production for the wet season commences at the beginning of the summer monsoon, which is

cropping season per year is no longer an option if the Philippines is to achieve rice self-sufficiency. The year-round multi-cropping production, particularly during the dry season, is only possible if there is sufficient water supply (Antiporda, 2014; Hafeez, Bouman, Van De Giesen, & Vlek, 2007) as 75 percent of the rice produced in the Philippines are generated from irrigated ecosystems (BAS, 2014b).

With water supply as a critical requirement to support increased rice cultivation in the Philippines, location and size of major river and irrigation systems are considered as primary criteria in identifying areas for expansion. In this regard, it is paramount to have insights of the locations and coverage of the major river basins as well as the scale of the irrigation systems. The River Basin Control Office (RBCO) of the Department of Environment and Natural Resources (DENR) recognizes 18 major river basins across 17 regions in the country (River Basin Control Office, 2014). In terms of irrigation systems, there are 217 national irrigation systems in the Philippines as of 2012, two of which are integrated irrigation systems (National Irrigation Authority, 2013).[8]

Soil. Brady (1981) noted that no other crop rivals rice in terms of the wide range of conditions under which it is grown. In 2012, there are around 125 countries from six continents producing rice (FAO, 2014) under various physical, geographical, hydrologic, and climatic states. This suggests that rice grows in a wide variety of soils (Blanche, Harrell, & Saichuk, 2014).

The dominant practice of rice production in the Philippines is with flood irrigation. The paddy rice system works better in soils with larger water holding capacity to prohibit excessive

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around May of each year. Right after the harvest for the wet season rice, the dry season production immediately follows as farmers want to utilize the rainfall at the end of the wet season (Koide, et al., 2013).

[8] An irrigation system is considered national in scale if it covers a service area of more than 1,000 hectares and the National Irrigation Administration (NIA) oversees its construction, operation and maintenance. Any irrigation system covering less than 1,000 hectares are considered communal and there is a joint responsibility between NIA and the farmers' associations—construction is a joint project and operation and maintenance are delegated to the farmers and irrigators associations. At present, two of the 217 national irrigation systems in the Philippines fall under the integrated irrigation system. A system is considered integrated if it is intended for complementary, yet sometimes, competing uses. For instance, the Upper Pampanga River Integrated Irrigation Systems (UPRIIS) which serves 89 municipalities in the provinces of Aurora, Bataan, Bulacan, City of Valenzuela, Caloocan City, Nueva Ecija, Nueva Vizcaya, Pampanga, Pangasinan, Quezon City, and Rizal, does not only provide water for agricultural and domestic use but also for hydropower generation (River Basin Control Office, 2014).

percolation. It is for this reason that the majority of rice production in the Philippines occurs in areas with soil texture ranging from medium to fine such as clay and loam soils (Brady, 1981).

There are nine soil orders found in the Philippines. Six of which have been identified to support rice production. Table 2.3 summarizes the major soil taxonomy in the Philippines in terms of importance to rice cultivation. This soil order and suborder summary is largely based on the work of Moormann (1978) and the soil classification by the Bureau of Soils and Water Management (BSWM) (2014).

The estimates of soil areas in the Philippines show that the entire country is built for rice production. Out of the 30 million hectares of land in the Philippines, 29.25 million hectares have soil identified to be of major or local importance to rice cultivation. This suggests that if based on soil alone, rice can be grown throughout the country.

Table 2.3: Estimated area of Philippine soils of major importance to rice production.

Soil Order	**Existing Suborders Used in Rice Production**		**Estimated Total Area (*in '000 hectares*)**
	Major Importance	***Local Importance***	
Alfisols	Ustalfs	Udalfs	3,973
Entisols	Aquents	Fluvents Orthents* Psamments*	1,520
Inceptisols	Aquepts Tropepts		14,652
Mollisols		Aquolls Udolls	266
Ultisols	Udults	Humults Ustults*	8,113
Vertisols		Uderts Usterts	733

*Considered of minor importance to rice production.

Land Use. Land use as opposed to land cover, which basically refers to the physical and biological canvas of the land, is characterized by the "arrangements, activities, and inputs people undertake in a certain land cover type to produce, change, or maintain it" (Di Gregorio & Jansen, 2000). Commonly, land use is defined in terms of human activities taking place on a particular land area. These uses could include subsistence or commercial agriculture, forestry, private or public settlements, and open spaces among others (Ellis, 2010).

It has been widely recognized that knowledge of and information on distribution and area of existing land use patterns are necessary to determine land allocation for different uses (Anderson, Hardy, Roach, & Witmer, 1976). Having a good understanding of the land utilization system in a region allows for better land management as well as determination of more suitable land uses to meet social, economic, and institutional needs. If the target under FSSP is to be achieved by 2016 and the Philippine government is serious to make sound plans for the attainment of staple food self-sufficiency, then serious consideration on how land is used and allocated towards staple food production is vastly important.

At present, land use classification in the Philippines vary in terms of institutions or levels of government involvement (Navata & Turingan, 2013; Lebrilla, 2011). There is no national land use policy framework that guides the allocation, utilization, and management of the land. Despite the absence of a common land use policy, land utilization in the Philippines are legally classified into forest lands and alienable and disposable lands (Department of Environment and Natural Resources, 2012).

According to the forestry statistics published by the Department of Environment and Natural Resources (2012), around 53 percent of lands in the Philippines are classified as forest lands and 47 percent as alienable and disposable lands. Forest lands include timberlands, forest reserves, national parks, game refuge, bird sanctuaries, wilderness areas, military reservations, civil reservations, and fishponds. Alienable and disposable lands, on the other hand, are areas available for disposition for various purposes to serve the needs of the population. With almost half of the Philippine land area classified as alienable and disposable, the potential of assessing, identifying, and managing areas of vital importance to support food staple self-sufficiency is critical.

Land Gradient. Unlike other crops, rice is known to have a wide topographic and climatic adaptability. It can grow over a diverse range of environments and conditions, from flooded river deltas to upland areas and from tropically humid areas to savannah regions (Hussain, Sohaib, Ahmed, & Khan, 2012; Cann & Diczbalis, 1988; Gupta & O'Toole, 1986; Brady, 1981). It is for this reason that rice farms can be found in extremely varied elevations with heterogenous gradients. Jing & Jichao (2012), Salgotra, Gupta, & Ahmed (2012), Paudel

(2011), Ahmadi (2004), Gupta & O'Toole (1986) found that rice has been cultivated in areas below sea level to as high as 3,000 meters above sea level with land gradients between zero to 30 percent.

In the Philippines, rice is largely cultivated in areas with a land gradient between zero to eight percent (Ines, Gupta, & Loof, 2002). Although this is the case, rice farms across the country can be found in flat to gently rolling lands as well as rolling to steeply hilly areas and even in the mountains (Garrity, Zandstra, & Hardwood, 1978) with slopes of as high as 18 percent (Miranda, 2014). Despite the considerable potential of upland or highland rice production, only a small proportion of areas with high elevation are allocated to rice production since the majority of government interventions are directed towards lowland rice production (Sun Star Davao, 2011). With expansion of rice cultivation in upland areas as one of the main thrusts of the Food Staples Sufficiency Program (FSSP), rice self-sufficiency may be highly feasible by 2016.

Cognizant that in land suitability assessment, each suitability attribute under consideration is represented by individual spatial layers in which a "degree of suitability with respect to a particular factor is ascribed to each unit area" (Feizizadeh & Blaschke, 2013), the development of thematic spatial layers for each suitability criteria is an important aspect of the assessment process. Climatic, edaphic, and environmental spatial data collected from the International Rice Research Institute (IRRI), the National Irrigation Administration (NIA), the Philippine Atmospheric, Geophysical and Astronomical Administration (PAGASA), and the Philippine Rice Research Institute (PhilRice) are used as vector or raster input data in the derivation of the thematic map layers using ArcGIS 10.2 processing software from ESRI.

Considering that the input data for the land suitability assessment were derived from different institutions with varying standards in producing spatial data, the integration of the thematic map layers primarily involved standardization of the projection and coordinate systems (Baiocchi, Lelo, Polettini, & Pomi, 2014). With each of the thematic attribute layers in conformance with internationally acceptable standards, binary maps of suitable and unsuitable areas are derived for each attribute subject to the suitability scales. These binary maps are then combined through an overlay process as a core component of any suitability analysis. To locate and estimate additional areas for rice production expansion, the overlay procedure depends on logical rules representing operations that are translated into spatial functions in the suitability exercise (Arafat, Patten, & Zwick, 2010).

In majority of the early and most recent works on land suitability assessment, the use of Boolean[9] overlay method to combine spatial data that exhibit characteristics in a multi-criteria fashion has been a common practice (Soltani, Mahiny, Monavari, & Alesheikh, 2012; Sugumaran & Degroote, 2010; Eastman, 2005; Malczewski, 2004). In land suitability assessment, the Boolean method transforms selected spatial suitability attributes into binary Boolean values of either one for "suitable" or zero for "not stuitable" given certain thresholds (Qiu, Chastain, Zhou, Zhang, & Sridharan, 2014; Flitter, Laube, LüscherPatrick, Rogers, & Hägi, 2013). Under the Boolean method, algebraic and logical mapping functions such as "AND," "OR," and "NOT" are employed to link two or more spatial datasets to generate new sets of spatial information that represents the suitability threshold values (Qiu, Chastain, Zhou, Zhang, & Sridharan, 2014; Flitter, Laube, LüscherPatrick, Rogers, & Hägi, 2013; Malczewski, 2004). The Boolean operator "AND" is an intersection function, which classifies areas as suitable if each spatial data meets the suitability threshold. The "OR" operator, conversely, is a union function, which identifies suitable areas if one or more of the spatial data satisfies the threshold value (Eastman, 2005; Malczewski, 2004).

Following the implicit Boolean method assumption of clear boundaries and the absence of associated vagueness in the specified criteria (Elaalem, 2012) i.e. "all attributes are considered as being equally relevant in determining land suitability" (Baiocchi, Lelo, Polettini, & Pomi, 2014), this study employs a graduated Boolean overlay process to identify suitable areas for possible expansion of rice production in the Philipines. The graduated approach involves a two-stage aggregation of the thematic attributes organized according to hierarchical suitability. The first stage is the aggregation of thematic binary layers mainly based on a set of priority criteria

[9] In his paper examining the integration of MCE methods and GIS, Eastman (2005) noted that the "term *Boolean* is derived from the name of the English mathematician, George Boole, who first abstracted the basic laws of set theory in the mid-1800s." Based on Boole's set theory, "areas are designated by a simple binary number system as either belonging or not belonging to the designated set." For the most part, the Boolean approach has been applied when the boundaries or classes of the attributes are clearly defined. It should be noted, however, that the Boolean method does not take into consideration uncertainties and partial membership of an object within a set (Elaalem, 2012).

(see Table 2.2). The second stage combines the priority criteria with auxiliary attributes (see Table 2.2).

In the two-stage process, the mode of aggregation is the Boolean union operator, "OR." For each of the criteria under various scales of suitability, a value of one, "1," is assigned to a particular spatial unit if the condition is spatially satisfied and a value of zero, "0," is given if the opposite is observed. For instance, under the maximum land area suitability scenario, areas identified within the five kilometer radius of communal irrigation systems (see Table 2.2) are given a true value of one, "1," representing suitable locations and all other areas outside this radial distance are assigned a false value of zero, "0," depicting unsuitable sites for expansion. This delineation process resulted in composite binary maps of suitable and unsuitable areas for rice cultivation.

To determine the size of additional hectares of land classified as suitable for rice production that can support the national food staple sufficiency target, it is important to know the baseline or current area size devoted towards rice. For this study, the baseline year is 2010 in which the Philippines has 4,354,161 hectares of harvested rice areas. Of these rice lands, 15.67 percent (681,901 hectares) are located in Central Luzon (BAS, 2014b). Based on these baseline information and the criteria listed under the different scales of suitability, the additional tonnage of rice that can be produced from potentially suitable areas are estimated using the mean of the national historical yield per hectare from 1987 to 2010, which is 3.12 metric tons.[10] The opportunity cost of allocating the areas determined as potentially suitable for rice production is also assessed against other best potential uses for the available lands.

One part of this assessment is to determine the amount of additional water resources that will be required to support expansion of rice production in the suitable areas. According to Bouman (2009), 2,500 liters of water either from rainfall or irrigation are required to produce a kilogram of rough rice. In addition to assessing the water requirement, another part of this analysis is to estimate the amount of bioenergy by-products that can be generated from the production expansion in potentially suitable lands. By using the proportion suggested by Militar (2014) and Gummert (2013) of 290 kilograms of rice straws and 200 kilograms of husk,

[10] See Appendix A for more details on the average annual historical volume of production and yield per hectare for rice.

respectively, for every metric ton of rice produced, the amount of by-products that suitable areas can produce are included in the suitability assessment.

Results and Discussion

Literature review of various rice land suitability analyses show that soil quality and texture is a foremost criterion in the assessment process.[11] The other commonly examined factors in the assessment of areas that may be suitable for rice cultivation include land use or land cover.[12] Land gradient or slope is a critical attribute also investigated in the works of Maddahi, Jalalian, Zarkesh, & Honarjo (2014), Sezer & Dengiz (2014), Dengiz (2013), and Kihoro, Bosco, & Murage (2013) among others.[13]

In concurrence with what the farmers in Nueva Ecija and Tarlac expressed during the household surveys in December 2013 and January 2014, respectively, availability of and access to irrigation or other sources of water is the most critical factor to a year-round rice production. Several other studies have also accounted for the same attribute in the land suitability analysis. The research by Maddahi, Jalalian, Zarkesh, & Honarjo (2014), Suwanwerakamtorn & Hirunkul (2012), Khoi & Murayama (2010), Perveen, Nagasawa, Ahmed, Uddin, & Kimura (2008), Abu Bakar (2007), and Mongkolsawat, Thirangoon, & Kuptawutinan (1997) state that proximity and access to irrigation or water sources is one of the primary factors that make an area suitable for rice production. Jemberu (2012), Abu Bakar (2007), and Boateng (2005) confirmed the water access attribute with precipitation criteria. The authors also asserted that for rainfed production ecosystems, the amount of rainfall is a critical factor to consider. In conjunction with the amount of precipitation, Kihoro, Bosco, & Murage (2013), Hussain, Sohaib, Ahmed, & Khan (2012),

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[11] The following literature finds soil as a very important factor to consider in land suitability assessment of staple food production: Maddahi, Jalalian, Zarkesh, & Honarjo (2014), Selassie, Ayalew, Elias, & Getahun (2014), Sezer & Dengiz (2014), Dengiz (2013), Halder (2013), Kihoro, Bosco, & Murage (2013), Suwanwerakamtorn & Hirunkul (2012), Kuria, Ngari, & Waithaka (2011), Khoi & Murayama (2010), Perveen, Nagasawa, Ahmed, Uddin, & Kimura (2008), Abu Bakar, (2007), Boateng (2005), Rasheed, Vidhya, & Venugopal (2003), Ayoubi, Givi, Jalalian, & Amini (2002), and Mongkolsawat, Thirangoon, & Kuptawutinan (1997).

[12] Maddahi, Jalalian, Zarkesh, & Honarjo (2014), Selassie, Ayalew, Elias, & Getahun (2014), Halder (2013), Kuria, Ngari, & Waithaka (2011), Perveen, Nagasawa, Ahmed, Uddin, & Kimura (2008), Mongkolsawat, Thirangoon, & Kuptawutinan (1997) identified land use and land cover as another critical factor in the rice land suitability assessment.

[13] The other research works with a similar finding include Jemberu (2012), Suwanwerakamtorn & Hirunkul (2012), Kuria, Ngari, & Waithaka (2011), Khoi & Murayama (2010), Abu Bakar (2007), Boateng (2005), and Rasheed, Vidhya, & Venugopal (2003).

and Rasheed, Vidhya, & Venugopal (2003) also included temperature and climate as factors in their land suitability assessment.

It is evident that land suitability for rice cultivation depends on a wide array of factors and these range of factors for suitability assessment are often selected from the attributes of the land and the requirements of the crop. Attributes such as irrigation, soil type, slope, precipitation, temperature, and land use designation more often than not influence the growth and distribution of many crops. Since in most land suitability assessment for rice crops, access to sources of water, availability of good soil, and feasible land use designations are the principal criteria, this study adopts the same criteria in the analysis. The inclusion of these factors in the assessment takes into consideration inputs from experts from the Philippine Rice Research Institute (PhilRice) and the International Rice Research Institute (IRRI). Each of these factors is examined in a thematic fashion together with the inclusion of land gradient as a suitability constraint for the land use criteria.

Thematic Criteria Assessment

An expert opinion from an irrigation engineer from the National Irrigation Administration (NIA) helped determine the practical optimum distance to consider in the suitability analysis. Labiano (2014) asserted that the range of service areas for communal irrigation systems has a centroid of between three to five kilometers from the system. For national irrigation systems, the centroid ranges from five to ten kilometers. The integrated irrigation systems, which is designed to provide water to as many as 120,000 hectares, has a centroid of 20 to 60 kilometers.

Given the range of centroids and the objective of optimizing the potential area that may be suitable for rice cultivation, this study used the maximum coverage extent of the irrigation and river systems. The major river systems were delineated based on the Philippine Atmospheric, Geophysical and Astronomical Administration (PAGASA) classification of major river basins that intersected with the river basins vector layer from the Philippine Rice Research Institute (PhilRice). By applying these optimum suitability constraints, Figures 2.4a and 2.4b show that the irrigation and major river systems can potentially cover a service area of about 18.09 million hectares at the national scale and 1.93 million hectares at the regional scale, respectively. With the assumption that there are no infrastructural limitations to access these water sources, the estimates suggest that 87 percent of Central Luzon can be potentially serviced by the existing irrigation and major river systems in the region.

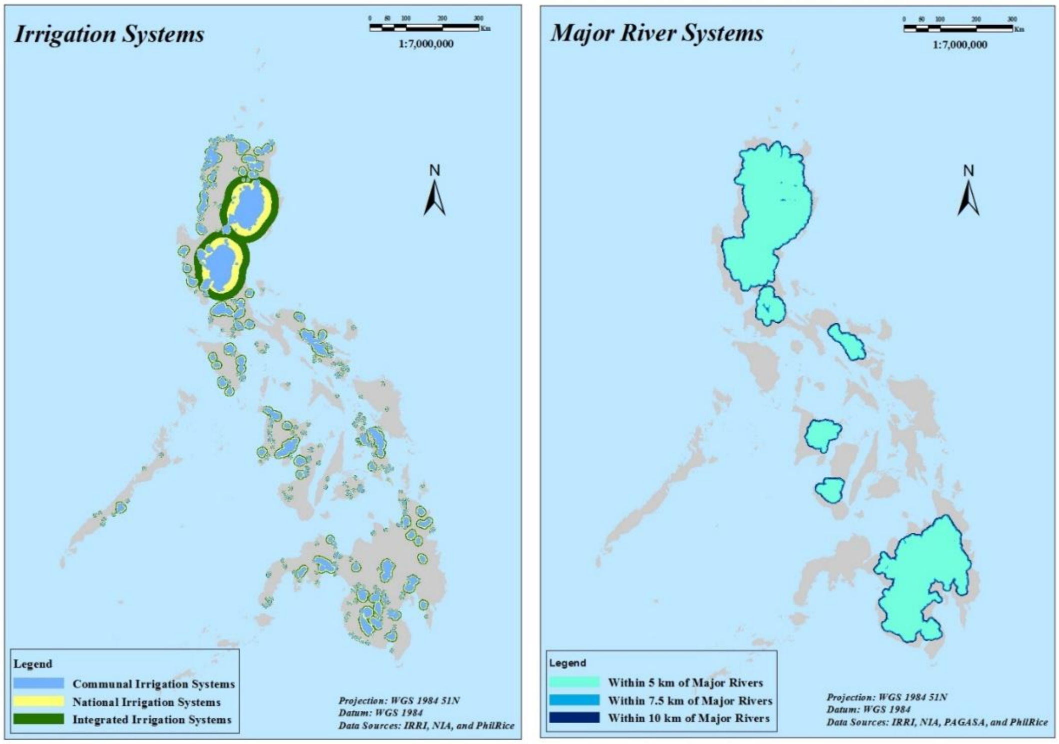

Figure 2.4a: Maximum coverage area of water sources at the national scale.

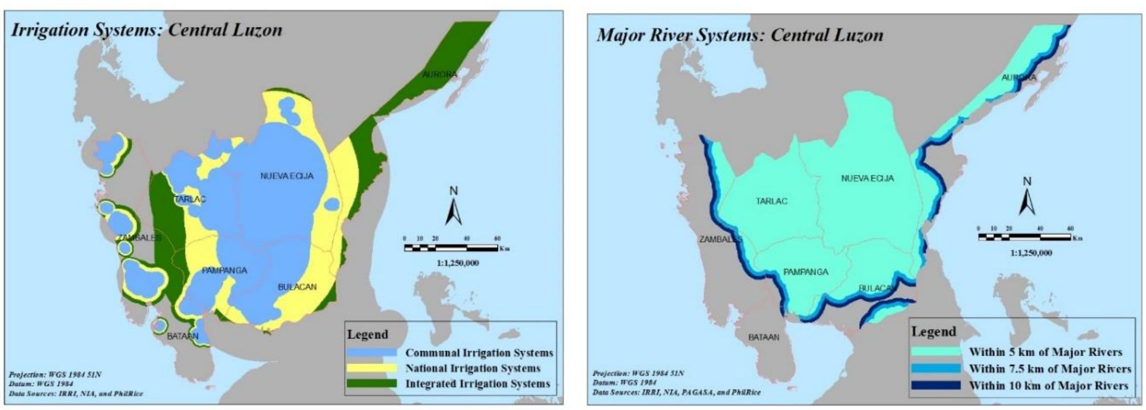

Figure 2.4b: Maximum coverage area of water sources in Central Luzon.

To determine the maximum area of land with suitable soil for rice production, this study conducted a generalized re-classification of the soil type categories derived from the spatial soil data of PhilRice. Based on the textural attributes from the spatial soil data and in relation to Moormann's (1978) classification of soils deemed important for rice production, a quantitative textural assessment of the different soil classes was conducted using the United States Department of Agriculture (USDA) Natural Resources Conservation Service's (NRCS) soil texture triangle (Figure 2.5). The textural assessment resulted in the following soil categories: clay, loam, silt, clay-loam, silt-loam, and silty-clay-loam.

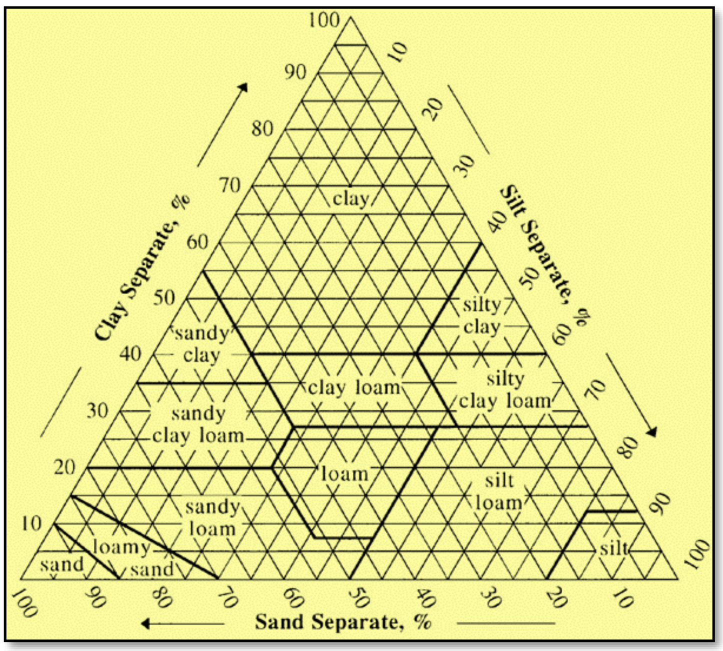

Figure 2.5: Soil texture triangle used to identify soil classes.
Source: Copied from USDA (2014).

As illustrated in Figure 2.6, clay and loam soils occupy 19 percent and 40 percent of the total Philippine land area, respectively. In Central Luzon, clay soils account for 14 percent of the region whereas loam soils occupy about 62 percent of the land area. The proportionate extent of the clay and loam soils is consistent with Moormann's (1978) soil classification as well as with the documentation of Carating, Galanta, & Bacatio (2014). The Bureau of Soils and Water Management (BSWM) (2014) estimated that 49 percent of Philippine soil have clay-loam, silty-clay-loam, and clay textures (Inceptisols).

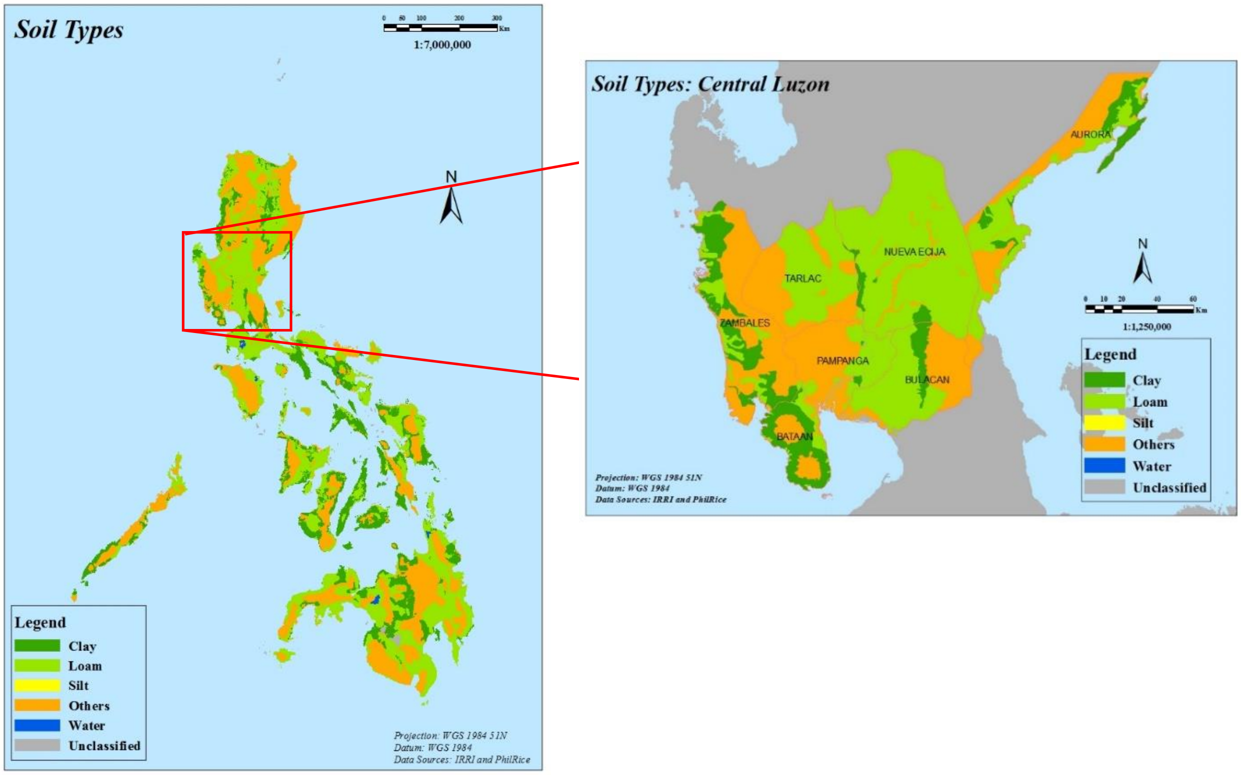

Figure 2.6: Maximum coverage area of different soil classes at the national and regional levels.

In the absence of a nationally or even a regionally instituted land use designation, the geo-referenced data generated from PhilRice which contains land cover and other land use classifications were primarily re-categorized into agricultural and non-agricultural lands. Non-agricultural areas include forest lands and those designated under the National Integrated Protected Areas System (NIPAS). Agricultural areas were further subdivided into prime rice areas, prime agricultural lands, and non-prime agricultural regions. Prime rice and prime agricultural lands are areas that are identified by the Department of Agriculture through the Bureau of Soils and Water Management (BSWM) and the National Mapping and Resource Information Authority (NAMRIA), which are delineated at the city and municipal levels. These areas which include all irrigated lands, potentially irrigable areas, agro-industrial croplands, and highlands that are suitable for high value crops are non-negotiable for conversion and should be protected from encroachment to ensure that lands are efficiently and sustainably used for food production to help achieve national food security (National Agricultural and Fishery Council, 2004).

The result of the land use re-categorization, as presented in Figure 2.7, shows that prime agricultural lands, which include prime rice lands, occupy 2.8 million hectares. The extent of non-prime agricultural areas is 4.6 million hectares. The coverage of prime and non-prime agricultural lands demonstrates the extent of potential areas that can be utilized for rice production. The range of potential agricultural lands, however, still exclude some alienable and disposable lands that can be partly allocated for agricultural use.

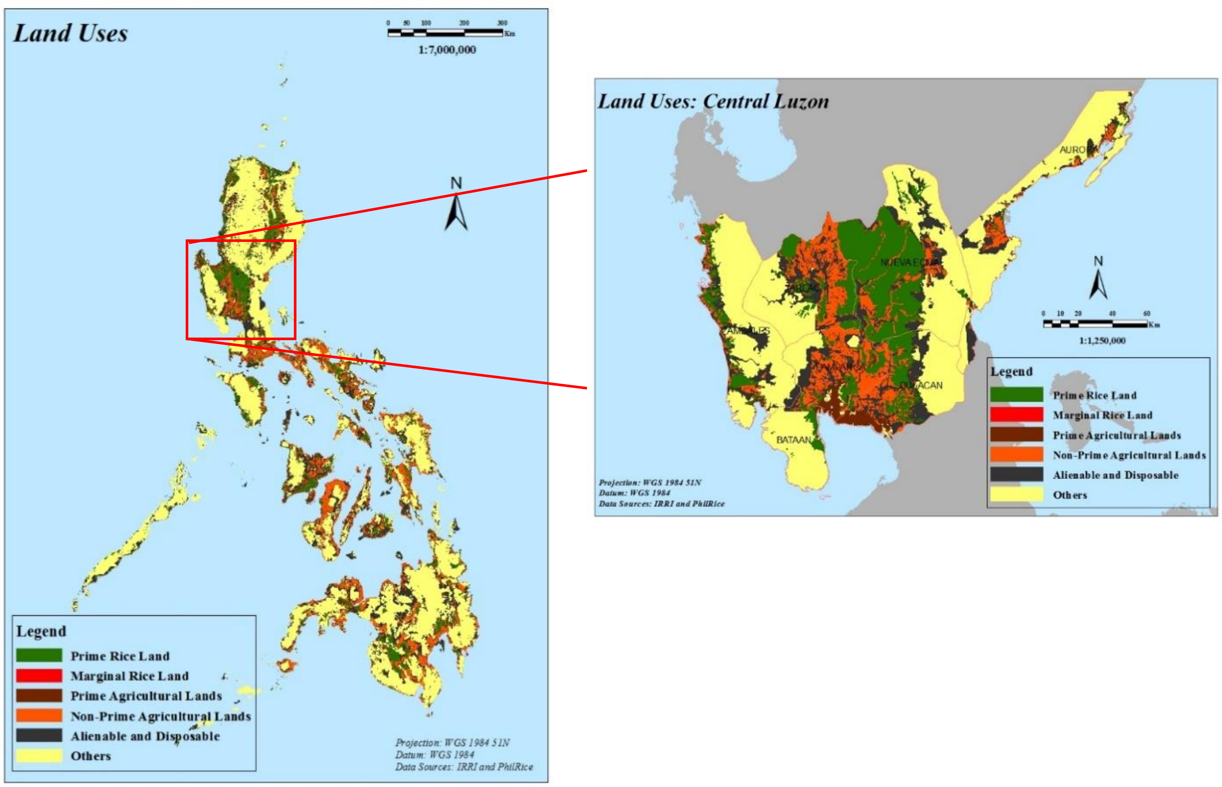

Figure 2.7: Maximum coverage area of different land uses at the national and regional levels.

To account for the available and undesignated alienable and disposable lands, the slope constraint was added to the suitability criteria. An estimated 40 percent of the total land area in the Philippines have a land gradient of zero to three percent. As shown on Figure 2.8, there are about 28 percent of the country with a land gradient of five to eight percent.

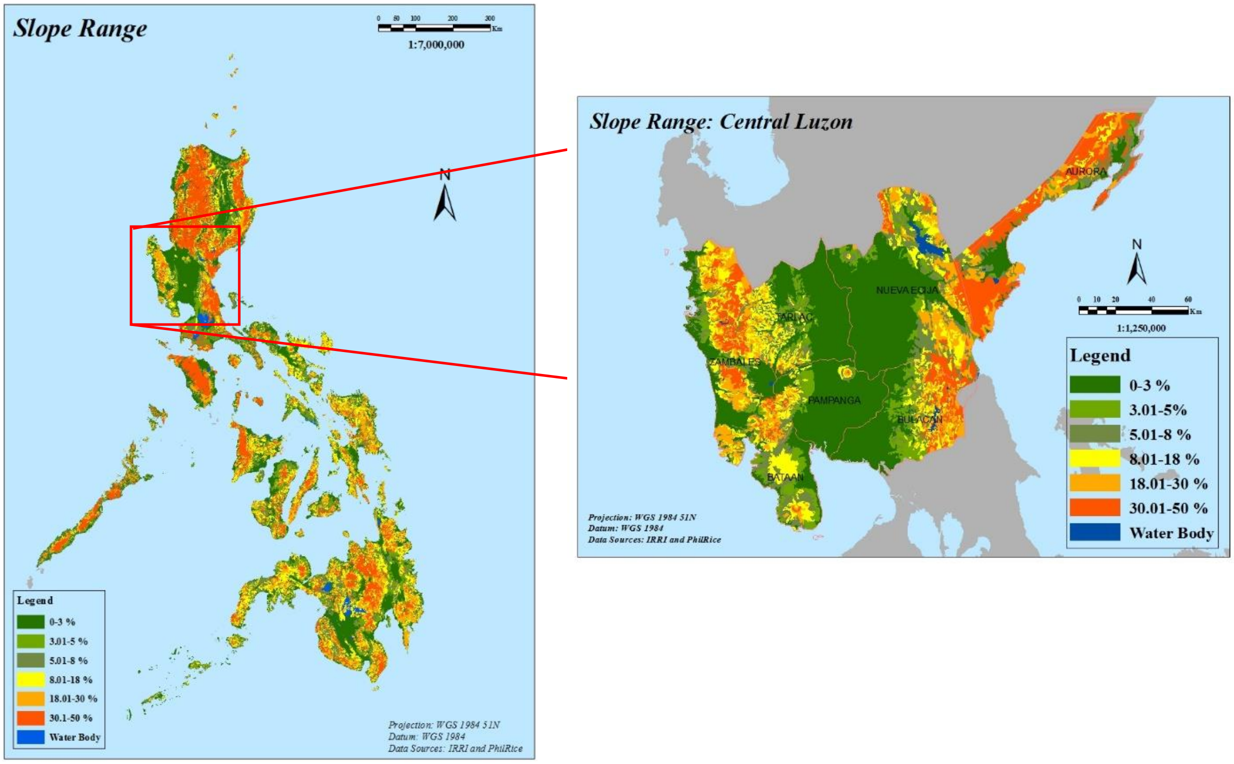

Figure 2.8: Maximum coverage area of different slope ranges at the national and regional levels.

Extent of Potential Areas Characterized as Suitable for Rice Production

The results of the thematic spatial mapping exercise clearly demonstrated the potential to expand rice production in the Philippines. The suitable areas for growing rice were delineated by integrating the thematic spatial information for each of the edaphic and environmental criteria identified as the most relevant to the system of cultivation in the Philippines and the target of the Food Staples Sufficiency Program (FSSP). On the basis of select threshold for water sources, soil, and land use designations, the maximum potential suitable land for rice cultivation was estimated by employing the Boolean membership function of one, “1,” for suitable and zero, “0,” for areas not meeting the criteria. The spatially aggregated range of suitable and not suitable area maps at the national and regional scales are presented in Figures 2.9, 2.10, and 2.11.

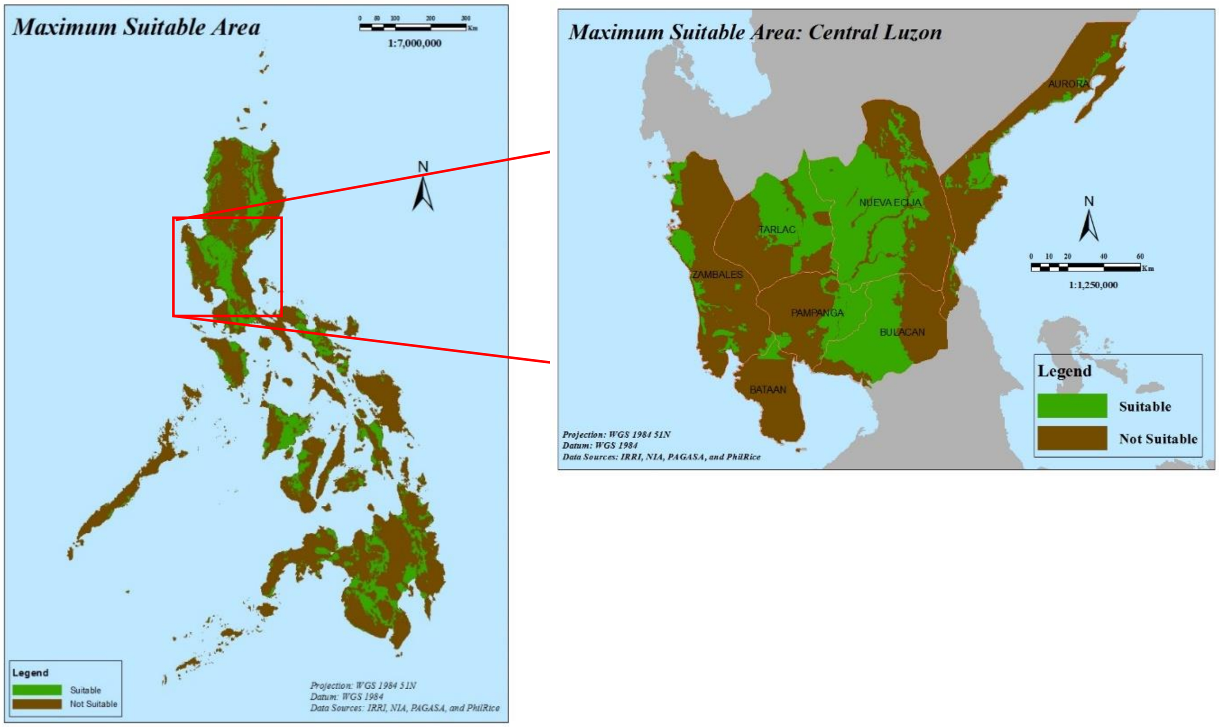

Figure 2.9: Maximum suitable area at the national and regional levels.

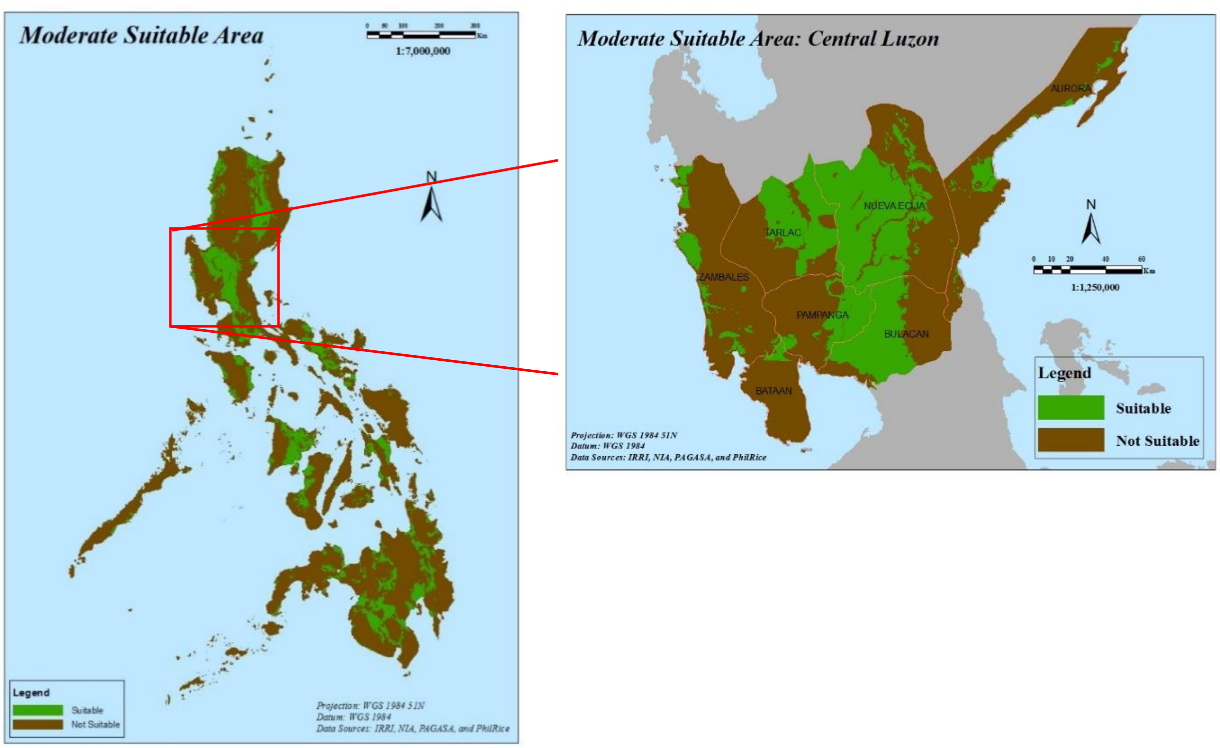

Figure 2.10: Moderate suitable area at the national and regional levels.

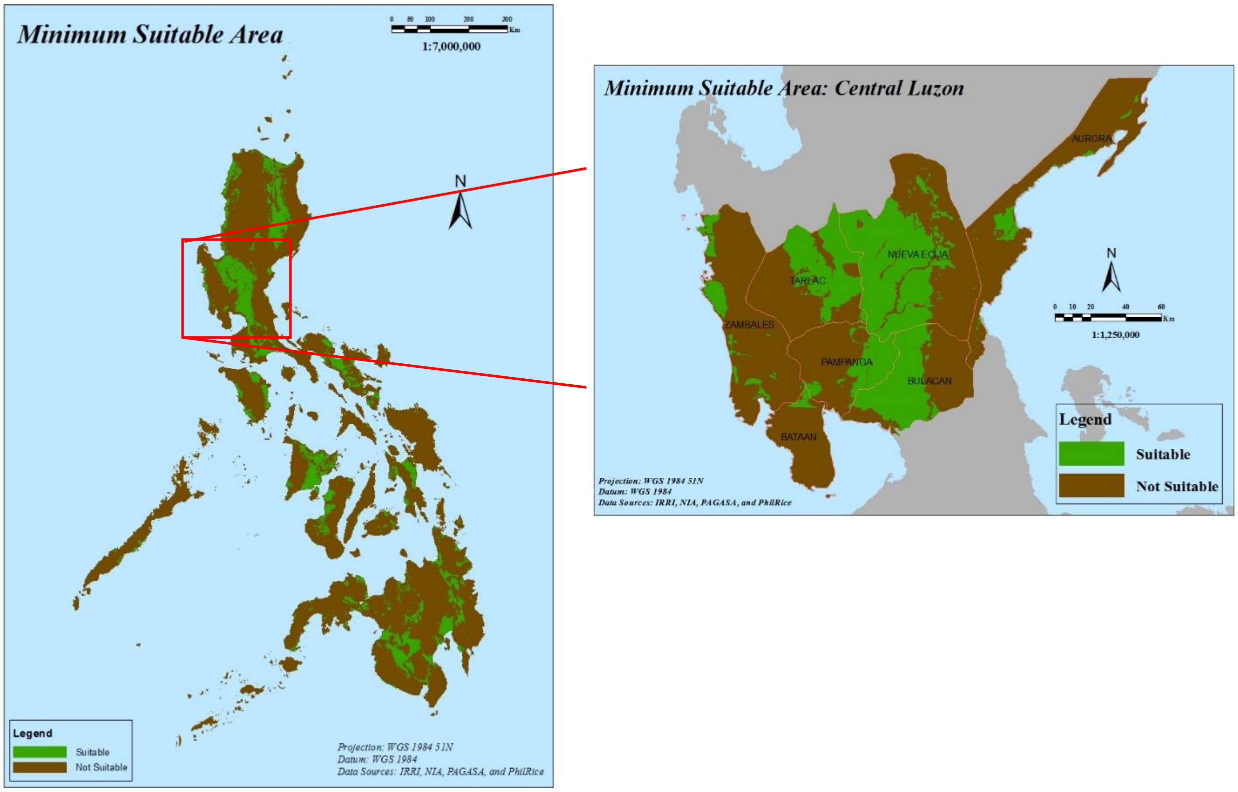

Figure 2.11: Minimum suitable area at the national and regional levels.

The application of the Boolean suitability assessment process shows that it is possible to expand rice production to almost 46 percent of the country's alienable and disposable lands.[14] This is 15 percent higher than the area of 4.35 million hectares devoted to rice in 2010. As presented in Table 2.4, the maximum additional areas potentially suitable for rice cultivation is 2.06 million hectares. At the regional level, when compared to the actual cultivated area for rice, the suitability assessment shows that Central Luzon can still accommodate expanded rice production to about 94,085 hectares of land in the region. Geographically, it should be noted that the areas for expansion in Central Luzon, to a certain extent, are mostly adjacent to areas already categorized as agricultural lands.

[14] Of the total Philippine land area, 14 million hectares are considered alienable and disposable lands (Navata & Turingan, 2013).

Table 2.4: Potentially suitable areas for rice production.

Coverage	Current rice area harvested (*in hectares*)	Additional potential harvestable areas for production expansion under various scenarios (*in hectares*)			Total potentially harvestable areas suitable for expansion under various scenarios (*in hectares*)		
	Status Quo *(2010)*	***Max.***	***Mod.***	***Min.***	***Max.***	***Mod.***	***Min.***
Philippines	4,354,161	2,065,818	1,491,040	663,495	6,419,979	5,845,201	5,017,656
Central Luzon	681,901	94,085	64,178	20,460	775,986	746,079	702,361

Note: Status quo data are from the Bureau of Agricultural Statistics (2014b). The other estimates are from author's calculation based on the results of the Boolean spatial integration. Max., Mod., and Min. refer to maximum, moderate, and minimum suitable land areas, respectively.

Is the National FSSP Production Target Achievable?

Given the magnitude of possible expansion at the national and regional levels, the Food Staples Sufficiency Program (FSSP) target of increasing rice production from 15.77 million metric tons in 2010 to 22.73 million metric tons in 2016 is attainable at an average yield of 3.54 metric tons per hectare under the maximum land area scenario (Table 2.5). Cognizant of yields in the last 25 years (1990-2014) that range from 2.62 metric tons to 3.89 metric tons with an average yield of 3.12 metric tons and a median yield of 3.07 metric tons, production at 3.54 metric tons per hectare is a viable yield target. If potential area for expansion is not maximized, the FSSP target is still attainable under moderate area expansion, which requires an average yield of 3.89 metric tons per hectare.

It is apparent that maintaining production given average historical yields is not an option since under the maximum land area scenario the largest possible production is 20.03 million metric tons. The achievability of the FSSP target clearly depends on a trade-off between the degree of expansion and the per hectare production yield. The target of 22.73 million metric tons in 2016 is attainable even if expansion is not maximized given that yield per hectare is set at the maximum historical yield. If maintaining the maximum historical yield is unobtainable, it remains possible to attain the FSSP target at a lower yield per hectare if expansion is maximized to 6.42 million hectares.

Table 2.5: Rice production yield needed under different land area scenarios in order to achieve the Food Staples Sufficiency Program (FSSP) target.

Yield	**Potential rice production under different suitable land area suitability scenarios**		
	Maximum Land Area Scenario	***Moderate Land Area Scenario***	***Minimum Land Area Scenario***
Minimum yield required per hectare (*in metric tons per hectare*)	3.54	3.89	4.53
Potential rice production given average historical yields (*in metric tons*)*	20,030,334	18,237,027	15,655,087
Potential rice production given maximum yields (*in metric tons*)**	24,973,718	22,737,832	19,518,682

*Average historical yield is 3.12 metric tons per hectare. ** Maximum historical yield is 3.89 metric tons per hectare.

Opportunity Cost of Expanding Land for Rice Production

As an archipelago, lands in the Philippines are vital resources that serve as primary platforms of a wide array of economic and social activities ranging from agricultural production to biodiversity protection and human settlements. Despite its sizeable land area of 30 million hectares, only about 47 percent of the Philippines' total land area is available for allocation to various social and economic uses as majority of the lands are considered as forest areas protected under national legislation. With approximately 14 million hectares available for various competing uses, the allocation of any parcel of land to a particular use commonly comes with a price. In the case of devoting lands to rice production, there are foregone benefits that could be derived from an alternative profitable land use. These forgone benefits are known as opportunity costs.

Corpuz (2013) and Pirard (2008) noted that opportunity cost of land use is based on the notions of scarcity, exclusiveness, and the monopolistic nature of the resource. Competing land uses such as staple food production could take place along with other uses for the purposes of settlements and infrastructure development as well as conservation and protection of ecological and enviromental systems, in a state where land scarcity is non-existent. However, since land is a scarce resource and exhibits exclusivity, two different land uses cannot occur simultaneously on the same parcel. This calls not only for purposeful land use allocation but also accounting for the costs that come with the geographic designation of different land areas for various purposes.

At present, there is no consistent and integrated national land use legislation or policy in the Philippines that guides how lands, including its mineral, water, and other natural resources, should be used. Current land use allocation has been devolved to local governments. The 1991 Local Government Code mandates and provides exclusive power to cities and municipalities to develop comprehensive land use plans (CLUP) in accordance with their local government development plans (Corpuz, 2013). As such, local governments have the liberty to devise a land use plan that supports its physical and sectoral development programs including employment growth, poverty alleviation, education and health development among others. This, according to Corpuz (2013), has led to what is called “spot zoning”, where lands are rezoned to unsuitable or irrelevant uses to provide incentives to and serve the vested interests of local government officials.

Because of “spot zoning,” land uses in most cities and municipalities are commonly biased to settlements and infrastructure development as these uses generate more income for the local governments. The rezoning can allow encroachment of built up land uses into agricultural and forest production areas as well as disaster-prone sites, which, at times, result in direct threats to public safety, decline in ecological systems, and scarcity of productive resources and support services. Under the practice of “spot zoning,” local governments give sporadic focus on protection land use, which allocates land to promote conservation and sustainable use of the country’s ecological and life-support systems. Further, due to lack of guidance to support national policy setting, the incentives for allocating land towards production uses has diminished. Spot zoning at the local level has restricted lands for food production (including crops, fishery, poultry and livestock), energy development, mineral production, tourism, and production of wood products to areas with 50 percent slope gradient (excluded from low lying areas).

Given these land use realities in the Philippines, it is apparent that the common land use classifications under the CLUPs of local governments include built up areas, agricultural lands, forestlands, and those for special uses as determined by the cities and municipalities. As such, the use of land for settlement purposes and profitable infrastructure (e.g., commercial) development appears as the best alternative available for land allocated to staple food (rice) production. Therefore, with the assumption that there are no barriers to the utilization of the most valuable land use alternatives to rice production in available and disposable areas, the opportunity cost forgone is assessed against two viable options.

The first option is the use of land for another type of crop production, corn. This option is considered because next to rice, corn is the second most important food crop in the Philippines with a third of the local farmers depending on corn production for their livelihood (Gerpacio, Labios, Labios, & Diangkinay, 2004). Furthermore, in the last two decades, national corn production in metric tons has increased by more than 80 percent compared to just over 70 percent for rice (BAS, 2016). The second option considered is the sale of the land for potential conversion to uses such as development projects for human settlements and infrastructure. By using 2010 rice and corn prices in nominal terms, the forgone costs for expanding rice production in areas determined as suitable is shown in Table 2.6.

The results of the opportunity cost approximation show that using market values of land use rents associated with alternative land utilization practices, the conversion of existing and potentially suitable areas for rice production to non-agricultural uses demonstrate substantially higher return. If crop production option is abandoned and areas categorized as potentially suitable are sold at the value of Ph₱ 67,000 per hectare (Ballesteros, 2010), the maximum opportunity cost of not converting the areas to other non-agricultural uses amounts to as much as Ph₱ 128 billion at the national level and Ph₱ 15 billion at the regional scale. Although these figures are a rough measure of opportunity costs of rice expansion, they provide land users estimates for assessing the economic viability of the available areas for different uses.

As further demonstrated in Table 2.6, the agricultural use of land for rice production provide a higher return than allocating areas for corn production. With an average farmgate price of Ph₱ 15.29 per kilogram for corn and Ph₱ 15.11 per kilogram for rice (BAS, 2014d) in 2010, under the maximum land area scenario, the opportunity cost of devoting the areas to corn is Ph₱ -126 billion and Ph₱ -15 billion at the national and the regional levels, respectively. This suggests that if agricultural land use is the sole option, farmers would be economically better off if rice would be the chosen crop as corn provides a lower return.

Table 2.6: Opportunity costs of rice expansion under various scenarios and types of best alternative land uses at the national and regional scales.

Type of Land Use	**Opportunity costs of rice expansion given values of different land uses*** *(in million Philippine Pesos)*		
	Maximum Land Area Scenario	***Moderate Land Area Scenario***	***Minimum Land Area Scenario***
Philippines			
All areas categorized as suitable allocated solely to rice production	302,658	275,561	236,548
All areas categorized as suitable allocated solely to corn production	175,709	159,978	137,329
All areas categorized as suitable converted (sold) solely for land use other than crop production (e.g., human settlements or housing)	430,139	391,628	336,183
Central Luzon			
All areas categorized as suitable allocated solely to rice production	36,582	35,173	33,112
All areas categorized as suitable allocated solely to corn production	21,238	20,420	19,223
All areas categorized as suitable converted (sold) solely for land use other than crop production (e.g., human settlements or housing)	51,991	49,987	47,058

*To estimate the forgone costs for rice and corn production land uses, the author used average annual historical yield per hectare from 1987 to 2010. Since the base year for this study is 2010, the year prior to the full implementation of the Food Staples Sufficiency Program (FSSP), the author used the 2010 farm gate prices in the calculation of the opportunity costs of rice and corn production in available and suitable land areas. Readers may refer to Appendix A and B for more details on the average annual historical volume of production, yield per hectare, farm gate prices, and value of production.

The opportunity cost assessment can be used as a decision-making tool not only for landowners and users to compare the costs and potential opportunities in expanding land area for rice cultivation. Policy makers can also use the forgone costs estimates to influence mindset and possibly alter land use behavior towards rice crop production. The results of the opportunity cost analysis in this study, however, should be used with prudence as it does not take into consideration the full value of the alternatives by failing to account for other monetary and non-market benefits of the different land use options.

The opportunity cost analysis presented in this study is oversimplified for demonstration purposes. It does not recognize other potential benefits that complement rice or corn production and the conversion of land to settlement and infrastructure areas. For instance, with the use of land for rice production, the analysis only accounted for the market value of raw rice traded at the local market for food consumption. The analysis did not consider the economic potential of deriving raw materials such as straws and husks from the production process, which can be used in the energy and construction sectors. The analysis also failed to attach a value on erosion control and sediment retention services as well as soil fertility benefits generated from the allocation of land for rice production (Wratten, Sandhu, Cullen, & Costanza, 2013). Flood mitigation and biodiversity habitat functions (e.g., avian habitats) of irrigated rice production systems, which are the dominant practice in the Philippines, was also not taken into account (Otieno, et al., 2015; Patiung, Santoso, Tyasmoro, & Hanani, 2013). The exclusion of the economic values of the raw by-products and the ecosystem services that can be generated from rice production has definitely underestimated the overall forgone benefits as presented in Table 2.6.

In terms of the corn production option, the diversified uses of corn other than as a staple food, e.g., fodder for livestock, starch for industrial and domestic uses, and biomass for ethanol production (Oladejo & Adetunji, 2012; Monlruzzaman, Rahman, Karim, & Alam, 2009) were correspondingly not considered in the opportunity cost analysis. By disregarding these other potential uses of corn, the analysis has inadequately accounted for the forgone benefits. With the market for corn-based ethanol at a more mature stage than utilization of rice by-products for energy production, the likelihood of corn yielding a higher return than rice is probable. The results of the opportunity cost analysis, therefore, manifest an undervaluation of the forgone benefits from corn production, which necessitates a cautious treatment of the results of the analysis.

Along with the intangible benefits unaccounted for in the opportunity cost analysis, the costs associated with expanding crop production in the upland areas for both rice and corn production land use options were not estimated as well. Under the assumption that production of either rice or corn in sloping gradients would follow the lowland practice, it should be noted that production and marketing expenditures including transaction costs incurred in upland areas would be relatively larger than that of lowland production systems. According to the Food and Fertilizer Technology Center (FFTC, 1997), crop producers in the upland areas commonly face similar problems of soil erosion vulnerability and unavailability of consistent water supply, particularly in the dry seasons. If irrigation infrastructure is to be provided to the upland areas, it will require a substantial investment either from the government or in partnership with the private sector. The costs attached to this type of investment were not included in the opportunity cost analysis. Further, the quantity of water required to expand rice or corn production areas was also excluded in the analysis. It should be noted, however, that under irrigated production system, rice requires about 2.5 times the amount of water needed to grow corn (Bouman, 2015). Given this water requirement, expansion of rice production would imply a higher demand for limited fresh water supplies. With the potential expansion impact on the water sector, it is imperative that this component be included in an extended opportunity cost analysis.

Due to distance from city centers, upland farmers also have to overcome the difficulty of accessing production inputs such as seeds, fertilizer, machinery, and labor (FFTC, 1997). With the sloping nature of the land, upland production requires specialized machinery, which may not be compatible with available lowland machinery. To complement machinery utilization, labor in the upland areas if not scarce may be exorbitantly pricey. On top of these production-related costs associated with expanding rice or corn production in the uplands, farmers are confronted by high marketing transportation costs during post-harvest. These expenditures, similar to the costs of irrigation, were also excluded in the analysis, which implies some level of underestimation of the opportunity costs associated with either rice or corn production.

Despite limitations of the opportunity cost analysis undertaken in this study, the rough estimates presented in Table 2.6 provide essential information to decision makers interested in pursuing land use options that can potentially yield larger economic benefits. Policy makers and farmers can use these rough estimates to make the argument on why rice expansion should be pursued or ignored. Decision makers should be mindful in using these results when allocating suitable areas for various uses since the intangible costs and benefits attached to each option can dramatically influence the basis for justifying total value of each land utilization option.

Natural Resource Input and Output By-Product Implications of Rice Production Expansion

Cognizant that unsustainble utilization of scarce biophysical and natural resources to support rice production poses a threat to achieving the Food Staples Sufficiency Program (FSSP) target, this study reframes rice self-sufficiency under the cross-sectoral paradigm of sustainability. To sustainably produce rice and satisfy the target, production as well as consumption must not be addressed in isolation with other sectors. Rather, rice production must be viewed from a broader lens of influences if its environmental impacts are to be minimized.

Given that at the global level, agriculture is the largest water consuming sector, accounting for approximately 70 percent of total withdrawal, and that the food production and supply chains consume about 30 percent of total global energy, and 90 percent of the global power generation relies on water (Rasul & Sharma, 2015; WWAP [United Nations World Water Assessment Programme], 2014), it is crucial to draw attention to the sustainability implications of expanded rice production on freshwater utilization and clean energy development. Bhaduri, Ringler, Dombrowski, Mohtar, & Scheumann (2015) argued that these sectors – water, food, and energy – are closely “interlinked by joint demand, price developments, technology, and resource constraints” as shown by the price trends in agricultural commodities including rice and fossil fuel, specifically crude oil. According to Rockstrom, et al., (2009), the average global demand for water, food, and energy is growing at an unprecedented rate while the resources required to generate them are facing scarcity. For this reason and in support of efficient and sustainable attainability of the FSSP target under the banner of producing more rice with less water and energy, this study investigates the spillover effects of expanding rice production on the water and energy sectors by quantitatively and qualitatively accounting for the potential economic, environmental, and social implications.

By limiting the sectoral spillover effect analysis to water, food, and energy, this study provides a potent entry point for achieving sustainability in rice production by providing fundamental information to help promote socially and economically rational decision making and efficient resource use in an environmentally-responsive fashion. This, however, does not suggest that this study discount the potential spillover of rice production expansion to other sectors including agriculture itself. The labor sector, for instance, will be impacted by the expansion in rice production as more production means increased demand for rural workers translating to more income generating opportunities, thus reducing rural-urban migration (Anderson, Stringer, Erwidodo, & Feridhanusetyawan, 2009). Acceleration in rice production also fosters spillover effects to other components of the agricultural sector as increases in the supply of rice may cause rice prices to fall enabling people to switch to rice and lowering demand for other food staples such as corn, banana, sweet potato, and cassava.

Increased domestic rice production also generates spillovers in the agricultural import and export sectors. When rice self-sufficiency is achieved, this means that the Philippines will no longer rely on imported rice and there is the likelihood of a rice surplus, which the country can use for export purposes. In the last two decades, the Philippines has exported less than 1,000 metric tons of rice, of which the majority are premium rice – red rice, black rice, and organic rice (Philippine Statistics Authority [PSA], 2015). With the Philippines as one of the top five countries importing rice from Thailand and Viet Nam, the attainment of rice self-sufficiency will definitely have a spillover effect on rice trade in the Southeast Asian region.

It is apparent that the spillover effects of rice production expansion is not confined within a few sectors. Under the aegis of sustainable and efficient production, however, the water and energy sectors are the most relevant and closely interlinked. As such, this study narrowly focuses on the natural resource input (water) and output by-product (rice straws and husks) implications of attaining the food staples sufficiency target.

Water as Natural Resource Input. Pimentel & Giampietro (1994) articulated that when dealing with the issue of food security, it is essential to take into consideration the different constraining inputs to generate adequate food supply. In agriculture, particularly rice production, the traditional relevant natural resource inputs include water and land. Water is necessary for rice growth as water helps control weed growth, regulate temperature, and create favorable microclimate to maintain soil moisture and distribute nutrients effectively (Shaxson & Barber, 2003; FAO, 1985).

Water in the form of irrigation or precipitation is a growth-limiting factor in rice production (Akinbile, Abd El-Latif, Abdullaah, & Yusoff, 2011; Ali & Talukder, 2008; Tao, et al., 2006; Ceesay, 2004). Adequate water supply has been identified as the major constraint for yield gaps and yield variability from rice experimental stations to farms (Papademetriou, Dent, & Herath, 2000). This means that without this resource, plant growth declines and fails to achieve their potential (Van Ittersum & Rabbinge, 1997).

Given that the potential area for rice production can possibly be expanded in 2016 by 47 percent more than the production area in 2010 (Table 2.4), the Department of Agriculture (2012) acknowledges that rice yields can be maximized if there is adequate water supply combined with the use of high-yielding rice varieties, efficient application of fertilizers, and crop management techniques. Adequacy, primarily, deals with water supply to the crop relative to its demand (Gorantiwar & Smout, 2005). Cognizant of the role of water to raise productivity and competitiveness, it is very crucial to assess the spillover effects or the potential impacts of rice expansion to existing water supply.

Increasing water input in rice production mainly through expanded irrigation can have high social, economic, and environmental impacts because water could have been diverted to other sectors where demand is growing such as domestic use in urban areas. Frenken (2012) reported that based on long-term annual flow of rivers and recharge of aquifers, the Philippines, on an annual average, has approximately 479 billion cubic meters of renewable water supply. Of which, 81,555 million cubic meters were withdrawn in 2009. In the same year, the agricultural sector used 82% (67,066 million cubic meters) of the total freshwater withdrawn, whereas the municipal (domestic) and industrial sectors utilized 8% (6,235 million cubic meters) and 10% (8,254 million cubic meters), respectively. Approximately, 244 million cubic meters and 110,079 million cubic meters of the country's renewable water supply are correspondingly allocated to non-consumptive uses such as recreation and hydropower.

Based on Bouman's (2009) estimate of 2,500 liters of water required to produce a kilogram of rice, a hectare of land with a historical average yield of 3.12 metric tons (Appendix A) needs 7,800 cubic meters of water.[15] Given this proportion, 56,817 million cubic meters of

[15] Unit conversion: 1 metric ton = 1,000 kilograms and 1 liter = 0.001 cubic meters.

water supply is required to achieve the target of 22.73 million metric tons at a production rate of 3.54 metric tons per hectare under the maximum land area scenario. If the target is to be achieved with moderate expansion and yield follows the current maximum historical production of 3.89 metric tons per hectare, the total water requirement will be 56,845 million cubic meters. As shown in Table 2.7, these water requirements regionally translate to 7,256 million cubic meters under the moderate land area scenario.

Table 2.7: Water input requirements to achieve the FSSP target under various land area and production scenarios at the national and regional scales.

Coverage	***Maximum Land Area Scenario***	***Moderate Land Area Scenario***	***Minimum Land Area Scenario***
Philippines			
Total potential area suitable for rice production (*in hectares*)	6,419,979	5,845,201	5,017,656
Water requirement given maximum yields (*in million cubic meters*)	62,434	56,845	48,797
Central Luzon			
Potential regional area suitable for rice production (*in hectares*)	775,986	746,079	702,361
Regional water requirement given maximum yields (*in million cubic meters*) **	7,546	7,256	6,830

** Maximum historical yield is 3.89 metric tons per hectare.

The demand for water resources in the Philippines is inferred to substantially increase by 281% for the domestic sector, 186% for the agricultural sector, and 124% for the industrial sector by 2025 (Dargantes, Batistel, Manahan, & Flores-Obanil, 2011). These estimates imply that if business as usual (BAU) scenarios with the Philippine water supply and withdrawal curves remain as that in 2009, at the maximum, about 93 percent of the water used for the agricultural sector will be devoted to rice production alone under the maximum land area scenario given highest historical yield. If agricultural water demand takes priority in support of the FSSP, allocation of water towards rice production poses a particular threat to other water-using sectors including non-rice agricultural entities. The alteration in the water allocation and distribution may result to potential sectoral trade-off conflict and, therefore, the planned acceleration of irrigation systems under FSSP should be approached with caution.

By-Products from Rice Production. In a paddy rice production process, there are usually several by-products or residues. The most common of these are the rice husks, also known as rice hulls, and the rice straws. Gummert (2013) estimated that 20% of rice paddy weight is husk. In an on-going study on assessing the potential of rice husks as energy source in Panay Island, Philippines, Militar (2014) ascertained that rice straws make up 29% of rice paddy weight. These residues have been traditionally considered as waste products and they have no commercial value. Due to its high calorific value, rice husks and straws, which consist mainly of ligno-cellulose and silica, have recently been identified to have great potential as a renewable energy source (Yerima & Isa, 2012; Cunha-Pereira, et al., 2011; Prasara-A & Grant, 2011; Maiti, Dey, Purakayastha, & Ghosh, 2006; Chungsangunsit, Gheewala, & Patumsawad, 2004; Summers, et al., 2003; Jenkins, et al., 1999; Yomogida & Jenkins, 1997; Kapur, Kandpal, & Garg, 1996; Tiangco, Goss, Jenkins, & Chancellor, 1989).[16]

Amidst the Philippine Department of Energy's campaign for the development of an energy system that utilizes local sources of energy in support of the Philippine Energy Plan 2011-2030 (PEP 2011-2030) and the Biofuels Act of 2006 (Republic Act 9367)[17], the need to maximize the potential of rice for other purposes other than satisfying food security needs is very timely. Given that along with other factors of production, affordable and clean energy is a vital and necessary input for economic and social development (Chontanawat, Hunt, & Pierse, 2008; Ghali & El-Sakka, 2004), the climate to promote and expand co-production of bioenergy from rice residues has never been more auspicious and favorable for the Philippines but today. For the Philippines to continue to induce economic growth and increase local food production, it has to recognize and unlock the potential that the rice sector has to offer in direct support of the energy sector.

In response to the country's renewable energy policy, the Philippine Rice Research Institute (PhilRice) has advocated the integration of energy generation into the rice production

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[16] Currently, rice husks are utilized as low quality feeds for livestock, bio-fertilizer additive, pest control agent, and inputs to manufacturing of some building materials. In terms of energy generation, limited applications of rice husks have been observed in Asia as sources of gas for cook stoves as well as electricity for heating air in rice dryers. The commercial application of rice husks in energy generation is still in its early experimental stages.

[17] The Biofuels Act require liquid fuels in the Philippines to have the following blended components: bioethanol – 5% ethanol blend for gasoline in 2009 and increasing to 10% in 2011; biodiesel – 1% blend for diesel in 2007 and increasing to 2% in 2009. The Act also aims to boost agricultural and rural farm workers' income and livelihood.

sector. The Institute has proposed the use of rice by-product biomass as alternative energy source. PhilRice research scientists have estimated that, on average, the country produces 2.90 million metric tons of rice husks annually (Frediles, 2012). Based on a heating value of 14 gigajoules per ton used in Orge & Abon (2012), the estimated rice husk residues translate to approximately 40.75 million gigajoules of energy or 1,083 million liters of oil.[18]

With the Food Staples Sufficiency Program (FSSP) currently in full swing and the rice expansion in motion, there is an anticipated overabundance of rice husks and straws, being the by-products of the rice harvesting and milling processes. If not properly utilized and if current practice of open fields dumping and burning continue, the surplus signals an increase in waste disposal problem as well as exacerbated local air pollution since rice by-products “left to decompose generate methane which is a more potent greenhouse gas than carbon dioxide” (Orge & Abon, 2012). Therefore, to complement the realization of the FSSP goals, it is important to explore ways to increase the use of rice by-products for energy generation, primarily by assessing the potential amount of energy that can be generated from the targeted increase in rice production under the FSSP. The potential utilization of rice by-products for energy production can in turn alleviate environmental degradation and at the same time provide additional livelihood opportunities for farmer.

If the FSSP target of producing 22.73 million metric tons of rice is achieved, there is a potential to produce 4.55 million metric tons of husks and 6.59 million metric tons of straws.[19] At this level of by-product production, rice husks have the potential to produce 1,699 million liters of oil with a power and energy equivalent of 254 megawatts and 2,228 million kilowatt-hours, respectively.[20] The utilization of rice straws as potential bioenergy resource can generate 260 megawatts of additional power with an energy equivalent of 2,275 million kilowatt-hours.[21]

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[18] By using the amount of rice hull generated in the Philippines in 2011, which is 3.7 million metric tons, Orge & Abon (2012) calculated that at the heating value of 14 gigajoules per ton, the Philippines could have generated around 52 million gigajoules of energy or 8.7 million barrels of oil.

[19] Rice husks are approximately 20% of the rice production weight (Militar, 2014; Gummert, 2013). Rice straws are approximately 29% of the rice production weight (Militar, 2014).

[20] On average, one metric ton of rice husks is equivalent to 490 kilowatt-hours (Militar, 2014). To generate the equivalent power supply, the annual energy equivalent was converted to megawatts based on a 24-hour period. There are 373.62 liters of oil for every metric ton of rice husk [derived from per barrel estimates as presented in Orge & Abon (2012)].

[21] On average, one metric ton of rice straws is equivalent to 345 kilowatt-hours [derived from proportion estimates as presented in Zafar (2014)].

Under different possible land expansion scenarios and given maximum historical rice yields, the range of rice husks that can be nationally generated is between 3.90 and 4.99 million metric tons (Table 2.8). This magnitude translates to 218 megawatts of power at the minimum and 279 megawatts at the maximum. With this supply of by-products, it is feasible to produce at least 1,913 million kilowatt-hours of energy and 1,459 million liters of oil. The amount of potential power that rice expansion may bring about is comparable to the capacity of some of the existing coal-fired power plants around the Philippines, which ranges between 100 megawatts to 1,200 megawatts (GEO, 2015). This implies that with cost-effective technology and directed investments, utilization of rice husks as alternative energy source can support at least one power plant that has the potential to complement if not replace existing facilities that employ inputs that are not environmentally favorable and may cause exacerbated greenhouse gas emissions resulting to severe climate change.

By considering the largest rice-producing region in the country, Central Luzon, Table 2.8 shows that at the regional scale, the production potential of rice husk is estimated to be between 0.44 to 0.60 million metric tons per year, which at its maximum can potentially satisfy about 14 percent of the national installation target of 250 megawatts of power from biomass sources (DOE, 2012). If husks from rice production in Central Luzon are utilized to its full potential as feedstock to renewable power generation, the region alone has the capability to meet nearly a quarter of the national biomass renewable energy target.[22] The likelihood of meeting approximately 25 percent of the target is not remote since at present, there is already 24.30 megawatts of mixed biomass power plants operating in Central Luzon.[23]

[22] A quarter of the national biomass renewable energy target is equivalent to 62.5 megawatts. Of which 34 megawatts can be potentially generated from rice husks. When combined to existing bioenergy facilities in Central Luzon, potential energy from rice husks and current sources can together generate close to 60 megawatts of power.

[23] The Philippine Department of Energy reported in 2012 that there is a 12 megawatt reciprocating grate steam boiler facility in Mariveles, Bataan. There is also a 2.4 megawatt multi-fuel biomass power plant facility in San Leandro, Nueva Ecija. Recently, a 9.9 megawatt biomass power plant known as iPower was commissioned in San Jose City, Nueva Ecija.

Table 2.8: Bioenergy potential from rice husks under various land area expansion and rice production scenarios at the national and regional scales.

Coverage	*Maximum Land Area Scenario*	*Moderate Land Area Scenario*	*Minimum Land Area Scenario*
Philippines			
Based on Maximum Historical Yield[a]			
National annual supply of rice husk (*in metric tons*)[b]	4,994,744	4,547,566	3,903,736
Annual energy supply equivalent (*in million kilowatt-hours*)[c]	2,447	2,228	1,913
Annual power supply equivalent (*in megawatts*)[d]	279	254	218
Oil supply equivalent (*in million liters*)[e]	1,866	1,699	1,459
Central Luzon			
Based on Maximum Historical Yield[a]			
Regional annual supply of rice husk (*in metric tons*)[b]	603,717	580,449	546,437
Annual energy supply equivalent (*in million kilowatt-hours*)[c]	296	284	268
Annual power supply equivalent (*in megawatts*)[d]	34	32	31
Oil supply equivalent (*in million liters*)[e]	226	217	204

[a] The maximum historical yield is 3.89 metric tons per hectare. [b] Rice husks are approximately 20% of the rice production weight (Militar, 2014; Gummert, 2013). [c] On average, one metric ton of rice husks is equivalent to 490 kilowatt-hours (Militar, 2014). [d] To generate the equivalent power supply, the annual energy equivalent was converted to megawatts based on a 24-hour period. [e] There are 373.62 liters of oil for every metric ton of rice husk [derived from per barrel estimates as presented in Orge & Abon (2012)].

The feasibility of using rice straws as feedstock for bioenergy production and raw material for power generation plants is in its infant stages in the Philippines. In 2012, the Philippine Rice Research Institute (PhilRice) signed an agreement with a French company, ENERTIME, to assess the feasibility of using rice straw for power generation (Yap, 2012). The project examines the possibility of collecting, transporting, and conditioning rice straws to be used as renewable feedstock in electricity generation.

Based on the proportion suggested in Militar (2014) and Zafar (2014), it was calculated that with the maximum land area expansion and rice production scenarios, 7.24 million metric tons of rice straws can be generated at the national level (Table 2.9). Of these, 12 percent can be generated from Central Luzon. With this potential amount of rice straws, the national grid can gain an additional 285 megawatts of power at the most.

Table 2.9: Bioenergy potential from rice straws under various land area expansion and rice production scenarios at the national and regional scales.

Coverage	***Maximum Land Area Scenario***	***Moderate Land Area Scenario***	***Minimum Land Area Scenario***
Philippines			
Based on Maximum Historical Yield[a]			
National annual supply of straws (*in metric tons*)[b]	7,242,378	6,593,971	5,660,418
Annual energy supply equivalent (*in million kilowatt-hours*)[c]	2,499	2,275	1,953
Annual power supply equivalent (*in megawatts*)[d]	285	260	223
Central Luzon			
Based on Maximum Historical Yield[a]			
Regional annual supply of straws (*in metric tons*)[b]	875,390	841,652	792,333
Annual energy supply equivalent (*in million kilowatt-hours*)[c]	302	290	273
Annual power supply equivalent (*in megawatts*)[d]	34	33	31

[a] The maximum historical yield is 3.89 metric tons per hectare. [b] Rice straws are approximately 29% of the rice production weight (Militar, 2014). [c] On average, one metric ton of rice straws is equivalent to 345 kilowatt-hours [derived from proportion estimates as presented in Zafar (2014)]. [d] To generate the equivalent power supply, the annual energy equivalent was converted to megawatts based on a 24-hour period.

From by-products, which are basically waste products generated from the rice production and milling processes that hardly have substantial commercial value, results show that rice husks and rice straws can be turned into valuable co-products or sub-products in the rice production process by utilizing it as feedstock for bioenergy production. The Government of Thailand, one of the top five rice exporting countries, has globally demonstrated how national food staple self-sufficiency and reduction in the dependence on fossil fuel can be attained simultaneously through rice production. In a study on co-product performance of the current main use of rice husk for electricity generation in Thailand, Prasara-A & Grant (2011) showed that if rice husks are used as a co-product of traditional rice production in the electric power sector, significant reduction on the reliance on imported fossil fuels can be observed.

As shown in Tables 2.8 and 2.9, if both rice husks and rice straws are jointly utilized as potential renewable energy resources, the power generation potential ranges from approximately 441 to 564 megawatts at the national scale. This means that by following the average amount of petroleum required to produce one kilowatt-hour of energy as estimated by the U.S. Energy Information Administration (2014), reliance on imported petroleum can be reduced by at least

1,169 million liters and 1,498 million liters at the most.[24] It is apparent that it is very plausible to mutually aim for food staple self-sufficiency and bioenergy targets.

The viability of using by-products from rice production for renewable energy generation in the Philippines has been exhibited at relatively smaller scale. The urgency to bolster the practicability of intimately linking food staple self-sufficiency initiatives with the energy sector has never been more significant than at this juncture. By taking staple food production and energy generation as inter-dependent sectors, national food self-sufficiency and energy security may be at hand.

Conclusion and Recommendations

The apparent and potential risks of food shortage at various sectoral levels have set off many governments, including the Philippines, to adopt food staple self-sufficiency policies. Even if this policy strategy is known to have an elusive success rate and doubts have been casted over its feasibility, the Philippines remains optimistic that food staple self-sufficiency is a viable goal. In 2012, the Philippines promoted rice self-sufficiency through its Food Staples Sufficiency Program (FSSP) by espousing for the expansion of rice plantation and irrigation areas to complement introduction of high yielding varieties and widespread mechanization of the rice industry.

Given the specific strategies identified in the FSSP, this study employed a multi-criteria spatial land suitability assessment using the geographic information systems (GIS) to determine the extent of areas that may be suitable for rice production and expansion. In accordance with their perceived importance to rice production, data on edaphic and environmental attributes were identified and processed using GIS tools and techniques to derive thematic map layers. The integration of the thematic map layers resulted in a range of scenarios of the potential magnitude of land area that can be devoted to overall rice production and targeted expansion.

With the spatial analysis, it became possible to determine the production intensity per hectare to achieve the FSSP target. The maximum production possibilities at the national and

[24] Under certain heating rate and heating content assumptions, the U.S. Energy Information Administration (2014) estimated that 0.3028329 liters of petroleum is necessary to generate one kilowatt-hour of energy.

regional scales have been derived as well in the land suitability assessment. The results clearly emphasized the spatial extent of potentially suitable areas, of which majority are largely already under rice cultivation. From an applied standpoint, the information from the suitability assessment demonstrates the capabilities and limitations of certain areas in supporting rice production. Decision-makers can use the maps as a guide to channel investment plans and enhance rice expansion initiatives across the country.

To view rice merely as food staple is fallacious since rice production as demonstrated by this study and several other research works transcends the food staple self-sufficiency issues. Based on various land area expansion scenarios together with historical yields per hectare, this study estimated the spillover effects from achieving the FSSP target on agricultural water and energy sectors. It is imperative that water remain available for use in rice production and by-products become potential energy supply sources. One way to ensure sustainability in the rice production sector is to employ policy mechanisms that promote reduction in water consumption while maintaining if not increasing rice yield and farmers' income. Further, to develop an energy-relevant policy in sync with the rice self-sufficiency target, it is important to understand the quality, quantity, and practicability of using rice by-products.

In future studies, more detailed climatic attributes and socioeconomic characteristics, which largely influence land use decisions should be added into the spatial analysis. The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) revealed that local temperature increases of two degrees Celsius or more above the late 20th century levels in low-latitude regions such as the Philippines can potentially result in rice yield losses of nine to 12 percent, on average, in irrigated regions (Porter, et al., 2014). Through meta-analysis of 228 experimental observations, AR5 demonstrated that potential increases in carbon dioxide due to climatic changes, can reduce the edible portion of rice between ten and 14 percent. For these reasons, and because "relationship between weather and yields is often crop and region specific," as stated in AR5, it is imperative to incorporate climate in the biophysical assessment by taking into account not only the edaphic and the natural attributes that influence rice production but also "the duration and timing of crop exposure to various conditions." By including climatic factors in the spatial analysis, agricultural planners and policy professionals may be able to identify and develop adaptation strategies and management options that would help reduce the impacts of climatic changes on rice production.

Since the intimate link between energy resources, rice self-sufficiency, and water security is seldom thought of together in the food staples self-sufficiency equation, it may be necessary to tie the food staples self-sufficiency program with the water and energy security initiatives at various scales of planning. Correspondingly, expanding land area is only one way to increase production. Increasing efficiency levels of rice production is another way by stimulating an upward shift in the production function that may result in a gradual instead of abrupt land expansion. To attain the targeted rice output, decision-makers should explore ways to increase efficiency in financial, natural, and human resource inputs without extensive area expansion for rice production.

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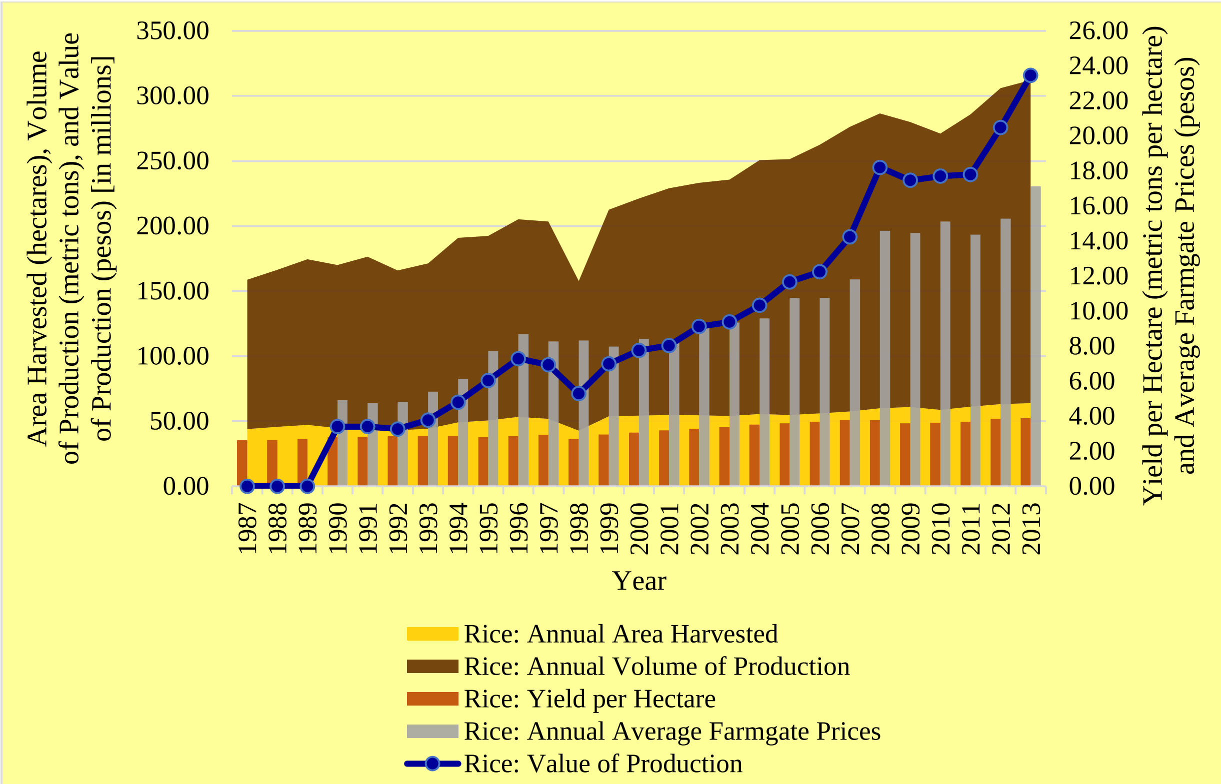
Appendices

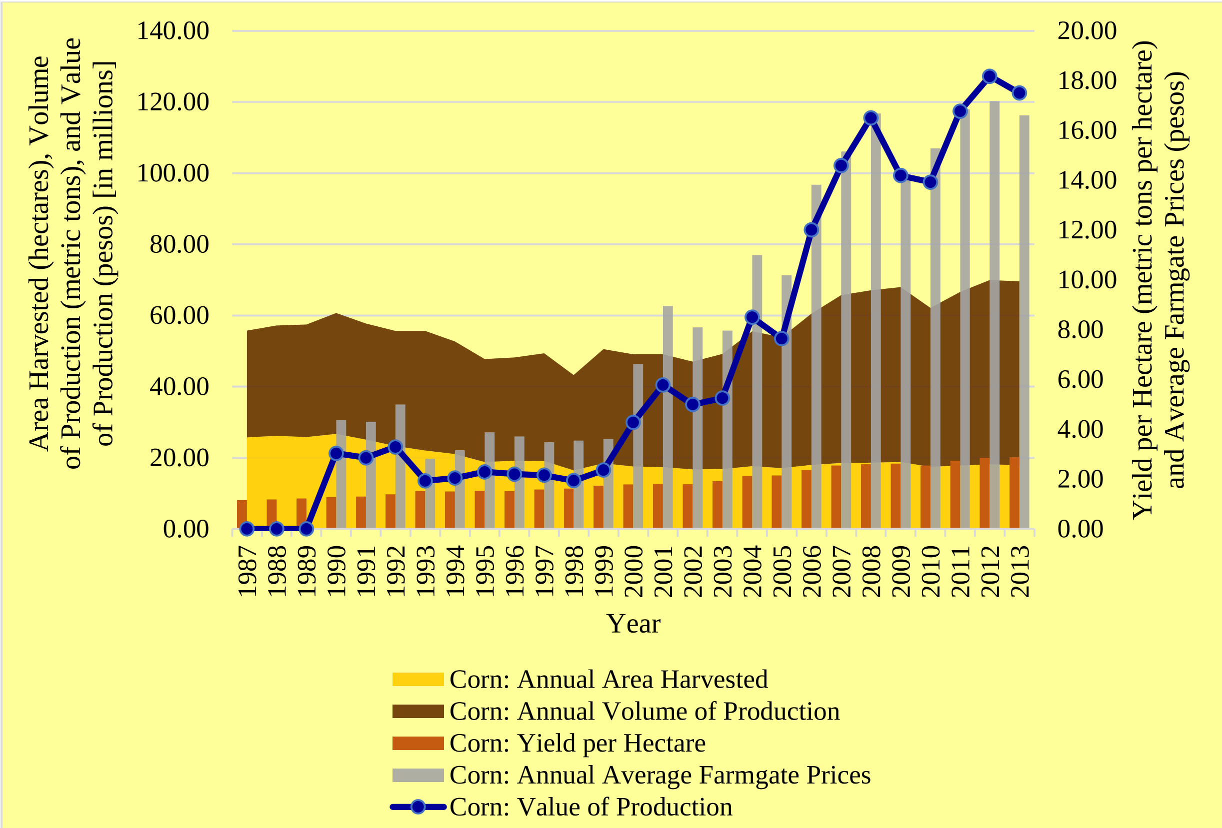
Appendix A. Tabulation and illustration of the national annual historical average area harvested, volume of production, yield per hectare, farm gate prices, and value of production for rice.

Year	Area Harvested *(in million hectares)*	Volume of Production *(in million metric tons)*	Yield per Hectare *(in metric tons per hectares)*	Annual Average Farm Gate Prices *(in Philippine Pesos per kilogram)*	Value of Production *(in million Philippine Pesos)*
1987	3.26	8.54	2.62	Data not available	0.00
1988	3.39	8.97	2.64	Data not available	0.00
1989	3.50	9.46	2.70	Data not available	0.00
1990	3.32	9.32	2.81	4.93	45.90
1991	3.42	9.67	2.82	4.74	45.80
1992	3.20	9.13	2.85	4.82	44.00
1993	3.28	9.43	2.87	5.40	50.94
1994	3.65	10.54	2.89	6.14	64.70
1995	3.76	10.54	2.80	7.72	81.37
1996	3.95	11.28	2.86	8.70	98.11
1997	3.84	11.27	2.93	8.28	93.25
1998	3.17	8.55	2.70	8.32	71.18
1999	4.00	11.79	2.95	7.98	94.06
2000	4.04	12.39	3.07	8.42	104.32
2001	4.07	12.95	3.19	8.35	108.11
2002	4.05	13.27	3.28	9.26	122.82
2003	4.01	13.50	3.37	9.35	126.22
2004	4.13	14.50	3.51	9.59	139.02
2005	4.07	14.60	3.59	10.76	157.06
2006	4.16	15.33	3.68	10.76	164.84
2007	4.27	16.24	3.80	11.81	191.72
2008	4.46	16.82	3.77	14.58	245.09
2009	4.53	16.27	3.59	14.46	235.13
2010	4.35	15.77	3.62	15.11	238.32
2011	4.54	16.68	3.68	14.36	239.58
2012	4.69	18.03	3.84	15.29	275.63
2013	4.75	18.44	3.89	17.13	315.87


Area Harvested (hectares), Volume of Production (metric tons), and Value of Production (pesos) [in millions]
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
26.00
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Yield per Hectare (metric tons per hectare) and Average Farmgate Prices (pesos)
1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Year
Rice: Annual Area Harvested
Rice: Annual Volume of Production
Rice: Yield per Hectare
Rice: Annual Average Farmgate Prices
Rice: Value of Production

Appendix B. Tabulation and illustration of the national annual historical average area harvested, volume of production, yield per hectare, farm gate prices, and value of production for corn.

Year	Area Harvested *(in million hectares)*	Volume of Production *(in million metric tons)*	Yield per Hectare *(in metric tons per hectares)*	Annual Average Farm Gate Prices *(in Philippine Pesos per kilogram)*	Value of Production *(in million Philippine Pesos)*
1987	3.68	4.28	1.16	Data not available	0.00
1988	3.75	4.43	1.18	Data not available	0.00
1989	3.69	4.52	1.23	Data not available	0.00
1990	3.82	4.85	1.27	4.39	21.30
1991	3.59	4.66	1.30	4.30	20.03
1992	3.33	4.62	1.39	5.00	23.09
1993	3.15	4.80	1.52	2.82	13.53
1994	3.01	4.52	1.50	3.17	14.33
1995	2.69	4.13	1.53	3.89	16.05
1996	2.74	4.15	1.52	3.72	15.43
1997	2.73	4.33	1.59	3.49	15.11
1998	2.35	3.82	1.62	3.56	13.59
1999	2.64	4.58	1.74	3.61	16.56
2000	2.51	4.51	1.80	6.64	29.93
2001	2.49	4.53	1.82	8.95	40.51
2002	2.40	4.32	1.80	8.10	34.99
2003	2.41	4.62	1.92	7.97	36.77
2004	2.53	5.41	2.14	10.99	59.49
2005	2.44	5.25	2.15	10.19	53.50
2006	2.57	6.08	2.37	13.82	84.07
2007	2.65	6.74	2.54	15.16	102.13
2008	2.66	6.93	2.60	16.68	115.56
2009	2.68	7.03	2.62	14.12	99.34
2010	2.50	6.38	2.55	15.29	97.50
2011	2.54	6.97	2.74	16.85	117.45
2012	2.59	7.41	2.86	17.18	127.23
2013	2.56	7.38	2.88	16.61	122.51



Area Harvested (hectares), Volume of Production (metric tons), and Value of Production (pesos) [in millions]
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Yield per Hectare (metric tons per hectare) and Average Farmgate Prices (pesos)
1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Year
Corn: Annual Area Harvested
Corn: Annual Volume of Production
Corn: Yield per Hectare
Corn: Annual Average Farmgate Prices
Corn: Value of Production

Chapter 3. Productivity Hot Spots and Cold Spots: Setting Priorities for Achieving Food Staples Sufficiency Target in the Philippines

Abstract

Rice is a Philippine food constant. In the last two decades, local supply is not able to keep pace with local demand making the Philippines a net importer of rice. Reliance on rice imports increases the country's vulnerability to unanticipated or sudden price and supply shocks in the international rice market. It is for this reason that the Philippines took much of the brunt of the global rice crisis that started in late 2007 and continued to mid-2008.

In the wake of the rice crisis in 2008, the government introduced the Food Staples Sufficiency Program (FSSP) in 2012 with the belief that improvement is possible to the country's dependence on rice imports and the Philippines can attain rice self-sufficiency. The Program has a target to increase rice staples from 15.77 million metric tons in 2010 to 22.73 million metric tons in 2016. To attain the target, the government promoted classical approaches of (1) expanding land area under rice production, (2) increasing productivity per unit area through cropping intensification and introduction of high yielding varieties, and (3) strengthening food system connectivity by reducing farm-to-plate rice wastes.

Given that only 20 percent of the necessary increase in production can be expected from land expansion, the remaining 80 percent can be generated through increased productivity. Stimulating an upward shift in the production function by increasing efficiency levels is crucial if the Philippines is to attain the FSSP target. Cognizant of the relationship between efficiency of rice production and achieving the FSSP target, stochastic production frontier analysis revealed that the average technical efficiency of farms in Central Luzon, Philippines ranges between 0.76 and 0.92 in the wet and dry seasons, respectively. Increases in agricultural efficiency levels of farmers enable them to produce more with the same level of resources.

Empirical results show that participation in the national irrigation system, attendance at training sessions, distance to input markets, and access to water resources affect technical efficiency at the farm level. Increasing farm productivity can help attain the FSSP target by potentially increasing yield per hectare to 7.32 and 5.63 metric tons per hectare at the maximum in the dry and wet seasons, respectively, in Guimba. For Tarlac City, farmers can maximize rice

yield to 4.78 metric tons per hectare in the dry cropping season and 3.90 metric tons in the wet cropping season.

Given that average annual regional technical efficiency in Central Luzon is 0.827 and is representative of farm performance across the country, with adequate provision of agricultural water to farmers and training programs, it is possible to increase national yield above 3.89 metric tons per hectare. At this rate and with the amount of land devoted to rice in 2010, which is 4.3 million hectares, it is possible to surpass the FSSP target of 22.73 million metric tons. This indicates that the FSSP target is achievable without expansion of land areas devoted to rice.

To design policies that address the specific and geographic production needs of rice farmers, this study extends previous work that investigated productivity increases through technical efficiency enhancement by evaluating how geospatial attributes influence farmer production performance within the overall context of achieving the FSSP target. A combination of spatial econometrics with geostatistical tools demonstrated the presence of spatial dependence in yield and farm performance. Results show significant clustering of best and worst performing farms, specifically in Tarlac City.

The optimized hotspot analysis suggests that proximity to high performing farms influences yield per hectare and the level of technical efficiency. The villages of Sapang Maragul, Tibag, and Tibagan are the technical inefficiency hot spot locations in Tarlac City. These areas represent high incidence of low levels of technical efficiency.

The attainment of the FSSP target depends on the ability of the rice producers to increase farm technical efficiency. It is imperative that policy interventions prioritize productivity cold spot areas and hot spot zones for technical inefficiency. These are the locations where agricultural planners and policymakers can make greater impacts on rice yields. Relevant policies and initiatives, therefore, should take into account the appropriate geographical level to ensure the greatest contribution to the attainment of the FSSP target.

Introduction

Rice is a Philippine food constant to 92 million Filipinos.[1] Any meal in the Philippines will not be complete without some form of rice on the table. It is, therefore, not surprising that

[1] Population measure used estimates from the 2010 Philippine census.

the domestic per capita consumption of rice has been increasing from 105.77 kilograms in 2000 to 114.27 kilograms in 2012 (BAS, 2013a). On top of being the main staple, rice is the source of 56.80 percent of the dietary nutrients consumed in the Philippines (Philippine Statistics Authority, 2014).[2]

Because of its importance, rice has become the most socially-, culturally-, economically-, and politically-sensitive commodity in the Philippines and ensuring adequate, stable, and affordable supply is paramount.[3] Across the Philippines, rice is cultivated on about one-third of the country's alienable and disposable lands (Navata & Turingan, 2013).[4] It accounts for 21 percent of the PhP 1,293 billion gross value added (GVA) in agriculture and fishing (BAS, 2013b).

Since the genesis of the Green Revolution and beyond its epilogue, the Philippines has experienced almost a 53 percent increase in per hectare rice production between 1987 and 2014.[5] Despite this substantial growth, local supply is not able to keep up with local demand making the Philippines a net importer of rice since 1995.[6] Reliance on rice imports has made the country vulnerable to any unanticipated or sudden price and supply shocks in the international rice market. It is for this reason that the Philippines took much of the brunt of the global rice crisis that started in late 2007 and continued to mid-2008. Freedman (2013), Reymond (2012), Shigetomi, Kubo, & Tsukada (2011), Dawe (2010), and Childs & Kiawu (2009) documented how the Philippines fared during the crisis.

The increasing vulnerability of the Philippines to supply and demand shocks from the global rice market puts pressure on the government to ensure availability of and accessibility to

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[2] According to the Philippine Statistics Authority (PSA) (2014), *dietary nutrients (energy) consumed as proportion to RENI* refers to the level of intake of energy as percentage of Recommended Energy and Nutrient Intake (RENI) which is an average of 2000 kilocalories per capita. The per capital proportion is estimated with dietary nutrient consumption (DNC) equals to net food disposable in energy equivalent divided by RENI.
[3] Drilon Jr. & Goldberg (1969) noted that policies concerning rice production have invariably become political issues especially during election years.
[4] Alienable and disposable lands are areas available for disposition for various purposes to serve the needs of the population. Although the Philippines has a total land area of 30 million hectares, alienable and disposable lands only account for a little more than 14 million hectares. Forestlands comprise the remaining portion.
[5]Historical data from the Bureau of Agricultural Statistics show that yield per hectare rose from 2.62 metric tons in 1987 to 4 metric tons in 2014 (BAS, 2014a; BAS, 2014b).
[6] Between 1995 and 2013, the Philippines has an average rice self-sufficiency ratio of 88 percent (BAS, 2013c). Schmidhuber & Tubiello (2007) noted that self-sufficiency is assessed based on the proportion of domestic food produced to the total food consumed locally.

rice by every citizen. In the wake of the rice crisis in 2008, the Philippine government launched a marching mandate to address this staple food insufficiency. In 2012, the government introduced the Food Staples Sufficiency Program (FSSP) with the belief that it is possible to reduce the country's dependence on rice imports and attain rice self-sufficiency.

Being consistent with historical paths in agriculture – the era of expansion, the age of productivity, and the emerging epoch of connectivity – the FSSP targets the proposed increase in rice staples from 15.77 million metric tons in 2010 to 22.73 million metric tons in 2016 (Department of Agriculture, 2012). To increase domestic rice production and enable the country to be rice self-sufficient by 2016, the Department of Agriculture espoused classical approaches of (1) expanding land area under rice production, (2) increasing productivity per unit area through intensification of two or more cropping per year and introducing high yielding varieties to narrow yield gaps; and (3) strengthening connectivity of food systems to minimize farm-to-plate rice wastes (Laborte, et al., 2012; Pearson, 2012). Correspondingly, Bruinsma (2009) estimated that only 20 percent of increased in production can be expected from land expansion and 80 percent can be generated through increased productivity. Stimulating an upward shift in the production function by increasing efficiency levels is, therefore, crucial if the Philippine is serious in attaining the FSSP target.

Cognizant of the strong relationship between efficiency of rice production and achieving the FSSP target, this study estimates parameters of the farm-level rice stochastic production frontier for two cropping seasons in Central Luzon, Philippines. Because enhancement of farmer agricultural efficiency levels enables producing more given the same level of resources, this study also examines factors which influence technical efficiency at the farm level. Finally, to help design policies that address the specific geographic production needs of rice farmers, this study extends previous work on technical efficiency by evaluating how geospatial attributes affect production performance of farmers within the overall context of achieving the FSSP target.

Technical Efficiency and Staple Food Production: A Brief Survey

Technical efficiency is a widely used criterion to assess how well a farmer performs. Although it is defined extensively in various ways in literature (see Asante, Wiredu, Martey, Sarpong, & Mensah-Bonsu, 2014; Ogundari, 2014; Gomez & Neyra, 2010; Tipi, Yildiz, Nargeleçekenler, & Çetin, 2009; Bravo-Ureta, et al., 2007; Idiong, 2007; Bakhsh, Ahmad, & Hassan, 2006; Gragasin, Maruyama, Marciano, Fujiie, & Kikuchi, 2005; Villano, Lucas, & Pandey, 2005; Umetsu, Lekprichakul, & Chakravorty, 2003; Thiam, Bravo-Ureta, & Rivas, 2001; Coelli, 1995; Battese, 1992; Dawson, Lingard, & Woodford, 1991; Kalirajan, 1989; Fare, Grabowski, & Grosskopf, 1985; Kalirajan & Flinn, 1983), technical efficiency commonly refers to the measure of how one can produce more with less – more output with less inputs or resources used given the best available technology. In the last three decades, the role of enhanced technical efficiency in improving crop yield of food staples is well documented.

Among the major food staples in the Philippines, which include white corn, banana (*saba*), and root crops such as cassava (*kamoteng kahoy*) and sweet potato (*kamote*), rice has received relatively more attention in terms of the assessment of the technical efficiency of its production sector. Pate & Tan-Cruz (2007), Villano & Fleming (2006), Villano & Fleming (2004), and Coelli (1995) provided a chronological review of technical efficiency of rice farms in various parts of the Philippines since the 1980s. This historical documentation highlights the considerable methodological and geographical efforts devoted to assessing efficiency of rice farmers.

The literature surveys show that the earliest publications examining technical efficiency of rice farms in the country were reported in 1983. The present paper, however, found that Pachico (1980) recognized that Mandac & Herdt (1978) provided initial indication on the importance of technical and allocative efficiency in rice production for the Philippines. Herdt & Mandac (1981) in a later publication identified that technical inefficiency among farmers can be attributed to the farmers' age, level of education, time spent on farming activities, and technical know-how. The burgeoning interest on the topic of technical efficiency of rice farms in the Philippines, therefore, began prior to the studies of Kalirajan & Flinn (1983) on 79 farmers in Bicol region and Lingard, Castillo, & Jayasuriya (1983) on 32 rice farms in Central Luzon.

The overriding subject of most of the studies documented in this paper (see Appendix A) is the investigation of the sources of inefficiencies and the examination of factors that explain why certain farmers operate more efficiently than others.[7] In the Bicol region, Larson &

[7] Appendix A provides an updated version of the literature surveys of Pate & Tan-Cruz (2007), Villano & Fleming (2006), and Coelli (1995).

Plessmann (2002), Evenson, Kimhi, & DeSilva (2000), and Kalirajan & Flinn (1983) found evidence that seedling transplanting practices, farming experience, interaction with agricultural extension agents, intense labor supervision, accumulated wealth, and investment in education have direct positive effect on farm efficiency, which according to Kalirajan & Flinn (1983) ranges between 0.38 and 0.91. Timing and method of crop establishment, access to credit and non-farm income (Kalirajan & Shand, 1990; Shand, Mangabat, & Jayasoriya, 1989) as well as access to irrigation (Yao & Shively, 2007; Antle & Crissman, 1990) and secure land tenure arrangements (Michler & Shively, 2015) characterize technically efficient farms in the provinces of Antique, Iloilo, and Palawan.

The province of Laguna and those in Central Luzon when compared to the rest of the Philippines have the largest concentration of studies on technical efficiency of rice farms.[8] Between the late 1970s to 2015, this study identified 15 empirical research work devoted on assessing technical efficiency of rice farms in these areas. The level of technical efficiency of rice farms in Central Luzon ranges from 0.54 to 0.95 (Koirala, Mishra, & Mohanty, 2014a; Koirala, Mishra, & Mohanty, 2014b; Villano & Fleming, 2006; Villano, O'Donnell, & Battese, 2005; Rola & Quintana-Alejandrino, 1993; Dawson, Lingard, & Woodford, 1991), whereas in Laguna, it is between 0.54 and 0.82 (Koirala, Mishra, & Mohanty, 2014a; Koirala, Mishra, & Mohanty, 2014b; Velarde & Pede, 2013; Kalirajan, 1990). Variations in the technical efficiency of rice farms in Central Luzon and Laguna can be attributed to availment of extension services (Kalirajan, 1984), timing and method of application of inputs (Koirala, Mishra, & Mohanty, 2014a; Kalirajan, 1990), farmers' level of education, access to capital or credit, and tenurial status (Rola & Quintana-Alejandrino, 1993; Lingard, Castillo, & Jayasuriya, 1983), non-farm income (Villano & Fleming, 2006), and investment allocation for chemical inputs (Velarde & Pede, 2013).

With the recent initiative on achieving rice self-sufficiency in the Philippines and the renewed interest of increasing producer efficiency, this study examines and summarizes technical efficiency attributes investigated by previous studies (Table 3.1). The assessment of rice production and technical efficiency in this paper, however, is extended beyond the inclusion

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[8] This is partly due to the presence of two rice institutes in these areas – the International Rice Research Institute in Laguna and the Philippine Rice Research Institute in Nueva Ecija.

of managerial and socioeconomics characteristics. Spatial, social capital, and sustainable management attributes are incorporated in this study, which to the author's knowledge has not been explored in preceding research.

Table 3.1: Major determinants of technical efficiency from previous rice production studies in the Philippines.

Study	Location(s)	Factors Affecting Technical Efficiency
Kalirajan (1984)	Central Luzon	Extension service
Shand, Mangabat, & Jayasoriya (1989)	Antique	Crop establishment timing and method Pest control measures Age of household head
Kalirajan (1990)	Laguna	Non-farm income Method of crop establishment Extension service
Kalirajan & Shand (1990)	Antique	Crop establishment timing and method Tenurial status
Antle & Crissman (1990)	Iloilo	Rice variety Irrigation
Fukui (1993)	Central Luzon	Farm size Female labor ratio
Rola & Quintana-Alejandrino, (1993)	Central Luzon, Central Mindanao, and Cagayan Valley	Tenurial status Education
Evenson, Kimhi, & DeSilva (2000)	Bicol	Gender Transaction costs
Larson & Plessmann (2002)	Bicol	Technological adoption Weather Education
Villano & Fleming (2004 and 2006)	Central Luzon	Education Adult ratio Non-farm income
Yao & Shively (2007)	Palawan	Education Number of farm workers Farm size Tractor utilization Tenurial status
Mariano, Villano, & Euan (2010)	Philippines	Age Education Farming experience Training attendance Household size

Study	Location(s)	Factors Affecting Technical Efficiency
		Non-farm income Tenurial status Machine ownership Farm-to-market distance
Koirala, Mishra, & Mohanty (2014a and 2014b)	Central Luzon and Laguna	Time of planting Farm size Fuel cost Fertilizer cost
Michler & Shively (2015)	Palawan	Tenurial status Farm size

Geography Matters: Evidence at the Farm Level

Various types of production processes recognize the geographic concentration of many economic activities. In the manufacturing industry, for instance, McCann & Folta (2008) cited several examples of firms producing electronic and medical devices exhibiting geographical congregation across the United States, India, and the United Kingdom. Schettini, Azzoni, & Paez (2010) found that successful manufacturing sectors geographically cluster in Brazil. Sangalli & Lamieri (2015) observed the same aggregation in Italy. Similarly, Wang, Madhok, & Li (2014) and Fusco & Vidoli (2013) observed the importance of geography in the growth of the winemaking industry in Canada and Italy, respectively. These empirical cases demonstrate that in production, geography does matter.

The staple food industry is no different to the manufacturing sector. Areal, Balcombe, & Tiffin, (2010), Beddow, Pardey, Koo, & Wood (2010), Nelson (2002) acknowledge that agricultural food production is a spatial phenomenon and one of its salient features is that location matters. According to Bockstael (1996), location does matter in agriculture because factors such as land characteristics, landscape configurations, and climatic conditions exhibit spatial variability. Further, Cho, Chen, Yen, & English (2007) added that even agricultural technology, market, and extension systems display some form of spatial heterogeneity.

The last few decades witnessed the increasing interest in illustrating the unequivocal stance that location plays an important role in efficient agricultural production. Building upon Tobler's (1970) first law of geography, the empirical works of Chopin & Blazy (2013), Larochelle & Alwang (2013) and Druska & Horrace (2004) showed how "everything is related to everything else, but near things are more related than distant things” in crop production at the farm level. As elaborated by Griffith (1992), this means that “what belongs in a given areal unit somehow migrates to adjacent areal units” such as the use of fertilizer in farm plots that rain can wash portions of the chemicals to neighboring plots causing a positive spillover.

Druska & Horrace (2004) particularly observed the spatial spillover effect on Indonesian rice farms where geographic proximity and weather exhibited location-based correlations and displayed productivity shock spillovers. Correspondingly, Larochelle & Alwang (2013) found that there are yields forgone and that production efficiency losses increase when potato farms are not located in the core geographic potato production clusters in Bolivia. In Martinique in the Carribean, Chopin & Blazy (2013) also examined spatial variability in banana yields and the results allowed for the elaboration of spatially targeted policies to improve crop yields. Lakner, von Cramon-Taubadel, & Brummer (2011) confirmed that performance of organic farms in Germany are influenced by the geographic localization of the farms across the country. These spatial gradients in production have also been observed in the livestock industry as shown in the reports of Areal, Balcombe, & Tiffin (2012), Gerber, Robinson, Wassenaar, & Steinfeld (2010), MacDonald, Ribaudo, Livingston, Beckman, & Huang (2009), and Lesschen, Verburg, & Staal, (2005).

In contribution to the growing spatio-economic literature on agricultural production, this study investigates spatial productivity and efficiency patterns as well as geographic variability in rice production in Central Luzon, Philippines. Combining spatial information and agricultural economic production data have serious implications on agricultural policies and farm management strategies as Areal, Balcombe, & Tiffin (2010), Barrios & Lavado (2010), and Weiss (1996) asserted. This spatio-economic exercise is, therefore, particularly relevant to the Philippine government’s campaign on staple food self-sufficiency as this may help in the implementation of site-specific development interventions to optimize agricultural efficiency and improve economic returns.

Data and Empirical Approach

To determine how to utilize spatio-economic information in identifying priority initiatives to help achieve the target under the Food Staples Sufficiency Program (FSSP), this study obtained cross-sectional data from rice farming villages in the provinces of Nueva Ecija and Tarlac in Central Luzon, Philippines. With the aid of an objective-oriented structured questionnaire (see Appendix B), the household surveys conducted between December 2013 and January 2014 elicited socio-demographic, farm production, and spatio-economic data for the 2013 dry and wet seasons.[9] Stochastic production frontier analysis and the spatial econometric assessment are dependent on these socio-spatio-economic data.

Study Area

Central Luzon is the largest rice-producing region in the Philippines. The region lies at the heart of the main island of Luzon, 66 kilometers away from Manila, the National Capital Region. There are 12 cities and 118 municipalities from the seven provinces of Central Luzon namely, Aurora, Bataan, Bulacan, Nueva Ecija, Pampanga, Tarlac, and Zambales (DENR, 2014; Lugos, 2009). Of these provinces, the Philippine Rice Research Institute (PhilRice) ranked Nueva Ecija, Tarlac, Bulacan, Pampanga, Aurora as five of the country's major rice producing provinces based on average rice harvest area (Bordey & Malasa, n.d.).

This research initially selected three Central Luzon provinces equally represented in each stratum categorized according to their equal share in harvest area as presented in Bordey & Malasa (n.d.).[10] The selected provinces were Nueva Ecija representing the top stratum, Tarlac for the mid stratum, and Aurora for the bottom group. The study, however, directed its focus to Nueva Ecija and Tarlac after a strong typhoon devastated the province of Aurora in August 2013.

Pursuant to the harvest area rationale used in the "Regular Monitoring of Rice-Based Farm Households" project of PhilRice, this research elected to conduct the rice farming household surveys in the municipalities of Guimba in Nueva Ecija and Tarlac City in Tarlac (Figure 3.1). These are the two areas within the two provinces that have the highest number of rice growers and largest area devoted to rice production. The Barangay Agricultural Profiling Survey (BAPS) released in 2012 shows that out of the 32 municipalities in Nueva Ecija, eight

[9] Dry season is between December to May and the wet season is between June to November.
[10] Bordey & Malasa (n.d.) provides an extensive documentation of the sampling procedure employed in the "Regular Monitoring of Rice-Based Farm Households" project of PhilRice. The project adopted a two-stage sampling process with the provinces as the study domain. Based on five-year average ranking of rice harvest area, the sampling exercise ranked each province in descending order and divided them into four strata in approximately equal share to the total harvest area.

and ten percent of the province's rice area and rice farmers can be found, respectively, in Guimba (BAS, 2012). In comparison to 17 other municipalities, Tarlac City accounts for 13 percent of the total provincial rice farmers and 11 percent of the rice area. These two municipalities also have a wide representation of different farm sizes as well as a diversity of irrigation sources.

Guimba is located 153 kilometers northwest of Manila with a land area of 25,853 hectares. There are 64 villages in Guimba laying on relatively flat areas with slope of zero to three percent and elevation of zero to 500 meters above sea level. More than 90 percent of the villages in Guimba are rural farming villages with rice as the main crop. From the 2010 census, 104,894 people reside in Guimba (Municipality of Guimba, 2012 and National Statistics Office, 2010).

The city of Tarlac is the provincial capital with a land area of 27,466 hectares and has a population of 318,332 according to the 2010 census (National Statistics Office, 2010). The city is approximately 110 kilometers north of Manila. Although Tarlac is categorized as an urban municipality, about 46 percent of its 76 villages are classified as rural (National Statistics Office, 2010). The rural villages are still very agricultural with rice and sugarcane as the main products.

Farming Households

The random selection of sample villages was contingent on proportional zonal distribution of the villages in the northeast, southeast, southwest, and northwest regions of the two municipalities. In identifying the sample villages, this sampling procedure considered data from the municipal agricultural government agency on the number of rice farming households in each village. The randomized process resulted in the selection of 27 sample villages. The 18 sample villages in Guimba include Agcano, Balingog East, Banitan, Bantug, Caballero, Caingin

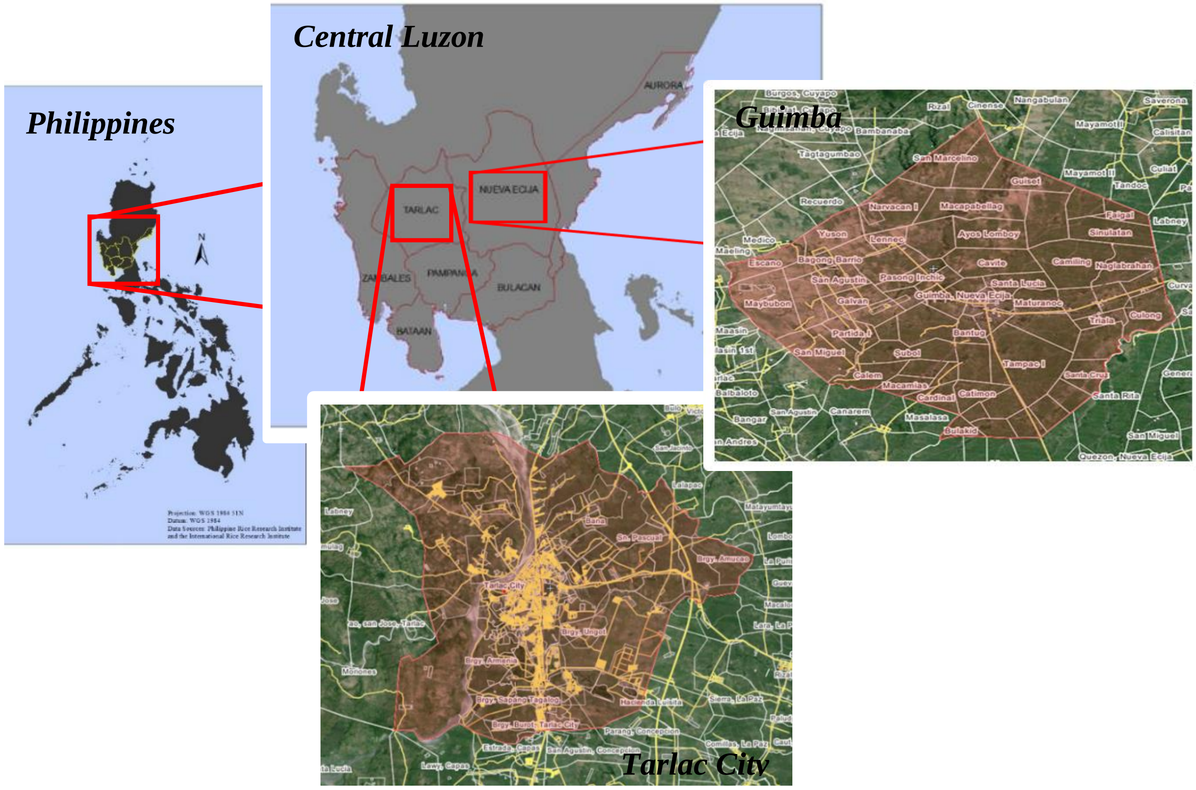

Figure 3.1: Study area location of the municipality of Guimba and the city of Tarlac.[11]

Tabing Ilog, Catimon, Cawayan Bugtong, Macatcatuit, Manacsac, Nagpandayan, San Bernardino, Santa Cruz, Subol, Tampac I, II, and III. In Tarlac City, the villages of Armenia, Atioc, Balibago II, Banaba, Care, De La Paz, Sapanag Maragul, Tibag, and Tibagan were included in the sample.

By adopting the right coverage approach employed by PhilRice, this study randomly administered the survey to 471 rice farming households – 301 in Guimba and 170 in Tarlac City.[12] Of these, 294 and 150 sets of household data were determined valid from Guimba and

[11] The author derived the municipal and city maps for Guimba and Tarlac City from http://wikimapia.org/, a collaborative online mapping platform.

[12] This study adopted a modified version of the right coverage approach. With this approach, the survey selected rice-based sample households from a pre-determined landmark within the village. An enumerator begins the survey from the right side or right path of the pre-determined landmark and every so many house thereafter. As explained in Bordey & Malasa (n.d.), this process aims to randomize sample selection in the absence of a list of rice farmers in each village.

Tarlac City, respectively.[13] In all villages, males are the dominant head of households with an average age of 54 in Guimba and 51 in Tarlac City. Majority of the male farmers have attained eight years of formal schooling, which is equivalent to two years of high school education. In terms of rice farming experience, farmers in Guimba have four additional years of farming practice compared to Tarlac City farmers. A typical rice farming household of five members in Guimba generates Ph₱50,000 more income from rice production than households in Tarlac City.[14] Table 3.2 summarizes the socio-demographic characteristics of the farm households.

Farmers in the two municipalities are largely small-scale rice producers with an average landholding of less than two hectares per household. As shown in Table 3.2, agricultural land accounts for more than 90 percent of the total landholding for most farmers. Largest rice parcels in Guimba and Tarlac ranges between one and 1.35 hectares.

Given the modest size of the rice land, farmers in Guimba are able to produce 6.76 metric tons of rice per hectare during the 2013 dry season (December 2012 to May 2013). In the wet season (June to November 2013), they produced 4.63 metric tons per hectare. Rice farms in Tarlac produce about 57 percent of that in Guimba during the dry season and 64 percent in the wet season.

Understanding the underlying reasons for the per hectare yield difference in the municipalities is inherently important in the campaign to elevate rice production in support of the Food Staples Sufficiency Program (FSSP) target. One possible reason for this variation is the inefficient utilization of resources as part of the production practice. For this reason, an examination of the rice production process is necessary to shed light on the discrepancy. Production and economic analyses are fundamental to identify areas for field operation improvement and enhanced farm management.

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[13] The determination of the sample size of farmers from each municipality depended on the following assumptions: 5 percent level of error to tolerate, 95 percent level of confidence and 20 percent sample buffer. With these assumptions, this study used the sample calculator from http://www.custominsight.com/articles/random-sample-calculator.asp to derive proportionally the number of farmers to survey. There are 192,278 rice growers in Nueva Ecija and Tarlac combined (BAS, 2012). Of this total, 63 percent are in Nueva Ecija and 37% are in Tarlac. Based on this distribution, the study targeted to survey 460 farmers – 288 in Guimba and 172 in Tarlac. The target respondents of 460 farmers include the 20 percent sample buffer. It should be noted that the actual data collected surpassed the targeted total. The survey team collected data from 471 farmers.

[14] The peso-dollar conversion as of 31 December 2013 is US$ 1 = Ph₱ 44.45 according to http://www.oanda.com/currency/converter/.

Table 3.2: Characteristics of farm households and rice farms.

Variables	Description	Guimba (n=294) Mean	Guimba (n=294) Standard Deviation	Tarlac City (n=150) Mean	Tarlac City (n=150) Standard Deviation
Farmer (Head of Household)					
Age	Age	53.55	12.35	50.67	12.01
Education	Number of years of formal schooling	8.46	3.00	7.79	2.98
Experience	Number of years of rice farming experience	31.62	14.49	27.73	14.79
Size	Number of people in the household	4.80	1.91	5.13	2.01
Income	Annual rice farming income of the household (in Philippine Pesos)	157,596.10	195,479.50	107,687.80	98,469.55
Network In	Number of people in the farmer's social network within the village	21.30	27.40	23.07	23.327
Network Out	Number of people in the farmer's social network outside the village	11.03	17.90	9.01	10.88
Landholdings					
Total	Total farm and non-farm landholdings (in hectares)	1.38	1.53	1.73	1.20
Ag Land	Agricultural landholdings (in hectares)	1.25	1.43	1.57	1.02
Rice Land	Size of largest parcel (in hectares)	1.00	0.79	1.35	0.90
Yield	Yield per hectare during the dry season (in metric tons per hectare)	6.76	1.68	3.84	1.41
	Yield per hectare during the wet season (in metric tons per hectare)	4.63	1.24	2.96	2.02

Note: The means of all variables are statistically different for the two study sites with the exception of the number of people in the household.

Analytical Framework

Stochastic Production Frontier Analysis

For decades, farming systems around the world have depended on economic analyses to investigate ways to improve rates of production (Quilty, McKinley, Pede, & Buresh, 2014). Much of the analyses trace its roots from the seminal work of Farrell (1957) on production efficiency, which examined a firm's ability to produce maximum output given a set of inputs and technology.[15] In measuring the firm's productivity and efficiency correspondingly in terms of yield and inputs per hectare, different methodologies and strategies have been proposed, of which one of the most frequently and widely used in agriculture is the stochastic frontier analysis (SFA), which was simultaneously yet independently developed by Aigner, Lovell, & Schmidt (1977) and Meeusen & van den Broeck (1977).[16]

Considering the neoclassical production function specification developed by Cobb & Douglas (1928) [Eq. 1][17] and following the pioneering models introduced by Aigner, Lovell, & Schmidt (1977), Battese & Corra (1977), and Meeusen & van den Broeck (1977), this study adopts an output-oriented stochastic production frontier model [Eq. 2][18] with an exponential distribution assumption following a maximum likelihood framework. Specifically, y_i denotes the potential output of a production unit i whereas x_j are the inputs or resources used to produce y_i

[15] Farrell (1957) decomposed a firm's efficiency into technical, allocative, and economic efficiencies. In his groundbreaking article, he described technical efficiency from an input-oriented (IO) perspective and an out-oriented (OO) view. The IO perspective measures how to minimize input utilization given a certain level of output. The OO view assesses potential increase in output given some level of inputs. Allocative efficiency takes into account optimal input use and increase in potential returns given certain level of prices. Economic efficiency is the sum of the technical and the allocative efficiencies of the firm.
[16] Iliyasu, Mohamed, Ismail, & Abdullah (2014), Ogundari (2014), Bravo-Ureta, et al. (2007), Thiam, Bravo-Ureta, & Rivas (2001), Coelli (1995), Bravo-Ureta & Pinheiro (1993), and Battese (1992) documented the wide application of the SFA method in agriculture.
[17] Bhanumurthy (2002) revisited the applicability of the Cobb-Douglas production function in stochastic frontier analysis and found that it is an appropriate specification because it can handle multiple inputs in its generalized form. As a functional form, Cobb-Douglas does not introduce distortions of its own even with market imperfections. Further, Bhanumurthy (2002) argued that the Cobb-Douglas production function exhibits explicit uniformity, parsimony, and flexibility. The stochastic Cobb-Douglas production model also accounts for problem of simultaneity. More recently, Reynes (2011) showed that a Cobb-Douglas model could approximate a large class of production functions since the specification only requires the use of the first order approximation "while respecting the theoretical curvature conditions of the isoquants."
[18] Coelli, Rao, & Battese (1998) and Coelli (1995) noted that for agricultural production, stochastic production frontier models are more appropriate since agriculture is prone to measurement errors, missing data, and erratic weather conditions.

and β_j are the parameters for estimation. This model assumes that production data are subject to some form of measurement errors, statistical noise, and random shocks that are beyond the control of the producer such as weather, natural disasters, and political instability. The presence of these measurement errors and noise in the data is accounted in the v_i component of the model, which follows the identical, independent, and normal distribution assumption, $v_i \sim iid\ N(0, \sigma_v^2)$. The random variable u_i, which is independent of v_i and exponentially distributed, $u_i \sim \xi(\sigma_u)$, is associated with the technical inefficiency of the producer (Belotti, Daidone, Ilardi, & Atella, 2012).

$$y_i = A \prod_{i=1}^{n} x_j^{\beta_j} \quad \text{[Eq. 1]}$$

$$y_i = A \prod_{i=1}^{n} x_j^{\beta_j} e^{\varepsilon_i}, \text{ where } \varepsilon_i = v_i - u_i \quad \text{[Eq. 2]}$$

Given that u_i measures the output shortfall from its maximum possible value given by the stochastic frontier, this study employs the estimation suggested by Jondrow, Lovell, Materov, & Schmidt (1982) to determine the level of producer-specific inefficiency. With a density function of $f(x) = \frac{e^{\left(-\frac{u}{\sigma_u}\right)}}{\sigma_u}$, the technical inefficiency error term, u_i, follows one parameter exponential distribution. The proposed estimation takes into account the conditional expected value distribution of u_i given ε_i. By considering the mean of the distribution as the point estimate for u_i, the representation for the individual producer's technical inefficiency for the exponential model is:

$$E[u|\varepsilon] = z + \frac{\sigma_v \phi\left(\frac{z}{\sigma_v}\right)}{\Phi\left(\frac{z}{\sigma_v}\right)}, \quad \text{[Eq. 3]}$$

where $z = \varepsilon - \theta\sigma_v^2$, ϕ describes standard normal density function, and Φ represents cumulative distribution function (Neupane & Moss, 2015; Wang, 2001). From the producer-specific point estimates of u_i, the derivation of technical efficiency, which takes values between zero and one, is as follows:

$$TE_i = e^{-u_i} = \frac{A \prod_{i=1}^{n} x_j^{\beta_j}}{A \prod_{i=1}^{n} x_j^{\beta_j} e^{v_i}} \text{ given } E[u|\varepsilon].^{19} \qquad \text{[Eq. 4]}$$

Spatial Dependence Analysis

Stochastic production frontier models commonly assume independence between observations. With agricultural production generally organized according to locational clusters, the violation of the independence assumption is more than likely given the possible presence of spatial dependence or spatial autocorrelation[20] (Fusco & Vidoli, 2013). The classical production analysis clearly fails to account for the geographic association of agricultural production units. Such deficiency, according to Anselin (2001) may lead to inefficient and biased estimates as well as misleading inferences.

Given that location-specific attributes can conceivably influence agricultural production performance and overall efficiency, this study investigates incidence of spatial dependence among rice farms in Central Luzon using geostatistical tools in ArcGIS 10.2. Through the application of spatial econometric techniques, this paper independently examines rice productivity and farm efficiency with and without spatial effects. Areal, Balcombe, & Tiffin (2012) asserted that spatial dependence in technical efficiency is highly likely because farmers tend to emulate each other, they use common property resources such as irrigation, and topographic conditions may be homogeneous where the farm is located. As such, to detect statistically significant spatial concentrations of high and low production and efficiency or inefficiency values, this study performs the optimized hot spot (OHS) analysis[21].

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[19] For further details on the step-by-step derivation of the stochastic production and the technical efficiency functions following a maximum likelihood framework, the author refers the reader to check out Kumbhakar, Wang, & Horncastle (2015), Belotti, Daidone, Ilardi, & Atella (2012), Fried, Lovell, & Schmidt (2007), Coelli, Rao, O'Donnell, & Battese (2005), Kumbhakar & Lovell, (2003), Coelli, Rao, & Battese (1998), Coelli (1995), Waldman (1984), Jondrow, Lovell, Materov, & Schmidt (1982), Aigner, Lovell, & Schmidt (1977), and (Meeusen & van den Broeck, 1977).

[20] This study assumes that spatial dependence and spatial autocorrelation follow the same definition; hence, the concepts are interchangeably used.

[21] Optimized hot spot (OHS) analysis is a spatial statistics tool available from ArcGIS 10.2. OHS is a tool that can help delineate areas where there are a high incidence of data points representing specific ranges of productivity and inefficiency estimates. The focus of this particular analysis is the presence or absence of a range of estimate in a geographical area rather than measured attributes associated with each observation. OHS is a suitable tool for the production and technical inefficiency estimates since they are incident point data.

Spatial dependence demonstrates how values or attributes observed at one location depend on the values or attributes present at neighboring or nearby locations (Fusco & Vidoli, 2013; LeSage & Pace, 2009; Anselin, 1988). To measure the degree of such dependence, it is necessary to first construct a spatial weights matrix, W, to represent the spatial relationships between observations and among the attributes of interest (Getis, 2009; Getis & Aldstadt, 2004; Anselin, 1988). With the geo-referenced data – latitude and longitude of farm and dwelling coordinates – collected during the field survey, this study adopts a row-standardized[22] inverse distance spatial weights matrix. This selection of the matrix form is mainly in support of the hypothesis that productivity and efficiency at the farm level decreases with distance from the best performing producers. Further, an inverse distance matrix has been determined to respond well to measures of spatial dependence (Getis & Aldstadt, 2004).

The prevailing measure of spatial dependence or spatial autocorrelation for continuous cross- sectional data is the Moran's I statistic. For a variable x observed at various locations, the estimation of the Moran's I is according to the cross products of the deviations from the mean for n observations. Its formal definition is:

$$I = \left(\frac{n}{S_0}\right) \frac{\left[\sum_{i=0}^{n} \sum_{j=0}^{n} W_{ij}(x_i - \bar{x})(x_j - \bar{x})\right]}{\left[\sum_{i=0}^{n} (x_i - \bar{x})^2\right]} \qquad \text{[Eq. 5]}$$

where $\bar{x}$ is the mean of x and W_{ij} represents the weight between observations i and j with $i \neq j$. S_0 is the sum of the elements of the weight matrix, W_{ij} (Moran, 1950).[23] The Moran's I statistic ranges between negative one and positive one. A coefficient closer to positive one indicates positive spatial autocorrelation, which means there is clustering of similar values. A Moran's I statistic near negative one means that dissimilar values are next to each other and there is negative spatial autocorrelation. A coefficient of zero indicates no spatial autocorrelation and geographically dispersed values.

[22] Row standardization means that each weight is divided by the row sum of the weights given a certain distance band. As noted by Getis & Aldstadt (2004), row standardization is helpful in weighting observations equally. This approach also provides a favorable interpretation of autoregressive parameters and Moran statistics.

[23] Moran's I is one of many possible representations of spatial autocorrelation. For a more extensive review of the Moran's I and other measures of spatial dependence, the author refers the reader to check Getis (2007), Getis & Ord (1992), and Moran (1950). Applications of some of these measures are provided in Cliff & Ord (1970).

Granted that the specification of the spatial weights matrix properly captures the spatial dependence between observations, this study takes explicit spatial econometric approaches to examine how spatial effects influence factors of production and sources of efficiency or lack thereof. Endogenous spatial interaction effects are introduced to assess the geographic influence between the dependent variables[24] and the error terms in the standard production and efficiency regression models following a maximum likelihood process. Cognizant that the level of production (output), y_i, depends on the levels of y_j at nearby locations, the spatial specification is the spatial autoregressive (lag) model (SAR) defined as:

$$y = \rho W y + X\beta + \varepsilon \qquad \text{[Eq. 6]}$$

where y contains a $n \times 1$ vector of production outputs, ρ is the spatial autoregressive parameter, and Wy denotes the endogenous interaction effects of the dependent variable through a $n \times n$ spatial weights matrix, W.[25] The term X, which is a $n \times k$ matrix of observations with $k \times 1$ associated regression coefficients β represent the explanatory variables. The expression ε denotes a vector of disturbance terms.

To account for the spatial interaction through the error terms, the spatial error model (SEM) is applied. In this model, the spatial dependence is a nuisance term, which has some similarity with how statistical approaches would treat serial temporal correlation as something to be excluded (Ward & Gleditsch, 2008). In its formal form, the SEM expression is:

$$y = X\beta + \varepsilon, \text{ where } \varepsilon = \lambda W \varepsilon + v. \qquad \text{[Eq. 7]}$$

The SEM expression decomposes the disturbance into two components, ε and v. The v error term is spatially uncorrelated and it satisfies the standard regression assumptions. The error term ε denotes the spatial component of the disturbance term. Given a $n \times n$ spatial weights

[24] The dependent variables refer to the yield per hectare and technical efficiency estimates.
[25] Wy is the spatial lag of the dependent variable. According to LeSage & Pace (2009), it is an explanatory variable vector constructed using an average of values from neighboring regions. Anselin (1988) noted that in contrast to the time series counterpart of the spatial lag model, the lag term Wy correlates with the disturbances even if the error terms follow an identical, independent, and normal distribution.

matrix, W, the parameter λ demonstrates the extent of spatial autocorrelation of the error terms for each observation in nearby locations (Ward & Gleditsch, 2008).

Building on the spatial autoregressive and error models, this study also examines spatial effects by simultaneously incorporating spatial spillovers in the endogenous variable and the disturbances. This particular form of the spatial econometric model is referred to as spatial autoregressive (lag) model with autoregressive (error) disturbance (SARAR) (Kelejian & Prucha, 2010). According to Sangalli & Lamieri (2015), this combined model allows for the inclusion of both a direct and indirect spatial dependence between observations. The spatial lag component of the model captures the direct spatial dependence whereas the introduction of spatial structure in the error term can exhibit indirect spatial autocorrelation.[26] Integrating [Eq. 6] and [Eq. 7], SARAR's formal structure expression is:

$$y = \rho W y + X\beta + \lambda W \varepsilon + v \qquad \text{[Eq. 8]}$$

The formal and in-depth derivation of the above spatial econometric models using the maximum likelihood method is beyond the scope of this paper. Several recent texts discuss at length the derivations for the various models included in this study. For a discussion of the step-by-step derivations, see Arbia (2014), Griffith & Paelinck (2011), Kelejian & Prucha (2010), LeSage & Pace (2009), Arbia & Baltagi (2009), Ward & Gleditsch (2008), Arbia (2006), Anselin, Florax, & Rey (2004), Anselin & Florax (1995), Anselin (1988) and the references cited therein.

Results and Discussion

Following conventional agricultural production models, the ensuing sections describe the empirical results of the stochastic production frontier analysis. Specifically, the discussion below

[26] Direct spatial impact occurs when a change in a particular observation associated with any of the explanatory variables including the spatial lag produces a change to the same observation of interest. When the observed change is in other observations, the impact is referred to as the indirect spatial effect. Hypothetically, for example, a model with yield as the endogenous variable and machinery as one of the exogenous variables with a coefficient of 5.50 does not necessarily mean that a one percent increase in the utilization of machinery would result in a 5.50 percent increase in yield. The estimate accounts for the short-run direct impact of the machinery directly on the yield of Farmer A. It also accounts for the indirect impacts of machinery on the yield of other rice growers other than Farmer A. For more information on the estimation of these direct and indirect effects, see Elhorst (2010).

presents estimation of the different levels and determinants of technical efficiencies in the dry and wet seasons. In emphasizing the geographic effects of farm and dwelling locations on productivity and technical efficiency of rice farms, the subsequent discussion present findings from the spatial econometric and optimized hot spot analysis.

Productivity and Efficiency: Room for Improvement to Help Achieve the Food Staples Sufficiency Program (FSSP) Target

Being consistent with production theory, the analysis specified a Cobb-Douglas stochastic production frontier function for the dry and wet cropping seasons as:

$$y_{i_{dry}} = \beta_0 + \sum_{j=1}^{8} \beta_j X_j + v_i - u_i \quad \text{[Eq. 9]}$$

$$y_{i_{wet}} = \beta_0 + \sum_{j=1}^{9} \beta_j X_j + v_i - u_i, \quad \text{[Eq. 10]}$$

where $u_i = \delta_i \sum_{j=1}^{12} Z_i + \omega_i$ captures the farm-specific technical inefficiency in production. In [Eq. 9] and [Eq. 10], $y_i$is the rice yield in metric tons per hectare. The term X_j represents the inputs in the rice production process for the two seasons, which includes seeds (X_1) and fertilizer (X_2) in kilograms per hectare, pesticides (X_3) quantified in terms of grams of active ingredients per hectare,[27] irrigation(X_4), machinery(X_5), and animals (X_6) measured in terms of pesos per hectare, and labor (X_7) in person-days per hectare. To account for the utilization of hybrid seeds, a dummy variable of one referring to a hybrid user and zero to non-user is included as X_8. For the wet season, a dummy variable, (X_9), is added to capture the effects of the typhoons in rice production with one indicating farm devastation from the severe weather and zero as otherwise. Given that the expression of the aforementioned X_j variables are in different units, this study transformed [Eq. 9] and [Eq. 10] into the following logarithmic form for the dry and wet seasons:

$$\ln y_i = \beta_0 + \sum_i^n \beta_j \ln x_j + v_i - u_i. \quad \text{[Eq. 11]}$$

[27] Pesticides include insecticides, herbicides, fungicides, rodenticides, nematicides, and molluscicides. To standardize the units among the different types of pesticides, this study estimated the amount of active ingredients for each pesticide type identified by the farmers during the survey. This made it possible to combine the different types of pesticides into one category following some form uniform units.

In view of the possible influence of farmer's socio-demographic background, household characteristics, and farm-specific attributes on the efficiency level of the farm operation and management, the analysis included the selected factors in the inefficiency equation, $u_i = \delta_j \sum_{j=1}^{12} Z_j + \omega_i$.[28] As represented by the Z_j term, the technical inefficiency determinants include the following socio-demographic and household attributes: age of the head of the farm household (Z_1), education or number of years of formal schooling of the head of the farm household (Z_2), number of years of rice farming experience (Z_3), and size of the farmer's social agricultural network (Z_4). In terms of operation- and management-related aspects of rice production, connectivity to the National Irrigation Administration (NIA) water infrastructure (Z_5), technology adoption (Z_6), distance to production input markets (Z_7), attendance at agricultural training sessions (Z_8), and interaction with agricultural technicians or extension agents (Z_9) are taken into consideration. The impact of production-associated problems on farm inefficiency such as high input prices (Z_{10}), high labor costs (Z_{11}), and lack of water (Z_{12}) are also taken into account.[29]

Table 3.3 and Appendix C summarize the parameter estimates for the stochastic production function and the technical inefficiency model. These estimates were obtained with use of Stata 14.0 software and the one-step maximum likelihood approach as proposed in Wang & Schmidt (2002). As noted by Liu (2006), this procedure reduces bias and provides more consistency as compared to the two-step process where the frontier function is estimated first and followed by an estimation of a linear regression of the inefficiency terms as a function of a set of explanatory variables.[30]

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[28] The terms δ_i and ω_i respectively denote parameters to be estimates and unobservable random variables assumed to be independently distributed.

[29] Farmers have different ways of sourcing inputs and labor. While farmers with readily available capital pay for inputs and labor upfront on cash basis, some farmers expressed that when they source inputs on credit, the suppliers imposed higher prices due to the length of payment period. Some farmers also experience the same in terms of sourcing work force especially during the planting season. For these reasons and in recognition that changes in the ability of farmers to readily acquire necessary production inputs can shift their production prospects, this study included input price and labor costs as potential determinants of technical efficiency of farmers in Central Luzon.

[30] The bias results from the lack of consistency in the assumptions about the distribution of inefficiency that leads to misspecification of the model in the two-step procedure. The other source of bias according to Liu (2006) is that the assessment of the inefficiency term generated in the first part of the two-step approach is correlated with the exogenous factors. Thus, to address the bias, Wang & Schmidt (2002) proposed "a one-step procedure based on the correctly specified model for the distribution of y given x, and z."

The maximum likelihood estimates for the stochastic production function illustrate output elasticities of inputs in the rice production process. For example, the use of machinery at various stages of rice cultivation from land prepartion to crop establishment, care, and harvest significantly influences yields across locations and seasons. In Guimba, a 10 percent increase in machinery expenditure results in increasing yield per hectare by 0.98 percent during the dry season and by 0.76 percent in the wet season, *ceteris paribus*. For the same level of increase in machinery expenditure, per hectare production in Tarlac can increase by 3.65 and 3.75 percent respectively in the dry and wet seasons, *ceteris paribus*. For a given increase in machinery use, *ceteris paribus*, the percentage increase in output is less for Tarlac than Guimba reflecting the lower use of machinery on average in Tarlac than Guimba.

Other than machinery, the use of fertilizer and hybrid seeds are statistically significant with positive coefficients for both the dry and wet cropping seasons in Guimba implying that an increase in the use of these two inputs would generate an increase in production. On average, farmers in Guimba use almost 200 kilograms more fertlizer than farmers in Tarlac. The utilization of hybrid seeds although significant has negative coefficients in Tarlac. One possible reason is that there is very low adoption of hybrid seeds in Tarlac with only two percent of the farmers using hybrid varieties and that the varieties of hybrid rice cultivated are not well-adapted to the farm conditions in the area resulting in lower yields than expected. The use of hybrid rice seed varieties[31] in Guimba, however, exhibited positive and significant coefficients. For Guimba, a 10 percent increase in the use of hybrid rice cultivars can result in a 0.71 percent increase in yield per hectare in the dry season and 0.62 percent increase in yield per hectare in the wet season, *ceteris paribus*.

As expected, typhoon or some form of climate-related devastation during the wet season affects yield per hectare significantly as shown by a 1.5 percent and 1.86 percent decline in yield per hectare for a 10% increase in the number of farmers affected by a typhoon in Guimba and Tarlac, respectively. In 2013, there were 31 tropical depressions detected in the Philippine Area of Responsibility (PAR), of which 13 formed into full-blown typhoons. Two strong typhoons hit

[31] Modern rice seed varieties are rice cultivars that are a product of crossbreeding.

Table 3.3: Selected mean and maximum likelihood estimates of the stochastic production and technical inefficiency models.

Variables	Unit and Description	Guimba (n=294)				Tarlac (n=150)			
		Dry		Wet		Dry		Wet	
		Mean (S.D.)	*Coefficient (S.E.)*	*Mean (S.D.)*	*Coefficient (S.E.)*	*Mean (S.D.)*	*Coefficient (S.E.)*	*Mean (S.D.)*	*Coefficient (S.E.)*
Production Function									
Constant	Intercept		0.232 (0.311)		0.205 (0.281)		-2.249*** (0.382)		-1.867*** (0.416)
Seeds	kilogram/hectare	83.727 (42.423)	0.030 (0.036)	93.837 (35.346)	0.065* (0.038)	102.282 (49.763)	0.082* (0.046)	87.218 (34.105)	0.036** (0.018)
Fertilizer	kilogram/hectare	452.593 (214.376)	0.135*** (0.037)	366.258 (196.069)	0.060* (0.036)	279.149 (122.260)	0.053 (0.048)	195.499 (142.741)	0.056 (0.036)
Pesticides	gram of active ingredients/hectare	665.283 (865.546)	-0.004 (0.006)	720.431 (788.235)	0.002 (0.007)	638.707 (692.493)	0.033** (0.014)	623.370 (796.453)	0.004 (0.013)
Machinery	Philippine Pesos/hectare	5,865.083 (2,539.742)	0.098*** (0.023)	4,911.540 (2,308.813)	0.076*** (0.024)	3,657.347 (1,999.054)	0.365*** (0.046)	2,307.485 (1,892.956)	0.375*** (0.053)
Animals	Philippine Pesos/hectare	796.943 (676.209)	0.001 (0.005)	631.741 (527.459)	-0.002 (0.005)	94.129 (398.410)	0.018** (0.009)	72.634 (321.008)	0.018* (0.010)
Labor	person-days/hectare	59.454 (25.296)	-0.044 (0.032)	58.315 (25.921)	0.067** (0.033)	41.112 (20.164)	-0.006 (0.039)	45.639 (27.670)	0.005 (0.013)
Hybrid*Seeds	1=hybrid seed user 0=otherwise	0.184 (0.388) *n=54*	0.071*** (0.022)	0.020 (0.142) *n=6*	0.062* (0.037)	0.020 (.140) *n=3*	-0.062** (0.029)	0.013 (0.115) *n=2*	-0.063* (0.038)
Typhoon	1=farm was affected by the typhoon during wet season 0=otherwise			0.289 (0.454) *n=85*	-0.150*** (0.029)			0.407 (0.493) *n=61*	-0.186*** (0.048)
Inefficiency Function									
Constant	Intercept		-13.121 (8.939)		-10.911 (11.684)		-5.834** (2.438)		-1.595 (1.616)
Irrigation	1=connection to the National Irrigation	0.993 (0.082)	5.659 (8.703)	0.997 (0.058)	7.858 (11.637)	0.487 (0.501)	-1.884*** (0.504)	0.467 (0.501)	-0.135 (0.466)

Variables	Unit and Description	Guimba (n=294)				Tarlac (n=150)			
		Dry		Wet		Dry		Wet	
		Mean (S.D.)	***Coefficient (S.E.)***	***Mean (S.D.)***	***Coefficient (S.E.)***	***Mean (S.D.)***	***Coefficient (S.E.)***	***Mean (S.D.)***	***Coefficient (S.E.)***
	Administration infrastructure 0=otherwise	*n=292*		*n=293*		*n=73*		*n=70*	
Distance	Distance of the rice farm from input market (in kilometers)	6.576 (5.016)	0.0365 (0.043)	6.604 (5.002)	0.023 (0.031)	6.045 (8.736)	0.026 (0.024)	5.381 (8.262)	0.044* (0.025)
Training	1=farmer attended an agricultural training 0=otherwise	0.507 (0.501) *n=149*	-0.265 (0.615)	0.493 (0.501) *n=149*	-0.575* (0.332)	0.500 (0.502) *n=75*	-0.466 (0.537)	0.500 (0.502) *n=75*	-0.120 (0.530)
Labor	1=farmer experienced high labor costs 0=otherwise	0.439 (0.497) *n=129*	0.583 (0.627)	0.497 (0.501) *n=146*	0.265 (0.337)	0.927 (0.262) *n=139*	0.167 (0.851)	0.0920 (0.272) *n=138*	-1.117 (0.719)
Water	1=rice farm experienced shortage in or lack of water supply 0=otherwise	0.303 (0.460) *n=89*	1.442** (0.681)	0.241 (0.429) *n=71*	0.170 (0.389)	0.880 (0.326) *n=132*	1.654* (0.953)	0.807 (0.396) *n=121*	1.077** (0.524)
Diagnostic Statistics									
σ_u		0.082		0.212		0.260		0.330	
σ_v		0.183		0.151		0.150		0.147	
Log Likelihood		53.626		0.0691		-10.757		-34.406	

Notes:
(1) Tabulated data are from the author's own calculation.
(2) *** significant at 1%, ** significant at 5%, * significant at 10%.
(3) S.D. stands for standard deviation and S.E. is for standard error.
(4) The respective coefficients and the standard errors of the coefficients are correct to three significant digits.

various parts of Central Luzon during the 2013 wet season, leaving the region with a combined total of almost PhP 3 billion worth of agricultural damages (Flora, 2013; Suarez, 2013).

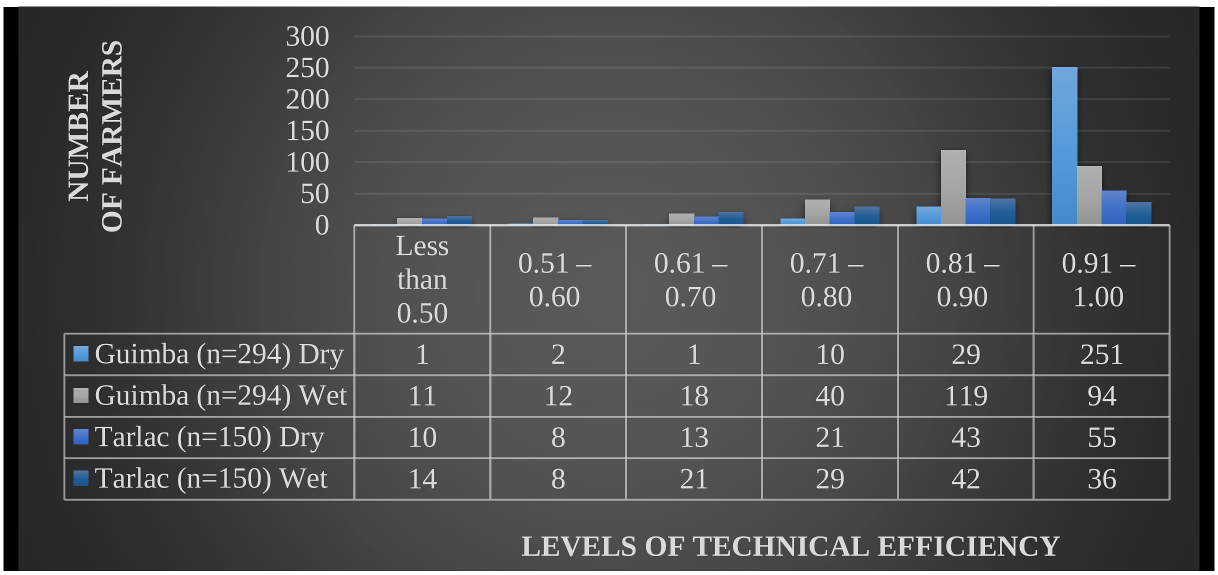
The results also indicated that labor (in person-days) is significant during the wet cropping season in Guimba. In Tarlac, the use of pesticides is significantly influencing yield during the dry season whereas animal draft power is found significant for both seasons. In the field survey, Tarlac farmers expressed problems with rodents and snails during the dry season. The use of pesticides, although not directly influencing yield growth, helps reduce losses from pest infestations as expressed by Rola & Pingali (1993) and Magallona (1989) in an investigation of the effects of pesticides in rice ecosystems.

In both the dry and wet seasons for the two municipalities, the returns to scale is less than unity suggesting a decreasing return to scale production process. This implies that if all inputs are increased by k percent, production will increase by less than k percent. In Guimba, a 10 percent increase in all inputs would result in a 3.01 and 3.30 percent change in the yield for the dry and wet seasons, respectively. Correspondingly, the quantitative change in yield per hectare in Tarlac is higher given the same proportionate change in the level of inputs. In the dry season, the returns to scale for Tarlac farmers is 4.81 percent, whereas in the wet season, it is 4.31 percent.

In light of the Food Staples Sufficiency Program (FSSP) target, the findings of the present analysis support the initiatives set in place under the FSSP. For one, to raise productivity and competitiveness, the FSSP advocates the adoption of suitable high quality seeds and increased use of fertilizers. The FSSP also promotes mechanization of on-farm and post-harvest operations to help increase yield. The results show that fertilizer and hybrid seed utilization can increase rice yields. The mechanization of rice production compared to all other factors of production as shown by the present analysis can substantially increase productivity.

Because of decreasing returns to scale observed in the two municipalities as well as the assessment of the actual potential of farmers in achieving the FSSP target, it is necessary to examine their levels of efficiency. Based on current production practices, Guimba farmers are operating more efficiently than Tarlac farmers are, with an average technical efficiency of 0.923

in the dry season and 0.823 in the wet season (Figure 3.2).[32] The efficiency levels of rice farms in Tarlac are correspondingly lower by 0.07 and 0.12 for the wet and dry seasons (note 3 for Figure 3.2 confirms that at the means, these efficiency differences are statistically significant). Despite the relatively high average efficiency levels in the two municipalities, there are still a number of rice farms that can make substantial improvement in their production operation and farm management to increase their efficiency levels. In Guimba, for instance, during the wet season, about 28 percent of the rice farms have efficiency levels lower than 0.80. This number grows to 35 and 48 percent, respectively, for Tarlac in the dry and wet seasons.



	Less than 0.50	0.51 – 0.60	0.61 – 0.70	0.71 – 0.80	0.81 – 0.90	0.91 – 1.00
Guimba (n=294) Dry	1	2	1	10	29	251
Guimba (n=294) Wet	11	12	18	40	119	94
Tarlac (n=150) Dry	10	8	13	21	43	55
Tarlac (n=150) Wet	14	8	21	29	42	36

	Guimba (n=294)		Tarlac (n=150)	
	Dry	*Wet*	*Dry*	*Wet*
Average Technical Efficiency	0.923 (0.078)	0.823 (0.135)	0.803 (0.165)	0.759 (0.179)
Regional Average	0.827			

Figure 3.2: Distribution of technical efficiency levels for farmers in Guimba and Tarlac during the dry and wet cropping seasons.

Notes: (1) All values are from the author's own calculation. (2) Values in parentheses denote standard deviation. (3) The average technical efficiency estimates are statistically different for the two study sites.

[32] Barker, Herdt, & Rose (1985) noted that when rice has adequate water during the dry season, "higher level of solar radiation leads to better nutrient uptake and higher yields. The authors observed higher fertilizer productivity arises from higher solar radiation. Specifically, they found that the "average productivity of fertilizer in the dry season is 50 percent higher in the Philippines and 70 percent higher in India than in the wet season."

Given the variation in the levels of technical efficiency among Guimba and Tarlac farmers, there is definitely potential and opportunity for them to produce more efficiently and improve their productivity. For instance, farms in Guimba can potentially increase production to 7.32 and 5.63 metric tons per hectare at the maximum in the dry and wet seasons, respectively. Equivalently, in Tarlac, farmers can increase rice yield to 4.78 metric tons per hectare in the dry cropping season and 3.90 metric tons in the wet cropping season.

Farm-specific technical efficiency estimates are important since they can provide information to farmers and policymakers on the nature of operation and management practices implemented in various farm locations. This allows farmers and decision-makers to assess ways to increase productivity without increasing the levels of input application. As shown in Figure 3.2, there is variation in the range of technical efficiencies of farmers in Guimba and Tarlac. To understand the divergence in the efficiency rankings, it is imperative to examine factors that could be causing the inefficiency of the farms across the two municipalities.

From Table 3.3 and Appendix C, it is apparent that farm operation and management practices as well as production-specific problems greatly influence the inefficiency of farmers in the two municipalities. Across Guimba and Tarlac, water shortage during the two cropping seasons increases farmer inefficiencies. In Tarlac, efficiency levels of rice farms connected to the National Irrigation Administration's (NIA) water infrastructure amplify this finding. In accordance with the finding of Rola & Quintana-Alejandrino (1993), the present analysis shows that in the dry season, the inefficiency of Tarlac farmers significantly decreases when they are connected to NIA irrigation systems. This implies that if the Philippines is to achieve the rice self-sufficiency target, there is a need to improve water availability in order to manage two or more croppings per year. [33] The year-round multi-cropping production, particularly during the dry season, is only possible if there is a sufficient water supply (Antiporda, 2014; Hafeez, Bouman, Van De Giesen, & Vlek, 2007). The acceleration of irrigation service areas under the FSSP is, therefore, very relevant and promising as far as reducing inefficiencies of farmers.

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[33] Rice production in the Philippines has two cropping seasons: wet (rainy) season and dry season. Typically, rice production for the wet season commences at the beginning of the summer monsoon, which is around May of each year. Right after the harvest for the wet season rice, the dry season production immediately follows as farmers want to utilize the rainfall at the end of the wet season (Koide, et al., 2013).

Distance of farms to input markets and attendance in agricultural training programs also significantly influence farmer inefficiency in the wet season in Tarlac and Guimba. The influence of distance is consistent with the findings of DeSilva (2011) and Evenson, Kimhi, & DeSilva (2000) in Bicol, Philippines. In the present analysis, if farms are six kilometers or more away from the input market, inefficiency increases. This is particularly important in Tarlac during the wet season since the majority of input markets are located in the city center while farms are on the outskirts. In support of the FSSP target, the government may want to introduce some form of mobile agricultural input store program that is akin to the mobile library program that some municipalities are promoting. With this program, farmers in remote areas need not go to the city center to acquire most needed inputs, which in turn can help reduce the overall transportation and hauling costs of inputs.

The noticeable significance of attendance at agricultural training sessions specifically during the wet season in Guimba is interesting. As the results indicate, attendance to training programs decreases inefficiency. Speculation suggests that the pertinence of such a factor during the wet season is due to the possibility that there were more training programs offered to the farmers in the cropping season of interest relative to other periods.

The results of the one-step stochastic production frontier analysis are in accord with the findings from similar studies on rice in the Philippines such as that of Michler & Shively (2015), Villano, Bravo-Ureta, Solis, & Fleming (2015), Koirala, Mishra, & Mohanty (2014a), Koirala, Mishra, & Mohanty (2014b), Mariano, Villano, & Fleming (2011), Gomez & Neyra (2010), Odchimar & Tan-Cruz (2007), Pate & Tan-Cruz (2007), Yao & Shively (2007), Villano & Fleming (2006), Villano & Fleming (2004), Umetsu, Lekprichakul, & Chakravorty (2003), Larson & Plessmann (2002), Fukui (1993), Rola & Quintana-Alejandrino (1993), Dawson, Lingard, & Woodford (1991), Galang (1990), and Kalirajan & Shand (1990) among the most recent works. As shown in the current analysis, increasing technical efficiency of farmers in Guimba and Tarlac can lead to an increase in rice yield per hectare. Under the Food Staples Sufficiency Program (FSSP), the campaign to construct and modernize new irrigation systems should continue as well as strengthened rehabilitation and restoration of existing irrigation facilities as access to reliable water sources can help increase farmers' efficiency especially in Tarlac.

Farm Locations and Dwelling Clusters: Do They Make Production and Technical Efficiency Spatially Contagious?

The notion of how location factors influence agricultural production has its roots from the agricultural location theory that started with the classical work of von Thunen (1826). Under the limiting assumptions: (1) land is uniformly fertile, (2) there is only a single population cluster in its center, (3) factors of production are available at a given location with prices that linearly increase with distance from input markets, and (4) agricultural product price and demand are fixed for all products, von Thunen (1826) argued that in order for farmers to maximize profit, their farms have to be located at a strategic distance from the market center. With these conditions, at certain distances clustering of profit-maximizing farmers can be detected.

While von Thunen's (1826) agricultural location theory provided the foundation for why location matters in agricultural production, there are some weaknesses in the argument. In their review of the early work in modern agricultural location theory, Lucas & Chhajed (2004) and Block & DuPuis (2001) noted that von Thunen's descriptive approach is very simplistic and does not accurately represent reality. In an earlier examination of von Thunen's (1826) work, Garrison & Marble (1957) described the model as crude and inarticulate given that perfect competition, perfect information, and geographic uniformity were assumed.

Cognizant that rice production is a dynamic process that takes place in areas with varying fertility, soil types, and production resource endowments such as water, this study contends that productive, efficient, and even inefficient farms cluster according to their physical distance to other best or worst performing farms and not necessarily due to their distance from a particular market center. Following the complementarity argument made by Porter (2000, 1998, 1990) on industrial clustering that the performance of a firm in a cluster affects the performance of the other cluster members, the present analysis assumes that increased productivity at the farm level would be similar to that of the agglomerated firms since transmission of information as well as access to specialized inputs and labor are more fluid in neighboring farms or dwellings than those distant from one another. Proximity to highly efficient or inefficient farms permits practical or possibly unrealistic accumulation and diffusion of information on technological changes and technical possibilities, which according to Looijen & Heijman, (2013) can help or hurt producers in enhancing their productivity and getting them closer to their production frontier.

An initial exploratory spatial data analysis (ESDA) of the geolocations of rice farms and farmers' dwelling place shows that some evidence of yield and technical efficiency and inefficiency agglomeration exist. Through the application of the high/low spatial statistics tool, the analysis identified spatial concentration of highly productive and best performing farms. As illustrated in Appendix D, there are high clusters for dry season yields but not for the wet season in both Guimba (Appendices D.1 and D.2) and Tarlac (Appendices D.3 and D.4). This suggests that high yielding farms during the dry season are closely located to each other. When plotted according to dwelling locations, the analysis derived an interesting finding – Guimba farmers producing high yields during the dry season do not reside next to each other whereas the wet season best performing farmers in terms of yield are residentially clustered. In contrast, wet season high yielding producers in Tarlac do not exhibit any form of clustering both at the farm and dwelling locations. It appears that there is some seasonal effect on yield level clustering.

When technical efficiency levels of farmers are examined, the ESDA shows that for the two seasons there is no clustering observed among Guimba farmers given farm and dwelling locations (Appendices D.5 and D.6). In Tarlac, on the other hand, clustering is present for both the dry and wet seasons. Appendix D.7 shows that farms with high technical efficiency in the dry season are closely located to each other. The same finding, though, does not hold for Tarlac farmers in the wet season. Rather, it is the inefficient farms which exhibit conglomeration in the wet season (see Appendix D.8).

The ESDA findings, thus far, demonstrate spatial patterns that support the hypothesis that, in part, higher (lower) yields and technical efficiency (inefficiency) of rice farms spatially depend on either farm or dwelling locations and on proximity of these locations to each other. To complement the high/low spatial clustering analysis, this study assessed the non-random patterns of production yield, technical efficiency, and technical inefficiency estimates by calculating the degree of spatial dependence or spatial autocorrelation among these attributes over a set of spatial units. Specifically, the present analysis estimated the Moran's *I* statistic for yield and technical efficiency as well as technical inefficiency attributes.[34]

The results of the Moran's *I* analysis affirmed the findings from the high/low clustering analysis.[35] Table 3.4 shows that yield estimates in the study areas exhibit positive spatial autocorrelation. For Tarlac (also see Figure 3.3), the estimated Moran's *I* statistic suggests a higher and significantly stronger autocorrelation for the two seasons in the case of both farm and dwelling locations. Guimba, on the other hand, displays a less intense spatial dependency pattern with estimates close to zero and significant at the ten and five percent levels with the Moran's *I* statistic being statistically insignificant in the dry season for farmers' residence (also see Figure 3.4).

Table 3.4: Spatial dependence or autocorrelation in yield and efficiency estimates.

Attributes	Moran's I for Guimba (n=294)				Moran's I for Tarlac (n=150)			
	Dry Season		Wet Season		Dry Season		Wet Season	
	Farm	*Res*	*Farm*	*Res*	*Farm*	*Res*	*Farm*	*Res*
Yield	0.038*	0.029	0.069**	0.059**	0.262***	0.227***	0.224***	0.234***
Technical Efficiency	-0.023	-0.051*[36]	0.010	-0.004	0.298***	0.302***	0.077**	0.099***
Technical Inefficiency	-0.027	-0.016	0.014	-0.006	0.292***	0.294***	0.244***	0.290***

Notes:
(1) Res refers to residence or dwelling locations.
(2) *** significant at 1%, ** significant at 5%, * significant at 10%.
(3) The respective coefficients are correct to three significant digits.

[34] To estimate the Moran's *I* this study used the row-standardized inverse distance approach to generate the spatial weights matrix. The derivation of the spatial weights matrix also used particular distance bands based on the largest minimum distance for each site. The spatial weights matrix calculation used minimum distance to ensure that each observation would have at least one neighboring observation.

[35] Moran's *I* takes the value between negative one to positive one. Positive autocorrelation occurs when the value is closer to positive one, which suggests clustering. When values are negative and closer to negative one, it means that dissimilar values are next to each other. A coefficient of zero indicates no spatial autocorrelation and geographically dispersed values.

[36] For the dry season, Guimba exhibits statistically significant but weak negative spatial autocorrelation as the coefficient is closer to zero than negative one. The significance of the Moran's *I* coefficient for the dry season in the residential areas is attributable to the diverse range of high technical efficiency values in a village. For instance, one farmer respondent in Village A has a technical efficiency value of .98. Three other farmer respondents from the same village have technical efficiency values of .89, .94, and .83. These values from the same village, although relatively high, demonstrate dissimilarity given that there is a wide deviation of values and the incidence of similar values is low. Many of the villages in Guimba are under similar circumstance, which likely caused the significance in the Moran's *I* coefficient.

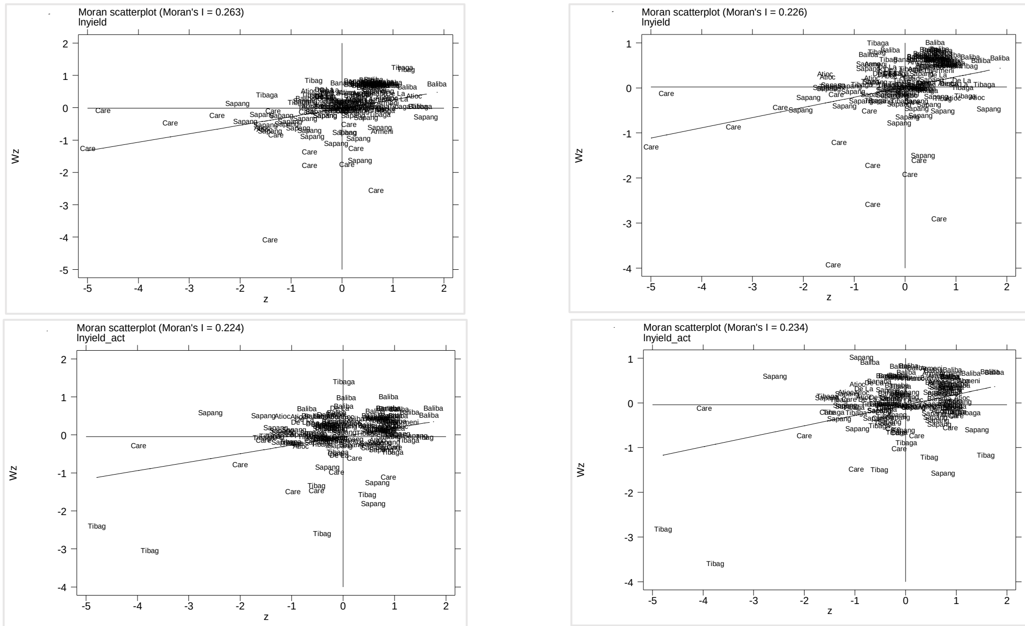


Figure 3.3: Moran's *I* scatter plot for yield estimates considering farm (left) and dwelling (right) geolocations in Tarlac for the dry (top) and wet (bottom) seasons.

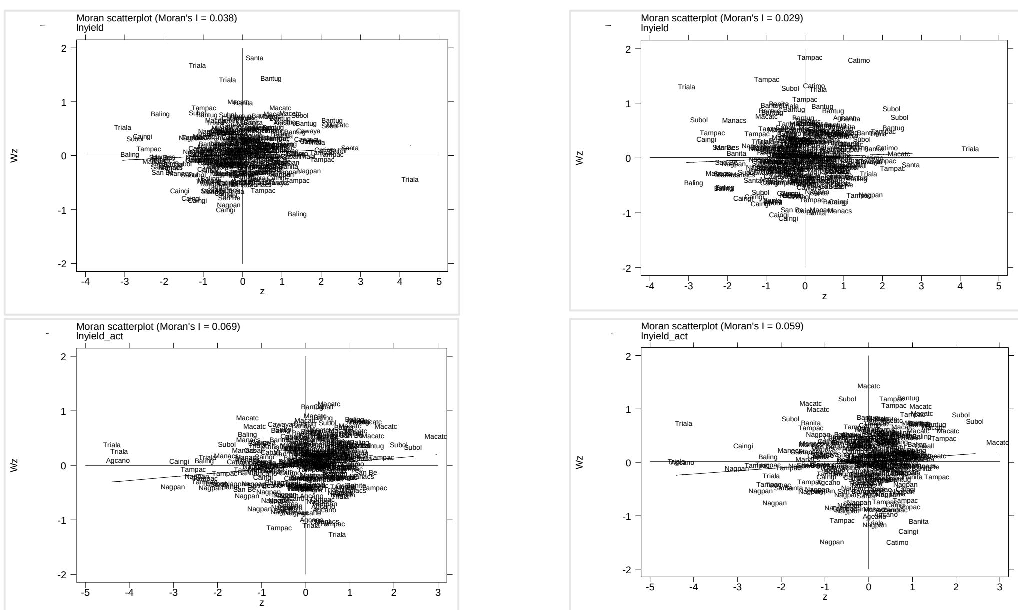


Figure 3.4: Moran's *I* scatter plot for yield estimates considering farm (left) and dwelling (right) geolocations in Guimba for the dry (top) and wet (bottom) seasons.

Consistent with the initial ESDA findings, technical efficiencies and inefficiencies are significant and spatially dependent for the two seasons in Tarlac in view of the farm and dwelling locations (Figure 3.5).[37] On the contrary, for the same attributes, results show that there is negative and insignificant spatial autocorrelation in Guimba with the exception of the dry season estimates for residential locations (Figure 3.6). This indicates dissimilarity in spatial technical efficiency and inefficiency for both farm and dwelling locations in Guimba.

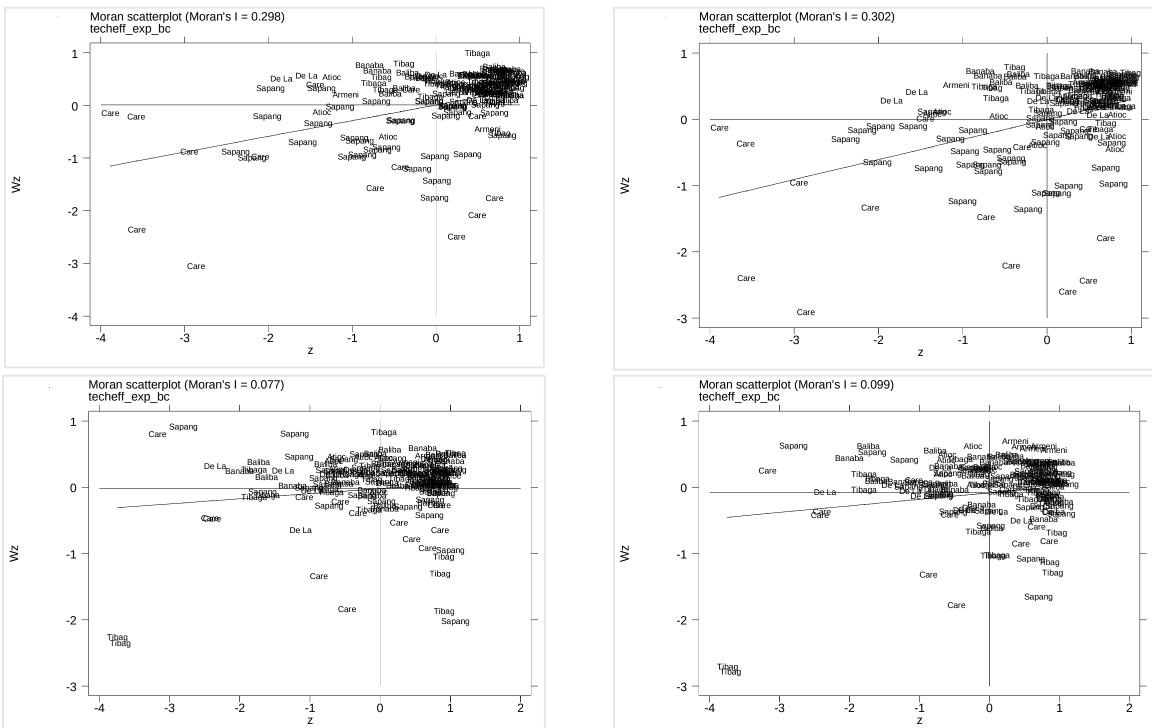


Figure 3.5: Moran's *I* scatter plot for technical efficiency estimates considering farm (left) and dwelling (right) geolocations in Tarlac for the dry (top) and wet (bottom) seasons.

[37] Appendix E presents the Moran's *I* scatter plot for the technical inefficiency estimates.

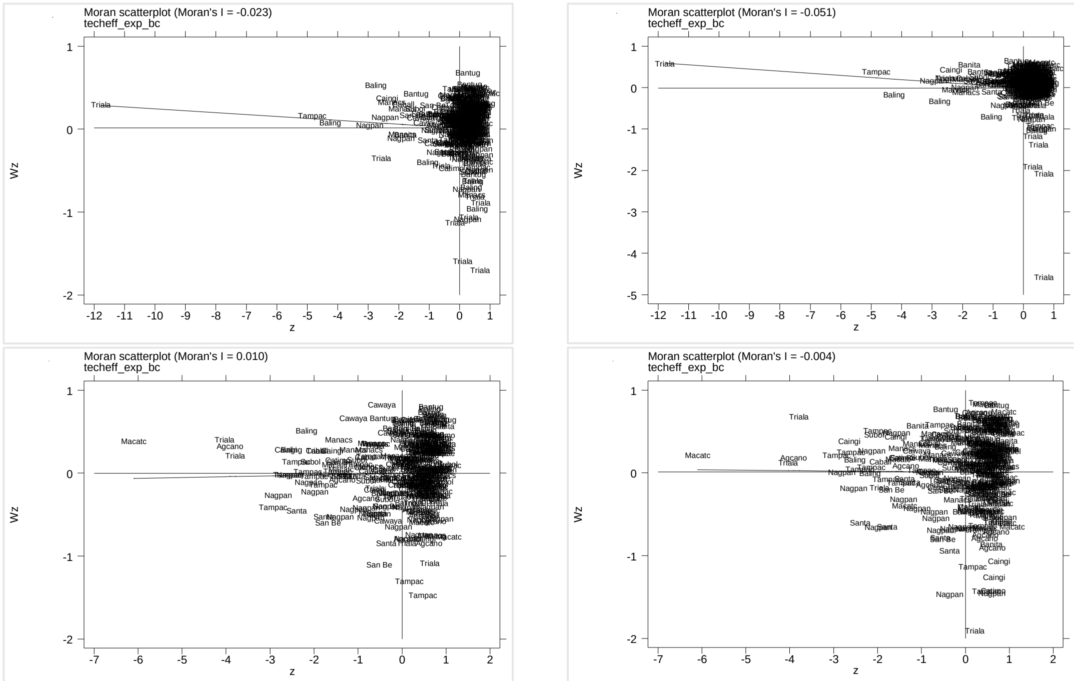
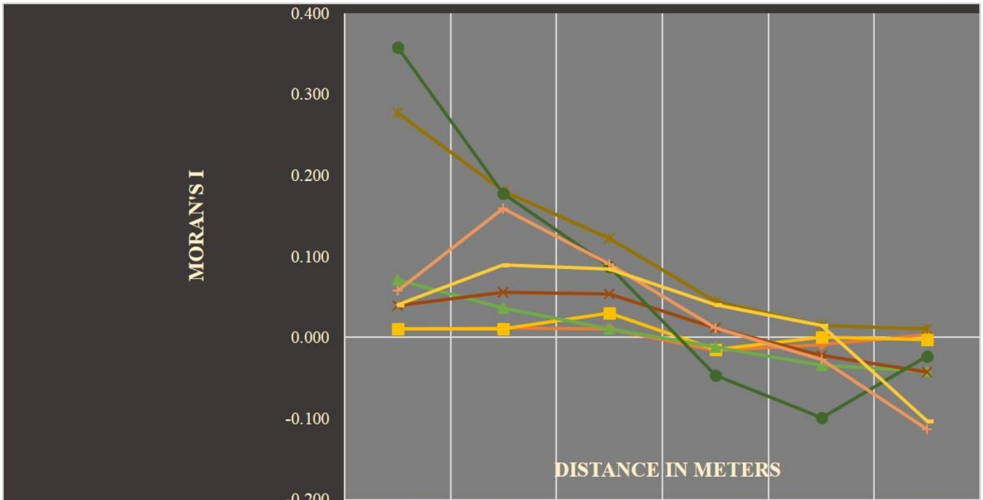


Figure 3.6: Moran's *I* scatter plot for technical efficiency estimates considering farm (left) and dwelling (right) geolocations in Guimba for the dry (top) and wet (bottom) seasons.

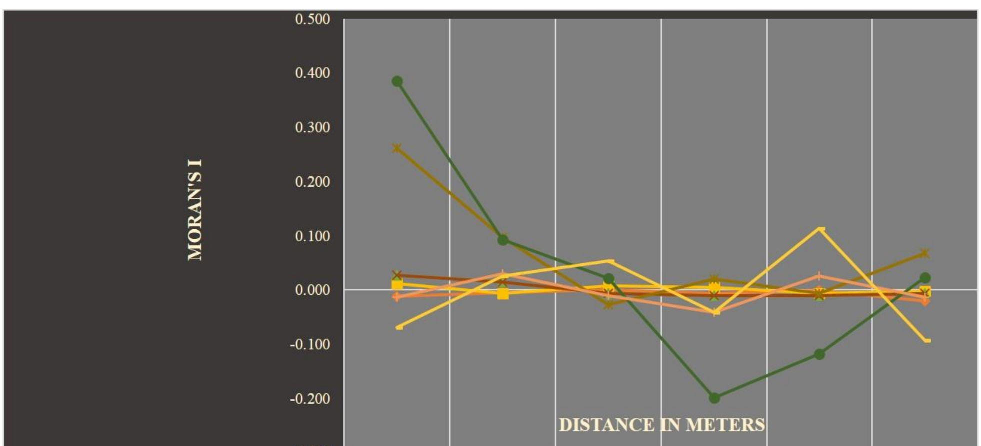
With the assumption that spatial dependence between observations declines as the distance between farms and residences increases, this study also investigated the proximity or distance at which spatial autocorrelation reaches a relative maximum. Using the shortest maximum distance identified in the spatial weights matrix as the cut-off point, Figures 3.7 and 3.8 derived as spatial correlograms show that within the proximity of two kilometers from each other, for either farm or dwelling location, the degree of positive spatial autocorreleation reaches its relative maximum.[38] Beyond two kilometers, the Moran's *I* shows a decreasing degree of spatial dependence, which at times yield negative spatial autocorrelation. This signifies that for a farmer to experience the spillover effect from the best or probably the worst performing producer, the farm or the residence must be located within two kilometers.

[38] Spatial correlograms are a way to examine patterns of spatial autocorrelation in the observations and the residuals of the model. Figures 3.7 and 3.8 show how autocorrelation values behave as distance classes' increase. This study considered six distance classes. The observed Moran's *I* is highest in the first distance class of one to two kilometers.



	(1000-2000]	(2000-3000]	(3000-4000]	(4000-5000]	(5000-6000]	(6000-7000]
Guimba Dry Season Yield (Farm)	0.010	0.012	0.010	-0.016	-0.009	0.003
Guimba Dry Season Yield (Residence)	0.011	0.011	0.030	-0.015	0.000	-0.003
Guimba Wet Season Yield (Farm)	0.071	0.036	0.010	-0.012	-0.035	-0.042
Guimba Wet Season Yield (Residence)	0.039	0.056	0.054	0.012	-0.022	-0.043
Tarlac Dry Season Yield (Farm)	0.277	0.180	0.122	0.044	0.015	0.011
Tarlac Dry Season Yield (Residence)	0.358	0.177	0.087	-0.047	-0.099	-0.023
Tarlac Wet Season Yield (Farm)	0.058	0.159	0.090	0.012	-0.027	-0.113
Tarlac Wet Season Yield (Residence)	0.040	0.089	0.084	0.040	0.015	-0.103

Figure 3.7: Spatial correlogram showing yield estimate dependence across farms and dwelling distances in the study areas.



	(1000-2000]	(2000-3000]	(3000-4000]	(4000-5000]	(5000-6000]	(6000-7000]
Guimba Dry Season Tech. Eff. (Farm)	-0.012	-0.005	0.000	-0.007	-0.001	-0.020
Guimba Dry Season Tech. Eff. (Residence)	0.012	-0.007	0.007	0.004	-0.006	-0.003
Guimba Wet Season Tech. Eff. (Farm)	0.027	0.015	-0.006	-0.011	-0.011	-0.007
Guimba Wet Season Tech. Eff. (Residence)	0.027	0.015	-0.006	-0.011	-0.011	-0.007
Tarlac Dry Season Tech. Eff. (Farm)	0.261	0.096	-0.028	0.020	-0.007	0.067
Tarlac Dry Season Tech. Eff. (Residence)	0.385	0.093	0.022	-0.199	-0.118	0.023
Tarlac Wet Season Tech. Eff. (Farm)	-0.013	0.029	-0.011	-0.042	0.025	-0.014
Tarlac Wet Season Tech. Eff. (Residence)	-0.070	0.025	0.054	-0.042	0.113	-0.093

Figure 3.8: Spatial correlogram showing dependence of technical efficiency estimate across farms and dwelling distances.

The evidence from the exploratory spatial data analysis shows how geolocations of farms and residences can potentially influence productivity, efficiency, and inefficiency levels. When positive and significant spatial autocorrelation is detected, recent literature such as Griffith & Paelinck (2011), Kelejian & Prucha (2010), and Anselin, Florax, & Rey (2004) among others suggest that spatial effects must be incorporated into the model specification and that the model must be estimated using appropriate techniques such as the maximum likelihood approach. To quantitatively account for the apparent influence of observed spatial clustering and spatial dependence on the productivity and technical efficiency as well as inefficiency of farmers in Guimba and Tarlac, this study employed spatial econometric techniques.

Following recommendations from the literature (Druska, 2012; Areal, Balcombe, & Tiffin, 2010; Druska & Horrace, 2004), the production and technical inefficiency functions previously specified in the stochastic production frontier analysis are re-analyzed by incorporating spatial dependence effects into the models. The spatial regression analysis evaluates how spatial autocorrelation previously detected in the exploratory spatial data analysis influence the significance of the different factors of production and determinants of technical inefficiency. In particular, a standard linear regression model without spatial effects is compared to several spatial regression models.

Since the level of yield and technical inefficiency of the farmers are presumed to be influenced by the levels attained by other farmers in neighboring locations, the appropriate model according to literature would be the spatial autoregressive (lag) model (SAR), which "incorporates spatial dependence explicitly by adding a 'spatially lagged' dependent variable into the model" (Ward & Gleditsch, 2008). Spatial dependence, however, is not usually restricted to the spatial interactions of the dependent variables. In some cases, spatial dependence can be attributed to the erroneous omission of spatially correlated variables, which can be captured in the error term resulting in a spatial error model (SEM) (de Graaff, van Montfort, & Nijkamp, 2006). Every now and then, a stand alone model such as the SAR or the SEM may not be sufficient to account for spatial dependence. Such circumstance necessitates a combination of the SAR and the SEM, which is known as the spatial autoregressive (lag) autoregressive (error) model (SARAR).

As an initial attempt to demonstrate the importance of taking into account spatial dependence in the rice production and technical inefficiency model specifications, this study does not restrict the analysis to the approrpriate spatial model specification suggested by the results of the spatial diagnostic tests. As shown in Table 3.5, the spatial autoregressive (lag) model has the more suitable spatial regression specification for Tarlac where spatial dependence is more pronounced in the dry and wet seasons. Although this is the case, for demonstration and comparison purposes, the present analysis includes results also from the SEM and SARAR models.

Table 3.5: Lagrange multiplier diagnostic test for spatial dependence.[39]

Production:	**Guimba (n=294)**				**Tarlac (n=150)**			
	Dry Season		**Wet Season**		**Dry Season**		**Wet Season**	
	Farm	***Res***	***Farm***	***Res***	***Farm***	***Res***	***Farm***	***Res***
Spatial error model	0.519	0.519	1.579	0.269	12.205***	23.852***	7.319***	17.668***
Spatial lag model	0.893	0.632	2.467	0.934	20.387***	21.526***	9.271***	16.807***
Technical Efficiency:	**Guimba (n=294)**				**Tarlac (n=150)**			
	Dry Season		**Wet Season**		**Dry Season**		**Wet Season**	
	Farm	***Res***	***Farm***	***Res***	***Farm***	***Res***	***Farm***	***Res***
Spatial error model	0.013	0.123	0.431	0.072	2.773*	2.736*	3.769**	5.115**
Spatial lag model	0.001	0.002	0.308	0.002	8.39***	10.687***	2.76*	5.234**

Notes:
(1) Res refers to residence or dwelling locations.
(2) *** significant at 1%, ** significant at 5%, * significant at 10%.
(3) The respective coefficients are correct to three significant digits.

Tables 3.6 and 3.7 present results for the production and technical inefficiency baseline models of no spatial effects. The tables also include findings for the three spatial models under consideration – the SAR, SEM, SARAR specifications. Selected results for Guimba are organized in Table 3.6, whereas findings for Tarlac are summarized in Table 3.7. Appendices F and G present the complete results for the two sites.

[39] Anselin (1988) proposed the Lagrange Multiplier test as a diagnostic for spatial econometric models. Based on the ordinary least squares estimation of the model, this test detects model misspecification due to spatial dependence in the form of omitted lagged dependent variable and spatial residual (Bera & Yoon, 1993). This test, among other asymptotic tests such as the Likelihood Ratio and Wald statistics, has been widely accepted in the literature (Varga, 1998).

As is apparent in Table 3.6, when spatial dependence is incorporated in the spatial models, the estimates and the signs of the coefficients are consistent with those obtained in the model with no spatial effects. This is in accord with the weak spatial autocorrelation detected in the exploratory spatial data analysis. The lambda and rho estimates under the SAR and SEM models in Guimba in the two seasons are close to zero and statistically insignificant, which cause the spatial models, $y = \rho W y + X\beta + \varepsilon$ and $y = X\beta + \lambda W\varepsilon + v,$ to reduce to the baseline model of having no spatial effect. The insignificance of the lambda and rho values strongly suggests that the variation in the production and technical inefficiency functions for Guimba in the dry and wet seasons are not significantly affected by spatial dependence in either the yield or technical inefficiency estimates. This indicates that geolocations of either the best performing farm or the most inferior producers do not influence how farms generally perform in Guimba – that any disparity in the farm yield or technical efficiency are not attributable to the spatial relationship at the farm or dwelling locations.

In the SARAR model, the lambda and rho values are also statistically insignificant in Guimba. This finding confirms that even in the combined model, the geography and proximity of farms and farmers to one another have no influence in the level of production as well as the technical efficiency or inefficiency at the farm level. Substantively, the general results for Guimba show that the standard linear regression model adequately accounts for the divergence in the yield per hectare, technical efficiency, and inefficiency estimates at the farm and residence levels. The geolocations of farms or dwelling locations do not influence production and performance at the farm level.

Unlike Guimba where spatial dependence effects do not significantly influence productivity as well as efficiency and inefficiency levels, it is a different story in Tarlac. As predicted from the exploratory spatial data analysis, significant clustering within the farm locations and the dwelling areas is apparent in the yield and inefficiency estimates. The Moran's I confirmed that this agglomeration is due to the strong spatial autocorrelation in the village areas.

Table 3.6: Selected results of the spatial models for the production and technical inefficiency functions in Guimba.

Variables	Guimba (n=294): Dry Season with Spatial Effects							Guimba (n=294): Wet Season with Spatial Effects						
Production Model	**No Spatial Effects**	**SEM**		**SAR**		**SARAR**		**No Spatial Effects**	**SEM**		**SAR**		**SARAR**	
		Farm	***Res***	***Farm***	***Res***	***Farm***	***Res***		***Farm***	***Res***	***Farm***	***Res***	***Farm***	***Res***
Fertilizer	0.137***	0.138***	0.139***	0.137***	0.138***	0.139***	0.139***	0.079*	0.080*	0.079*	0.080*	0.082*	0.079*	0.076*
Machinery	0.106***	0.104***	0.103***	0.105***	0.105***	0.099***	0.103***	0.124***	0.119***	0.122***	0.122***	0.122***	0.119***	0.122***
Labor	-0.036	-0.036	-0.034	-0.035	-0.034	-0.037	-0.032	0.067*	0.065*	0.068*	0.065*	0.067*	0.067*	0.070*
Hybrid*Seeds	0.056***	0.057***	0.057***	0.056***	0.056***	0.059***	0.059***	0.033	0.034	0.034	0.031	0.033	0.033	0.036
Typhoon								-0.218***	-0.216***	-0.216***	-0.215***	-0.214***	-0.216***	-0.215***
Lambda		0.061	0.067			0.313	0.133		0.110	0.046			-0.105	0.108
Rho				0.078	0.066	0.911	1.412				0.124	0.079	2.371	1.149
Inefficiency Model	**No Spatial Effects**	**SEM**		**SAR**		**SARAR**		**No Spatial Effects**	**SEM**		**SAR**		**SARAR**	
		Farm	***Res***	***Farm***	***Res***	***Farm***	***Res***		***Farm***	***Res***	***Farm***	***Res***	***Farm***	***Res***
Age	0.001	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.003*	0.003**	0.003**	0.003**	0.003**	0.003**	0.003**
Education	0.004*	0.004***	0.004***	0.004***	0.004***	0.004***	0.004***	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004
Experience	-0.001	-0.001**	-0.001**	-0.001**	-0.001**	-0.001**	-0.001**	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
Technology	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***	-0.005	-0.005	-0.005	-0.005	-0.005	-0.006	-0.006
Distance	0.002***	0.002***	0.002***	0.002***	0.002***	0.002***	0.002***	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Training	-0.011	-0.011	-0.011	-0.011	-0.011	-0.011	-0.011	-0.058**	-0.058**	-0.058**	-0.058**	-0.058**	-0.059**	-0.064**
Extension	-0.023***	-0.023***	-0.023***	-0.023***	-0.023***	-0.023***	-0.023***	-0.041*	-0.041*	-0.041*	-0.041*	-0.041*	-0.042*	-0.041*
Prices	0.036***	0.036***	0.036***	0.036***	0.036***	0.036***	0.036***	-0.011	-0.010	-0.010	-0.010	-0.011	-0.008	-0.009
Labor	0.023***	0.022***	0.022***	0.022***	0.022***	0.022***	0.022***	0.025	0.025	0.025	0.025	0.025	0.024	0.024
Water	0.063***	0.063***	0.063***	0.063***	0.063***	0.063***	0.063***	0.0.17	0.016	0.017	0.016	0.017	0.015	0.021
Lambda		-0.051	-0.014			-0.508	0.068		0.031	0.011			0.309	-1.222
Rho				-0.049	-0.009	-1.047	-0.226				0.033	-0.004	1.044	1.992

Notes: (1) Res refers to residence or dwelling locations. SEM refers to spatial error model. SAR is the spatial autoregressive (lag) model. SARAR is the spatial autoregressive (lag) autoregressive (error) model. (2) *** significant at 1%, ** significant at 5%, * significant at 10%. (3) The respective coefficients are correct to three significant digits.

Upon closer investigation, results from the spatial regression analysis show that the spatial error and spatial autoregressive (lag) models (SEM and SAR) demonstrate that yield as well as technical efficiency and inefficiency levels are attributable to the neighboring locations of the farms and the residences. In the production model (see Table 3.7), lambda and rho have estimated values of 0.382 and 0.314, which are significant at the one percent level under the SEM and the SAR specifications, respectively for the dry season. A similar pattern emanates for dwelling locations. Alongside these findings, spatial dependence also apparently influences yield estimates for the wet season. Taking into account farm locations, the lambda and rho values for the SEM and the SAR specifications are 0.313 and 0.271, respectively for the wet season. The significant lambda and rho coefficients indicate that there is considerable spatial autocorrelation in the rice production systems in Tarlac and other covariates do not account for this degree of spatial effect if only the baseline model is considered.

The inefficiency model for both the dry and wet seasons in Tarlac follow the results of the production model. Spatial dependence is very prominent in the spatial error and spatial autoregressive (lag) models as exhibited by the lambda and rho coefficients. The SARAR model, however, delivers mixed and insignificant results with the exception of the rho coefficient in the production model given the dwelling locations.

Table 3.7 prominently demonstrates that ignoring spatial dependence in the production and technical inefficiency functions is likely to yield biased results. For instance, in the model with no spatial effects, seeds, fertilizer, pesticides, machinery, and animals are the significant production inputs during the dry season. In the model with spatial dependence, seeds, pesticides, and machinery remain as the significant production inputs.

For the wet season, machinery, animals, hybrid seeds, and typhoon variables are the significant factors affecting production. When spatial autocorrelation is added to the baseline model, the significant variables are reduced to fertilizer, machinery, animals, and the dummy variables for typhoon. Among all the factors of production between the two seasons in Tarlac, machinery is consistently significant in the baseline model and in the specifications with spatial effects.

Table 3.7: Selected results of the spatial models for the production and technical inefficiency functions in Tarlac.

Variables	Tarlac (n=150): Dry Season with Spatial Effects							Tarlac (n=150): Wet Season with Spatial Effects						
Production Model	**No Spatial Effects**	**SEM**		**SAR**		**SARAR**		**No Spatial Effects**	**SEM**		**SAR**		**SARAR**	
		Farm	***Res***	***Farm***	***Res***	***Farm***	***Res***		***Farm***	***Res***	***Farm***	***Res***	***Farm***	***Res***
Constant	-3.957***	-3.326***	-3.579***	-3.936***	-4.033***	-3.903	-3.913	-2.812***	-2.423***	-2.481***	-2.725***	-2.799***	-2.960	-2.798***
Seeds	0.173**	0.215***	0.213***	0.205***	0.194***	0.184***	0.214***	0.005	-0.002	0.008	-0.003	-0.0001	0.005	0.016
Fertilizer	0.143*	0.065	0.109	0.084	0.104	0.131*	0.110	0.161	0.117*	0.088	0.126**	0.110*	0.160***	0.156**
Pesticides	0.041**	0.033*	0.042**	0.036**	0.040**	0.041**	0.048***	-0.003	-0.002	0.003	-0.002	-0.003	0.001	-0.002
Machinery	0.418***	0.374***	0.379***	0.393***	0.403***	0.415***	0.411***	0.403***	0.385***	0.412***	0.380***	0.391***	0.419***	0.406***
Animals	0.022*	0.011	0.010	0.011	0.016	0.020	0.018	0.040***	0.032**	0.031**	0.037**	0.037**	0.041	0.034**
Hybrid*Seeds	-0.020	-0.021	-0.028	-0.021	-0.022	-0.020	-0.024	-0.032*	-0.024	0.063	-0.016	0.032	-0.036	0.081
Typhoon								-0.184***	-0.200***	-0.202***	-0.194***	-0.198***	-0.184***	-0.175***
Lambda		0.382***	0.420***			0.487	-0.013		0.313***	0.435***			0.187	-0.313
Rho				0.314***	0.286***	0.657	1.323**				0.271***	0.347***	-0.831	1.576**
Inefficiency Model	**No Spatial Effects**	**SEM**		**SAR**		**SARAR**		**No Spatial Effects**	**SEM**		**SAR**		**SARAR**	
		Farm	***Res***	***Farm***	***Res***	***Farm***	***Res***		***Farm***	***Res***	***Farm***	***Res***	***Farm***	***Res***
Constant	0.012	0.014	-0.024	-0.075	-0.093	0.013	0.011	0.583	0.366	0.365	0.331	0.279	0.577**	0.570**
Network	0.001	0.002**	0.002**	0.002*	0.002*	0.002*	0.001*	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Irrigation	-0.208***	-0.150***	-0.137**	-0.160**	-0.161***	-0.215***	-0.208***	-0.037	-0.009	-0.016	-0.006	-0.008	-0.035	-0.035
Distance	0.003	-0.002	-0.003	0.000	0.001	0.003	0.003	0.007*	0.008***	0.007***	0.007**	0.007**	0.007**	0.007**
Training	-0.0423	-0.071	-0.088*	-0.052	-0.059	-0.040	-0.043	-0.014	-0.041	-0.053	-0.016	-0.028	-0.019	-0.015
Extension	0.024	0.040	0.034	0.028	0.032	0.025	0.024	0.080*	0.143***	0.150***	0.106*	0.126**	0.084	0.082
Labor	0.023	0.024	0.032	0.019	0.029	0.026	0.022	-0.234	-0.173*	-0.177*	-0.208**	-0.201**	-0.234**	-0.238**
Water	0.141***	0.141**	0.123*	0.131**	0.129**	0.139**	0.141**	0.165***	0.240***	0.213***	0.189***	0.200	0.166**	0.157**
Lambda		0.383***	0.387***			-0.406	0.038		0.498***	0.509***			0.110	0.455
Rho				0.294***	0.284***	0.496	-0.018				0.422***	0.490***	0.279	-0.044

Notes: (1) Res refers to residence or dwelling locations. SEM refers to spatial error model. SAR is the spatial autoregressive (lag) model. SARAR is the spatial autoregressive (lag) autoregressive (error) model. (2) *** significant at 1%, ** significant at 5%, * significant at 10%. (3) The respective coefficients are correct to three significant digits. (4) The lambda and rho coefficients are statistically not different between farm and residential locations for the production and inefficiency functions in both the SEM and SAR models with the exception of statistically different rho coefficients in the inefficiency function under the SAR model for the residential areas.

Comparing coefficients of the significant production inputs from the specifications with spatial effects to the baseline model, the elasticity of seed in the dry season increased from 0.173 in the baseline model to 0.215 under the spatial error model (SEM). The coefficients for pesticides and machinery, on the other hand, relatively declined in the same season and geolocation. For the wet season, elasticities for machinery, animals, and the typhoon dummy variable also decreased when spatial effects are included in the spatial error model. The coefficient for fertilizer increased from being insignificantly different from zero to 0.117 (SEM). In general, the SEM results for the production model indicate that by excluding spatial autocorrelation, a standard regression model has the tendency to overestimate and understate the elasticities of various production inputs.

Given that the spatial autoregressive (lag) model (SAR) involves feedback between the dependent variable, which in the production model is yield, prudence is necessary in interpreting the coefficients from the SAR model. For instance, with the seed coefficient in the dry season, a ten percent change in per kilogram seed utilization does not necessarily translate to 2.05 percentage change in yield. With SAR, the estimate accounts for the short-run direct impact of seeds on yield as well as its indirect impact given that one farm's yield feeds through to the yields in neighboring locations. To account for the direct and indirect effects, the present analysis follows the suggested estimation in Elhorst (2010), which prescribe direct effect as $\frac{(N-\rho^2)}{N(1-\rho^2)}\,\beta_i$ and the indirect effect equal to $\frac{(N\rho+\rho^2)}{N(1-\rho^2)}\,\beta_i$, where N denotes the number of observations. As shown in Table 3.8, when spatial dependence is accounted for with the SAR model, a 10 percent increase in modern seed utilization will result in a direct effect of 2.27 percent increase in the yield given farm locations. At the same utilization level, the indirect effect to neighboring farm's yield is .72 percent, something that is not accounted for when the specification is restricted to the baseline model.

Incorporating the spatial autocorrelation effect in the technical inefficiency function for Tarlac is analogous to the trend observed in research literature for the production function. In the specification with no spatial effects, connectivity to the National Irrigation Administration's (NIA) infrastructure facility, distance of farms from input markets, interaction with agricultural extension agents and technicians, and water supply problems are the factors significantly affecting the technical inefficiency of farmers in Tarlac. With spatial dependence included in the specification, the spatial error model includes additional significant factors in the dry season (e.g., the number of people in the farmer's agricultural network and attendance in training programs). The cost of labor during the wet season is also a significant factor affecting technical inefficiency for wet season results.

Table 3.8: Direct and indirect effects of the significant production coefficients under the spatial autoregressive (lag) model (SAR).

Significant Production Input Variables	Direct Effect under SAR Model				Indirect Effect under SAR Model			
	Tarlac Dry		*Tarlac Wet*		*Tarlac Dry*		*Tarlac Wet*	
	Farm	Res	Farm	Res	Farm	Res	Farm	Res
Seeds	0.227	0.211			0.072	0.061		
Fertilizer			0.136	0.125			0.037	0.043
Pesticides	0.040	0.044			0.013	0.012		
Machinery	0.436	0.439	0.410	0.448	0.137	0.126	0.111	0.156
Animals			0.040	0.042			0.011	0.015
Typhoon			-0.209	-0.225			-0.057	-0.078

Notes: (1) Res refers to residence or dwelling locations. (2) *** significant at 1%, ** significant at 5%, * significant at 10%. (3) The respective coefficients are correct to three significant digits.

As shown by the results in Table 3.7, a seasonal connection to the NIA irrigation facility will decrease the farmer's dry season inefficiency by 0.137 (given residential geolocations) to 0.150 (given farm geolocations) points instead of 0.208 points as derived in the baseline model. Correspondingly, for the water supply factor, the bias of not accounting for spatial dependence is also apparent in both the dry and wet seasons. Interestingly but not surprising, when residential geolocations in the dry season are considered, attendance at training sessions becomes a significant factor under the SEM specification but not in the SAR and SARAR models. This is likely because organizations conduct majority of the rural training programs in the village meeting halls, which are near dwelling areas but farther away from the farms. Further the insignificance can possibly be attributed to the spatial component attached to the standard error, which is not present under SAR.

The anticipated signs for the agricultural social network in the dry season, interaction with extension personnel in the wet season, and high labor cost in the wet season are contrary to expectations. The agricultural social network coefficient demonstrates that a larger farmer network can lead to a greater farm inefficiency in the dry season. O'Reilly III (1980) explained that increased amounts of information from various sources commonly lead to better decision-making. However, when there is information overload of both relevant and irrelevant information, the decision-maker's abilities to sift out useful information diminishes, thereby reducing the overall decision-making performance of the individual. This may be the case with farmers with large social networks in Tarlac during the dry season when roads are dry allowing them easy exchange of pertinent and unnecessary farming information.

Studies by Kalirajan (1984) and Kalirajan & Flinn (1983) found contact with extension agents or agricultural technicians to be a significant factor in either decreasing inefficiency or increasing the efficiency levels of rice farmers. However, the current SEM and SAR results for Tarlac reveal discrepancies with these earlier findings. Contact with extension services significantly increases the wet season inefficiency level of Tarlac farmers both in the baseline case and in the models with spatial effects (SEM and SAR). It appears that the interaction of farmers with extension workers is not beneficial in enhancing farming performance, which is akin to Antiporta's (1978) finding of weak association between efficiency and extension services. For Tarlac, weather in the wet season may be a deterent to extension worker-farmer interaction and information exchange. Further, extension service-related information is required to shed more light on this result.

The negative and significant coefficient on the high costs of labor variable indicates that as farmers in Tarlac experience high labor costs in the wet season, they experience a decline in their inefficiency level. Although highly unexpected, this may be a typical case for the agricultural villages in Tarlac. During the gathering of household survey data, farmers expressed that working in the fields is more difficult during the wet season due to the soggy and muddy conditions, which in turn usually requires more person-days of work (see Table 3.3). Because of this situation, laborers charge more during the wet season. To reduce labor costs, farmers engage family members who are not usually involved in rice production activities to work on the farms as unpaid workers. With the enlistment of family members as laborers, farmers are not required to restrict the length of workdays as compared to hired laborers. Also, by using family labor, more time can be spent on the farm leading to a likely reduction in farm inefficiency.

The results of the spatial autoregressive (lag) model (SAR) for the technical inefficiency function are consistent with the findings from the spatial error model (SEM). The number of people in the farmer's agricultural network, connectivity to the National Irrigation Administration's (NIA) infrastructure facility, and water supply problems are the significant factors directly and indirectly affecting the inefficiency of the Tarlac rice farms in the dry season. In the wet season, the significant factors include distance of farms from input markets, interaction with agricultural extension agents and technicians, high labor costs, and water supply problems. Of special interest in the SAR specification is the determination of the direct and indirect effects of spatial dependence on the inefficiency of farmers. Table 3.9 presents the different range of direct and indirect effects for factors found that significantly affect technical inefficiency levels of farms in Tarlac. A farm's connection to the irrigation facility facilitates a decrease of 0.146 points on that farm's inefficiency level and a corresponding decline of 0.052 at its neighboring farm's inefficiency score. The lack of water or water shortage at the farm locations correspondingly induces a 0.120 and 0.155 points direct effect increase in the inefficiency levels during the dry and wet seasons. This increase in inefficiency spill over to neighboring farms at a rate of 0.042 and 0.097 in the dry and wet seasons, respectively.

Table 3.9: Direct and indirect effects of the significant technical inefficiency model coefficients under the spatial autoregessive (lag) specification (SAR).

Significant Technical Inefficiency Function Covariates	**Direct Effect under SAR Model**				**Indirect Effect under SAR Model**			
	Tarlac Dry		***Tarlac Wet***		***Tarlac Dry***		***Tarlac Wet***	
	Farm	**Res**	**Farm**	**Res**	**Farm**	**Res**	**Farm**	**Res**
Network	0.002	0.002			0.001	0.001		
Irrigation	-0.146	-0.148			-0.052	-0.050		
Distance			0.006	0.005			0.004	0.005
Extension			0.087	0.096			0.055	0.082
Labor			-0.171	0.152			-0.107	-0.130
Water	0.120	0.119	0.155		0.042	0.040	0.097	

Notes: (1) Res refers to residence or dwelling locations. (2) *** significant at 1%, ** significant at 5%, * significant at 10%. (3) The respective coefficients are correct to three significant digits.

The above analyses, although not the first to assess stochastic production frontier for rice is certainly one of the pioneering investigations that assessed the impacts of farm and dwelling geolocations on rice productivity and farm efficiency in the Philippines. The results of the spatial econometric analysis are not very conclusive given that findings in Guimba are contrary to expectations, however, findings in Tarlac suggest that spatial dependence does influence productivity and efficiency. As these findings show, failure to account for geography, space, and proximity in the production and technical efficiency analyses can bias the estimation results.

Implications of the Hot Spots and Cold Spots Areas in the Achievability of the Food Staples Sufficiency Program (FSSP) Target

To complement the results from the spatial econometric analysis and to provide better guidance to policymakers, especially in the case of Guimba where spatial dependence is insignificant, this section presents findings from the optimized hot spot (OHS) analysis. As a spatial statistics tool available from ArcGIS 10.2, OHS helps delineates areas where there are a high incidence of data points representing specific ranges of productivity and inefficiency estimates. The focus of this particular analysis is the presence or absence of a range of estimate in a geographical area rather than measured attributes associated with each observation. OHS is a suitable tool for the production and technical inefficiency estimates since they are incident point data.[40]

Figures 3.9 and 3.10 highlight the areas where there are incidences of high yield per hectare values for the dry and wet seasons given farm and dwelling locations. From these geographical representations, three categories are derived – hot spot areas, warm spot locations, and cold spot sites. With the yield per hectare attribute, hot spot areas are the residential or farm

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[40] ArcGIS 10.2 described the optimized hot spot analysis as a tool that uses the Getis-Ord Gi* statistic [Eq. 12] to estimate the associated Z-score for each feature. A high Z-score indicates a higher potential of being part of the hot spot areas. To aggregate the Z-scores, OHS applies the average and the median nearest neighbor calculations given incremental distances between observations as estimated using the incremental spatial autocorrelation tool.

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j}\, x_j - \bar{X} \sum_{j=1}^{n} w_{i,j}}{S\sqrt{\frac{n \sum_{j=1}^{n} w_{i,j}^2 - (\sum_{j=1}^{n} w_{i,j})^2}{n-1}}}, \qquad \text{[Eq. 12]}$$

where x_j is the attribute value for the feature under consideration for observation j, $w_{i,j}$ represents the spatial weights between observations, n as the total number of observations, $\bar{X} = \frac{\sum_{j=1}^{n} x_j}{n}$, and $S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - (X)^2}$.

neighborhood where there is a prevalence of high production values. The determination of these high value areas is with respect to the local yield average as compared to the overall average for all the observations.

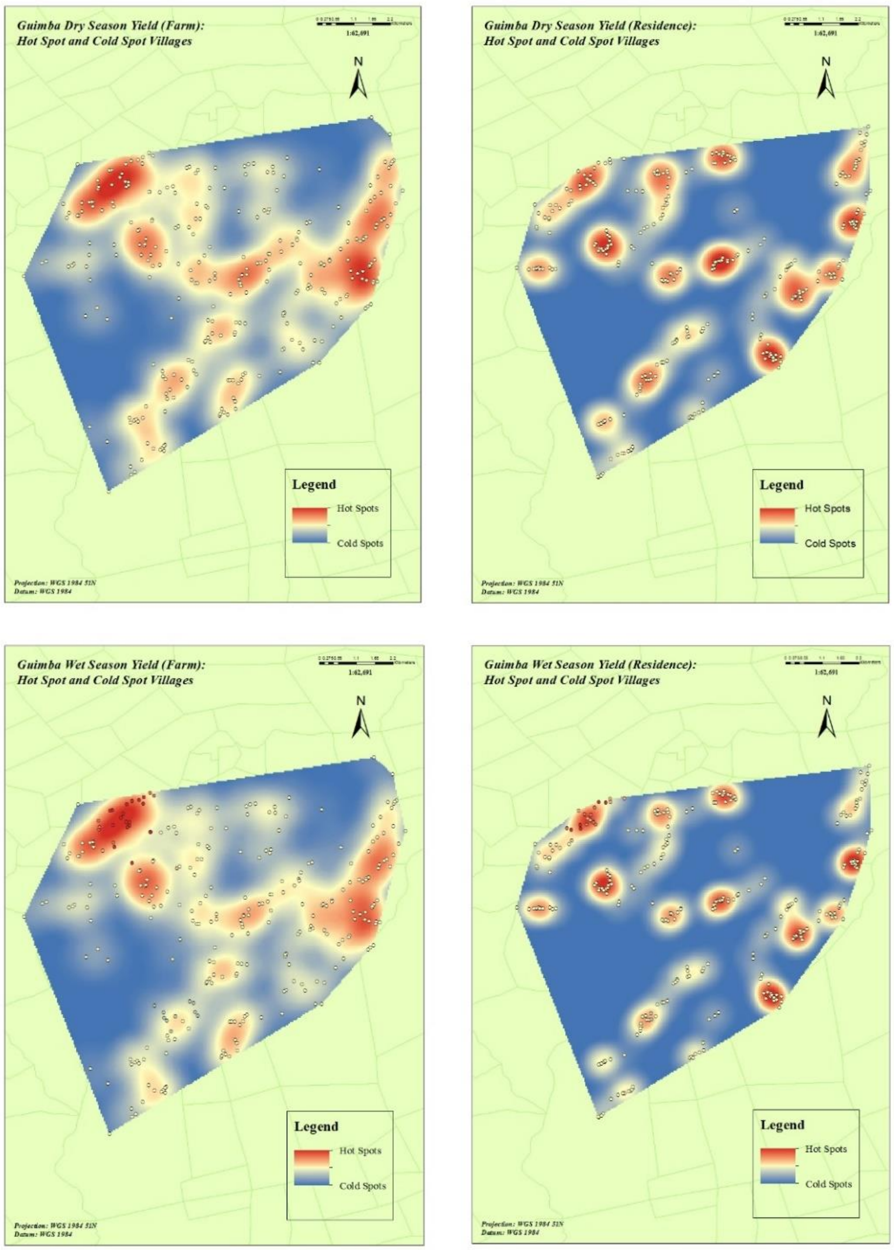

Figure 3.9: Production (yield per hectare) hot spots and cold spots for farm areas (left) and dwelling places (right) in Guimba for the dry (top) and wet (bottom) seasons.[41]

[41] Although the maps are visually distinct, the locational and seasonal difference between the yield hot spot maps in Guimba is statistically not significant.

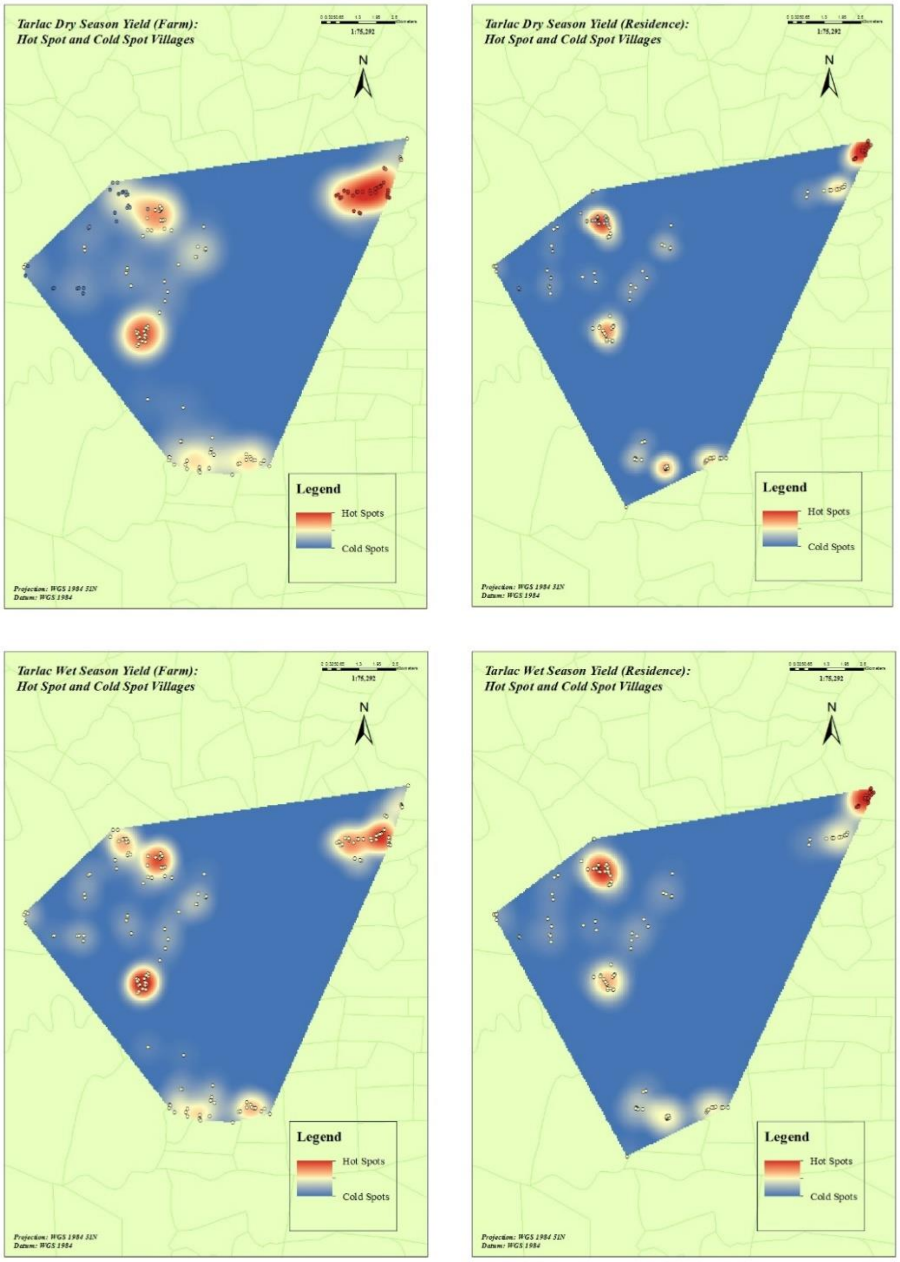

Figure 3.10: Production (yield per hectare) hot spots and cold spots for farm areas (left) and dwelling places (right) in Tarlac for the dry (top) and wet (bottom) seasons.[42]

[42] While the maps are visually distinct, the locational and seasonal difference between the yield hot spot maps in Tarlac is statistically not significant.

The focus of the OHS analysis for yield estimates is the identification of cold spot locations and warm spot zones since these are sites that may need support in order to enhance productivity. Cold spot locations refer to sites with high incidence of low production. Warm spot areas are zones exhibiting a mix of high and low values of yield per hectare.

Villages that are hot, warm, and cold spots vary depending on geolocations – farm or dwelling areas. In the dry season for Guimba, for instance, farm neighborhoods in the villages of Agcano, Balingog West, Banitan, Bantug, Cawayan Bugtong, Manacsac, Nagpandayan, San Bernardino, Tampac II & III, and Triala are in cold spot areas where the presence or high incidence of relatively lower yield values per hectare were detected. For dwelling neighborhoods, the cold spot villages include only three areas – Agcano, Banitan, and Tampac II & III. Table 3.10 provides a comparative summary of the hot spot, warm spot, and cold spot villages given varying geolocations. It is apparent that the seasonal areas of particular interest such as the cold spot villages change according to perceived geolocations of importance.

Conversely, the results of the optimized hot spot analysis are consistent for Tarlac across seasons and geolocations. The villages of Armenia, Care, De La Paz, and Tibag are the cold spot localities regardless of which geolocation is considered, farm or dwelling areas. Despite these coherent findings in terms of cold spot locations, geolocation discrepancy persists with hot spot and warm spot areas in Tarlac as shown in Table 3.10.

It is evident from Table 3.10 that the decision on which geolocation to consider is crucial, as this will influence the development of policies and geographical prioritization, particularly in Guimba where the discrepancy is very striking. If the intent is to enhance farm production relative to the production rate of the leading farms, policies should take into consideration the geographic patterns of cold spot areas given the rice field geolocations in Guimba. Targeting the cold spot villages may have a greater effect on production than focusing on areas where yield is already high.

As previously argued, achieving the Food Staples Sufficiency Program (FSSP) target is contingent on improving the overall levels of technical efficiency of farmers. In this regard, it is necessary to develop programs and initiatives that target areas exhibiting high levels of inefficiency. To guide such policy, decision-makers need to know the areas where to implement the needed technical support. Figures 3.11 and 3.12 spatially show the distribution of technical

Table 3.10: Hot, warm, and cold spot villages considering yield per hectare across seasons and geolocations in the study areas.

Optimization Category	Guimba (n=294)				Tarlac (n=150)			
	Dry Season		Wet Season		Dry Season		Wet Season	
	Farm	*Res*	*Farm*	*Res*	*Farm*	*Res*	*Farm*	*Res*
Hot Spots	• Macatcatuit • Santa Cruz • Subol	• Balingog East • Caingin Tabing Ilog • Manacsac • Tampac I	• Macatcatuit • Santa Cruz • Subol	• Balingog East • Caballero • Caingin Tabing Ilog • Manacsac • Tampac I	• Atioc • Balibago II • Banaba • Tibagan	• Balibago II • Sapang Maragul	• Atioc • Balibago II • Banaba	• Balibago II • Sapang Maragul
Warm Spots	• Balingog East • Caballero • Caingin Tabing Ilog • Catimon • Tampac I	• Balingog West • Bantug • Caballero • Catimon • Cawayan Bugtong • Macatcatuit • Nagpandayan • San Bernardino • Santa Cruz • Subol • Triala	• Balingog East • Caballero • Caingin Tabing Ilog • Tampac I	• Balingog West • Bantug • Catimon • Cawayan Bugtong • Macatcatuit • San Bernardino • Santa Cruz • Subol	• Sapang Maragul	• Atioc • Banaba • Tibagan	• Sapang Maragul • Tibagan	• Atioc • Banaba • Tibagan
Cold Spots	• Agcano • Balingog West • Banitan • Bantug • Cawayan Bugtong • Manacsac • Nagpandayan • San Bernardino • Tampac II & III • Triala	• Agcano • Banitan • Tampac II & III	• Agcano • Balingog West • Banitan • Bantug • Catimon • Cawayan Bugtong • Manacsac • Nagpandayan • San Bernardino • Tampac II & III • Triala	• Agcano • Balingog West • Nagpandayan • Tampac II & III • Triala	• Armenia • Care • De La Paz • Tibag	• Armenia • Care • De La Paz • Tibag	• Armenia • Care • De La Paz • Tibag	• Armenia • Care • De La Paz • Tibag

inefficiency hot spots in the dry and wet seasons for Guimba and Tarlac given farm and dwelling geolocations. These locations are areas for potential government intervention or assistance that likely requires location-specific strategies.

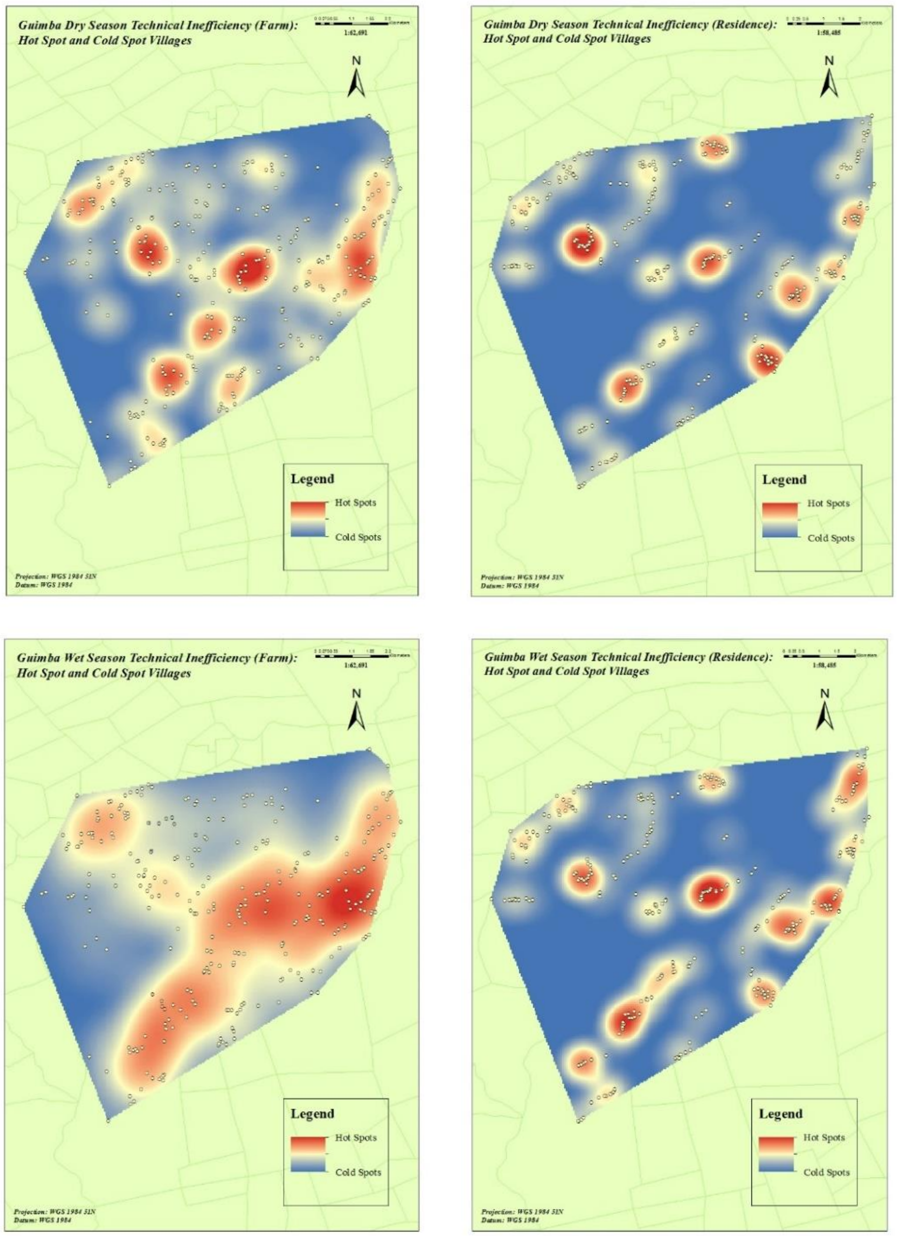

Figure 3.11: Technical inefficiency hot spots and cold spots for farm areas (left) and dwelling places (right) in Guimba for the dry (top) and wet (bottom) seasons.[43]

[43] The visually distinct features between the hot spot maps for technical inefficiency according to geolocations and seasons in Guimba are statistically not significant.

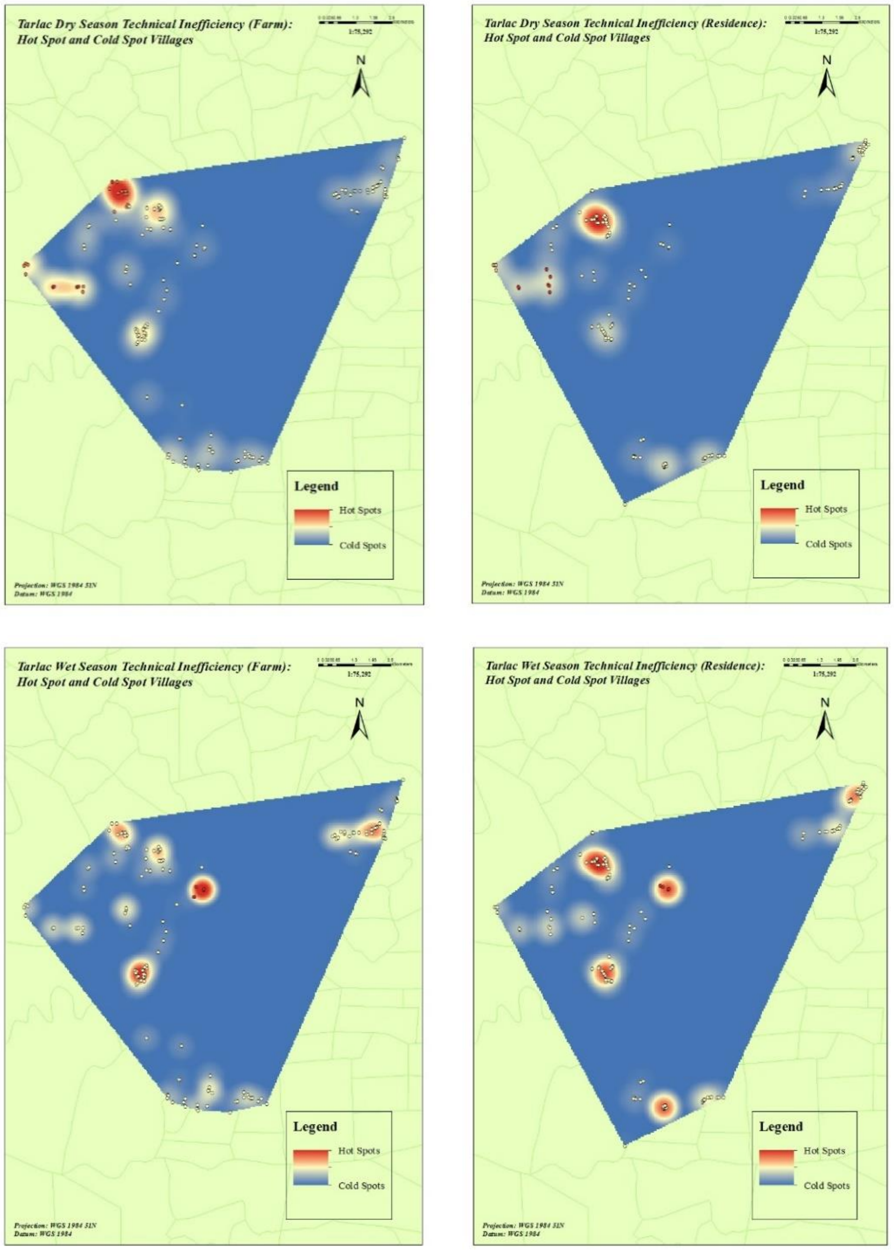

Figure 3.12: Technical inefficiency hot spots and cold spots for farm areas (left) and dwelling places (right) in Tarlac for the dry (top) and wet (bottom) seasons.[44]

[44] The visual difference in the technical inefficiency hot spot maps in Tarlac according to geolocations and seasons is statistically not significant.

In contrast with the degree of variation found in the production cold spots regions, the results of the optimized hot spot analysis for the technical inefficiency attribute conform across seasons and geolocations. For the two seasons in Guimba considering farm and dwelling locations, the villages of Balingog East, Caballero, Santa Cruz, and Tampac I are consistent locations for producers with high inefficiency rates. As listed in Table 3.11, the villages of Sapang Maragul, Tibag, and Tibagan in Tarlac are the technical inefficiency hot spots areas. If the policy goal is to increase farm level efficiency, then priority interventions should primarily target the hot spot locations followed by the warm spot areas, as these localities have the potential for efficiency improvement.

It is interesting to note from the results of the optimized hot spot analysis that in certain villages, low production does not necessarily imply high inefficiency. The villages with a high incidence of low yields are not the same the hot spot locations for technical inefficiency as summarized in Tables 3.10 and 3.11. Taking note of this location-specific disassociation between production and efficiency hot spots is important and can affect policy design. Considering the results of the stochastic production frontier, for instance, the findings clearly suggest the potential for improving efficiency in the two study areas, which can eventually lead to yield increases that help achieve the FSSP target. In this regard, the suitable policy may be one that accounts for inefficiency that specifically addresses the needs of those villages in the inefficiency hot spot locations.

Conclusion and Recommendations

When the Philippine government launched the Food Staples Sufficiency Program (FSSP) with a target to increase rice supply by nearly 50 percent in 2016 given production levels in 2010, many cast doubt on the likelihood of achieving this goal. The stochastic frontier analysis performed in this study shows that there is potential and opportunity for farmers to produce more efficiently and improve rice yields in order to reach the production target. Farms in Guimba can potentially increase production to 7.32 and 5.63 metric tons per hectare at the maximum in the dry and wet seasons, respectively. In Tarlac, farmers can maximize rice yield at 4.78 metric tons per hectare in the dry cropping season and 3.90 metric tons in the wet cropping season.

Table 3.11: Hot, warm, and cold spot villages considering the level of technical inefficiency across seasons and geolocations.

Optimization Category	Guimba (n=294)				Tarlac (n=150)			
	Dry Season		Wet Season		Dry Season		Wet Season	
	Farm	*Res*	*Farm*	*Res*	*Farm*	*Res*	*Farm*	*Res*
Hot Spots	• Balingog East • Santa Cruz • Tampac I	• Balingog East	• Caballero • Santa Cruz	• Santa Cruz • Tampac I	• Sapang Maragul	• Sapang Maragul	• Tibag • Tibagan	• Sapang Maragul • Tibagan
Warm Spots	• Caballero • Caingin Tabing Ilog • Macatcatuit • Manacsac • Nagpandayan • San Bernardino • Subol	• Balingog West • Bantug • Caballero • Caingin Tabing Ilog • Catimon • Cawayan Bugtong • Manacsac • Nagpandayan • San Bernardino • Santa Cruz • Tampac I	• Agcano • Caingin Tabing Ilog • Catimon • Macatcatuit • Nagpandayan • San Bernardino • Subol • Tampac I • Tampac II & III • Triala	• Agcano • Balingog East • Caballero • Catimon • Cawayan Bugtong • Macatcatuit • Manacsac • Nagpandayan • San Bernardino • Triala	• Atioc • Balibago II • Banaba • Care • Tibagan	• Atioc • Banaba • Care • Tibagan	• Atioc • Balibago II • Banaba • Sapang Maragul	• Armenia • Atioc • Balibago II • Banaba • Tibag
Cold Spots	• Agcano • Balingog West • Banitan • Bantug • Catimon • Cawayan Bugtong • Tampac II & III • Triala	• Agcano • Banitan • Macatcatuit • Subol • Tampac II & III • Triala	• Balingog East • Balingog West • Banitan • Bantug • Cawayan Bugtong • Manacsac	• Balingog West • Banitan • Bantug • Caingin Tabing Ilog • Subol • Tampac II & III	• Armenia • De La Paz • Tibag	• Armenia • Balibago II • De La Paz • Tibag	• Armenia • Care • De La Paz	• Care • De La Paz

Given the average regional technical efficiency of 0.827 as representative of rice farm performance across the country, with adequate provision of agricultural water to farmers and training programs, it is possible to increase national yield above 3.89 metric tons per hectare. At this rate and with the amount of land devoted to rice in 2010 (*i.e.*, 4.3 million hectares), it is possible to surpass the FSSP target of 22.73 million metric tons. At this level, achieving the FSSP target does not require expansion of land areas devoted to rice.

The stochastic production frontier and technical efficiency as well as inefficiency analyses generate information useful to agricultural planners and policymakers. With the addition of spatial dependence into the production and inefficiency models, the resulting analysis demonstrates clustering of field-level yields and efficiency estimates. Accounting for spatial effects on the production and inefficiency models lowers coefficients for the production and technical inefficiency models compared to the classical specification. This suggests to agricultural decision-makers that location-specific strategies are probably more appropriate. For instance, in Tarlac spatial interaction at the farm and dwelling locations exist in rice farming communities. By taking into account the spatial aspect of rice production, agricultural planners and stakeholders may be able to identify specific geographical locations where enhanced production is possible without increasing resource allocation such as in the villages of Balingog East, Santa Cruz, and Tampac I in Guimba and in the villages of Sapang Maragul and Tibagan in Tarlac.

This study also recognizes the importance of accounting for spatial effects in the production and inefficiency models. Because it is not a common practice to incorporate the spatial effect in a one-step stochastic production model, this study applied the two-step approach in assessing the spatial effects. This study, however, attempted the one-step procedure incorporating spatial effects as conducted in a handful of studies but it resulted in a mathematical non-convergence in the solution. For future research, this study recommends the simultaneous addition of parameters that measure spatial dependence in the analysis.

Notwithstanding some of its limitations, the combined results from the stochastic production frontier and spatial econometric analyses suggest that under these scenarios – without a spatial component or with a spatial effect – farmers can increase the level of production given current input allocations and achieve the FSSP target. In the no spatial effect scenario for the dry season, results demonstrate that for statistically significant production variables such as seeds, fertilizer, pesticides, machinery, and animals, yield per hectare can increase between 0.56 and 1.37 percent in Guimba and 0.22 to 4.18 percent in Tarlac for every ten percent increase in input utilization. Incorporating spatial component using the spatial error model (SEM) shows that for the same level of input utilization, yield in Guimba can increase by 0.57 to 1.38 percent, whereas yield in Tarlac can increase by 2.15 to 3.74 percent.

Findings from the spatial regression models convey the necessity of spatial components in the unbiased assessment of how to attain the FSSP target. This makes a compelling case for policies aimed at enhancing both yield and production efficiency to take into account the appropriate geographical planning level. Policies need not necessarily be all-encompassing strategies that are implementable from national-scale instead farm- or village-specific interventions might be more pertinent.

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Appendices

Appendix A. Technical efficiency studies on rice production in the Philippines (1978-2015)

Author(s) and Year of Publication	Location(s)	Production Model/ Method of Analysis
Mandac & Herdt (1978)*	Nueva Ecija	Global engineering production function
Herdt & Mandac (1981)*	Nueva Ecija	Global engineering production function
Kalirajan & Flinn (1983)**	Bicol	Stochastic production frontier model
Lingard, Castillo, & Jayasuriya (1983)**	Central Luzon	Covariance analysis
Kalirajan (1984)*	Central Luzon	Stochastic production frontier model
Fare, Grabowski, & Grosskopf (1985)**	Philippines	Data envelopment analysis
Dawson & Lingard (1989)**	Central Luzon	Stochastic production frontier model
Kalirajan (1989)***	Philippines	Stochastic production frontier model
Shand, Mangabat, & Jayasoriya (1989)*	Antique	Stochastic production frontier model
Kalirajan (1990)*	Laguna	Stochastic production frontier model
Kalirajan & Shand (1990)*	Antique	Stochastic production frontier model
Antle & Crissman (1990)*	Iloilo	Moment-based production model
Galang (1990)*	Nueva Ecija	Translog profit function
Dawson, Lingard, & Woodford (1991)**	Central Luzon	Stochastic production frontier model
Fukui (1993)*	Central Luzon	Stochastic production frontier model
Rola & Quintana-Alejandrino, (1993)**	Central Luzon, Central Mindanao, and Cagayan Valley	Stochastic production frontier model
Evenson, Kimhi, & DeSilva (2000)*	Bicol	Stochastic production frontier model
Larson & Plessmann (2002)**	Bicol	Stochastic production frontier model
Umetsu, Lekprichakul, & Chakravorty (2003)**	Philippines	Malmquist index
Villano & Fleming (2004)*	Central Luzon	Stochastic production frontier model
Gragasin, Maruyama, Marciano, Fujiie, & Kikuchi (2005)**	Mindoro and Cavite	Stochastic production frontier model
Villano, Lucas, & Pandey (2005)*	Northwest Luzon	Stochastic production frontier model
Villano, O'Donnell, & Battese (2005)*	Central Luzon	Stochastic production frontier model
Villano & Fleming (2006)*	Central Luzon	Stochastic production frontier model
Odchimar & Tan-Cruz (2007)*	Mindanao	Stochastic metafrontier production model
Pate & Tan-Cruz (2007)*	Philippines	Stochastic production frontier model
Yao & Shively (2007)*	Palawan	Stochastic production frontier model
Mariano, Villano, & Euan (2010)*	Philippines	Stochastic metafrontier production model
Velarde & Pede (2013)*	Laguna	Stochastic production frontier model
Koirala, Mishra, & Mohanty (2014a)*	Central Luzon and Laguna	Stochastic production frontier model
Koirala, Mishra, & Mohanty (2014b)*	Central Luzon and Laguna	Stochastic production frontier model
Michler & Shively (2015)*	Palawan	Stochastic production frontier model

*Based on author's own research. **Based on Villano & Fleming (2006). ***Based on Coelli (1995).

Appendix B. Survey instrument used in the field data collection and the University of Hawaii Committee on Human Subjects (Human Studies Program) letter of approval for the study.

UNIVERSITY of HAWAI'I MĀNOA

Production, Technical Efficiency, Spatial Dependence, and Social Capital Assessment: The Case of Farmers in Nueva Ecija and Tarlac, Philippines

IRRI INTERNATIONAL RICE RESEARCH INSTITUTE

☐☐☐☐☐☐

Geographical Information and Respondent Profile

Geographical Information

1. Province: **1**: Nueva Ecija **2**: Tarlac
2. City/ Municipality: **1**: Guimba **2**: Tarlac City
3. Barangay (Village): ____________________
4. Residence Coordinates: N = ____________ E= ____________
5. Largest Parcel Coordinates: N=____________ E= ____________

Respondent Profile

6. Name of Rice Farm Household Decision Maker (DM) (Last, First) (Optional):
   ____________________, ____________________
7. Gender: **1** Male **2** Female
8. Age (as of interview day): __________
9. Civil Status: **1** Single **2** Married **3** Widow/er **4** Annulled **5** Separated
10. Years in school: __________
11. Years in rice farming: __________
12. Household size: __________
13. Type of family: **1** Nuclear **2** Extended
14. In the 2013 cropping season, did you plant and harvest rice for BOTH the dry season (*December 2012 to May 2013*) and wet (*June 2013 to November 2013*)? **1** Yes **2** No
15. A. Total size of land holdings (ha): __________ 15 B. Total agricultural area (ha): __________

Enumerator Identification

Enumerator Identification

16. Last Name: ____________________
17. First Name: ____________________
18. Date of Interview (MM/DD/YR):
    ☐☐/☐☐/☐☐
19. Start Time (12:30 PM):
    ☐☐:☐☐ ☐☐
20. End Time (12:30 PM):
    ☐☐:☐☐ ☐☐
21. Signature of Enumerator:
    ____

22. **Socioeconomic and Demographic Profile of Farmer/Respondent Household**

22A. Name	**22B. Relation to respondent** **1.** Husband **2.** Wife **3.** Son **4.** Daughter **5.** Other male **6.** Other female	**22C. Gender** **1.** Male **2.** Female	**22D. Age**	**22E. Civil status** 1. Single 2. Married 3. Widow/er 4. Annulled 5. Separated	**22F. Years in school**	**22G. Years in farming**	**22H. Primary occupation[a]** (primary source of income)	**22I. Secondary occupation** (secondary source of income)	**22J. Migrant worker[b]** **1.** Yes **2.** No

a: 1 Rice farming; **2** Non-rice farming; **3** Self-employment/business; **4** Off-farm labor; **5** Livestock production; **6** Salary employment (private or gov't.); **7** OFW remittances; **8** Others (specify).
b: The question is asking if the individual is a migrant worker. A migrant worker is one who is employed outside the village and stay in that place for at least three (3) months.

23. **Annual Household Income in the last Cropping Season (Dry:** December-May; **Wet:** June-November)

Source	**Household member**				**Source**	**Household member**			
	23A. Husband	**23B. Wife**	**23C. Other male**	**28D. Other female**		**23A. Husband**	**23B. Wife**	**23C. Other male**	**28D. Other female**
1. Rice farming					6. Salary employment (private or gov't)				
2. Non-rice farming					7. OFW remittances				
3. Self-employment/ business					8. Others (specify): Pension____________ ________________ ________________ ________________				
4. Off-farm labor									
5. Livestock production									

24. **Agricultural Land Profile**

*24.1. **Dry season***

24.1A. Parcel no.	**24.1B. Location**[a]	**24.1C. Ecosystem type**[b]	**24.1D. Land type/Topo-graphy** **1**: Low **2**: Medium **3**: High	**24.1E. Soil type**[c]	**24.1F. Tenurial Status**[d]	**DRY SEASON (2013)**					
						24.1G. Area (hectares)	**24.1H. Crop planted**	**24.1I. Seed source**[e]	**24.1J. Variety type** **1.** Traditional **2.** Modern **3.** Hybrid	**24.1K. Name of rice variety**	**24.1L. Production**[f] (in kg)

a: 1 Within the village; **2** Outside the village but within the municipality; **3** Outside the municipality but within the province; **4** Outside the province.
b: 1 Irrigated (with functional irrigated canals); **2** Partially irrigated (with canal no assured source of water); **3** 100% Rainfed.
c: 1 Sandy; **2** Clayey; **3** Loamy; **4** Silty; **5** Others (specify).
d: 1 Owner-cultivator (has certificate of land title/fully paid); **2** Amortizing owner (partially paid); **3** Lessee; **4** Tenant; **5** Others (specify).
e: 1 Own harvest; **2** From other farm; **3** Seed growers/agri stores; **4** Dept. of Agriculture
f: If farmers give value in sacks/cavan or tons, indicate on the side of the column and convert to kilograms.

*24.2. **Wet season** (for superscripts, please refer to 24.1. Dry season superscripts)*

24.2A. Parcel no.	**WET SEASON (2013)**					
	24.2B. Area (hectares)	**24.2C. Crop planted**	**24.2D. Seed source**[e]	**24.2E. Variety type** **1.** Traditional **2.** Modern **3.** Hybrid	**24.2F. Name of rice variety**	**24.2G. Production**[f] (in kg)

24.3. ***FOR THE LARGEST PARCEL ONLY***

24.3A. Parcel no.	24.3B. Water source[a]		24.3C. Method of crop establishment[b]		24.3D. Seeding method[c]		24.3E. Seedbed preparation[d]		24.3F. Common Disease Problem[e]	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet

a: 1 National Irrigation System (NIS) canal – gravity; **2** NIS canal – pump; **3** Communal Irrigation System (CIS) canal – gravity; **4** CIS – pump; **5** Rivers/streams – gravity; **6** Rivers/streams – pump; **7** Shallow tube well (STW) – pump; **8** Open well/dug well; **9** Deepwell – pump; **10** Small water impounding project (SWIP); **11** Free flowing; **12** Rain only; **13** Others (specify).
b: 1 Transplanting; **2** Broadcasting; **3** Dibbling.
c: 1 Manual; **2** Mechanical.
d: 1 Dapog method; **2** Wet bed method; **3** Dry bed method; **4** Not applicable.
e: 1 Tungro; **2** Rice blast; **3** Bacterial leaf blight; **4** Others (specify).

25. **Rice Production and Disposal in the last Cropping Seasons (Dry:** December-May; **Wet:** June-November)

SEASON	25A. Total Pro-duction (kg) = a+b+c+d +e+f+g+ h+i+j+k +l+m+n	25B. Price/ kg	25C. Amt. SOLD (kg) or (% of 25A) a	25D. Amount for SEEDS (kg) or (% of 25A) b	25E. Amount for OWN CONSUM (kg) or (% of 25A) c	25F. Amount for LEASE RENTAL/ SHARE FOR THE LAND-OWNER (kg) or (% of 25A) d	25G. Amount for HAR-VESTER SHARE (kg) or (% of 25A) e	25H. Amount for THRESH -ER SHARE (kg) or (% of 25A) f	25I. Amount for PERMA NENT LABOR SHARE (kg) or (% of 25A) g	25J. Amount for OTHER LABOR SHARE (kg) or (% of 25A) h	25K. Amount for IRRI-GAT-ION (kg) or (% of 25A) i	25L. Amount for FEEDS for animals (kg) or (% of 25A) j	25M. Amount GIVEN AWAY (kg) or (% of 25A) k	25N. Amount for OTHER PURPO-SES (kg) or (% of 25A) l
DRY SEASON														
WET SEASON														

26. **Input Utilization for the LARGEST PARCEL in the last Cropping Seasons (Dry:** December-May; **Wet:** June-November)

Material Inputs	Unit (if different from specified unit)	DRY			WET		
		Quantity	Price/unit	Total Cost	Quantity	Price/unit	Total Cost
26A. Seeds (in kg.)							
26B. Fertilizers:							
1-							
2-							
3-							

Material Inputs	Unit (if different from specified unit)	DRY			WET		
		Quantity	Price/unit	Total Cost	Quantity	Price/unit	Total Cost
26C. Insecticide:							
1-							
2-							
3-							
26D. Herbicide:							
1-							
2-							
3-							
26E. Other Chemicals:							
1-							
2-							
3-							
26F. Water/Irrigation:							
Volume of water (cubic meters) [a]							
Irrigation service fee (in pesos)							
Pump used for irrigation (hours used) [b]							
Fuel used for irrigation (in liters) [b]							
Electricity used for irrigation (kWh) [b]							
26G. Electricity Used Related to Rice Production (kilowatt hours):							
Wattage [c]							
Electric bill [c]							
26H. Other Costs [d]:							
1- Land tax							
2-							
3-							

a: Provide if known. If not sure, provide best guess estimate.

b: Provide best guess estimate. For electricity, if wattage is not known, just ask for approximate electricity bill paid related to irrigation.

c: If wattage is not known, just ask for approximate electricity bill paid related to irrigation.

d: Others may include other equipment and implements, land tax, amortization fee (if included, indicate annual payment in total cost field); repair and maintenance costs for equipment/machinery; transportation costs incurred when buying inputs or selling outputs and traveling to and from the farm during the cropping season; packing materials such as sacks and twines. For other costs, just indicate total cost.

27. **Machine and Fuel Inputs for the LARGEST PARCEL in the last Cropping Seasons (Dry:** Dec.-May; **Wet:** June-November)

Activities		27A. Source of power[a] 1-Machine (own) 2-Machine (rent) 3-Animal (own) 4-Animal (rent) 5-Vehicle (specify)		RENTED						OWN					
				DRY			WET			DRY			WET		
		DRY	WET	**27B.** Rental fee per day	**27C.** No. of days used or rent-ed	**27D.** Total rental cost	**27E.** Rental fee per day	**27F.** No. of days used or rent-ed	**27G.** Total rental cost	**27H.** Amount of fuel/ gasoline/ diesel used (in liters)	**27I.** Price per unit	**27J.** Total fuel cost	**27K.** Amount of fuel/ gasoline/ diesel used (in liters)	**27L.** Price per unit	**27M.** Total fuel cost
Land preparation	Seedbed preparation														
	Plowing														
	Harrowing														
	"Dukit"														
	Other														
Crop establishment	Pulling of seedlings														
	Hauling of seedlings														
	Transplanting														
	Thinning & gap filling														
	Other														
Crop care	Fertilizer application														
	Hand weeding														
	Herbicide application														
	Insecticide application														
	Other														
Harvest and Post-harvest	Harvesting														
	Threshing														
	Hauling														
	Drying														
	Other														

a: Machine may include but not limited to the following: transplanter, two-wheel tractor, four-wheel tractor, rotavator, disc plow, moldboard plow, disc harrow, spiketooth harrow, irrigation pump, hydraulic (motorized) sprayer, manual sprayer, drum seeder, weeder, thresher, mechanical dryer, reaper, husker, generator, incubator, aerator.

28. **Labor Utilization for the LARGEST PARCEL in the last Cropping Seasons (Dry:** December-May; **Wet:** June-November)

*28.1. **Dry season***

ACTIVITIES		FAMILY LABOR						EXCHANGE LABOR[a]						HIRED LABOR							FOR CONTRACT	Food expenses for hired and contract labor (in peso)
		MALE			FEMALE			MALE			FEMALE			MALE			FEMALE			FOR HIRED		
		Persons	Days	Hours/day	Persons	Days	Hours/day	Persons	Days	Hours/day	Persons	Days	Hours/day	Persons	Days	Hours/day	Persons	Days	Hours/day	Daily wage rate of hired labor[b] (in Peso)	Contract cost of labor (in Peso or % of sharing arrangement)	
Land preparation	Seedbed prep.																					
	Cleaning and repair of dikes																					
	Plowing																					
	Harrowing																					
	"Dukit"																					
	Other																					
Crop establishment	Pulling of seedlings																					
	Hauling of seedlings																					
	Transplanting																					
	Thinning and gap filling																					
	Other																					
Crop care	Fertilizer app.																					
	Hand weeding																					
	Herbicide app.																					
	Insecticide app.																					
	Other																					
Harvest and Post-harvest	Harvesting																					
	Threshing																					
	Hauling																					
	Drying																					
	Other																					

a: Exchange labor is a form of cooperative labor. For instance, one farm household extended five days of labor to a neighbor's farm. In return, the neighbors are also expected to help in the other neighbor's farm one way or another based on a gentleman's agreement.

b: Include cash + in-kind payment.

28.2. ***Wet season***

ACTIVITIES		FAMILY LABOR						EXCHANGE LABOR[a]						HIRED LABOR							FOR CONTRACT	Food expenses for hired and contract labor (in peso)
		MALE			FEMALE			MALE			FEMALE			MALE			FEMALE			FOR HIRED		
		Persons	Days	Hours/day	Persons	Days	Hours/day	Persons	Days	Hours/day	Persons	Days	Hours/day	Persons	Days	Hours/day	Persons	Days	Hours/day	Daily wage rate of hired labor[b] (in Peso)	Contract cost of labor (in Peso or % of sharing arrangement)	
Land preparation	Seedbed prep.																					
	Cleaning and repair of dikes																					
	Plowing																					
	Harrowing																					
	"Dukit"																					
	Other																					
Crop establishment	Pulling of seedlings																					
	Hauling of seedlings																					
	Transplanting																					
	Thinning and gap filling																					
	Other																					
Crop care	Fertilizer app.																					
	Hand weeding																					
	Herbicide app.																					
	Insecticide app.																					
	Other																					
Harvest and Post-harvest	Harvesting																					
	Threshing																					
	Hauling																					
	Drying																					
	Other																					

a: Exchange labor is a form of cooperative labor. For instance, one farm household extended five days of labor to a neighbor's farm. In return, the neighbors are also expected to help in the other neighbor's farm one way or another based on a gentleman's agreement.
b: Include cash + in-kind payment.

Other Production-Related Topics

29. Where do you usually obtain inputs used in your largest parcel?
  1 Private company **2** Seed grower **3** Cooperative **4** Paddy trader **5** Input trader **6** Others (specify): ______________________

30. Average distance to the nearest market where major trading of farm input and output occurs (in kilometers):

Category	Residential	Farm
Farm input		
Farm output		

31. Mode of transportation from largest parcel to the nearest market? **1** Jeep **2** Tricycle/Motorcycle **3** Truck **4** Others (specify): __________

32. In the 2013 rice production seasons, what were your main source(s) of production capital? **1** Own **2** Borrowed **3** Both

33. If borrowed or both on question #32, what are the main sources?
  1 Rural bank **2** Cooperative **3** Family/relatives **4** Lending investor **5** Private bank
  6 Other non-relative/non-family member farmers **7** Others (specify): ____

34. What are your sources of market or price information for your inputs and outputs? 34A Inputs: ________ 34B. Output: ____________
  1 Government **2** Private company **3** Seed grower **4** Cooperative **5** Paddy trader **6** Input trader
  7 Radio/media **8** Co-farmer **9** Miller **10** Others (specify): _________________________ **11** None

35. Have you experienced production loss in the 2013 rice season?
  Dry season: **1** Yes Reason: ____ **2** No
  Wet season: **1** Yes Reason: ____ **2** No

36. Did you avail government services to help in your 2013 rice production? **1** Yes **2** No

Organizational Membership and Exposure to Trainings, Seminars, Extension Workers, and Sources of Information

37. Are you a member of a rice/rice-based farm organization/s? **1** Yes: _____ (number of organizations) **2** No (If yes, please fill in the following table)

37A. Name of farmer's organization	**37B. Type of farmer's organization[a]**	**37C. Position in the organization[b]**	**37D. Active in the organization** (regular attendance and participation)? **1. Yes 2. No**	**37E. Main reason(s) for joining[c]**
Husband				
Wife				

a: 1 Cooperative; **2** Irrigator's Association; **3** Farm Association; **4** Environmental Organizations; **5** Others (specify): ________________
b: 1 Leader/Head/President; **2** Officer other than the leader/head/president; **3** Member
c: 1 Learn new technologies; **2** Share learning with other farmers; **3** Increase harvest ; **4** Avail of freebies; **5** Others (specify): ________

38. Have you or another household member attended any seminar/training related to rice farming in the last three years?
38A. Farmer/Respondent: **1** Yes **2** No 38B. Other Household: **1** Yes **2** No

39. If yes to above, who are the sponsoring agencies/organizations of these trainings or seminars?
1 Seed/chemical companies **2** Local government unit **3** Agricultural training institute **4** National government agency
5 International agency **6** Non-govt. org./People's org. **7** Others (specify): ______

40. Does a local government or any government agricultural technician visit your farm/barangay in the last five years? **1** Yes **2** No

41. How often do you come in contact (communicate/consult) with the technician in one year (approximate number of days of contact)? ______

42. What is your common mode of contact with the technician?
1 Face-to-face contact **2** Telephone/cell phone **3** E-mail **4** Mail/telegram **5** Others (specify): ______

43. What is the most effective source of information related to rice farming?
1 Organizational sources **2** Print sources **3** Extension workers **4** Broadcast/audio material sources **5** ICT sources
5 Others (specify): ______

44. What are your major sources of information on rice farming in the last five years?
44A. Organization source
1 PhilRice **2** IRRI **3** Rice Sufficiency Officer **4** Local Government Unit
5 Agricultural Training Institute **6** State Colleges and Univ. **7** Chemical Companies **8** Seed Growers
9 Farmer Cooperatives **10** Fellow Farmers **11** Others (specify): ______ **12** None

44B. Print source
1 Newspapers **2** Technology Bulletins **3** Posters or pamphlets **4** Billboards **5** Calendars **6** Books
7 Others (specify): ______ **8** None

44C. Extension source
1 PalayCheck **2** Farmer Field School **3** Field Days **4** Techno-Demos **5** Seminars/Meetings **6** Technical Visits
7 Others (specify): ______ **8** None

44D. Broadcast/audio material source
1 TV Programs **2** Radio Programs **3** Plays and Jingles **4** Others (specify): ______ **5** None

44E. ICT source
1 Videos/CDs/DVDs **2** Internet **3** Call and Text messages **4** Others (specify): ______ **5** None

Awareness and Use of Technology for the Largest Parcel

45. Indicate your awareness and utilization of the following technology and practices.

Technology/Practice	AWARENESS 1 Yes 2 No	ADOPTION 1 Yes 2 No		Technology/Practice	AWARENESS 1 Yes 2 No	ADOPTION 1 Yes 2 No	
		Dry	Wet			Dry	Wet
No high/low soil spots after leveling				Organic fertilizer application			
Riding type-hand tractor				Leaf color chart (LCC)			
Community trap barrier system				Intermittent irrigation			
No spraying within first 30 days of trans-plant. or 40 days of seeding for defoliators				80 kg or less of seedling rate for dir. seeded rice/hectare for all seed class			
40 kg or less seedling rate for transplanted rice per hectare for all seed class				Alternate wetting and drying (use of observation well)			
400 square meter seedbed size per hectare				Integrated pest management (IPM)			
Straight row planting				Use of combine harvester-thresher			
Use of drum seeder for direct seeded rice				Thresh palay 0-1 day after harvest			
Synchronous planting				Carbonized rice hull			
Minus-One Element Technique (MOET)				Rice hull carbonizer			
Basal fertilizer application				Rice straw soil incorporation			
Rice straw composting							

Major Problems Encountered in the Largest Parcel and Views on Rice Related Issues and Programs

46. Did you experience any of the following during the 2013 rice cropping seasons?

Problems	EXPERIENCE 1 Yes 2 No		Problems	EXPERIENCE 1 Yes 2 No		Problems	EXPERIENCE 1 Yes 2 No	
	Dry	Wet		Dry	Wet		Dry	Wet
High price of inputs			Low price of palay			Lack of machinery/postharvest facility		
Access to technology			Pests/diseases			Inadequate water supply		
High cost of labor			Lack of capital			Others (specify):		

47. What are your thoughts on how the following items are associated to your rice production?

Issues	THREAT 1 Yes 2 No 3 Don't know	HELPFUL 1 Yes 2 No 3 Don't know	Technology/Practice	THREAT 1 Yes 2 No 3 Don't know	HELPFUL 1 Yes 2 No 3 Don't know
Climate change			Organic rice farming		
Rice self-sufficiency program			Land conversion		
Golden rice			Water scarcity		

Sustainable Management Practices: Water and By-Products

48. What is your perception on water availability for your largest parcel?
    48A. *Dry season*: **1** Insufficient **2** Sufficient **3** Excessive 48B. *Wet season*: **1** Insufficient **2** Sufficient **3** Excessive

49. On an average year what percentage of your irrigation water in your largest parcel is supplied by:
    49A. Ground water: _______% 49B. Surface water irrigation: _______%

50. In the past five years, do you have any concerns about the quantity and quality of your water for rice production?
    50A. *Quantity*: **1** Yes **2** No 50B. *Quality*: **1** Yes **2** No

51. Do you incorporate water conservation practices in your rice production in both the wet and dry season? **1** Yes (specify):_________________ **2** No

52. Do you think that water conservation efforts should be implemented in rice farming? **1** Yes **2** No

53. Would you support water conservation efforts in rice farming? **1** Yes **2** No

54. Would you financially support water conservation efforts in rice farming? **1** Yes **2** No

55. Would you support water conservation efforts in rice farming by accepting changes in your irrigation water pricing scheme? **1** Yes **2** No

56. If yes to question #54, which of the following pricing schemes would you support? *Please specify the percentage of the payment that the farmer wants to be allocated towards water conservation (e.g., watershed management) to ensure water supply to the rice fields*.
    1 Volumetric charge (water charge by the amount of water used) with **_______%** of the payment going to water conservation (e.g., watershed management)
    2 Charge through quota by area combined with marginal volumetric pricing with **_______%** of the payment going to water conservation efforts

57. If yes to question #54, how much of your annual income (in peso) from rice production are you willing to pay for irrigation water?
    Minimum (in peso): ____________________ Maximum (in peso): ____________________

58. In terms of rice by-products – rice husk and straw, what percentage are:
    Burnt: _____% Sell: _____% Use as animal feeds: _____% Use as mulch: _____% Use in mushroom production: _____%
    Use as compost with inoculants: _____% Scattered and incorporated in soil: _____% Leave in threshing area to decompose: _____% Others: _____%

59. Are you aware that rice husk and straw can be used to produce alternative energy (to support electricity and ethanol production)? **1** Yes **2** No

60. Do you think rice husk and straw should be used to produce bio-energy products? **1** Yes **2** No

61. Would you support a government- or private sector-led program that utilizes rice husk and straw to produce bio-ethanol or butanol products? **1** Yes **2** No

62. If a market for rice husk and straw is set-up to support bio-energy production in Central Luzon, how much percentage of your straw and husk would you be able to steadily supply to the bio-energy market? 62A. Rice straw: ________% 62B. Rice husk: _______%

Farmer's Social Network

Question	Total Number of People Talked To and Approached	No. of Relatives and Family Members	No. of People Considered as Friends
63. Regardless of issues, how many people do you regularly (<u>*at least once a month*</u>) talk to and personally approach *within the village?*			
64. In terms of **agricultural topics/issues/concerns**, how many people do you regularly (<u>*at least once a month*</u>) talk to and personally approach *within the village?*			
65. Regardless of issues, how many of people do you regularly (<u>*at least once a month*</u>) talk to and personally approach *outside the village?*			
66. In terms of **agricultural topics/issues/concerns**, how many people do you regularly (<u>*at least once a month*</u>) talk to and personally approach *outside the village?*			

Looking back at the last rice cropping seasons, who are the people with whom you discussed rice production-related topics or issues. On the table below, please tell us the names of the (at most five) mostly consulted or contacted individuals in the last rice cropping seasons.

67A. Name of five mostly interacted with individuals in the 2013 rice season (First and last Names)	**67B. Gender** 1: Male 2: Female	**67C. Age** (best guess)	**67D. Highest educational attainment** 1: College 2: High Sch. 3: Elemen.	**67E. Distance from the farmer** (approx. distance in kilometers)	**67F. How did you get to know this individual?** 1: Family/relative 2: Friend 3: Workplace 4: Res. Neighbor 5: Farm Neighbor 6: Church 7: Ag Ext. Worker 8: Same Org. Mem. 8: Other (specify)	**67G. How long have you known this individual (in months or years)?**	**67H. How well do you know this person** (how close are you)**?** 1: Not at all 2: Very little 3: Fairly well 4: Quite well 5: Very well
1-							
2-							
3-							
4-							
5-							

Indi-vidual	**67I. What is your mode of interaction with these individuals?** 1: Face-to-face 2: Tele/Cell phone 3: Internet 4: Others (specify)	**67J. How often do you get in contact or communicate with each individual** (number of days per month)**?**	**67K. Do you exchange technical information related to rice production with this individual?** 1 Yes 2 No	**67L. Have you or has the listed individual borrowed/ exchanged financial favors to support rice production?** 1 Yes 2 No	**67M. Does the individual help you during planting or harvesting phase?** 1 Yes 2 No
1-					
2-					
3-					
4-					
5-					

Indi-vidual	67N. Do any of the individuals listed hold a position in the community or organization(s) they belong in? **1** Yes **2** No	67O. Do any of the individuals listed actively take part in the community or organization(s) they belong in (regular attendance)? **1** Yes **2** No	67P. Between you and the person listed, who usually ask for advice on rice related issues? You or the other person? **1**: Me/Farmer **2**: Other Person	67Q. Would you turn towards the person listed in the event of a personal crisis? **1** Yes **2** No	67R. How well do you trust each individual listed? **1**: Not at all **2**: Very little **3**: Fairly well **4**: Quite well **5**: Very well
1-					
2-					
3-					
4-					
5-					

Indi-vidual	67S. To the best of your knowledge, who does each individual interact more in terms of rice topics, issues, and concerns (include all that applies)? **1**: Me/Farmer **2**: Individual 1 **3**: Individual 2 **4**: Individual 3 **5**: Individual 4 **6**: Individual 5	67T. Think about the relationship between listed individuals, would you say they are acquaintances, just friends, or especially close? **1**: Ind. is acquaintance to individual(s) _____. **2**: Ind. is friend to individual(s) ___________. **3**: Don't know/No idea. **Ex. Ind 1- Ans. 3: <u>2 and 5</u>**	67U. What type(s) of rice-related resources do you and the individuals listed have access to by interacting with each other (include all that applies)? **1**: Financing **2**: Materials **3**: Technology **4**: Market Info **5**: Others (specify)
1-			
2-			
3-			
4-			
5-			

68. Women Empowerment

WHO DETERMINES THE FOLLOWING ACTIVITIES	H only *Husband only*	H>W *Husband dominates*	H=W *Both husband & wife*	W>H *Wife dominates*	W only *Wife only*	N/A *Husband and wife not involve*
Choice of crop						
1. What crop to grow in the field	1	2	3	4	5	6
2. What rice variety to plant	1	2	3	4	5	6
Crop Management						
3. When to apply fertilizer/Amount of fertilizer to apply	1	2	3	4	5	6
4. When to apply insecticide/Amount of insecticide to apply	1	2	3	4	5	6
5. When to apply herbicide/Amount of herbicide to apply	1	2	3	4	5	6

6. When to irrigate rice	1	2	3	4	5	6
7. When to weed	1	2	3	4	5	6
8. When to hire laborer for specific operations	1	2	3	4	5	6
9. When to harvest rice	1	2	3	4	5	6
10. When to thresh rice	1	2	3	4	5	6
Post-harvest Operations						
11. Amount of rice to store or to sell	1	2	3	4	5	6
12. Where to sell rice of other crops	1	2	3	4	5	6
13. When to sell rice or other crops	1	2	3	4	5	6
14. Selecting of crop types and seed for next growing season	1	2	3	4	5	6
15. Where to store the seeds	1	2	3	4	5	6
Livestock and poultry management						
16. What and number of animals to raise	1	2	3	4	5	6
17. When and number of animals to sell	1	2	3	4	5	6
Monetary						
18. How much money to spend on farm inputs	1	2	3	4	5	6
19. How much money to spend on food	1	2	3	4	5	6
20. How much money to spend on farm capital investments (machinery, water pumps, etc.)	1	2	3	4	5	6
21. Whether or not should buy animals for raising	1	2	3	4	5	6
22. Expenditure on children's education	1	2	3	4	5	6
23. House repairs and constructions	1	2	3	4	5	6
24. When to borrow credit	1	2	3	4	5	6
25. Who will borrow credit	1	2	3	4	5	6
26. Allocation of remittances						6
27. Record-keeping of farm-related transactions (e.g., amount of inputs used, amount produced, amount sold, amount of profit or loss, etc.).	1	2	3	4	5	6
Politics						
28. Who decides whom you should vote for	1	2	3	4	5	6

Any other comments? ____

~ Thank you for your time and participation ~

Office of Research Compliance
Human Studies Program

UNIVERSITY of HAWAIʻI® MĀNOA

November 25, 2013

TO: Rusyan Jill Mamiit
Principal Investigator
Natural Resources & Environmental Management

FROM: Denise A. Lin-DeShetler, MPH, MA
Director

SUBJECT: CHS #21746- "Three Essays on Food Staples Sufficiency: Biophysical Assessment, Socioeconomic Analysis, and Policy Evaluation of the Rice Sector in Central Luzon, Philippines"

This letter is your record of the Human Studies Program approval of this study as exempt.

On November 25, 2013, the University of Hawai'i (UH) Human Studies Program approved this study as exempt from federal regulations pertaining to the protection of human research participants. The authority for the exemption applicable to your study is documented in the Code of Federal Regulations at 45CFR 46.101(b)(Exempt Category 2).

Exempt studies are subject to the ethical principles articulated in The Belmont Report, found at http://www.hawaii.edu/irb/html/manual/appendices/A/belmont.html.

Exempt studies do not require regular continuing review by the Human Studies Program. However, if you propose to modify your study, you must receive approval from the Human Studies Program prior to implementing any changes. You can submit your proposed changes via email at uhirb@hawaii.edu. (The subject line should read: Exempt Study Modification,) The Human Studies Program may review the exempt status at that time and request an application for approval as non-exempt research.

In order to protect the confidentiality of research participants, we encourage you to destroy private information which can be linked to the identities of individuals as soon as it is reasonable to do so. Signed consent forms, as applicable to your study, should be maintained for at least the duration of your project.

This approval does not expire. However, please notify the Human Studies Program when your study is complete. Upon notification, we will close our files pertaining to your study.

If you have any questions relating to the protection of human research participants, please contact the Human Studies Program at 956-5007 or uhirb@hawaii.edu. We wish you success in carrying out your research project.

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Appendix C. Complete mean and maximum likelihood estimates of the stochastic production and technical inefficiency models.

Variables	Unit and Description	Guimba (n=294)				Tarlac (n=150)			
		Dry		Wet		Dry		Wet	
		Mean (S.D.)	*Coefficient (S.E.)*	*Mean (S.D.)*	*Coefficient (S.E.)*	*Mean (S.D.)*	*Coefficient (S.E.)*	*Mean (S.D.)*	*Coefficient (S.E.)*
Production Function									
Constant	Intercept		0.232 (0.311)		0.205 (0.281)		-2.249*** (0.382)		-1.867*** (0.416)
Seeds	kilogram/hectare	83.727 (42.423)	0.030 (0.036)	93.837 (35.346)	0.065* (0.038)	102.282 (49.763)	0.082* (0.046)	87.218 (34.105)	0.036** (0.018)
Fertilizer	kilogram/hectare	452.593 (214.376)	0.135*** (0.037)	366.258 (196.069)	0.060* (0.036)	279.149 (122.260)	0.053 (0.048)	195.499 (142.741)	0.056 (0.036)
Pesticides	gram of active ingredients/hectare	665.283 (865.546)	-0.004 (0.006)	720.431 (788.235)	0.002 (0.007)	638.707 (692.493)	0.033** (0.014)	623.370 (796.453)	0.004 (0.013)
Irrigation	Philippine Pesos/hectare	2,544.433 (1,172.838)	0.013 (0.023)	1,951.966 (923.071)	-0.0003 (0.015)	1,605.963 (2,277.670)	-0.002 (0.006)	796.468 (1,102.087)	0.0002 (0.006)
Machinery	Philippine Pesos/hectare	5,865.083 (2,539.742)	0.098*** (0.023)	4,911.540 (2,308.813)	0.076*** (0.024)	3,657.347 (1,999.054)	0.365*** (0.046)	2,307.485 (1,892.956)	0.375*** (0.053)
Animals	Philippine Pesos/hectare	796.943 (676.209)	0.001 (0.005)	631.741 (527.459)	-0.002 (0.005)	94.129 (398.410)	0.018** (0.009)	72.634 (321.008)	0.018* (0.010)
Labor	person-days/hectare	59.454 (25.296)	-0.044 (0.032)	58.315 (25.921)	0.067** (0.033)	41.112 (20.164)	-0.006 (0.039)	45.639 (27.670)	0.005 (0.013)
Hybrid*Seeds	1=hybrid seed user 0=otherwise	0.184 (0.388) *n=54*	0.071*** (0.022)	0.020 (0.142) *n=6*	0.062* (0.037)	0.020 (.140) *n=3*	-0.062** (0.029)	0.013 (0.115) *n=2*	-0.063* (0.038)
Typhoon	1=farm was affected by the typhoon during wet season 0=otherwise			0.289 (0.454) *n=85*	-0.150*** (0.029)			0.407 (0.493) *n=61*	-0.186*** (0.048)
Inefficiency Function									
Constant	Intercept		-13.121 (8.939)		-10.911 (11.684)		-5.834** (2.438)		-1.595 (1.616)

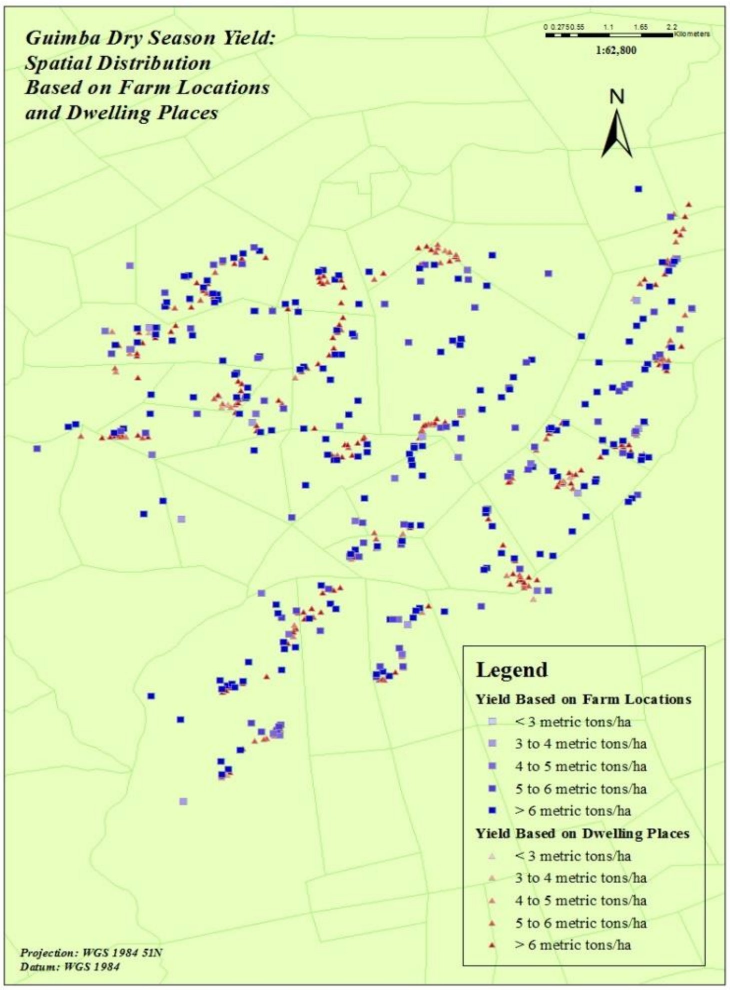
Variables	Unit and Description	Guimba (n=294)				Tarlac (n=150)			
		Dry		Wet		Dry		Wet	
		Mean (S.D.)	***Coefficient (S.E.)***	***Mean (S.D.)***	***Coefficient (S.E.)***	***Mean (S.D.)***	***Coefficient (S.E.)***	***Mean (S.D.)***	***Coefficient (S.E.)***
Age	Age of farmer/head of household	53.554 (12.354)	0.024 (0.032)	53.554 (12.354)	0.026 (0.020)	50.667 (12.009)	0.021 (0.025)	50.667 (12.009)	-0.020 (0.023)
Education	Number of years of formal schooling of farmer/head of household	8.459 (3.003)	0.076 (0.098)	8.459 (3.003)	-0.037 (0.050)	7.787 (2.978)	0.088 (0.079)	7.787 (2.978)	0.032 (0.071)
Experience	Number of years of rice farming experience	31.616 (14.487)	-0.011 (0.027)	31.616 (14.487)	-0.015 (0.018)	27.733 (14.786)	-0.016 (0.020)	27.733 (14.786)	0.006 (0.019)
Network	Number of people in the farmer's social-agricultural network	32.330 (40.391)	0.002 (0.008)	32.330 (40.391)	-0.002 (0.004)	32..087 (31.350)	0.009 (0.007)	32..087 (31.350)	-0.008 (0.007)
Irrigation	1=connection to the National Irrigation Administration infrastructure 0=otherwise	0.993 (0.082) *n=292*	5.659 (8.703)	0.997 (0.058) *n=293*	7.858 (11.637)	0.487 (0.501) *n=73*	-1.884*** (0.504)	0.467 (0.501) *n=70*	-0.135 (0.466)
Technology	Number of technology adopted in the rice farms	7.075 (2.979)	-0.120 (0.116)	7.027 (2.900)	-0.05 (0.057)	3.753 (2.270)	0.038 (0.122)	3.300 (2.636)	0.069 (0.098)
Distance	Distance of the rice farm from input market (in kilometers)	6.576 (5.016)	0.0365 (0.043)	6.604 (5.002)	0.023 (0.031)	6.045 (8.736)	0.026 (0.024)	5.381 (8.262)	0.044* (0.025)
Training	1=farmer attended an agricultural training 0=otherwise	0.507 (0.501) *n=149*	-0.265 (0.615)	0.493 (0.501) *n=149*	-0.575* (0.332)	0.500 (0.502) *n=75*	-0.466 (0.537)	0.500 (0.502) *n=75*	-0.120 (0.530)
Extension	1=agricultural technician or extension agent visited the rice farm 0=otherwise	0.340 (0.475) *n=100*	-0.584 (0.715)	0.337 (0.473) *n=100*	-0.375 (0.337)	0.393 (0.490) *n=59*	0.416 (0.477)	0.393 (0.490) *n=59*	0.501 (0.435)
Prices	1=farmer experienced high input prices 0=otherwise	0.704 (0.457) *n=207*	1.103 (0.878)	0.680 (0.467) *n=200*	-0.183 (0.361)	0.973 (0.162) *n=146*	0.290 (1.469)	0.973 (0.162) *n=146*	-0.252 (1.174)

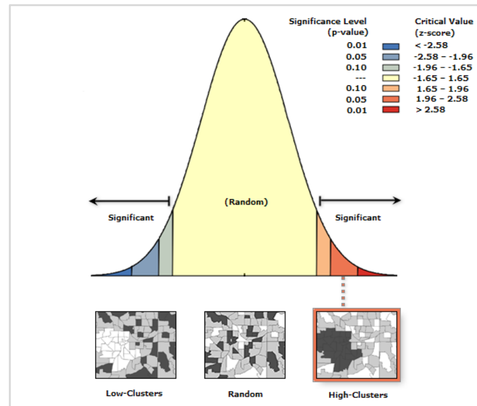
Variables	Unit and Description	Guimba (n=294)				Tarlac (n=150)			
		Dry		Wet		Dry		Wet	
		Mean (S.D.)	***Coefficient (S.E.)***	***Mean (S.D.)***	***Coefficient (S.E.)***	***Mean (S.D.)***	***Coefficient (S.E.)***	***Mean (S.D.)***	***Coefficient (S.E.)***
Labor	1=farmer experienced high labor costs 0=otherwise	0.439 (0.497) *n=129*	0.583 (0.627)	0.497 (0.501) *n=146*	0.265 (0.337)	0.927 (0.262) *n=139*	0.167 (0.851)	0.0920 (0.272) *n=138*	-1.117 (0.719)
Water	1=rice farm experienced shortage in or lack of water supply 0=otherwise	0.303 (0.460) *n=89*	1.442** (0.681)	0.241 (0.429) *n=71*	0.170 (0.389)	0.880 (0.326) *n=132*	1.654* (0.953)	0.807 (0.396) *n=121*	1.077** (0.524)
Diagnostic Statistics									
σ_u		0.082		0.212		0.260		0.330	
σ_v		0.183		0.151		0.150		0.147	
Log Likelihood		53.626		0.0691		-10.757		-34.406	

Notes:
(1) Tabulated data are from the author's own calculation.
(2) *** significant at 1%, ** significant at 5%, * significant at 10%.
(3) S.D. stands for standard deviation and S.E. is for standard error.
(4) The respective coefficients and the standard errors of the coefficients are correct to three significant digits.

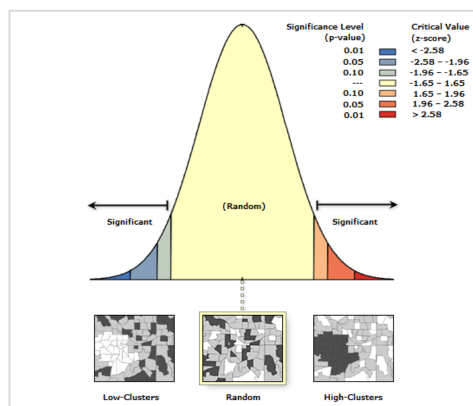
Appendix D. Distribution across space of the different levels of productivity and efficiency of sample farmers according to their farm locations and farmers' dwelling places.

Appendix D.1. Spatial pattern of different dry season yield levels of Guimba farmers plotted according to farm locations and dwelling places.

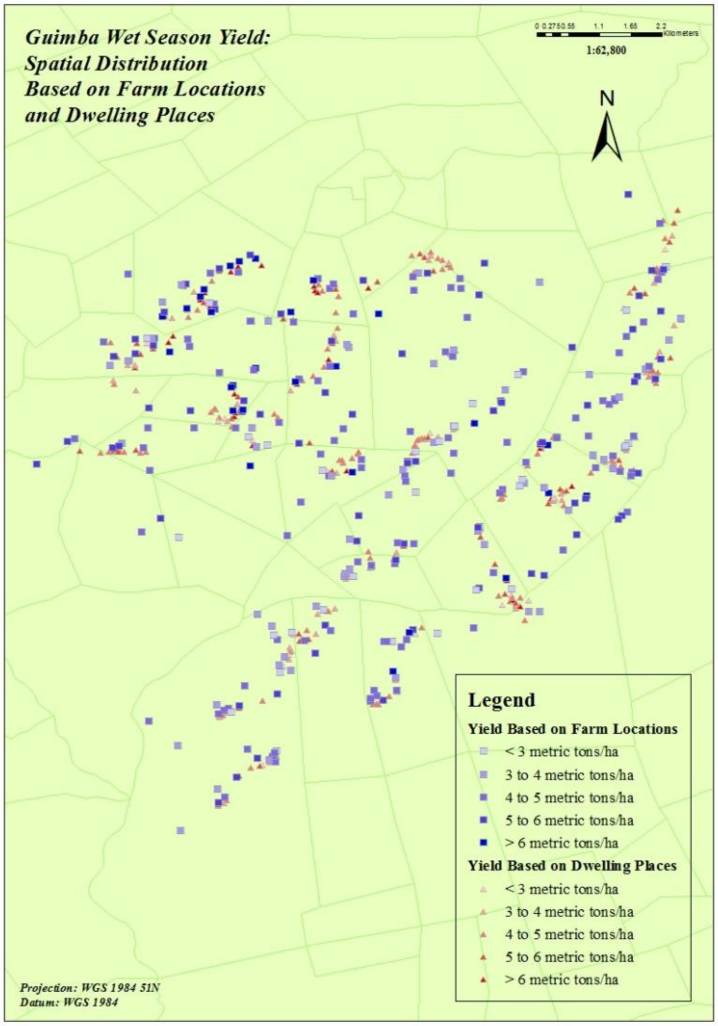


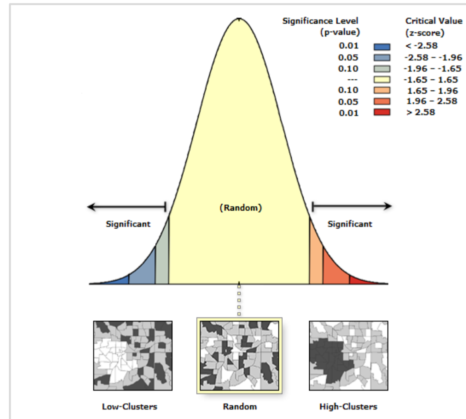


High-low clustering of yields based on farm (top) and dwelling (bottom) locations.

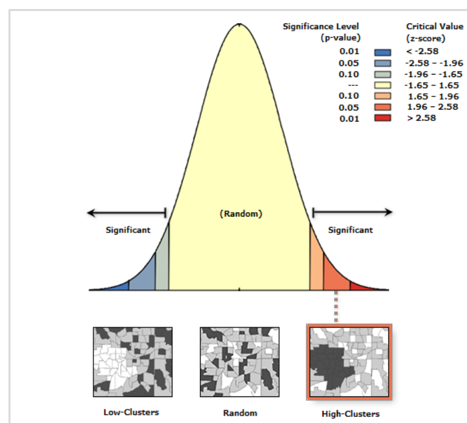


Appendix D.2. Spatial pattern of different wet season yield levels of Guimba farmers plotted according to farm locations and dwelling places.

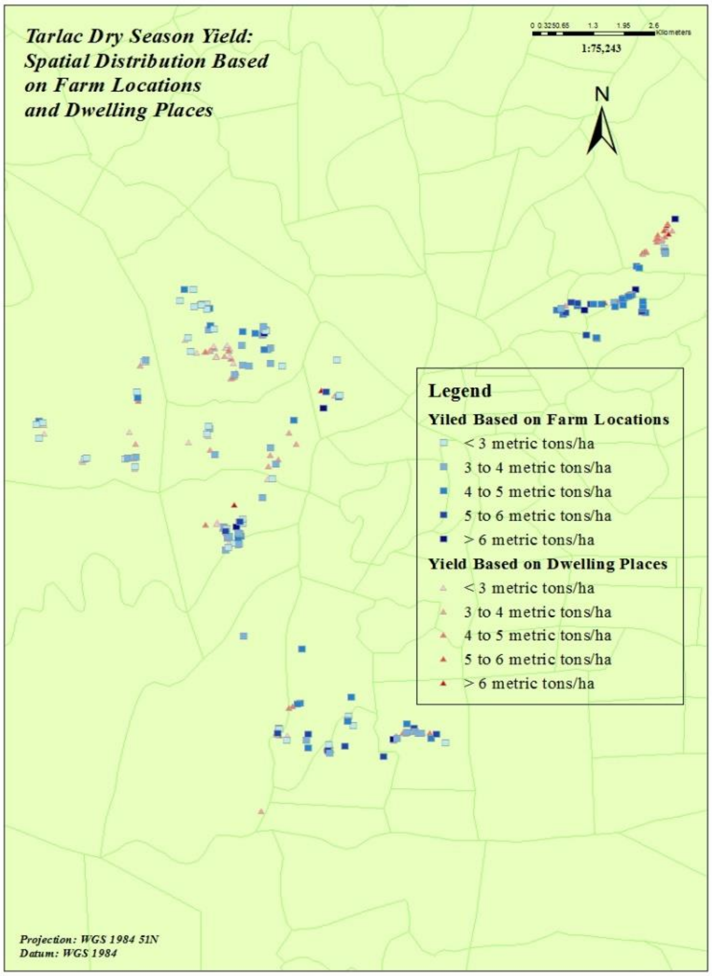


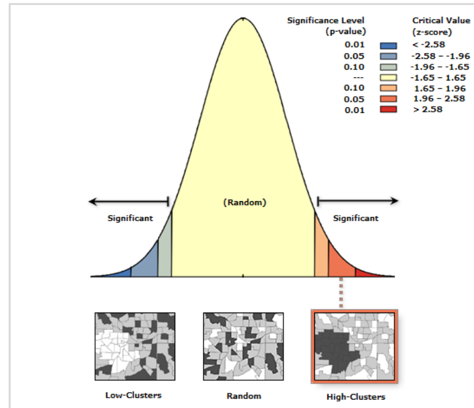


High-low clustering of yields based on farm (top) and dwelling (bottom) locations.

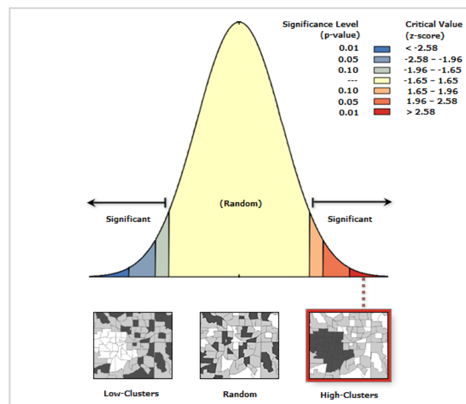


Appendix D.3. Spatial pattern of different dry season yield levels of Tarlac farmers plotted according to farm locations and dwelling places.

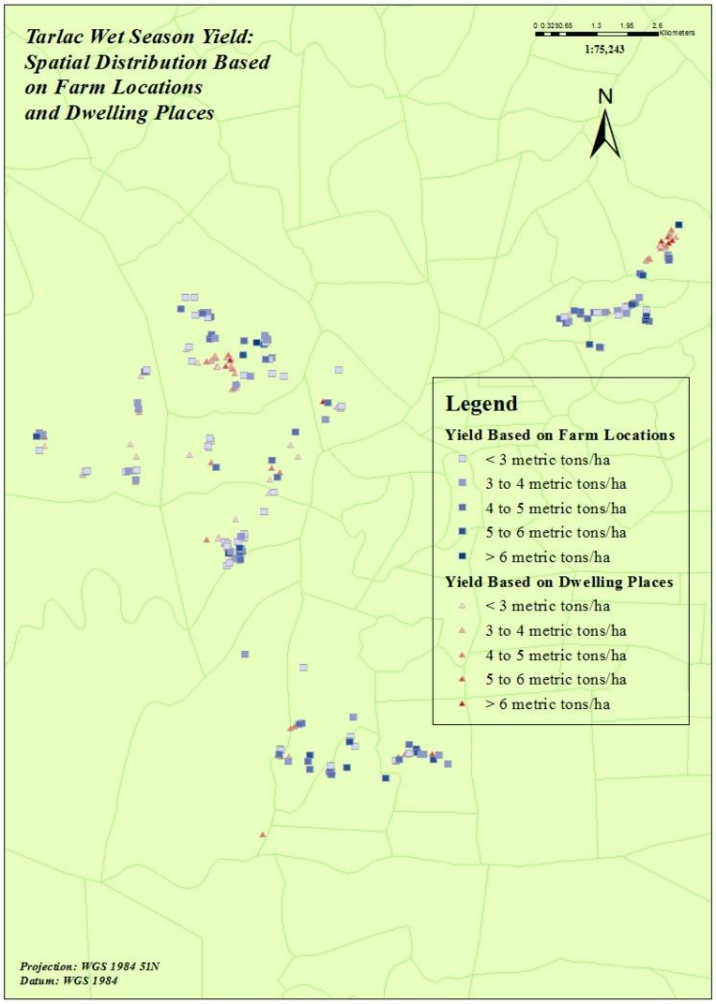


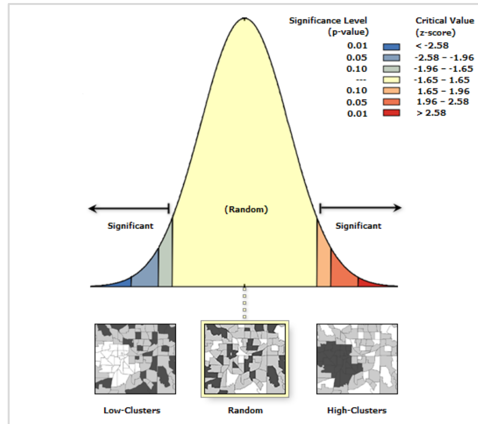


High-low clustering of yields based on farm (top) and dwelling (bottom) locations.

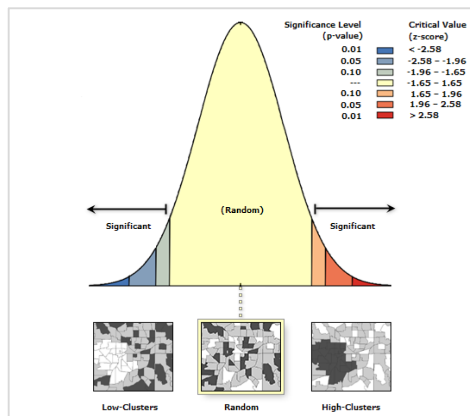


Appendix D.4. Spatial pattern of different wet season yield levels of Tarlac farmers plotted according to farm locations and dwelling places.

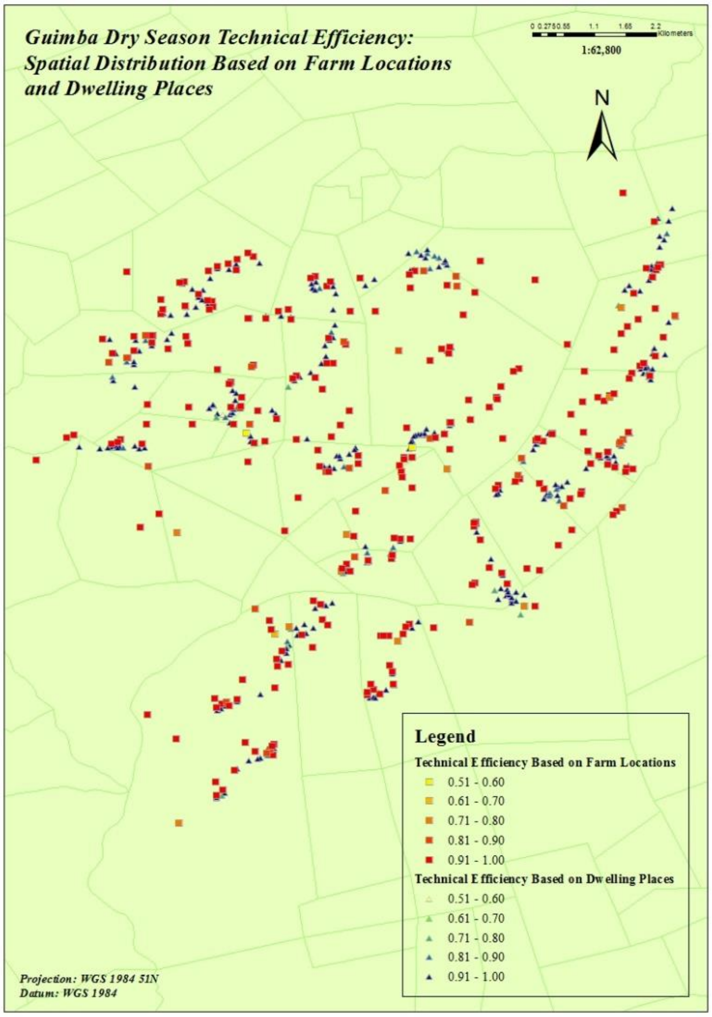


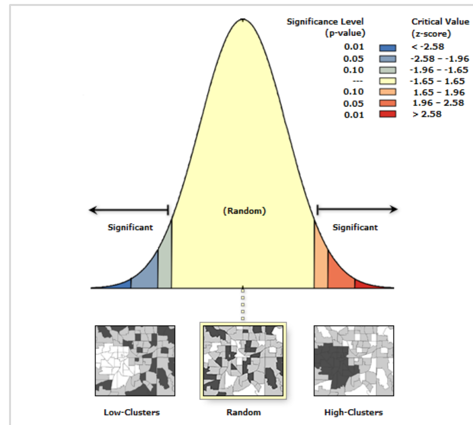


High-low clustering of yields based on farm (top) and dwelling (bottom) locations.

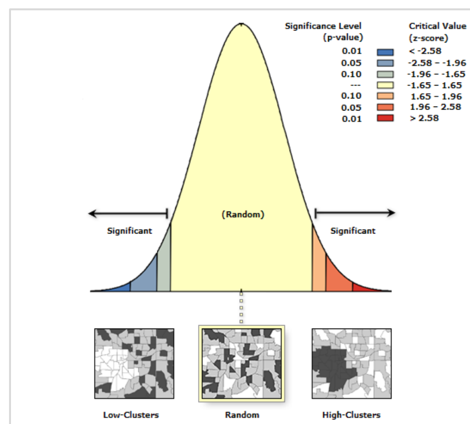


Appendix D.5. Spatial pattern of different dry season technical efficiency levels of Guimba farmers plotted according to farm locations and dwelling places.

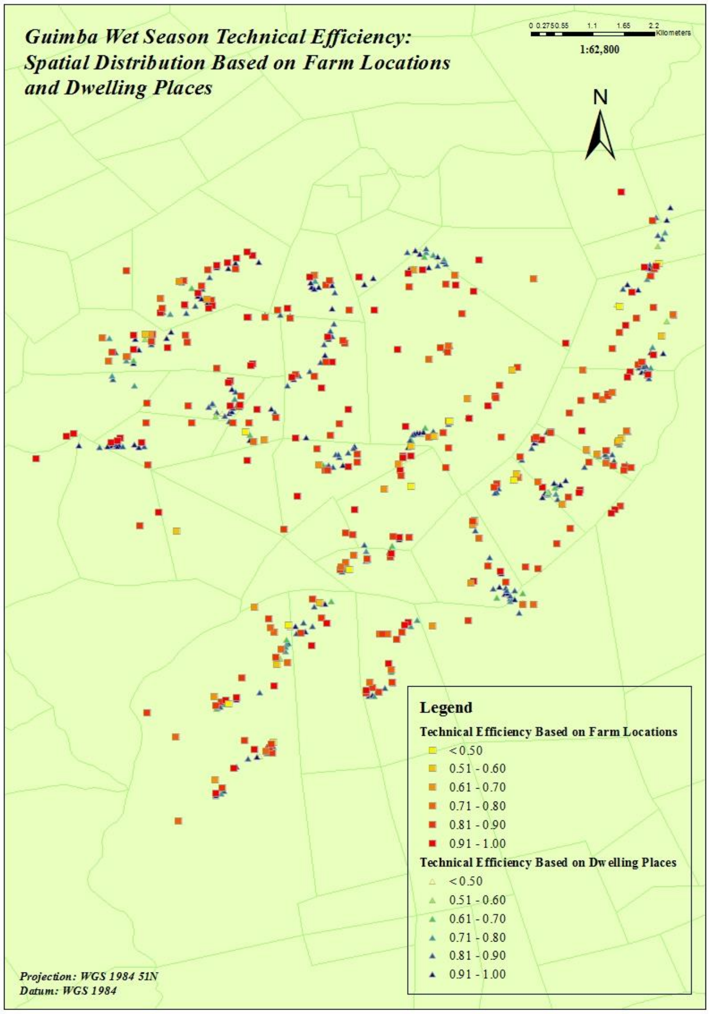


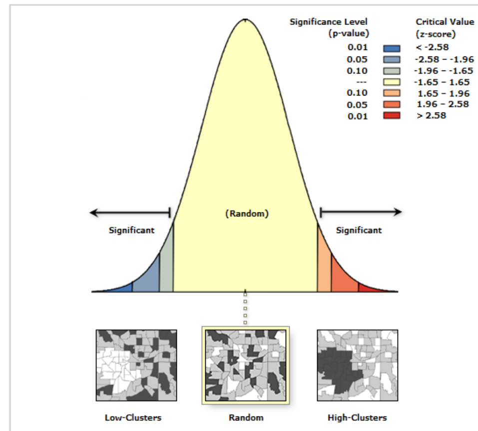


High-low clustering of yields based on farm (top) and dwelling (bottom) locations.

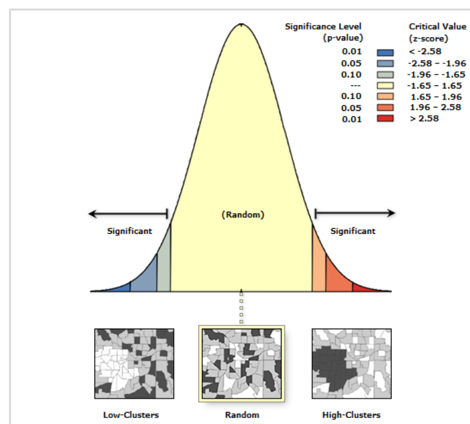


Appendix D.6. Spatial pattern of different wet season technical efficiency levels of Guimba farmers plotted according to farm locations and dwelling places.

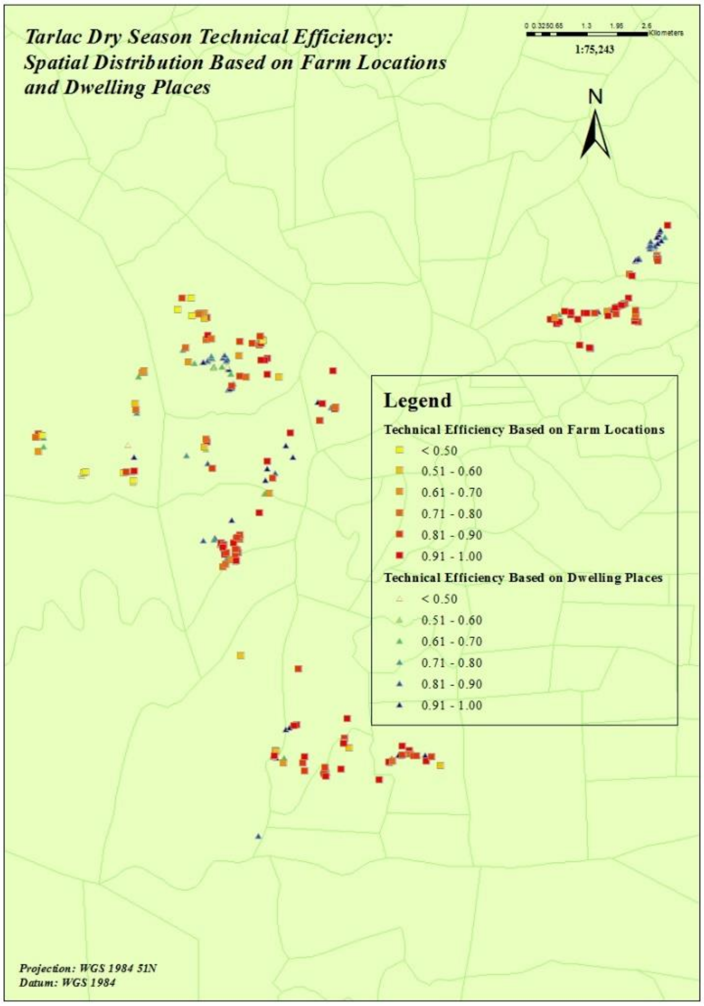


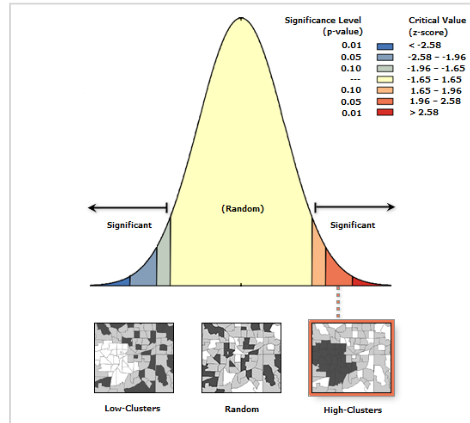


High-low clustering of yields based on farm (top) and dwelling (bottom) locations.

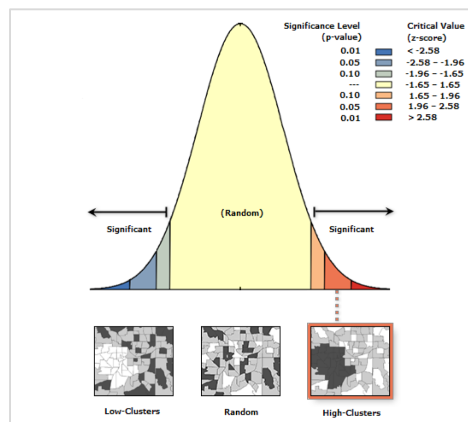


Appendix D.7. Spatial pattern of different dry season technical efficiency levels of Tarlac farmers plotted according to farm locations and dwelling places.

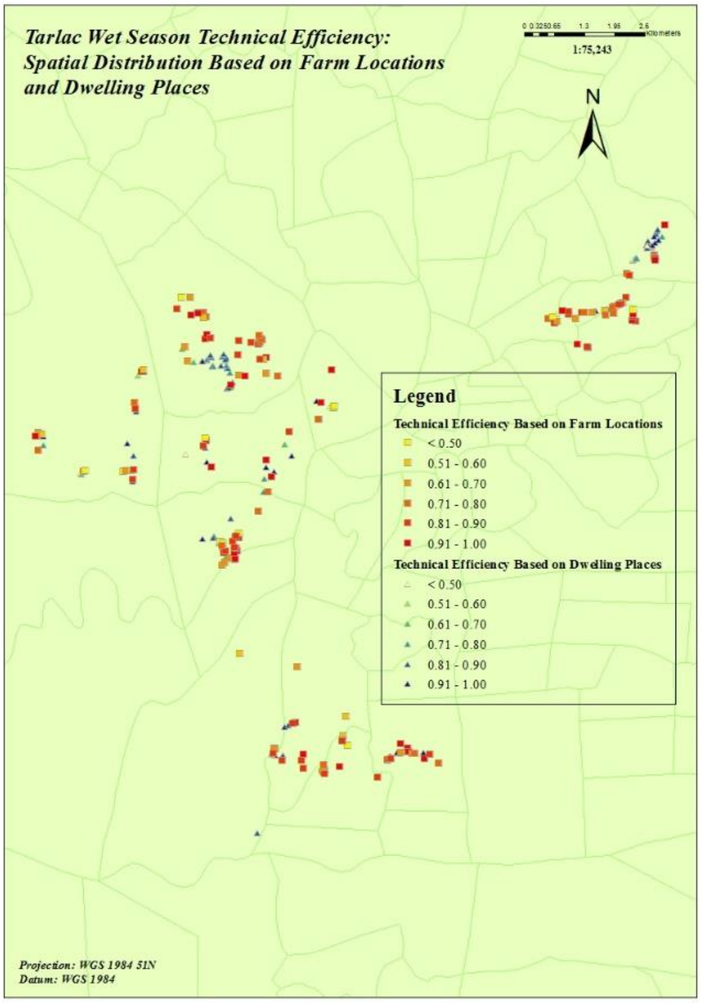


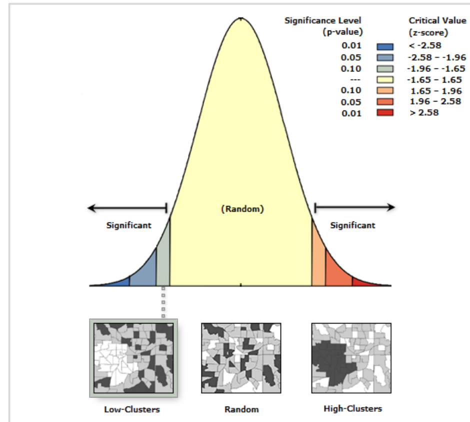


High-low clustering of yields based on farm (top) and dwelling (bottom) locations.

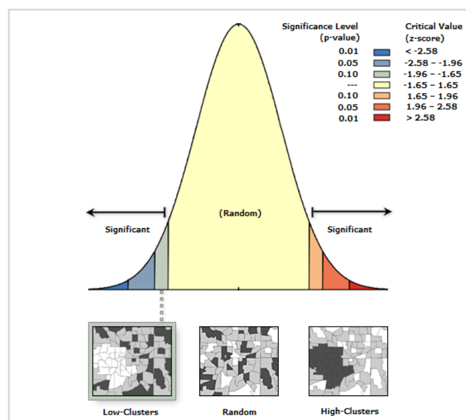


Appendix D.8. Spatial pattern of different wet season technical efficiency levels of Tarlac farmers plotted according to farm locations and dwelling places.



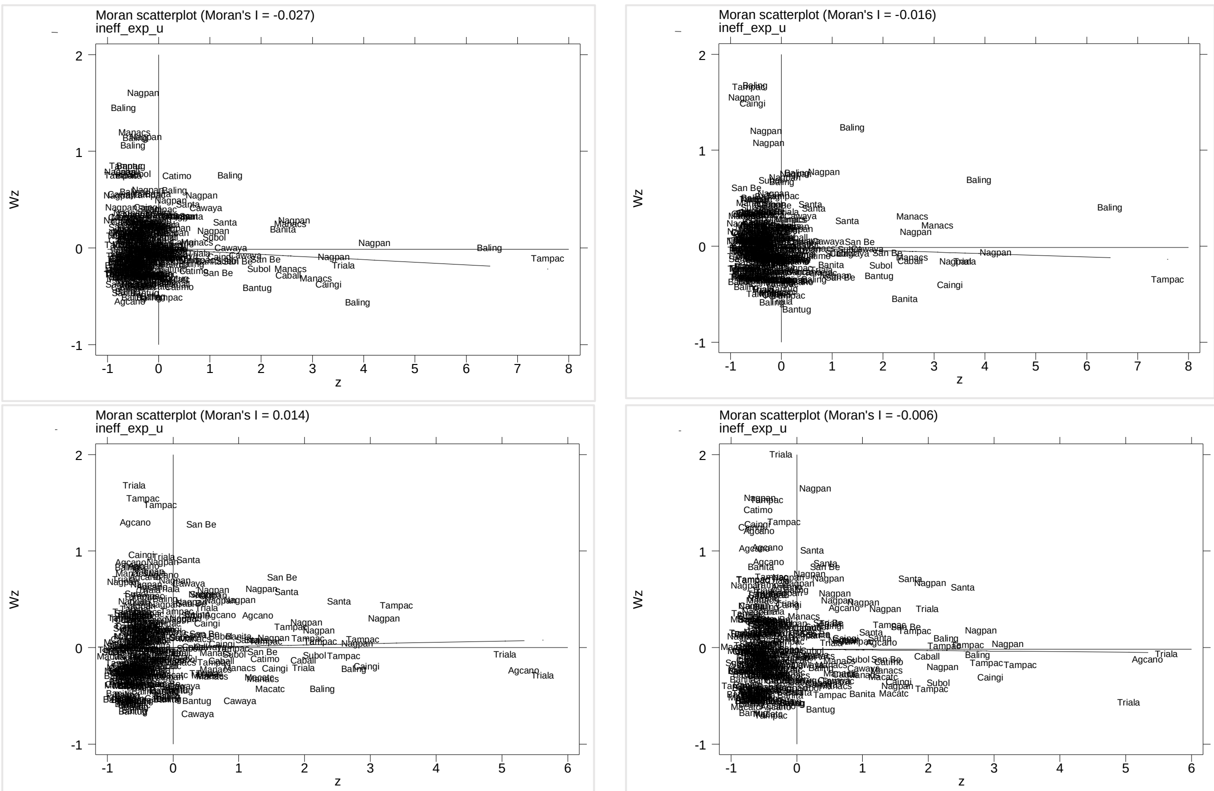


High-low clustering of yields based on farm (top) and dwelling (bottom) locations.

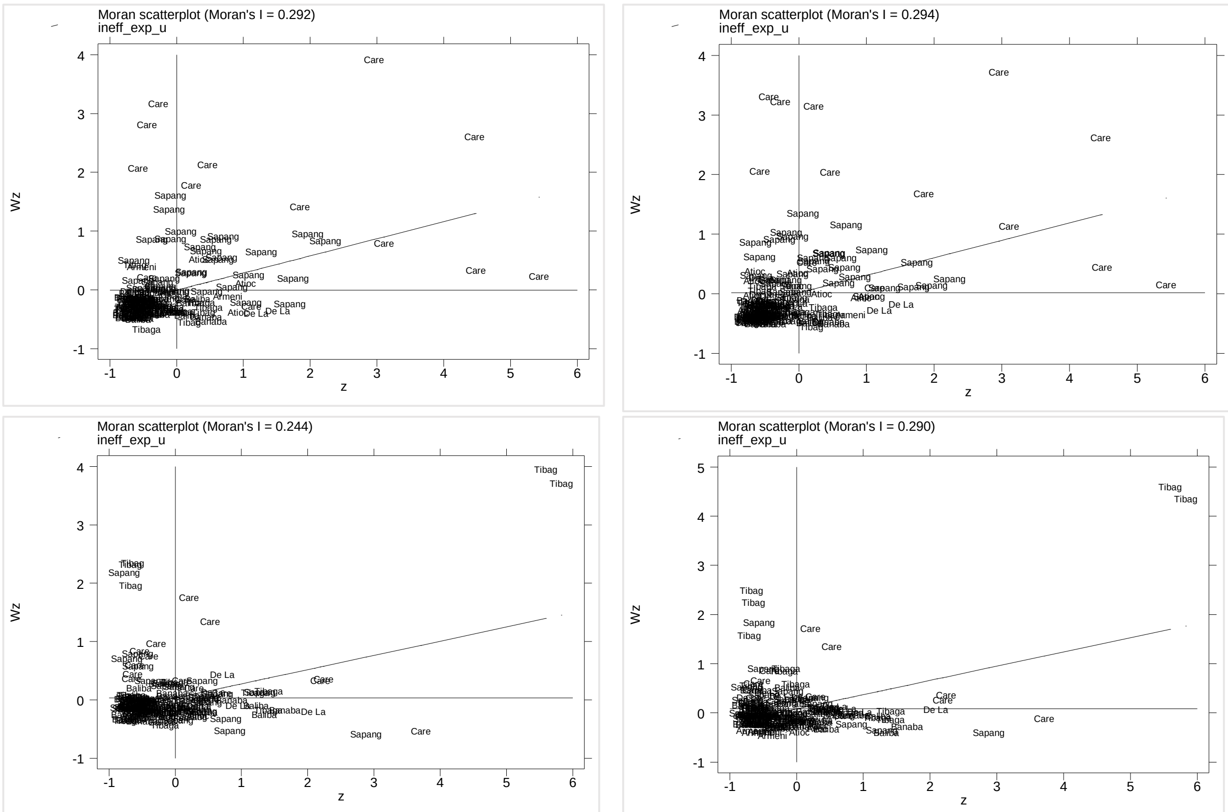


Appendix E. Moran's I scatter plot for technical inefficiency estimates

Appendix E.1. Moran's ***I*** scatter plot for technical inefficiency estimates considering farm (left) and dwelling (right) geolocations in Guimba for the dry (top) and wet (bottom) seasons.



Appendix E.2. Moran’s ***I*** scatter plot for technical inefficiency estimates considering farm (left) and dwelling (right) geolocations in Tarlac for the dry (top) and wet (bottom) seasons.



Appendix F. Complete results of spatial econometric models for the production and technical inefficiency functions in Guimba.

Variables	Guimba (n=294): Dry Season with Spatial Effects							Guimba (n=294): Wet Season with Spatial Effects						
Production Model	**No Spatial Effects**	**SEM**		**SAR**		**SARAR**		**No Spatial Effects**	**SEM**		**SAR**		**SARAR**	
		Farm	***Res***	***Farm***	***Res***	***Farm***	***Res***		***Farm***	***Res***	***Farm***	***Res***	***Farm***	***Res***
Constant	0.066	0.071	0.071	-0.079	-0.059	0.017	0.032	-0.179	-0.177	-0.191	-0.349	-0.305	-0.156	-0.233
Seeds	0.011	0.012	0.011	0.011	0.010	0.015	0.014	0.016	0.019	0.019	0.015	0.016	0.019	0.024
Fertilizer	0.137***	0.138***	0.139***	0.137***	0.138***	0.139***	0.139***	0.079*	0.080*	0.079*	0.080*	0.082*	0.079*	0.076*
Pesticides	-0.003	-0.003	-0.002	-0.003	-0.002	-0.001	-0.002	-0.00005	-0.0002	0.0004	0.000	0.0003	0.0002	0.001
Irrigation	0.022	0.023	0.021	0.022	0.021	0.023	0.019	-0.012	-0.009	-0.011	-0.011	-0.011	-0.010	-0.012
Machinery	0.106***	0.104***	0.103***	0.105***	0.105***	0.099***	0.103***	0.124***	0.119***	0.122***	0.122***	0.122***	0.119***	0.122***
Animals	0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.003	-0.002	-0.003	-0.002	-0.003	-0.002	-0.003
Labor	-0.036	-0.036	-0.034	-0.035	-0.034	-0.037	-0.032	0.067*	0.065*	0.068*	0.065*	0.067*	0.067*	0.070*
Hybrid*Seeds	0.056***	0.057***	0.057***	0.056***	0.056***	0.059***	0.059***	0.033	0.034	0.034	0.031	0.033	0.033	0.036
Typhoon								-0.218***	-0.216***	-0.216***	-0.215***	-0.214***	-0.216***	-0.215***
Lambda		0.061	0.067			0.313	0.133		0.110	0.046			-0.105	0.108
Rho				0.078	0.066	0.911	1.412				0.124	0.079	2.371	1.149
Inefficiency Model	**No Spatial Effects**	**SEM**		**SAR**		**SARAR**		**No Spatial Effects**	**SEM**		**SAR**		**SARAR**	
		Farm	***Res***	***Farm***	***Res***	***Farm***	***Res***		***Farm***	***Res***	***Farm***	***Res***	***Farm***	***Res***
Constant	-0.052	-0.052	-0.052	-0.049	-0.051	-0.049	-0.052	0.190	0.193	0.191	0.185	0.191	0.189	0.211
Age	0.001	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.003*	0.003**	0.003**	0.003**	0.003**	0.003**	0.003**
Education	0.004*	0.004***	0.004***	0.004***	0.004***	0.004***	0.004***	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004
Experience	-0.001	-0.001**	-0.001**	-0.001**	-0.001**	-0.001**	-0.001**	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
Network	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	0.000	0.000
Irrigation	0.028	0.028	0.028	0.029	0.028	0.029	0.027	0.010	0.007	0.009	0.008	0.010	0.005	0.015
Technology	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***	-0.005	-0.005	-0.005	-0.005	-0.005	-0.006	-0.006
Distance	0.002***	0.002***	0.002***	0.002***	0.002***	0.002***	0.002***	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Training	-0.011	-0.011	-0.011	-0.011	-0.011	-0.011	-0.011	-0.058**	-0.058**	-0.058**	-0.058**	-0.058**	-0.059**	-0.064**
Extension	-0.023***	-0.023***	-0.023***	-0.023***	-0.023***	-0.023***	-0.023***	-0.041*	-0.041*	-0.041*	-0.041*	-0.041*	-0.042*	-0.041*
Prices	0.036***	0.036***	0.036***	0.036***	0.036***	0.036***	0.036***	-0.011	-0.010	-0.010	-0.010	-0.011	-0.008	-0.009
Labor	0.023***	0.022***	0.022***	0.022***	0.022***	0.022***	0.022***	0.025	0.025	0.025	0.025	0.025	0.024	0.024
Water	0.063***	0.063***	0.063***	0.063***	0.063***	0.063***	0.063***	0.0.17	0.016	0.017	0.016	0.017	0.015	0.021
Lambda		-0.051	-0.014			-0.508	0.068		0.031	0.011			0.309	-1.222
Rho				-0.049	-0.009	-1.047	-0.226				0.033	-0.004	1.044	1.992

Notes: (1) Res refers to residence or dwelling locations. SEM refers to spatial error model. SAR is the spatial autoregressive (lag) model. SARAR is the spatial autoregressive (lag) autoregressive (error) model. (2) *** significant at 1%, ** significant at 5%, * significant at 10%. (3) The respective coefficients are correct to three significant digits.

Appendix G. Complete results of spatial econometric models for the production and technical inefficiency functions in Tarlac.

Variables	Tarlac (n=150): Dry Season with Spatial Effects							Tarlac (n=150): Wet Season with Spatial Effects						
Production Model	**No Spatial Effects**	**SEM**		**SAR**		**SARAR**		**No Spatial Effects**	**SEM**		**SAR**		**SARAR**	
		Farm	***Res***	***Farm***	***Res***	***Farm***	***Res***		***Farm***	***Res***	***Farm***	***Res***	***Farm***	***Res***
Constant	-3.957***	-3.326***	-3.579***	-3.936***	-4.033***	-3.903	-3.913	-2.812***	-2.423***	-2.481***	-2.725***	-2.799***	-2.960	-2.798***
Seeds	0.173**	0.215***	0.213***	0.205***	0.194***	0.184***	0.214***	0.005	-0.002	0.008	-0.003	-0.0001	0.005	0.016
Fertilizer	0.143*	0.065	0.109	0.084	0.104	0.131*	0.110	0.161	0.117*	0.088	0.126**	0.110*	0.160***	0.156**
Pesticides	0.041**	0.033*	0.042**	0.036**	0.040**	0.041**	0.048***	-0.003	-0.002	0.003	-0.002	-0.003	0.001	-0.002
Irrigation	-0.008	-0.011	-0.015	-0.011	-0.014	-0.009	-0.010	-0.006	-0.003	-0.009	-0.006	-0.008	-0.008	-0.007
Machinery	0.418***	0.374***	0.379***	0.393***	0.403***	0.415***	0.411***	0.403***	0.385***	0.412***	0.380***	0.391***	0.419***	0.406***
Animals	0.022*	0.011	0.010	0.011	0.016	0.020	0.018	0.040***	0.032**	0.031**	0.037**	0.037**	0.041	0.034**
Labor	0.018	0.027	0.015	0.024	0.017	0.003	0.017	0.002	0.012	0.002	0.008	0.000	-0.001	0.002
Hybrid*Seeds	-0.020	-0.021	-0.028	-0.021	-0.022	-0.020	-0.024	-0.032*	-0.024	0.063	-0.016	0.032	-0.036	0.081
Typhoon								-0.184***	-0.200***	-0.202***	-0.194***	-0.198***	-0.184***	-0.175***
Lambda		0.382***	0.420***			0.487	-0.013		0.313***	0.435***			0.187	-0.313
Rho				0.314***	0.286***	0.657	1.323**				0.271***	0.347***	-0.831	1.576**
Inefficiency Model	**No Spatial Effects**	**SEM**		**SAR**		**SARAR**		**No Spatial Effects**	**SEM**		**SAR**		**SARAR**	
		Farm	***Res***	***Farm***	***Res***	***Farm***	***Res***		***Farm***	***Res***	***Farm***	***Res***	***Farm***	***Res***
Constant	0.012	0.014	-0.024	-0.075	-0.093	0.013	0.011	0.583	0.366	0.365	0.331	0.279	0.577**	0.570**
Age	0.001	0.001	0.001	0.001	0.001	0.001	0.001	-0.002	-0.001	-0.001	-0.002	-0.001	-0.002	-0.002
Education	0.006	0.006	0.005	0.006	0.006	0.007	0.006	0.008	0.014	0.014	0.011	0.012	0.008	0.009
Experience	-0.001	-0.0005	-0.0001	-0.0004	-0.0003	-0.001	-0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001
Network	0.001	0.002**	0.002**	0.002*	0.002*	0.002*	0.001*	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Irrigation	-0.208***	-0.150***	-0.137**	-0.160**	-0.161***	-0.215***	-0.208***	-0.037	-0.009	-0.016	-0.006	-0.008	-0.035	-0.035
Technology	0.007	0.008	0.014	0.008	0.010	0.006	0.007	0.003	0.007	0.011	0.004	0.008	0.004	0.005
Distance	0.003	-0.002	-0.003	0.000	0.001	0.003	0.003	0.007*	0.008***	0.007***	0.007**	0.007**	0.007**	0.007**
Training	-0.0423	-0.071	-0.088*	-0.052	-0.059	-0.040	-0.043	-0.014	-0.041	-0.053	-0.016	-0.028	-0.019	-0.015
Extension	0.024	0.040	0.034	0.028	0.032	0.025	0.024	0.080*	0.143***	0.150***	0.106*	0.126**	0.084	0.082
Prices	0.064	0.013	0.077	0.064	0.081	0.065	0.064	-0.169	-0.237	-0.250	-0.181	-0.222	-0.169	-0.175
Labor	0.023	0.024	0.032	0.019	0.029	0.026	0.022	-0.234	-0.173*	-0.177*	-0.208**	-0.201**	-0.234**	-0.238**
Water	0.141***	0.141**	0.123*	0.131**	0.129**	0.139**	0.141**	0.165***	0.240***	0.213***	0.189***	0.200	0.166**	0.157**
Lambda		0.383***	0.387***			-0.406	0.038		0.498***	0.509***			0.110	0.455
Rho				0.294***	0.284***	0.496	-0.018				0.422***	0.490***	0.279	-0.044

Notes: (1) Res refers to residence or dwelling locations. SEM refers to spatial error model. SAR is the spatial autoregressive (lag) model. SARAR is the spatial autoregressive (lag) autoregressive (error) model. (2) *** significant at 1%, ** significant at 5%, * significant at 10%. (3) The respective coefficients are correct to three significant digits. (4) The lambda and rho coefficients are statistically not different between farm and residential locations for the production and inefficiency functions in both the SEM and SAR models with the exception of statistically different rho coefficients in the inefficiency function under the SAR model for the residential areas.

Chapter 4. The Role of Social Capital in Enhancing Farm Productivity and Technical Efficiency

Abstract

Rice is culturally, economically, and nutritionally important to millions of people. Any disruption to the rice market at either the national or the international levels increases the vulnerability of the rice sector, which has cascading impacts in terms of economic and food security. To ensure that domestic rice self-sufficiency remains viable, it is essential to examine the available sources of capital employed in the rice production process. Rice self-sufficiency is currently uncertain and reliant not only on the level of biophysical expansion, production cost reduction, and technical efficiency enhancement but on the ability of producers to access and utilize all the available resources or capital at its disposal. While some recent studies have examined the biophysical and economic resources that can support sustainable rice production, other forms of capital, including the social capital and social networks of producers, are less well understood.

Through structural equation modeling, this study demonstrates empirically the direct and indirect contribution of the social relations to building a farmer's social capital stock. These relationships are hypothesized to positively influence efficiency and productivity providing insight into how social dynamics of farmers' influence rice sustainability in the Philippines. The structural hypothesized models showed that ego (personal) network of farmers positively influences the acquisition of social capital in the form of access to resources such as technology, information, financing, and production materials among others. Through intermediary variables such as training and adoption of technology, the study demonstrates that increased in technical efficiency and productivity of rice farms is positively related to access to social capital assets and resources. In terms of adopting sustainable management practices, social capital has an overall positive effect on adoption of water conservation practices.

The results offer a different frame of reference for policy-makers attempting to develop new approaches to sustainable rice production. While social network information and social capital are rarely considered in sustainable development projects, the results indicate that these variables play a significant role in productivity and therefore potential sustainability. Farmers and decision-makers should view social capital as a potential source of strategic farm-level

enhancement in efficiency and production. If the conventional factors of production are leveraged with social capital assets and resources, there is a likelihood that rice self-sufficiency may be attainable.

Introduction

In the rice production system, several forms of capital produce definite flows of income or streams of benefits. The capital can be in the form of financial resources (e.g., cash or credit to buy seeds or other inputs), physical assets (e.g., land, machinery, equipment), natural endowments (e.g., river for irrigation), and human resources (e.g., skilled laborers).[1] A form of capital that is often less considered, but equally as important, is social capital that farmers accumulate in the form of relationships amongst farmers to other non-farm members of the community (Esser, 2008).

The concept of social capital has been around for several decades. It was in the late 1980s and the 1990s when the concept became popular among economists and other social scientists through the classic work by Loury (1977) on racial incomes, Bourdieu (1985) and Coleman (1988) on education as well as Putnam (1993) on civic participation and governance. Social scientists have defined social capital from multi-faceted perspectives (Vyncke, et al., 2013; Islam, Merlo, Ichiro, Lindstrom, & Gerdtham, 2006; Adler & Kwon, 2002). In spite of this diversity in interpretation, the common elements in the definitions include the importance of social network in building up one's social capital. In an extensive review of literature on the concept of social capital, Vyncke, et al. (2013) and Portes (1998) noted that an individual's social or personal network and all the resources within such network comprise the core elements of social capital that help facilitate trust, coordination, cooperation, and collective action for mutual benefit of the network participants.

Coleman (1988) asserted that "like other forms of capital, social capital is productive, making possible the achievement of certain ends that in its absence would not be possible. He continued, "unlike other forms of capital, social capital inheres in the structure of relations

[1] See Barrera-Mosquera, de los Rios-Carmenado, Cruz-Collaguazo, & Coronel-Becerra (2010) for an extended definition of each kind of capital. This study only presents five forms of capital. However, Barrera-Mosquera, de los Rios-Carmenado, Cruz-Collaguazo, & Coronel-Becerra (2010) included seven forms of capital. The other two types of capital not presented in this essay are cultural and political capital.

between actors and among actors. It is not lodged either in the actors themselves or in the physical implements of production." Nahapiet & Ghoshal (1998) described that unlike the other forms of capital, social capital increases with use and it exhibits characteristics of a public good such that it does not only benefit those who contributed toward its creation but it has multiplier effects that are potentially positive for development.

In Putnam's (1993) seminal work, he identified three areas where the presence of social capital can be easily observed and its impacts captured. These areas include farming communities, informal saving institutions, and the commons. In rural agrarian communities, this form of capital manifests itself in the form of relationships of farmers to fellow farmers or other non-farming members of the community.

In the analysis of economic activities such as crop production, Woolcock (2002) suggested that social capital is an under-appreciated factor of production and empirical evidence has shown that failing to account for social capital in agricultural production has the propensity to undermine productivity. In many instances, well established social capital has been touted as an important prerequisite in the adoption of agricultural innovations and technologies as well as sustainable production and climate adaptation practices that can affect levels of production in either the short- or long-run.

Recent studies have also noted the importance of social capital in influencing productivity and technical efficiency in various production systems. In multiple African countries, Pretty, Toulmin, & Williams (2011), van Rijn & Bulte (2011), Njuki, Mapila, Zingore, & Delve (2008), and Heemskerk & Wennink, (2004) assessed that social capital influences the adoption of agricultural innovations and sustainable practices among farmers. Pretty, Toulmin, & Williams (2011) found that farmers who share similar values exhibit social capital that led to the widespread adoption of integrated plant and pest management (IPPM), which resulted in higher rice yields in Senegal, Mali, Burkina Faso, and Benin. Rice productivity in Mali increased from 5.2 tons per hectare to 7.17 tons per hectare whereas in Senegal it increased from 5.19 to 6.84 tons per hectare. Van Rijn & Bulte (2011) discovered that the relationship of farmers with stakeholders having different views and values is positively associated with the adoption of agricultural innovations in Mozambique, Niger, Nigeria, and Uganda.

In Asia, the role of social capital and social networks has been well recognized in the rice farming communities. In the Philippines, for instance, Tatlonghari & Sumalde (2006) and Pretty

& Ward (2001) reported that social capital manifested in groups resulted in higher rice yields for farmers who belong to the government's national irrigation program. The rice yields of farmers in irrigation groups according to Pretty & Ward (2001) are 19 percent higher than those farming alone. In an evaluation of rice growers in Northwestern China, Wang, McIntosh, Watson, Zhang, & Lu (2013) investigated how social capital influences technical efficiency of small-scale irrigation to achieve food security and increase agricultural development. Using path analysis, the study showed that social capital could improve technical efficiency of irrigated agriculture. Also in China, Li & Li (2011) found that farmers with high social capital as characterize by denser and tighter social networks are more successful in implementing farm management practices such as collective water management, and this has a significant and positive effect on improving technical efficiency in rice production. In Malaysia, Yokoyama & Ali (2006) detected the influence of social capital on rice production by noticing that farmers who have deeper organizational affiliations, as a measure of social capital, perform better. A similar finding was observed in Nepal, where farmers with higher social capital or belongingness to a group achieved a 10 to 15 percent higher crop yield (Pretty & Ward, 2001).

With barely a year remaining to reach the target goal of producing 22.73 million metric tons of rice in 2016, the Philippine government remains confident of reaching rice self-sufficiency given current strategies and initiatives in place under the Food Staples Sufficiency Program (FSSP) (Valencia, 2014). Achieving this production target is subject not only to biophysical (land) expansion and production cost reduction through technical efficiency enhancement but also on the ability of producers to effectively utilize all available resources or capital at their disposal. For this reason, to ensure that domestic staple food self-sufficiency remains viable, it is equally essential to examine not only the financial, natural, physical, and human capital employed in the rice production process but also the influence of social capital and networking in improving productivity and meeting the FSSP target.

Available empirical shows that social capital is an essential component in many farming communities, including rice-producing regions. The recognition of the importance of social capital, however, has not been part of the policy-making mainstream, particularly in the Philippines. Given this policy gap, this study seeks to strengthen the science-policy interface in the rice sector by examining the role of social capital in enhancing farm efficiency and its implications for the goals of sustainability. This is particularly important since social capital is a farm asset that is commonly overlooked or ignored yet abundantly present during different stages of rice production.

Social capital, amidst the absence of a universal definition[2], is described in this study from the lens of a "relation-based resource that enhances welfare within a network" (Tsai, 2006). From this angle, the definition of social capital used in this study is the overall pattern of structural and relational connection and linkages between and among farmers in Central Luzon. This includes resources found in the personal formal or informal networks of the farmers and the ties that connect them in a certain network to have a means to access and use resources to produce rice for their own consumption, exchange, or sale (Lin, 2001; Rose, 2000). Structural pattern relates to the density, connectivity, and hierarchical dimension of the farmers' individual network, which include the number of family members, friends, or acquaintances in one's personal network (Nahapiet & Ghoshal, 1998). Relational linkages pertain to the degree of attachment, which can be determined in terms of trust or dependence of a farmer on people within his or her network. The emphasis on the relations within and the structure of the farmers' personal networks is very important because this is what policy makers can influence (Teilmann, 2012).

Based on the above definition, social capital in the context of this study is contingent on personal or individual networks of the farmers. Barnes-Mauthe, Gray, Arita, Lynham, & Leung (2014) contended that social capital assessed at the individual level using network concepts could be an important determinant of socioeconomic outcomes. This suggests that an individual farmer is not limited to its own resources but it can actually make use of the resources generated by its personal network to gain profits or to improve welfare (Portes, 1998). Lewis (2010) argued that the conception of social capital is best at the individual level although benefits can accrue to both individuals and collectives. It is for this reason that Teilmann (2012) advocated that in developing policy objectives for stimulating social capital, it is important to target the individual, which can lead to an increase in social capital on a larger scale such as the community or society.

[2] There is no consensus definition for social capital (Michelini, 2013; Teilmann, 2012; Dufhues, Buchenrieder, & Fischer, 2006;Yokoyama & Ali, 2006; Coleman, 1988). Social scientists have argued that with the lack of a universal definition, the analysis of social capital should be approached with caution and clear definition (Teilmann, 2012). This means that adopting a narrow definition depending on the context of the study in question is a more pragmatic approach (Wolz, Fritzsch, & Reinsberg, 2006).

Given that understanding and analyzing personal network structure are crucial to measuring social capital, which is inferred to influence productivity and efficiency, this study examines the individual or personal networks of farmers in Central Luzon. In particular, this paper investigates the level of influence of the farmer's individual social capital on factors affecting technical efficiency of farms in Central Luzon. Through structural equation modeling, this study also assesses the role that social capital plays in the adoption of sustainable management practices in rice farming.

This study recognizes that although the literature over the last decade has indicated a strong connection between social capital, farm production, and other related attributes, the Philippines has not strongly considered policies that attend to these dimensions resulting to a clear science and policy disconnect. Hence, in a country seeking sustainability at various sectors, particularly agriculture, this study generates basic information on the complex nature of staple food production system involving a wide array of factors. Through a hypothesized structural equation model, this study presents a case that demonstrates the need to develop policies that address the role of social capital given its importance in production efficiency, which has strong implications for the goals of sustainability.

Analytical Framework

Given the growing recognition of social capital as a form of agricultural production asset (Pretty, Toulmin, & Williams, 2011; Uphoff & Wijayaratna, 2000), the neoclassical approaches of accounting for conventional forms of capital including cash, stocks, and property among others, may be analytically incommensurate when measuring social capital, which is commonly done in qualitative terms. In consideration of the novelty of social capital as a production asset, the starting point for the analysis is to recognize approaches that quantify social capital in a similar manner with other forms of capital. To understand fully its role in agricultural production, the examination of theoretical propositions regarding the inter-linkages between social capital measures, productivity, and levels of technical efficiency is imperative.

Social Capital Assessment through the Ego (Personal) Network Analysis

A pivotal component of this study rests on the quality of farm-level relational data including farmers' social contacts, ties, connections, and group affiliations. Because relational data expresses the linkages between and among social actors, which in this case are the farmers from Central Luzon, Scott (2012) and Wasserman & Faust (1994) asserted that for these types of data, the appropriate analytical method is that of social network analysis (SNA). In conjunction with "quantitative and statistical counts of relations," Scott (2012) argued that to realize the robustness of the statistical significance of the relational patterns, qualitative measures of describing the network structure under SNA is indispensable.

In the SNA parlance, a network is comprised of nodes or egos representing individual social actors. Hanneman & Riddle (2005) noted that a network has as many egos as it has nodes. To measure the social capital of these nodes or egos, Dufhues, Buchenrieder, & Fischer (2006) cited that social network analysis provides a set of tools and techniques to assess this type of asset at the individual and collective levels. There are two common analytical perspectives used in assessing the connections between and among these nodes and egos – the whole network and the ego (personal) network dimensions.

Whole or complete networks[3] are a census of relationships of all the nodes or egos within a socially well-defined or geographically bounded population (Zhang, 2010). In this study, for instance, whole network would refer to all the farmers in Central Luzon together with all the measures of their social ties and connections with others, inside or outside of the region. Following a top-down approach in obtaining information, the intent of a whole network analysis is to describe the detailed structure of all the relationships, connections, or attributes of all the nodes or egos in the network.

If an individual is the focus of analysis and the objective is to describe the variation across individuals in a particular locality such as in the case of assessing each farmer's social capital in a municipality, the ego (personal) network analytical approach is the applicable technique. Ego or personal network analysis (ENA or PNA) considers relational structure of a limited part of a whole network from an individual's (ego) point of view (Matzat & Snijders, 2007). In ENA, the focal node is known as the ego and all the other nodes connected to the ego are called alters (Hansen, Shneiderman, & Smith, 2010; Hanneman & Riddle, 2005). Munasib

[3] Some literature would refer to this type of network as socio-centric network [see Perkins, Subramanian, & Christakis (2015); Barnett (2011); Mizruchi & Marquis (2006); Marsden (2002)].

(2007) contended that assessing social capital from an ego network perspective makes it "comparable to the economic idea of capital."

Following the personal network research design introduced in Halgin & Borgatti (2012) and the standard measurement procedure originally proposed by Burt (1984) and still being utilized in the periodic U.S. General Social Survey, this study implemented the name generator, name interpreter, and resource generator ENA techniques (Marsden, 2005). In the name generator technique, the heads of farm households (ego) were requested to list a limited number of individuals (alters) with whom they have discussed rice production-related topics or issues within the most recent cropping season.[4] The persons introduced by the ego comprise the personal social network of the farm household head.

To the best of the farmer's knowledge, the ego can provide additional information about the alter in terms of gender, age, level of education, location (domicile), etc. The provision of the alter's socioeconomic and demographic characteristics is part of the name interpreter technique under the ENA. Data obtained using the name interpreter technique is used to determine the composition, heterogeneity, and structure of the ego's social network. Liverpool-Tasie, Kuku, & Ajibola (2011) noted the importance of this technique since by simply summing up the number of people in one's personal network indicates very little about the types and intensity of social capital available within an individual's network.

Social Capital Measurement

In analyzing the concept of social capital at the individual level, Najarzadeh, Soleimani, & Reed (2014) emphasized that the key measure is the access to social resources, which represents categories and aspects of social capital. Dufhues, Buchenrieder, & Fischer (2006) explained that information and resource exchange is inherent in social relations that create social capital such as the connections of farmers in the study area with their families or fellow farmers. In this respect, this study employed the resource generator technique to solicit information on the

[4] With this type of technique, Matzat & Snijders (2007) documented that an ego typically lists between zero and eight alters. For large-scale surveys with time and funding constraints, Burt (1984) proposed limiting the list to five alters. Recently, Merluzzi & Burt (2013) investigated the minimum set of listed contacts needed to identify network effects and found that asking for five contacts using the name generator technique is the most cost-effectiove number of citations to record. In this study, the survey asked the farm household head to list at most five key individuals.

types and frequency of access to resources such as financing, technology, production inputs, materials, and labor among others.

To assess how social capital influences farm productivity and efficiency, it is necessary to quantify this type of asset and examine the factors that contribute to its accumulation. This study transforms the data derived through the resource generator technique into a measure that is used as a variable in the empirical estimation of the effect of social capital on rice production. As suggested by Bourdieu & Wacquant (1992), estimation of the individual's social capital is best operationalized as the sum of the resources that can be accessed or utilized through a network of social relationships. On this account, this study measures individual social capital following the expression used in previous literature (Van der Gaag & Webber, 2008; Dufhues, Buchenrieder, & Fischer, 2006; Van Der Gaag & Snijders, 2005; Snijders, 1999): $SC = \sum_{i=1}^{n} \sum_{j=1}^{m} r_{ij}\, p_{ij}$, where SC is the overall measure of the individual's social capital, which in this case is represented by the number (m) of r resources such as financing, technology, equipment, and materials sourced from interaction with n alters at various levels of probability (p). Based on the binary nature of the inquiry used in the resource generator technique, the probability (p)will take the value of one in the case of an affirmative response and zero otherwise.

Given that social capital is not a unidimensional concept (Putnam, 1995), the quantity and quality of resources that farmers can accrue as part of their social capital portfolio are better explained from a three domain model of cognitive, relational, and structural dimensions (Chang & Chuang, 2011; Chow & Chan, 2008; Nahapiet & Ghoshal, 1998). The cognitive domain, which some social scientists refer to as the content dimension (Widén-Wulff & Ginman, 2004; Hazleton & Kennan, 2000), is related to the common understanding of shared representations, interpretations, and systems of meanings manifested through shared vision and languages between and among farmers (Chiu, Hsu, & Wang, 2006). Information exchange, knowledge sharing, and communication facilitate the shared perspective of forming and utilizing social capital (Chang & Chuang, 2011; Hazleton & Kennan, 2000).

The relational dimension is concerned with the intensity and strength of relationships of farmers with each other. Relational trust and solidarity are the central factors within this domain (Bakker, Leenders, Gabbay, Kratzer, & Van Engelen, 2006; De Carolis & Saparito, 2006; Coleman, 1988). Trust at the farm-level emerges from repeated and reliable interaction of farmers with each other over time, which in turn becomes the basis of group or community solidarity (Cook, 2005; Adler & Kwon, 2002). When farmers reciprocate trust, they have greater motivation to express personal thoughts or opinions freely without fear of being judged. At the same time, when trust abounds within the farming community, farmers gain confidence that during good and especially during difficult times such as after a natural disaster or personal loss, there are members of the community that they can lean on for much needed social capital that includes moral, physical, and financial support.

If the relational domain of social capital is related to the quality of connections between and among farmers, the structural domain is more about the quantity and pattern of ties at the farm-level (Chiu, Hsu, & Wang, 2006; Moran, 2005; Nahapiet & Ghoshal, 1998). The structural dimension can be described in terms of the size and composition of the farmers' ego (personal) social network (Chow & Chan, 2008; Goddard, 2003). For instance, the structural composition can include the distribution of the social network according to gender, ethnicity, social status, and education. The other factors within the structural domain that influence the nature of the personal networks of individuals include heterogeneity attributes, homophily characteristics, and connective configuration of the different actors involved (Halgin & Borgatti, 2012).

Consistent with Borgatti, Jones, & Everett (1998), heterogeneity refers to the socioeconomic and demographic diversity of individuals within one's personal social network whereas homophily denotes the likelihood of association of an individual with people of similar status or background. In this study, heterogeneity is assessed using the Agresti's index of qualitative variation (IQV) and the Blau's index, which is also known as the Hirschman-Herfindahl index (HHI) (Biemann & Kearney, 2010). These indices expressed as $HHI = 1 - \sum_k p_k^2$ and $IQV = (1 - \sum_k p_k^2)/(1 - \frac{1}{k})$ are the most common measures of diversity in personal network analysis.[5]

[5] Blau's index, also referred as Hirschman-Herfindahl index in the literature, and the Agresti's index of qualitative variation (IQV) are commonly used measures for diversity-as-variety (Harrison & Klein, 2007). Both measures reflect the chance that two randomly selected group members belong to different categories. Despite this close relationship between these measures, the Blau's index falls short due to incomparability when the number of categories is different across diversity variables under consideration. For instance, one cannot compare Blau's index for gender with two categories, male or female, with educational background with maybe four categories, grade school, high school, college, graduate school. Hence, to address this shortcoming with Blau's index, Agresti & Agresti (1978) standardized Blau's index by dividing its theoretical maximum yielding the index of quality variation. As noted by Harrison & Klein (2007), these two indices are used in "social network research to operationalize entrée to unique sources of information or social capital." Theoretically, Blau and Agresti's indices

The configuration of connections accounts for what Burt (2009) calls as structural holes, which represents the open or close nature of the social network. When there are more unconnected individuals in one's social network, there is a high likelihood that the network is more open and that there are gaps or holes between and among the members of such network. Halgin & Borgatti (2012) noted that in many settings it is advantageous that a personal network has many structural holes. In the case of the farmers in Central Luzon this means that their connection to people who are themselves unconnected to the other members of the farmers' network places the farmer is in a strategic position. With this type of network structure, the ego has the direct ability to accumulate and control key information and resources from the network. To examine the influence of the presence of structural holes in the structural domain of social capital, this study adapts the measures proposed by Burt (1992) – constraint and hierarchy.

Burt (1992) explained that a network structure is constraint when there is a high incidence of network members' connections to one another or when the members of the network are indirectly connected by a central contact such as the head of a farm household in this study. When members of farmers' personal networks have multiple interconnections, the opportunity for farmers to act as information or resource link declines since the network members can interact without being linked to the farm head of households. Formally, the constraint index, C_i, follows the following expression: $C_i \equiv \sum_{i \neq j}(p_{ij} + \sum_{k \neq i, k \neq j} p_{ik} p_{kj})^2$, where p_{ij} is the proportion of time that farmer i has invested on network member j. Buskens & van de Rijt (2008) offer a more extensive discussion of the derivation of the constraint index as well as the role of the index in providing network benefits.

To assess whether the constraint in the farmers' personal networks are monopolized by a single network member or evenly distributed among the individuals in the farmers' networks, this study also estimates the degree of hierarchy in the network structure. Hierarchy is measured as $NH = [\sum_k r_{ek}\,(\ln r_{ek})]/[N_e\,(\ln N_e)]$, where NH stands for network hierarchy, k represents the members of the farmers' personal networks, r_{ek} is the constraint emanating from individuals

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can range between zero and one with zero indicating no diversity such as all members of a group are males, and one implying higher diversity (Eisenman, Farley-Ripple, Culnane, & Freedman, 2013). In expressions of the two indices, p_k represents the proportion of alters that fall in a particular category k. In this study, a sample category may be educational attainment represented by those who completed a college degree, those who received high school diploma, or those who completed elementary education. This study estimates the indices based on the number of individuals that belong to each categorical cluster.

k in relation to the mean constraint posed by the farmer, and N_e the number of individuals in the farmers' personal network (Burt, 2015). When there is one dominant member of the network, the value of NH is closer to one indicating high hierarchy. As NH gets closer to zero, the hierarchy in the network weakens. The level of hierarchical dominance exhibited by the farmers' personal network has an impact on how information and resources are channeled within the network, internally and externally.

Within the three-dimensional context of social capital – cognitive (information and resource exchange), relational (trust and solidarity), and structural (personal social network), this study investigates the direct and indirect effects of network composition and structural hole measures on the ego (personal) social networks of farmers in Nueva Ecija and Tarlac. This study used the E-Net software (Halgin & Borgatti, 2012) to generate the structural measures as Wellman (2007) noted that "standard social network software, such as UCINet and Pajek are optimized to analyze one whole network, and they cannot be easily used for the analysis of a large sample of personal networks." From the estimation of the ego (personal) network measures, the ensuing analysis includes the examination of how the three dimensions of social capital affect the acquisition of assets and resources that are useful in the rice production process.

Research Area and Empirical Approach

To assess how the composition and structure of a farmer's ego or personal network shape farm-level productivity and efficiency, this study obtained cross-sectional data from rice farming villages in the provinces of Nueva Ecija and Tarlac in Central Luzon, Philippines. With the aid of an objective-oriented structured questionnaire, this study conducted the household surveys between December 2013 and January 2014.[6] The models applied in this study depended on these sets of data.

Study Area

Central Luzon is the largest rice-producing region in the Philippines. The region is composed of 12 cities and 118 municipalities from the seven provinces, namely, Aurora, Bataan,

[6] Dry season is between December to May and the wet season is between June to November.

Bulacan, Nueva Ecija, Pampanga, Tarlac, and Zambales (DENR, 2014; Lugos, 2009). Of these provinces, the Philippine Rice Research Institute (PhilRice) ranked Nueva Ecija, Tarlac, Bulacan, Pampanga, Aurora as five of the country's major rice producing provinces based on average rice harvest area (Bordey & Malasa, n.d.).

This research initially selected three Central Luzon provinces equally represented in each stratum categorized according to their equal share in harvest area as presented in Bordey & Malasa (n.d.).[7] The selected provinces are Nueva Ecija representing the top stratum, Tarlac for the mid stratum, and Aurora for the bottom group. The study, however, directed its focus to Nueva Ecija and Tarlac after a major typhoon devastated the province of Aurora in August 2013.

Pursuant to the harvest area rationale used in the "Regular Monitoring of Rice-Based Farm Households" project of PhilRice, this research elected to conduct the study in the municipalities of Guimba in Nueva Ecija and Tarlac City in the province of Tarlac. These are the two areas within the two provinces that have the highest number of rice growers and the largest area devoted to rice production. These two municipalities also have a wide representation of different farm sizes as well as diversity of irrigation sources.

Guimba is located 153 kilometers northwest of Manila with a land area of 25,853 hectares. There are 64 villages in Guimba laying on relatively flat areas with slope of zero to three percent and elevation of zero to 500 meters above sea level. More than 90 percent of the villages in Guimba are rural farming villages with rice as the main crop. As of the 2010 census, 104,894 people reside in Guimba (Municipality of Guimba, 2012 and National Statistics Office, 2010).

The city of Tarlac is the provincial capital with a land area of 27,466 hectares and has a population of 318,332 according to the 2010 census (National Statistics Office, 2010). The city is approximately 110 kilometers north of Manila. Although Tarlac is categorized as an urban municipality, about 46 percent of its 76 villages are classified as rural (National Statistics Office, 2010). The rural villages are still very agricultural with rice and sugarcane as the main products.

[7] Bordey & Malasa (n.d.) provides an extensive documentation of the sampling procedure employed in the "Regular Monitoring of Rice-Based Farm Households" project of PhilRice. The project adopted a two-stage sampling process with the provinces as the study domain. Based on five-year average ranking of rice harvest area, the sampling exercise ranked each province in descending order and divided them into four strata in approximately equal share to the total harvest area.

Data Collection

This study adopted the right coverage approach employed by the Philippine Rice Research Institute (PhilRice) in its "Regular Monitoring of Rice-Based Farm Households" project. With this approach, the survey selected rice-based sample households from a pre-determined landmark within the village. An enumerator begins the survey from the right side or right path of the pre-determined landmark and every so many house thereafter. As explained in Bordey & Malasa (n.d.), this process aims to randomize sample selection in the absence of a list of rice farmers in each village.

There are 192,278 rice growers in Nueva Ecija and Tarlac combined (BAS, 2012). Of this total, 63 percent are in Nueva Ecija and 37% are in Tarlac. Based on this distribution and the assumption that there is five percent level of error to tolerate, 95 percent level of confidence, and 20 percent sample buffer, this study proportionally targeted the number of farmers to survey, 460 in total – 288 in Guimba and 172 in Tarlac. The study randomly administered the survey to 471 rice-farming households – 301 in Nueva Ecija and 170 in Tarlac. Of these, 294 and 150 sets of household data are determined valid from Nueva Ecija and Tarlac, respectively. Appendix B on page 174 of this document presents the survey instrument utilized in this study with sections on socio-demographic, farm production, technological adoption, sustainable management, and social network information for the 2013 dry and wet seasons.

Data Evaluation Approach

This research jointly applied the ego (personal) network analysis and structural equation modeling techniques to assess the directionality of the relationships among social and economic variables of farmers in Central Luzon. In particular, results from the ego (personal) network analysis were used as inputs in the structural equation model. The succeeding section discusses in detail the structural equation modeling approach employed in this study.

The Effect of Social Capital on Productivity, Technical Efficiency, and Adoption of Sustainable Management Practices: A Structural Equation Modeling Approach

Because the main interest of this study is to depict the direct and indirect causal relationships among social, economic, environmental, and agricultural variables, the application of traditional econometric methods may not be the most fitting procedure. In this case where the objective is to represent, estimate, and test the multiple causalities and network of relationships, Liverpool-Tasie, Kuku, & Ajibola (2011) suggested the utilization of structural equation modeling (SEM), which is a theory-oriented method involving the use of generalized multi-equation frameworks to analyze complex datasets (Lamb, Shirtliffe, & May, 2011; Grace & Bollen, 2005). In comparison to multivariate regression models, SEM includes more flexible assumptions that allows for distinct parameter interpretation even in the presence of multi-collinearity (Shadfar & Malekmohammadi, 2013; Wang & Huang, 2010). Measurement errors are also reduced in SEM through confirmatory factor analysis[8]. The graphical modeling interface also adds to the attractability of SEM over other modeling techniques.

Joreskog & Sorbom (2001) noted that SEM permits the simultaneous examination of causal relationships between latent[9] and observed[10] variables that can be either endogenous[11] or exogenous[12] in nature. The assessment of the causal associations of the variables typically involves a two-step SEM approach (Liu, et al., 2014; Wang, Wen, & Han, 2013). Through confirmatory factor analysis, the initial step is specifying the links between exogenous and endogenous latent variables and the indicators comprising them. The other step involves testing the causal relationships between and among exogenous and endogenous latent and observed variables. A set of linear equations describe these causal relationships:[13]

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[8] Confirmatory factor analysis assesses the validity and reliability of the proposed theoretical model through good ness of fit indices and evaluation of the consistency of the latent variable indicators (Shadfar & Malekmohammadi, 2013).

[9] In examining the application of latent variables in the field of psychology, Bollen (2002) noted that in the social science literature latent variables also refer to "unmeasured variables, factors, unobserved variables, constructs, or true scores." According to Tang, Folmer, & Xue (2013) latent variables are about postulations that a phenomenon exist even if it cannot be be directly observed or measured. As Bollen (2002) simply put it, these are "variables in the model not present in the data set." The common examples of latent variables include intelligence, attitude, awareness, sense of belongingness, feelings of morale, and trust among others. As stated in Tang, Folmer, & Xue (2013), latent variables are measured via correcpondence statemensts that relate to an array of observable or measurable indicators.

[10] These are variables that are directly observable or measured (Schumacker & Lomax, 2010).

[11] A variable is endogenous when other variables in the model determine or explain its value. Endogenous variables are tantamount but not exactly similar to dependent variables in econometric models. In this study for instance, technical efficiency and productivity can be classified as endogenous variables.

[12] Exogenous variables are factors in a model whose values are independent from that of the other variables. These types of variables are taken as given in the model. Exogenous variables can be compared to independent variables in a standard econometric model.

[13] These are the standard equations under SEM and the discussion provided on these equations is based on the work of Wang, Wen, & Han (2013).

$$x = \Lambda_x \eta + \delta \qquad \text{[Eq. 1]}$$
$$y = \Lambda_y \eta + \epsilon \qquad \text{[Eq. 2]}$$
$$\eta = \beta\eta + \Gamma\xi + \varsigma \qquad \text{[Eq. 3].}$$

Eq. 1 and Eq. 2 represent the initial step in the process whereas Eq. 3 denotes the subsequent step. In the SEM parlance, Eq. 1 and Eq. 2 are commonly known as the measurement model and Eq. 3 as the structural model. X is a vector of observed exogenous variables and y is a vector of observed endogenous variables. ξ is a vector of exogenous latent variables and η is a vector of endogenous latent variables. Λ_y and Λ_x represent matrices of regression coefficients of x on ξ and y on η, respectively. β is the structural coefficient matrix of η to be estimated. δ and ϵ are the corresponding vectors of measurement errors of x and y. Γ represents a matrix of structural coefficients of exogenous latent variables, ξ, in η. The vector of random disturbances uncorrelated with ξ is denoted by ς.

Model Hypotheses, Specification, and Fit Assessment

Following the two-stage SEM process, this study commenced with the development of theory-based hypotheses and model specification of the relationships between social connectivity measures, indices for ego (personal) networks, domains of social capital, production variables, and determinants of technical efficiency. The hypotheses in this study are categorically divided into: (1) influence of ego (personal) network on social capital asset or resource acquisition, influence of social capital asset or resource acquisition on (2) production and (3) adoption of sustainable management practices. Model specification in Figure 4.1 graphically illustrates these hypothesized relationships.

[H1] Hypothesis on Social Capital—The ego (personal) network of farmers positively influences the acquisition of social capital. The intimate linkage of social network and social capital theories is a fairly recent phenomenon that started to take off in the late 1990s. Borgatti, Jones, & Everett, Network (1998) and Lin (2001, 1999) are among those who early on recognized close connection in these two schools of thought in the social sciences. In an assessment of social network measures that formalize the notion of social capital, Borgatti, Jones, & Everett, Network (1998) identified that the greater number of social relationships one

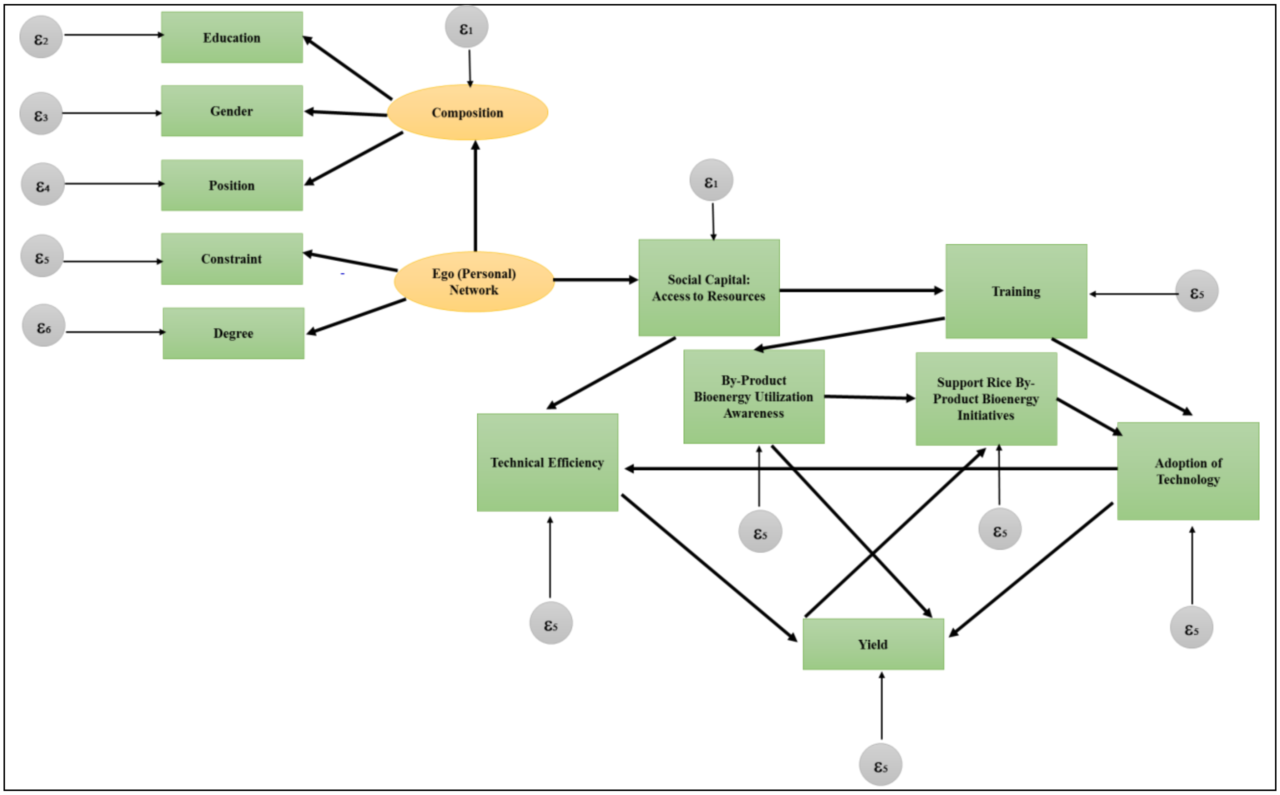

Figure 4.1: Model specification on the relationship between ego (personal) networks, social capital, productivity, technical efficiency, and sustainable management practices.

has, the increased chance that at least one of those connections has a useful asset or resource leading to more social capital. Further, using the structural hole measures that Burt (1992) proposed, the same assessment study determined that if a single individual dominates one's social network, this leads to fewer opportunities for the individual to access resources having possible valuable information. In a complementary research exploring deeper connection between social capital and social networks, Lin (1999) contended that when individuals invest in social relations, they gain access to resources that yield economic, political, and social returns. With these theoretical arguments, (see model specification in Figure 4.1), this study investigates the strength of ego (personal) network relationships and access to social capital assets and resources among farmers in Central Luzon.

[H2] Hypothesis on Social Capital and Production—Increase in technical efficiency and productivity of farmers is positively related with access to social capital assets and resources. Drawing from the social capital theory, Putnam (1993) argued that social capital does not only provide returns of investment but enhances the benefits of investments. Tying Putnam's (1993) discourse with economic production theory, Serageldin & Grootaert (1998) asserted that it is important to realize that social capital can be viewed as a production input and as a shift factor of the production function similar to technological innovations. At the farm-level, the impact of social capital on production is starting to be recognized. For instance, in Eastern Europe, Wolz, Fritzsch, Shterev, Buchenrieder, & Gomez y Paloma (2010) and Wolz, Fritzsch, & Reinsberg (2006) found that social capital functions are similar to traditional factors of production i.e., it increased not only agricultural income but also the efficiency of agricultural production in Bulgaria and Poland. Uphoff & Wijayaratna (2000) have similar findings in South Asia where they observed the role of social capital in increasing productivity and technical efficiency amidst water shortage specifically in the dry season.

[H3a] Hypothesis on Adoption of Water Conservation Practices—Access to social capital assets and resources positively influences the adoption of water conservation practices resulting in higher farmer efficiency and productivity. In agricultural sustainability theory, the major premise is the adoption of sustainable management practices for land and water resources as food production is impossible without these natural endowments (Hayati, Ranjbar, & Karami, 2010). In this regard, scholars have taken a particular interest in the nexus between social capital and technology diffusion theories. In the adoption of conservation practices in the rice sector, it is important to examine how, why, and at what rate sustainable practices and technologies are integrated in the production system. According to Rogers, (1995), technology and innovation diffusion is "communicated through certain channels over a period of time among the members of a social system." The social element in the diffusion process makes social capital a necessary component in the adoption of conservation practices that lead to higher farmer efficiency and productivity.[14]

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[14] Pretty & Ward (2001) documented the role of social capital in the adoption of new technologies and management practices for enhanced agricultural production and conservation. Social capital in the form of organizational engagement has been determined as a critical factor influencing the adoption of water harvesting and conservation programs in Burkina Faso, Niger, Kenya, and Guatemala. In the Philippines, Cramb & Culasero (2003) examined the influence of social capital on landcare programs, which includes adoption of soil and water conservation practices.

[H3b] Hypothesis on Support towards Bioenergy Initiatives—Access to social capital assets and resources positively influences awareness and support towards bioenergy initiatives leading to higher technical efficiency and productivity. In the rice sector, the concept of environmental sustainability is commonly emphasized in the land preparation, crop establishment, and crop care stages of production especially as it relates to land care, water utilization, and fertilizer application. For post-harvest rice production, not much emphasis is placed on sustainable management practices, particularly in dealing with post-harvest wastes such as rice husks and straws. The social capital, innovation systems, and actor network theories according to Devine-Wright, Fleming, & Chadwick (2001) provide system perspectives that are useful in understanding the interlinkages between access to social capital resources and support towards sustainable practices. The authors noted that actor network theory reflects the way in which a technology or practice gains acceptance as part of a normal custom. Through this theoretical perspective, this study can investigate how social capital influences the acceptance of using rice production waste products as an alternative energy source.

To investigate the plausibility of the above propositions as they relate to the rice communities in Central Luzon, this study identified a set of exogenous latent and observed variables as well as their endogenous counterparts. Table 4.1 lists all the variables included in the model specification. The level of education, gender, and position in community organizations of the members of the farmers' social network are the indicators for the endogenous latent variable composition. Degree, which is the number of people in the farmers' social network weighed against the strength of tie the farmer has per network member in terms of length of time known, and constraint, which represents limitations in the social investments of farmers within the particular social network, are the indicators composing the exogenous latent variable ego (personal) network. As an exogenous observed variable, social capital is the number of resources the farmer declares to have access to given his or her social network.[15] The remaining endogenous variables represent yield in metric tons per hectare, technical efficiency level, attendance at training sessions related to rice production, number of technology adoptions at the farm-level, water conservation practices adopted, and awareness and support towards the use of

[15] Please refer to preceding sections for more details.

rice production by-products, such as rice husks and wastes, as potential feedstock for bioenergy production.

Table 4.1: Variables included in the model specification corresponding to each hypothesis.

Variables	Exogenous	Endogenous
Latent	**[H1]:** Ego (Personal) Network	**[H1]:** Composition
Observed	**[H2], [H3a], and [H3b]:** Social Capital: Access to Resources	**[H1]:** Education, Gender, Position, Constraint, Degree, Social Capital: Access to Resources **[H2]:** Training, Adoption of Technology, Yield, Technical Efficiency **[H3a]:** Training, Adoption of Water Conservation Practices, Adoption of Technology, Yield, Technical Efficiency **[H3b]:** Training, Technical Efficiency, Adoption of Technology, Yield, By-Product Bioenergy Utilization Awareness, Support Rice By-Product Bioenergy Initiatives

When latent variables are included in the model, it is imperative to validate the reliability and consistency of the set of indicators describing such variables. This study estimated Cronbach alpha coefficients for each latent variable to validate reliability and consistency (Cronbach, 1951). As cited in prior research, a Cronbach alpha value that is greater than or equal to 0.70 indicates that the indicators are reliably related to each other and consistent in providing empirical meaning to the latent variables (Hurlimann, Hemphill, McKay, & Geursen, 2008). Along with the assessment of reliability and consistency of the indicators comprising latent variables, the specific model should also be examined for identification, which tests whether the results are unique for the variables included.[16]

To estimate the influence of each variable included in the model *vis-à-vis* each hypothesis, this study used pooled data from Nueva Ecija and Tarlac to represent Central

[16] For further information on how to determine if a model is identified, see Schumacker & Lomax (2012).

Luzon.[17] With pooled data, the study utilized the Stata 14 SEM statistical package to determine the direct and indirect effects of each variable using the maximum likelihood techniques. This is necessary since in contrast with standard multivariate linear regression models, variables in structural equation models reciprocally influence one another directly or as intermediary predictors (Bollen & Pearl, 2013; Wang, Wen, & Han, 2013; Hailu, Boxall, & McFarlane, 2005).

As a way to ascertain whether the data employed in the estimation supports the model, this study also assessed the goodness of fit of each model representing the hypotheses. As noted by Hailu, Boxall, & McFarlane (2005), the literature lacks consensus on the criteria used to assess goodness of fit of structural equation models. Given the situation, this study used a range of indices to examine model fit. The fit statistics include Chi-Square (χ^2/df), root mean squared error of approximation (RMSEA), comparative fit index (CFI), Tucker-Lewis index (TLI), and the standardized root mean squared residual (SRMR).

Results and Discussion

Examination of the influence of an individual's ego (personal) network on access to resources suggests that the build-up of social capital provide a fertile foundation for a deeper understanding of how the acquisition of such capital results in enhanced productivity and efficiency at the farm-level. Through the application of the ego (personal) network analysis and structural equation modeling techniques, this section presents empirical findings from key farming communities in Central Luzon. The discussion gives explicit focus to the dimensions of social capital and the relationships between social capital, production, and sustainability.

Head of Households, Landholdings, and Social Connections

In all villages in the study area, males are the dominant head of households with an average age of 54 in Nueva Ecija and 51 in Tarlac. Majority of the male farmers have attained eight years of formal schooling, which is equivalent to two years of high school education. In terms of rice farming experience, farmers in Nueva Ecija have four additional years of farming practice compared to Tarlac farmers. A typical rice farming household of five members in Nueva

[17] This study examined the plausibility of combining the data sets from the provinces of Nueva Ecija and Tarlac by performing t-tests to examine significant differences among variables.

Ecija generates Ph₽50,000 more income from rice production than households in Tarlac.[18] Table 4.2 summarizes the socio-demographic characteristics of the farm households.

Table 4.2: Characteristics of farm households (farm head of households).

Variables	Description	Nueva Ecija (n=294)		Tarlac (n=150)	
		Mean	Standard Deviation	Mean	Standard Deviation
Age	Age	53.55	12.35	50.67	12.01
Education	Number of years of formal schooling	8.46	3.00	7.79	2.98
Experience	Number of years of rice farming experience	31.62	14.49	27.73	14.79
Size	Number of people in the household	4.80	1.91	5.13	2.01
Income	Annual rice farming income of the household (in Philippine Pesos)	157,596.10	195,479.50	107,687.80	98,469.55

Note: The means of all variables are statistically different for the two study sites with the exception of the number of people in the household.

Farmers in the two municipalities are largely small-scale rice producers with an average landholding of less than two hectares per household. As shown in Table 4.3, agricultural land accounts for more than 90 percent of the total landholding of most farmers. Largest rice parcels in Nueva Ecija and Tarlac ranges between one to 1.35 hectares.

Given the modest size of the rice land, farmers in Nueva Ecija, on average, are able to produce 6.76 metric tons of rice per hectare during the 2013 dry season (December 2012 to May 2013). In the wet season (June to November 2013), they produced, on average, 4.63 metric tons per hectare. On average, rice yields in Tarlac are about 57 percent less than yields in Nueva Ecija during the dry season and 64 percent less in the wet season. At this production rate, the average levels of technical efficiency[19] of farmers in Nueva Ecija are between 92 and 82 percent for the

[18] The peso-dollar conversion as of 31 December 2013 is US$ 1 = Ph₽ 44.45 according to http://www.oanda.com/currency/converter/.

[19] Technical efficiency commonly refers to the measure of how one can produce more with less – more output with less inputs or resources used given the best available technology.

dry and wet seasons, respectively. Tarlac farmers attained an 80 percent average level of technical efficiency in the dry season and a mean efficiency level of 76 percent in the wet season.

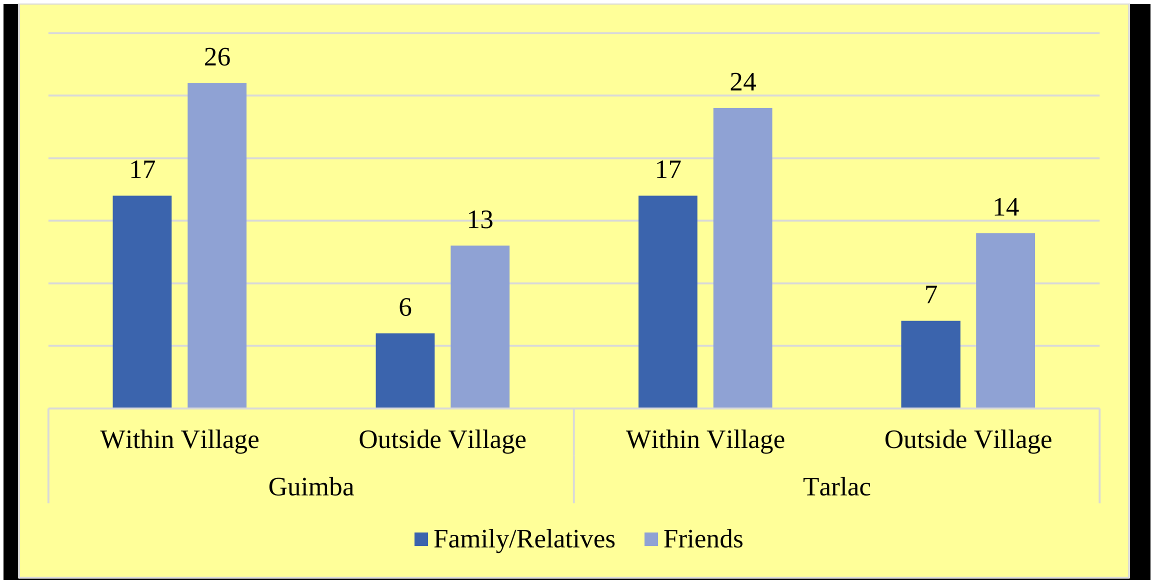
Table 4.3: Characteristics of landholdings and farm production.

Variables	Description	Nueva Ecija (n=294)		Tarlac (n=150)	
		Mean	Standard Deviation	Mean	Standard Deviation
Total Land	Total farm and non-farm landholdings (in hectares)	1.38	1.53	1.73	1.20
Ag Land	Agricultural landholdings (in hectares)	1.25	1.43	1.57	1.02
Rice Land	Size of largest parcel (in hectares)	1.00	0.79	1.35	0.90
Yield	Yield per hectare during the dry season (in metric tons per hectare)	6.76	1.68	3.84	1.41
	Yield per hectare during the wet season (in metric tons per hectare)	4.63	1.24	2.96	2.02
Technical Efficiency	Level of technical efficiency during the dry season (in percentage)	92.30	7.80	80.30	16.50
	Level of technical efficiency during the wet season (in percentage)	82.30	13.50	75.90	17.90

Note: The means of all variables are statistically different for the two study sites.

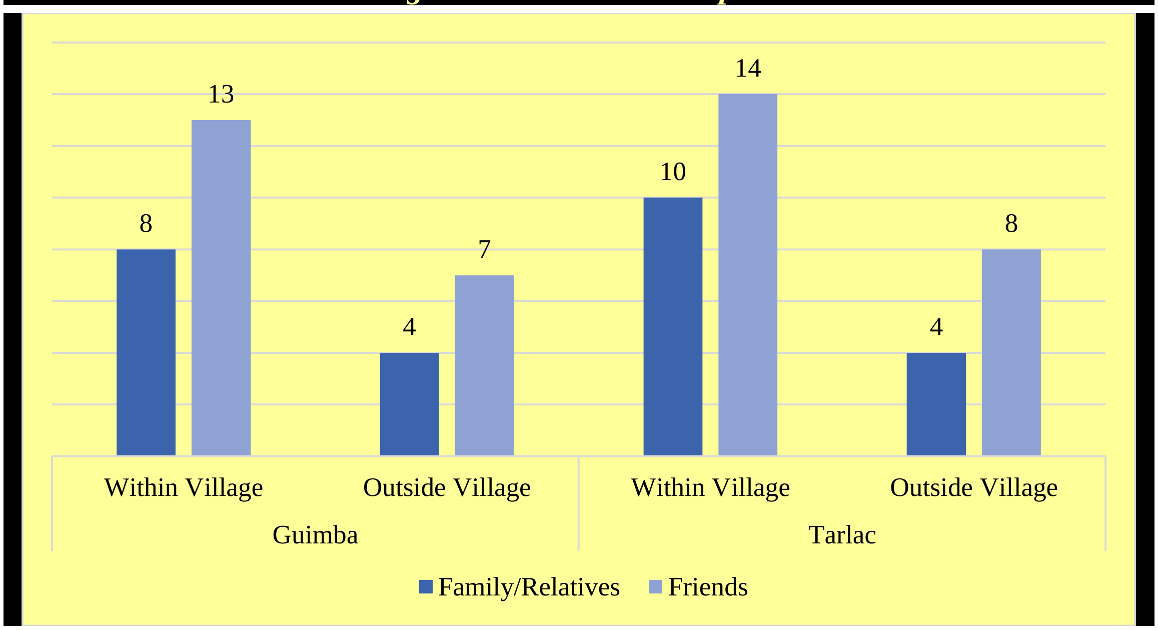
The social relationships of farmers in Guimba and Tarlac are correspondingly the same. The number of family members and friends that farmers come in contact with regardless of issues or topics of interest are not significantly different with an average of 62 individuals for both Nueva Ecija and Tarlac (Figure 4.2 and Appendix A). When dealing with agricultural-related issues, farmers in Tarlac have social connections with more family and friends within the same village compared to the rice growers in Nueva Ecija.

Generic Issues or Topics



Notes: (1) Family and relatives refer to the average number of family members or relatives regularly talked to and approached regardless of issue or topic (at least once a month). (2) Friends refer to the average number of people considered as friends regularly talked to and approached regardless of issue or topic (at least once a month).

Agricultural Issues or Topics



Notes: (1) Family and relatives refer to the average number of family members or relatives regularly talked to and approached regarding agricultural issues (at least once a month). (2) Friends refer to the average number of people considered as friends regularly talked to and approached regarding agricultural issues (at least once a month).

Figure 4.2: Characteristics of social connections of farmers in Central Luzon.

Dimensions of Social Capital of Central Luzon Farmers

Social capital has three distinct dimensions—structural, relational, and cognitive (Nahapiet & Ghoshal, 1998). Structural mainly pertains to the pattern of connections and relationships between and among the farmers and the social network, which this study assessed through standard ego (personal) network and structural hole measures. The relational dimension relates to the type and degree of social connections farmers have established through time. The cognitive facet of social capital refers to various social components shared within the network, which can include shared interpretation and representation. In this study, reciprocity among farmers captures the shared element of the cognitive dimension.

Structural Dimension. Farmers in Central Luzon have established relationships with individuals who are predominantly male between 49 and 50 years old who have completed basic education (43 percent) and general education (47 percent). As Table 4.4 and Appendix B show, only six percent of the farmers' ego (personal) network are females. This is typical of a farming-oriented region (Haugen, 1998) and is not surprising since the majority of farmers in the region are males as well.

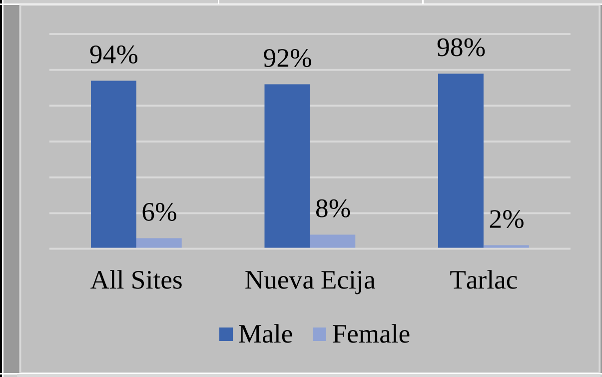
Between the two sites, Nueva Ecija and Tarlac, the structural characteristics of social capital are consistent. Farmers in the region have known the key individuals within their network between 30 and 32 years. This suggests that with the average age of farmers at 53, they have developed relationships with their network since their early 20s giving them solid social connections. This level of connection is expected when the average distance of the farmer from members of the ego (personal) network is less than a kilometer.

It is apparent that farmers in Central Luzon have connections not only with people who participate in community activities but also those holding key positions. About 87 percent of the farmers indicated that members of their social network are eminent members of the community (e.g., village head, officers at key organizations, and local politicians among others). Approximately 68 percent of the farmers characterize their ego (personal) networks as active participants in community organization.

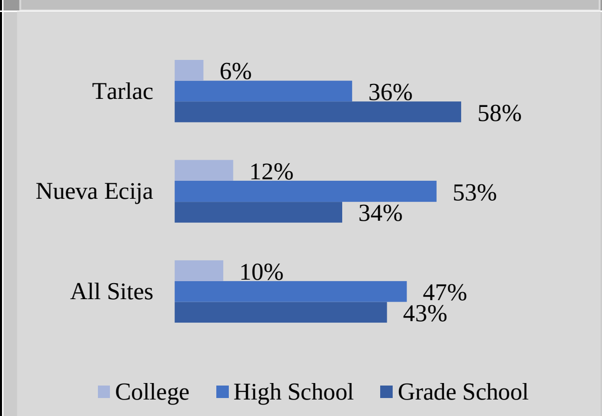
Table 4.4: Sociodemographic composition of the ego (personal) networks of farmers in Central Luzon.

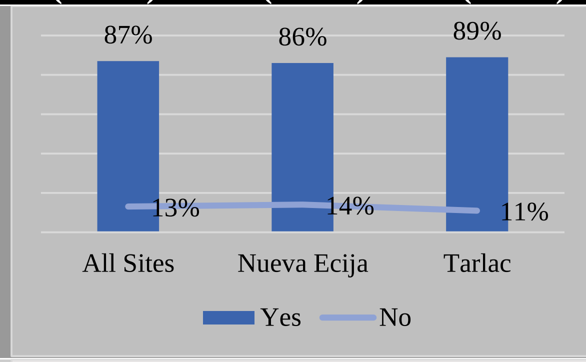
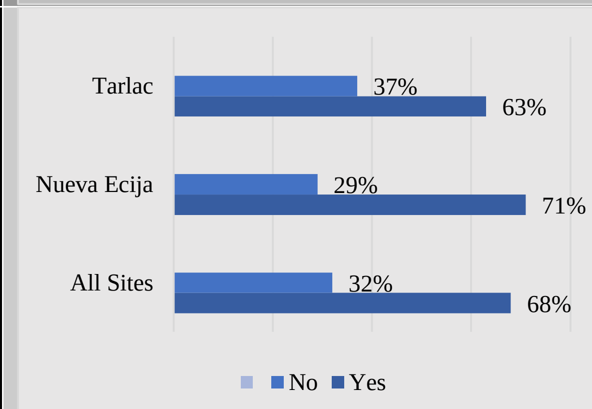
Ego (Personal) Network Sociodemographic Variables	All Sites (n=444)	Nueva Ecija (n=294)	Tarlac (n=150)
Alters			
Key Members of the Ego Network (Total)	2119	1372	747
Age			
Mean (in years)	48.89	48.52	49.60
Standard Deviation (in years)	7.46	7.84	6.61
Proximity(1)			
Mean (kilometers)	0.66	0.76	0.45
Standard Deviation (kilometers)	2.01	2.42	0.68
Length of Time Known(1)			
Mean (in years)	30.96	31.63	29.63
Standard Deviation (in years)	12.41	12.64	11.88

Gender



Education



Ego (Personal) Network Sociodemographic Variables	All Sites (n=444)	Nueva Ecija (n=294)	Tarlac (n=150)
Holding Position in Community			
Active in Village or Community Organizations			

Note: The means of all variables are statistically different at 95% confidence level for the two study sites with the exception of the age of the ego (personal) networks.

Recognizing the disconnection within a farmers' ego (personal) network is as important as understanding the close linkages. The dissociation in a network is commonly assessed using the structural hole measures proposed by Burt (1992). Results in Table 4.5 show that through assessment of names provided by the farmers, their social network exhibit high heterogeneity as demonstrated by HHI and IQV being closer to one.[20] This suggests that there is a high level of diversity in terms of different individuals making up the network, which according to Borgatti, Jones, & Everett (1998) has a positive influence on social capital accumulation. The low HHI and IQV values for gender are explained by the predominance of males in the network. The diversity in educational attainment is demonstrated by mid-range HHI and IQV.

[20] The heterogeneity indices range from zero to one, with one indicating the highest level of heterogeneity or diversity. The individual, gender, and education HHI and IQV are all statistically different from one. An index value closer to zero indicates that farmers fall into one particular category (see gender). An index value closer to one implies that there is good distribution of farmers in a given category such as the name (individual) category.

Table 4.5: Distribution of Central Luzon farmers' ego (personal) networks and structural hole measures vis-à-vis their theoretical relation to social capital.

Measure	All Sites (n=444)	Nueva Ecija (n=294)	Tarlac (n=150)	Relation to Social Capital [b]
Degree[a] The number of people in the farmers' network that the farmers are directly connected to weighted by strength of tie (length of time known).[b]				**Positive:** The more people you have relationships with, the greater the chance that one of them has the resource you need.
Mean	4.78	4.68	4.98	
Standard Deviation	0.60	0.70	0.18	
Heterogeneity The variety of people in the farmers' network with respect to relevant dimensions (e.g., gender, age, race, occupation, talents, etc.).[b]				**Positive:** Except when it conflicts with compositional quality. Compositional quality refers to the number of alters with high levels of needed characteristics such as total wealth or power or expertise or generosity.
HHI (Individual)[a]	0.78 (0.06)[c]	0.78 (0.07)[c]	0.80 (0.02)[c]	
IQV (Individual)[d]	0.99 (0.05)	0.99 (0.06)	0.99 (0.01)	
HHI (Gender)[a]	0.03 (0.11)	0.04 (0.13)	0.01 (0.08)	
IQV (Gender)[a]	0.07 (0.22)	0.09 (0.25)	0.03 (0.15)	
HHI (Education)[d]	0.32 (0.24)	0.33 (0.23)	0.30 (0.24)	
IQV (Education)[d]	0.58 (0.41)	0.59 (0.41)	0.54 (0.43)	
Constraint[a] The extent of connectivity to which all of the farmers' relational investments directly or indirectly involve a single or more individuals.[b]				**Negative.** The more constrained the actor, the fewer opportunities for action.
Mean	0.22	0.23	0.21	
Standard Deviation	0.06	0.06	0.03	
Hierarchy[d] The extent to which the constraint measure is monopolized by a single alter.				**Negative.** There is monopoly to information and access to resources when there is higher hierarchical dominance of an actor.
Mean	0.04	0.05	0.04	
Standard Deviation	0.09	0.10	0.08	

Notes:

[a] The mean measure difference in Nueva Ecija and Tarlac is statistically significant at 95% confidence level.

[b] The definitions are modified from Borgatti, Jones, & Everett (1998).

[c] Figures in parentheses are standard deviation estimates. Those without parentheses are mean estimates

[d] The mean measure difference in Nueva Ecija and Tarlac is not statistically significant at 95% confidence level.

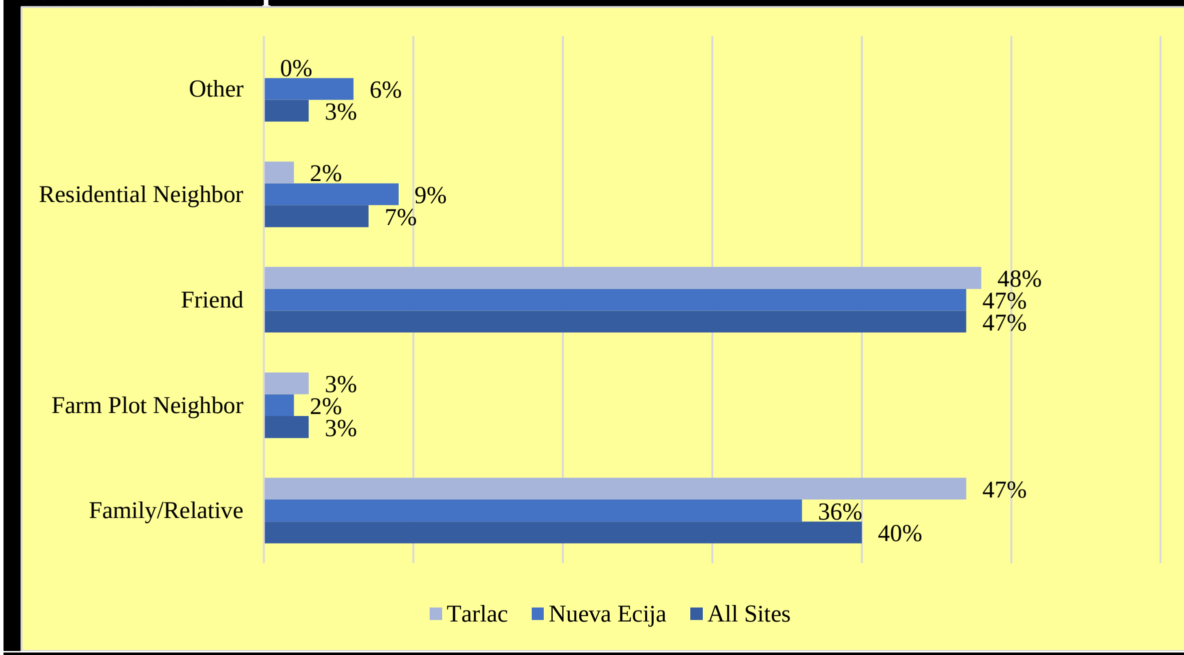
Burt (2000) asserted that an ego (personal) network is highly constrained when members have strong connections to another or there is a member monopolizing the connections (i.e., all are connected to this member only and there are no other connections among other members). When the latter is the apparent case, the network tends to be hierarchical. Borgatti, Jones, & Everett (1998) expressed that highly constrained and hierarchical ego (personal) networks negatively influence the acquisition of social capital. When one or two individuals are the key members connecting the network, it is likely that they hold resources and information which unconnected members are unable to access. In this study, the hierarchy level is very low, which implies that within the ego (personal) networks of the farmers, no single individual dominates the network. This finding is complemented by the level of constraint exhibited by the farmers' network, which suggests some degree of connections between and among the members of the network.

Relational Dimension. Atuahene-Gima & Murray (2007) note that in examining the relationship dimension of social capital, trust and supportive group norms are key elements as they demonstrate the quality of relationships. Following the relational dimensions summarized in Acquaah, Amoako-Gyampah, & Nyathi (2014), this study assessed the social capital of farmers in Central Luzon from a relational perspective. As shown in Table 4.6 and Appendix C, most of the social relationships of farmers in Central Luzon equally revolve around family members and people they consider as friends who they interact with almost daily. Given the types of social relationship and the level of sociability among farmers in the region, it is not surprising that the majority of farmers have a high level of closeness with the members of their social network. The social cohesion exhibited by the closeness of the network members allow the farmers to place a high level of trust on their ego (personal) networks that at the time of crisis they know that they can rely on them. In communities where the networks are comprised of family members and friends, this is the expected scenario. The levels of sociability, social cohesion, trust, and social support among farmers in Central Luzon foster an environment where people gain security and opportunity to explore ways that help them enhance their social capital (Atuahene-Gima & Murray, 2007).

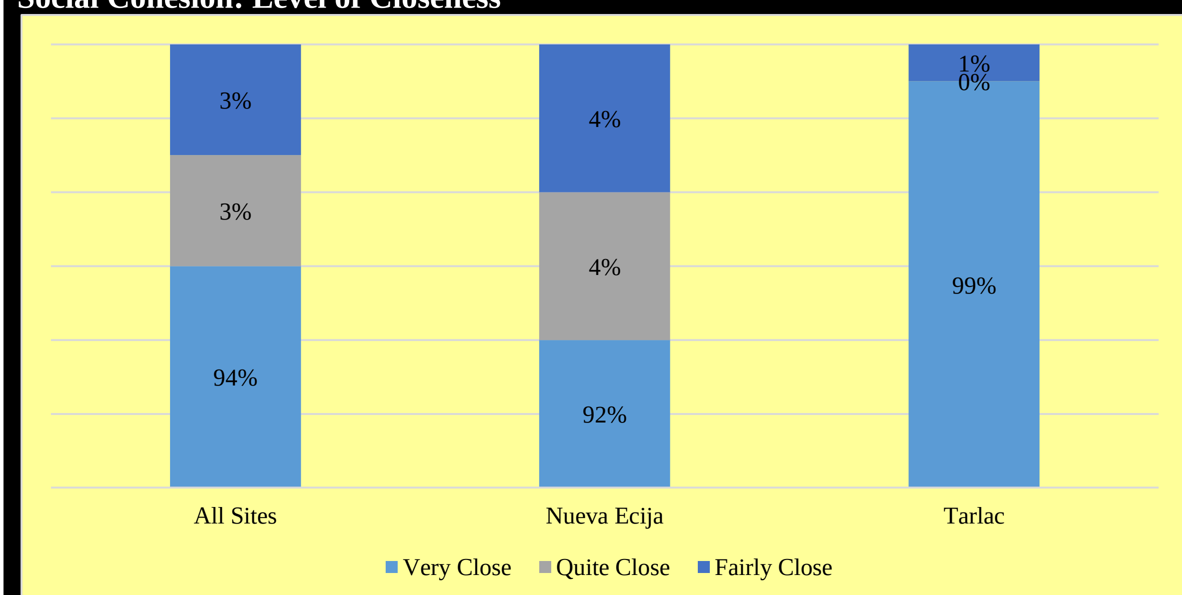
Table 4.6: Relational dimension of social capital among farmers in Central Luzon.

Measures of Relational Dimension[a]	All Sites (n=444)	Nueva Ecija (n=294)	Tarlac (n=150)
Alters			
Key Members of the Ego Network (Total)	2119	1372	747
Sociability: Frequency of Contact[b]			
Mean (in days per month)	26.35	26.41	26.25
Standard Deviation (in days per month)	6.68	6.36	7.28

Social Relationship

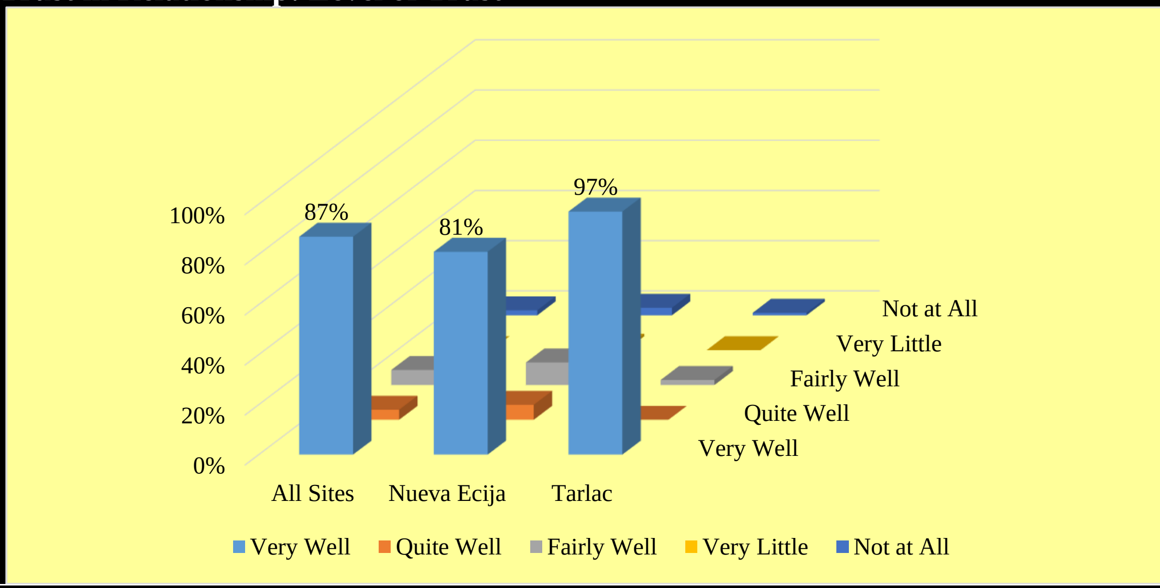


Social Cohesion: Level of Closeness

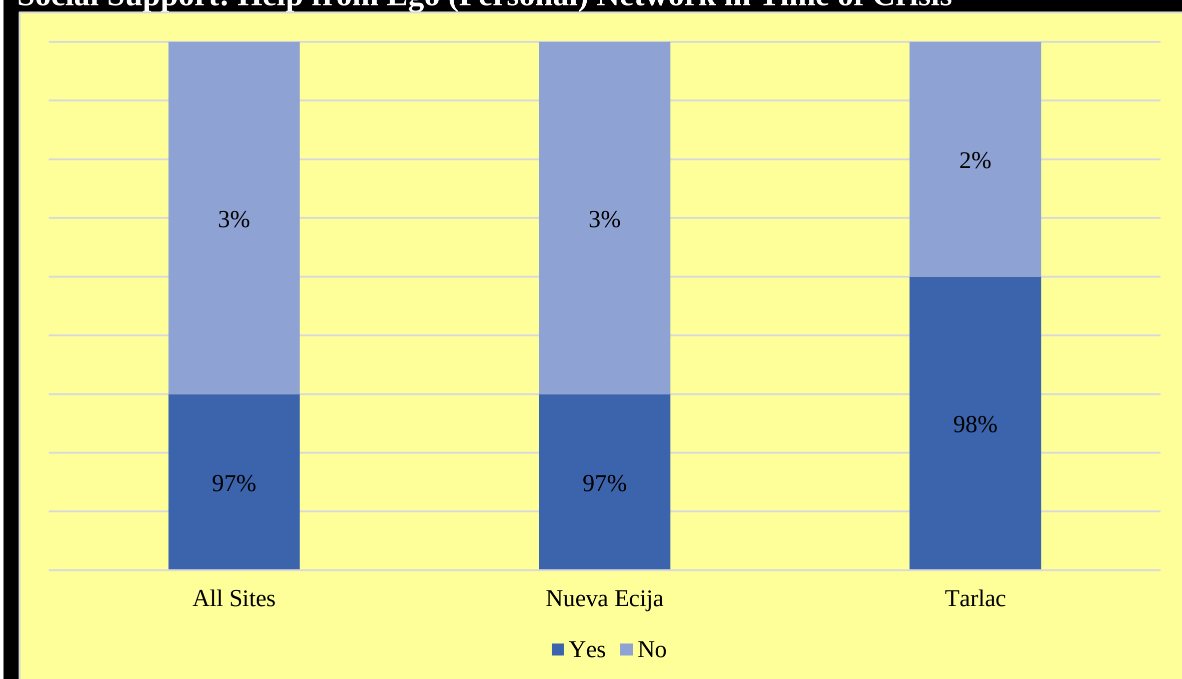


Measures of Relational Dimension[a]	All Sites (n=444)	Nueva Ecija (n=294)	Tarlac (n=150)

Trust in Relationship: Level of Trust



Social Support: Help from Ego (Personal) Network in Time of Crisis



Notes:
[a] The measures of relational dimension are adapted from Acquaah, Amoako-Gyampah, & Nyathi (2014).
[b] The mean frequency of contact between farmers and alters in Nueva Ecija and Tarlac is not statistically significant at the 95% confidence level. The most common mode of contact is face-to-face. Nueva Ecija farmers exhibit this form of contact to 96 percent of the members of their ego (personal) network. In Tarlac, face-to-face interaction is the only form of contact of farmers with the members of their ego (personal) network.
[c] Other under social relationship includes agricultural extension worker, co-worker, fellow church member, and fellow member in the same community organization.

Cognitive Dimension. Because the premise of this dimension is shared goals, norms, and culture, this study followed the norms of reciprocity proposed in Acquaah, Amoako-Gyampah, & Nyathi (2014) as measures of the cognitive dimension of social capital. Reciprocity is inherent in any social relationships and its effectiveness is a function of time (i.e., repeated contact) (Ferguson, 2013). It commonly involves exchanges to transfers of goods, services, information, and knowledge among others. In this study, the reciprocal relationship between the farmers and their ego (personal) networks is assessed through a myriad of factors such as technical information, financial favor, and labor exchange.

Farmers acknowledge that between them and their ego (personal) network, more often than not, they are the ones seeking advice from the members of their network especially on rice production issues (Table 4.7). Despite the fact that the farmer is the one commonly seeking advice, results show that the relationship is mutual as 98 percent of the farmers disclosed that there is reciprocal exchange of technical information in the community. The reciprocity seems to decline when mutual exchange involves money and farm labor. This is understandable in communities where there is scarcity in financial resources and limited availability of farm laborer. Even with the unevenness in the reciprocity distribution, it appears that reciprocal behavior is institutionalized in the rice communities in Central Luzon, which according to Ferguson (2013) motivates an atmosphere of trustworthiness leading to enhanced exchange and transfer of assets and resources.

Social Capital Assessment

The perception of social capital as an abstract concept makes it challenging to account quantitatively for its totality. Cognizant of this difficulty in measurement, Van der Gaag & Webber (2008) suggested that to quantify an individual's social capital, one must know the types of resources a person gets access to because of the social relations established. In addition to being able to identify the assets and resources, it is important to determine the probability of access to each of the resource.

Due to the nature of how the question was framed during the data collection, this study assumed a zero and one probability of access to the resources. If a farmer identified a particular resource, it is given an access probability of one for that farmer. This oversimplifies the estimation of social capital in terms of the measurement proposed by Van der Gaag & Webber (2008).

Table 4.7: Cognitive dimension of social capital among farmers in Central Luzon.

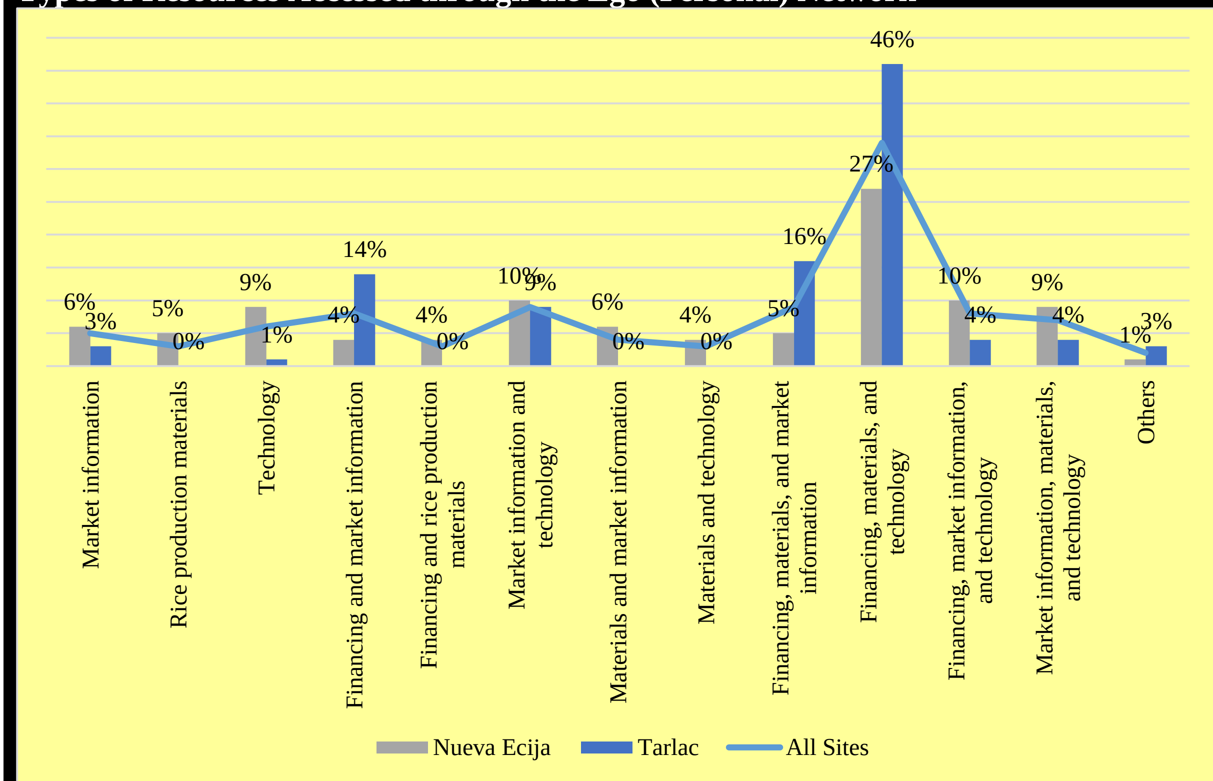
Measures of Cognitive Dimension	All Sites (n=444)	Nueva Ecija (n=294)	Tarlac (n=150)
Alters			
Key Members of the Ego Network (Total)	2119	1372	747
Reciprocity: Who Usually Seeks Advice on Rice Production?			
Farmer/head of household respondent (%)	52	50	56
Member of ego (personal) network (%)	37	40	33
Both (%)	10	10	11
Reciprocity: Rice Production Technical Information Exchange			
Yes (%)	98	98	99
No (%)	2	2	1
Reciprocity: Exchange of Financial Favors			
Yes (%)	72	80	58
No (%)	28	20	42
Reciprocity: Physical /Human Labor Exchange During Planting and Harvesting			
Yes (%)	57	52	68
No (%)	43	48	32

Note: The measures of cognitive dimension are adapted from Acquaah, Amoako-Gyampah, & Nyathi (2014).

The combined types of resources that most farmers access through their social network include financial resources and technological information as well as materials and equipment. This is reflected in the response of 34 percent of the farmers in the region (Table 4.8 and Appendix D). The types of resources identified by the farmers are consistent with the norms of reciprocity. In the assessment of the cognitive dimension of social capital, the farmers indicated that majority of them exchange technical information on farming, which is basically related to technological resources. The farmers also affirmed that more than half of them participate in financial resource exchange through informal or formal loans or credit.

Table 4.8: Social capital assessment in terms of access to resources.

Social Capital Measures in Terms of Access to Various Forms of Assets or Resources	All Sites (n=444)	Nueva Ecija (n=294)	Tarlac (n=150)
Alters			
Key Members of the Ego Network (Total)	2119	1372	747
Types of Resources Accessed through the Ego (Personal) Network			



Note: The basis of this assessment is the social capital measurement proposed by (Van der Gaag & Webber, 2008).

Ego (Personal) Network and Social Capital

Consistent with the work of Coleman (1988) and Burt (1992) on the social network theory, Adler & Kwon (2002) noted in a comprehensive review of the concept of social capital that the social network theory strongly influences social capital research as is reflected in the ego (personal) variant of the network analysis. They argued that the accumulation of social capital lies in the structure and composition of an individual's social relations. More often than not social network yields positive externalities or benefits that lead to an aggregation of social capital resources (Glaeser, Laibson, & Sacerdote, 2002). To examine if this theoretical view of having established ego (personal) network helps in the build up of one's social capital, this study investigated the social relationships among famers in Central Luzon through a structural equation model (SEM).

Social network such as the ego (personal) networks are commonly associated with the number of friends, colleagues, or associates that one is connected to. As such, the typical way of assessing it is by simply counting the individual social connections one has. This study, however, estimated the ego (personal) network concept beyond the tally/enumeration approach by setting it as a latent variable described by a set of compositional indicators including education, gender, and position as well as structural hole indicators such as constraint and degree. Results show that these items are consistent and reliable composite indicators for the ego (personal) network latent variables as its estimated Cronbach alpha coefficient is 0.92, which is greater than the 0.70 minimum requirement (Table 4.9). This suggests that selected indicators adequately represent the latent variable.

Table 4.9: Scale reliability of the latent variables.

Latent Variable	Measured Indicator	Distribution (n=444)	Cronbach Alpha
Composition	Level of education	Grade School (43 %) High School (47 %) College (10 %)	0.70
	Gender	Male (94 %) Female (6 %)	
	Position in a community organization	Yes (87 %) No (13 %)	
Ego (Personal) Network	Degree	Mean (4.78) Standard Deviation (0.60)	0.92
	Constraint	Mean (0.22) Standard Deviation (0.06)	

Given the soundness of the indicators selected, the two-step SEM procedure recommends that in addition to the validity assessment of the indicators for the measurement model, it is necessary to examine the fitness of the specified model. The goodness of fit statistics indicate that the data for the measurement model presented in Figure 4.3 are adequately represented by the model. The combination of observed variables, education, gender, position, constraint, and degree, together with composition and ego (personal) network as the latent construct shows a $\chi^2$of 6.769 ($prob = 0.149$), an RMSEA of 0.040, a CFI of 0.998, and an SRMR of 0.015.

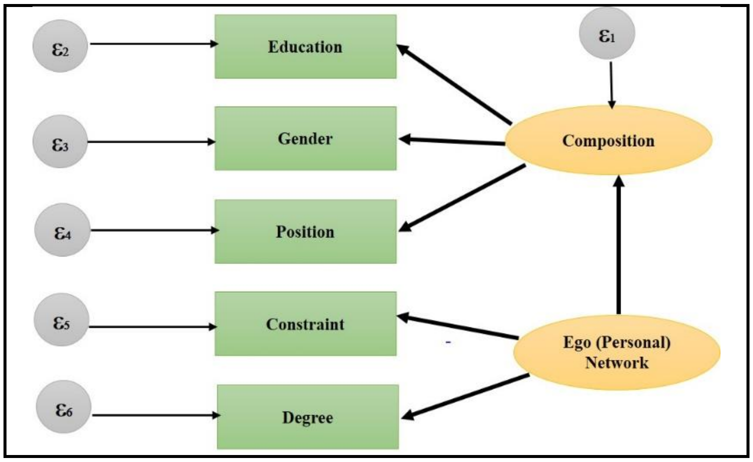


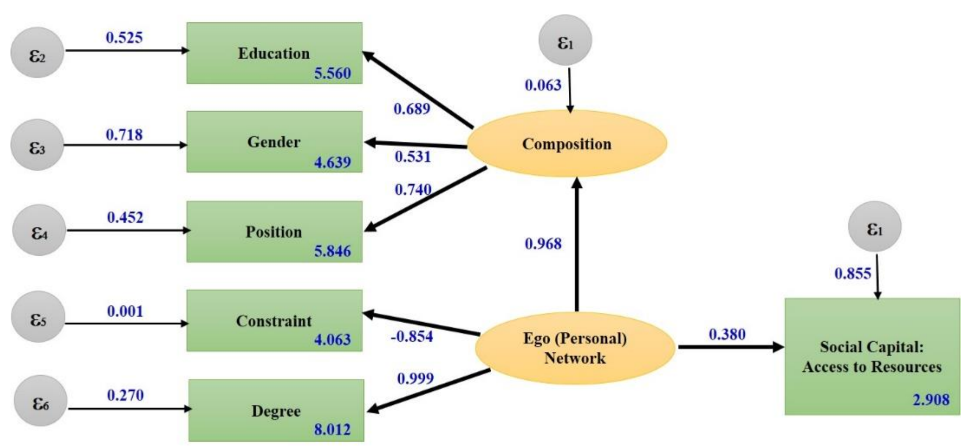
Figure 4.3: Latent construct structure.

To shed light on the hypothesis that the ego (personal) networks of farmers in Central Luzon have beneficial effect on their social capital acquisition, the social capital variable was added to the latent construct. The SEM analysis showed that the farmers social relations through their ego (personal) networks yields a positive effect on building up their social capital assets and resources, which include financing, market information, and technology. Table 4.10 lists the standardized direct and indirect effects in the model. According to Tsai (2014), direct effects pertain to the influence of one variable on another and are graphically represented by a single path. Indirect effects measure the impact of a variable on another as mediated by one or more variables. Total effects are simply the sum of the direct and indirect effects.

Results presented in Table 4.10 demonstrate that a one standard deviation increase in ego (personal) network of farmers in Central Luzon leads to a 0.380 increase in social capital resources. This is consistent with social network and social capital theories and suggests that with established social relations, farmers can gain access to resources that may help enhance their well-being. Although there is a paucity of studies investigating the same effect at the farm-level, the results of this study are nonetheless conceptually analogous to the general findings of other researchers applying different analytical techniques that social networks positively influence social capital at either the individual or firm level (see Inkpen & Tsang, 2005; Gargiulo & Benassi, 2000).

Table 4.10: Standardized effects of ego (personal) network on access to social capital assets and resources in tabulated and graphical formats.

Hypothesis on Social Capital: *The ego (personal) network of farmers positively influences the acquisition of social capital.*				
Variables	**Path**	**Direct Effects**	**Indirect Effects**	**Total Effects**
Education	←Composition	0.689	*no path*	0.689
	←Ego (Personal Network)	*no path*	0.667	0.667
Gender	←Composition	0.531	*no path*	0.531
	←Ego (Personal Network)	*no path*	0.514	0.514
Position	←Composition	0.740	*no path*	0.740
	←Ego (Personal Network)	*no path*	0.716	0.716
Constraint	←Ego (Personal Network)	-0.854	*no path*	-0.854
Degree	←Ego (Personal Network)	0.999	*no path*	0.999
Access to Social Capital Resources	←Ego (Personal Network)	0.380	*no path*	0.380
Composition	←Ego (Personal Network)	0.968	*no path*	0.968



Note: All coefficients are significant at 1%. Model fit: $\chi^2 = 7.046$ ($prob = 0.532$), $RMSEA = 0.000$, $CFI = 1.000$, $TLI = 1.001$, $SRMR = 0.014$.

If the policy intent is to increase the stock of farmers' social capital, it is therefore imperative to implement courses of action that would provide an environment for interaction between and among the network members. In this regard, the government can provide the enabling environment as well as the "basic ambience of rule-governed behavior" to promote productive informal social ties, enhance social capital and facilitate capacity building of farmers (Cavaye, 2000; Evans, 1996). The government can introduce a balance spectrum of interaction among farmers and position itself as a partner and facilitator of enhancing social network connections (Cavaye, 2000). Government programs, according to Evans (1996) can combine social capital formation with the delivery of public services. For instance, it can scale-up existing programs such as the farmer field school by providing additional transportation services to farmers so that rice producers from different communities can get together and interact through experiential learning beyond the borders of their farms. Some of the other possible programs that local governments can implement in cooperation with community organizations are the sponsorship of regular talk story breakfast or after work relaxer that offer farmers a venue and an atmosphere for resource exchange or transfer. These activities are proposed in addition to participation in other community organization meetings and trainings.

Social Capital, Productivity, and Technical Efficiency

The role of social capital in the agricultural sector has been well recognized particularly in rural communities in developing countries (Winters, Crissman, & Espinosa, 2004). In those parts of the world, the majority of the cases linking social capital to crop production and farm-level technical efficiency measure such type of capital through participation or membership in community organizations (see Solıs, Bravo-Ureta, & Quiroga, 2009; Katungi, Smale, Machethe, & Tushemereirwe, 2007; Binam, Tonye, Wandji, Nyambi, & Akoa, 2004; and Gorton & Davidova, 2004 among others). Veering off from this conventional way of assessing social capital and following Van der Gaag & Webber (2008) estimation, this study measured social capital in terms of the quantity and type of resources the farmers acquire due to the relationships they have developed with their family, friends, neighbors, co-workers, and even acquaintances. The influence of social capital on the technical efficiency and productivity of farmers in Central Luzon is then assessed through structural equation models (SEM).

This study posited that social capital can directly influence farm-level technical efficiency as demonstrated in other studies (see Omotesho, Falola, & Oshe, 2015; Solıs, Bravo-Ureta, & Quiroga, 2009; Binam, Tonye, Wandji, Nyambi, & Akoa, 2004). Further, productivity in terms of yield per hectare is assumed to be indirectly impacted by social capital through intermediary variables such as training and adoption of technology. The survey revealed that about 50 percent of the farmers participate in agricultural training offered by different organizations. Of those taking part in the training, they explained that they learn about training programs through their ego (personal) networks and it is through the training that they gain awareness of new technology or farm innovations, which usually aim to help farmer enhance production. On average, farmers in Central Luzon adopted three agricultural innovations in the 2013 cropping season.

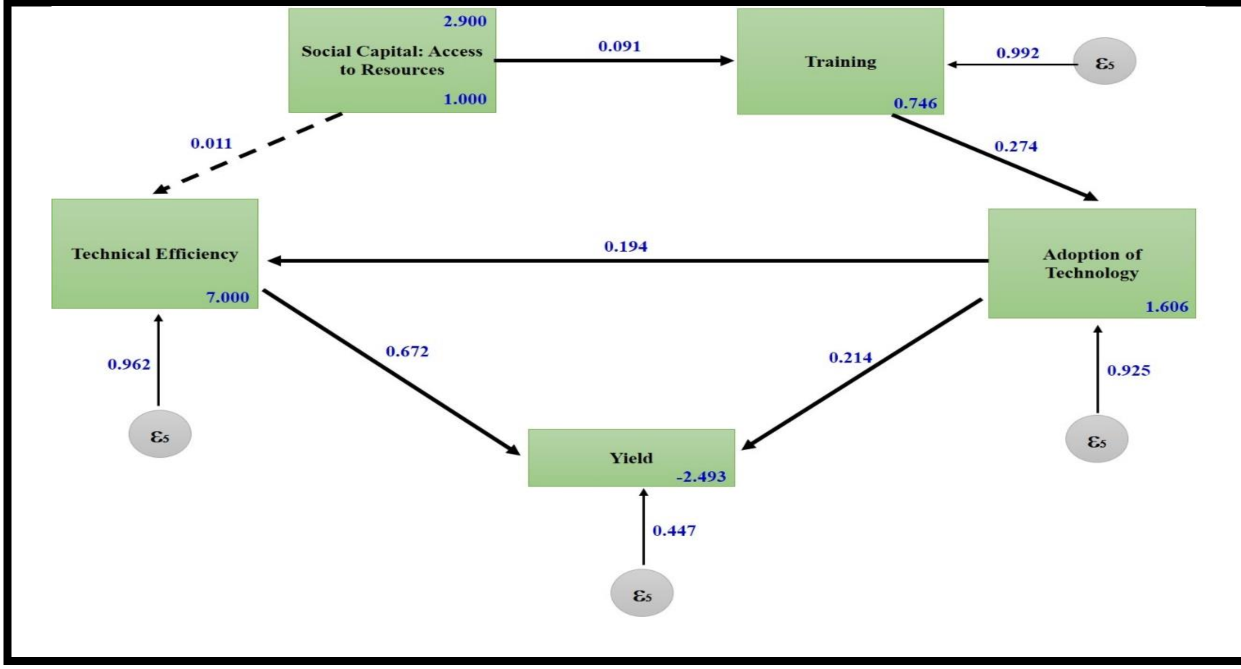
Results confirmed that social capital positively influences technical efficiency and rice yield. Table 4.11 explicitly shows that social capital in the context of this study has positive but statistically insignificant direct effect on technical efficiency. Indirectly, however, SEM results exhibit a positive and statistically significant impact on technical efficiency via training and adoption of technology. The analysis further demonstrates that through the information acquired from their social relations, farmers learn about programs that enable them to learn and get trained about farm technology and innovations, which leads to increased technical efficiency. As the results show, a one standard deviation increase in social capital leads to a 0.005 standard deviation increase in technical efficiency. Thus, given the average technical efficiency of 84.27 percent in Central Luzon with a standard deviation of 11.41 percent, farm-level efficiency can increase by 0.06 percent.

Table 4.11: Standardized effects of access to social capital assets and resources on technical efficiency and productivity in tabulated and graphical formats.

Hypothesis on Social Capital and Production: *Increased in technical efficiency and productivity of farmers is positively related to access to social capital assets and resources.*				
Variables	**Path**	**Direct Effects**	**Indirect Effects**	**Total Effects**
Training	←Social Capital: Access to Resources	0.091**	*no path*	0.091**
Technical Efficiency	←Training	*no path*	0.053***	0.053***
	←Adoption of Technology	0.194***	*no path*	0.194***
	←Social Capital: Access to Resources	0.011	0.005*	0.016
Yield	←Training	*no path*	0.095***	0.095***
	←Technical Efficiency	0.672***	*no path*	0.672***
	←Adoption of Technology	0.214***	0.131***	0.345***
	←Social Capital: Access to Resources	*no path*	0.016	0.016
Adoption of Technology	←Training	0.274***	*no path*	0.274***

Hypothesis on Social Capital and Production:
Increased in technical efficiency and productivity of farmers is positively related to access to social capital assets and resources.

Variables	Path	Direct Effects	Indirect Effects	Total Effects



Notes:
[a] *** significant at 1%, ** significant at 5%, * significant at 10%.
[b] – – –▶ refers to a path that is statistically not significant. Solid lines represent statistically significant paths.
[c] Model fit: $\chi^2 = 34.477$ ($prob = 0.000$), $RMSEA = 0.131$, $CFI = 0.930$, $SRMR = 0.051$.

Primarily, the total effects of social capital on training, technological adoption, yield, and technical efficiency are all positive and significant with the exception of insignificant direct and indirect effect on yield. The insignificant effect on yield is possible since social capital in this context is composed of access to technology, financing, planting materials, and equipment, which are not direct inputs to rice production. Nonetheless, training and technological adoption, which is positively impacted by social capital, can directly and indirectly increase yield by 0.095 and 0.345 units, respectively.

The results, in part, support the hypothesis on the impacts of social capital on production and technical efficiency. Social capital positively, yet indirectly, influences technical efficiency significantly, whereas impact on yield is insignificant. This can be attributed to the model fit, which shows that the model provides an adequate fit to the data given that the CFI and SRMR criteria are met while χ^2 and RMSEA fail to meet the recommended fit statistic. Although this is the case, the goodness of model fit is indicative that the model is acceptable (O'Rourke & Hatcher, 2013).

Because social capital facilitates the access to technology leading to higher level of efficiency, it is important for policy makers and agricultural workers to consider social relations within a target region before deployment of any technological innovations. It is necessary that the development of technical efficiency-enhancing programs take into account how farmers gain access to social capital resources. Engagement of different community groups might be necessary for successful implementation.

Social Capital and Sustainable Management Practices

Agriculture is one of the key sectors where the application of the diffusion of innovations (DOI) theory can be empirically observed. The focus of the DOI theory is on the adoption of a new idea or technological breakthrough. Since the Green Revolution, there has been a vast number of empirical literature documenting the diffusion and adoption of agricultural technology.

Diffusion, as explained by Rogers (1995), is the process by which a new idea or technology is communicated through various channels over time among members of a social system. This definition suggests that for any idea, technology, or practice to be adopted at the farm-level, farmers need to be aware of it and there should be a reliable channel of communication within a social structure that would allow them to gain knowledge about the innovation over a period of time. The temporal and social elements are important since they foster a learning atmosphere for farmers to assess costs and benefits so they can make an informed decision on whether they will adopt or not.

The rice farming sector is a classic representation of how diffusion of innovations have thrived. The innovative ideas and technology in the rice sector are commonly in the form of new varieties of seeds, new types of pesticides, new lines of fertilizers, and efficient machineries among others (Mannan & Shahrina, 2014; Bruce, Donkoh, & Ayamga, 2014; Adesina & Baidu-Forson, 1995; Adesina & Zinnah, 1993). The introduction and adoption of sustainable management practices such as the alternate wetting and drying to conserve water resources or conservation tillage for soil quality improvement have not been part of the conventional suite of agricultural rice production innovations until recently when decline in production has been attributed to water shortage and poor soil quality (Bouman, Humphreys, Tuong, & Barker, 2007; Khan, Tariq, Yuanlai, & Blackwell, 2006; Tao, et al., 2006; Tan, Lal, & Wiebe, 2005; George, Magbanua, Garrity, Tubana, & Quiton, 2002; Rosegrant, Cai, & Cline, 2002; Gami, et al., 2001; Scherr, 1999). As such, this study examined not only the adoption of these sustainable management practices but also the influence of social capital in supporting and implementing sustainable agricultural innovations in Central Luzon. The two sustainable management practices investigated in this study include the adoption of water conservation practices and support towards bioenergy initiatives.

Adoption of Water Conservation Practices. Water in the form of irrigation or precipitation is a growth-limiting factor in rice production (Akinbile, Abd El-Latif, Abdullaah, & Yusoff, 2011; Ali & Talukder, 2008; Ceesay, 2004; Tao et al., 2006). Adequate water supply has been identified as the major constraint for yield gaps and yield variability from rice experimental stations to farms (Papademetriou, Dent, & Herath, 2000). This means that without this resource, plant growth declines and fails to achieve their potential (Van Ittersum & Rabbinge, 1997).

Increasing water input in rice production mainly through expanded irrigation can have high social, economic, and environmental impacts because water could have been diverted to other sectors where demand is growing, such as domestic use in urban areas. The demand for water resources in the Philippines is inferred to substantially increase by 281 percent for the domestic sector, 186 percent for the agricultural sector, and 124 percent for the industrial sector by 2025 (Dargantes, Batistel, Manahan, & Flores-Obanil, 2011). These estimates imply that if business-as-usual scenarios with the Philippine water supply and withdrawal curves remain as that in 2009, at the maximum, about 93 percent of the water used for the agricultural sector will be devoted to rice production alone. If agricultural water demand takes priority in support of rice self-sufficiency, allocation of water towards rice production poses a particular threat to other water-using sectors, including nonrice agricultural entities. The alteration in the water allocation and distribution may result to potential sectoral trade-off conflict. In the face of this challenging trade-off, adoption of water conservation in the rice production system has never been more relevant.

Through the application of structural equation models (SEM), this study assessed how social capital influences adoption of water conservation practices in Central Luzon. Findings from the SEM show that social capital has a significant indirect positive effect on the adoption of water conservation practices, which translates to higher level of efficiency and production yield. This implies that when an innovation such as water conservation is embraced through as sequential decision process—acceptance phase through training participation, adoption phase through initial application of the technology, and continued use phase through application of the technology in an extended period of time—production goals are achievable (Graaff, et al., 2008).

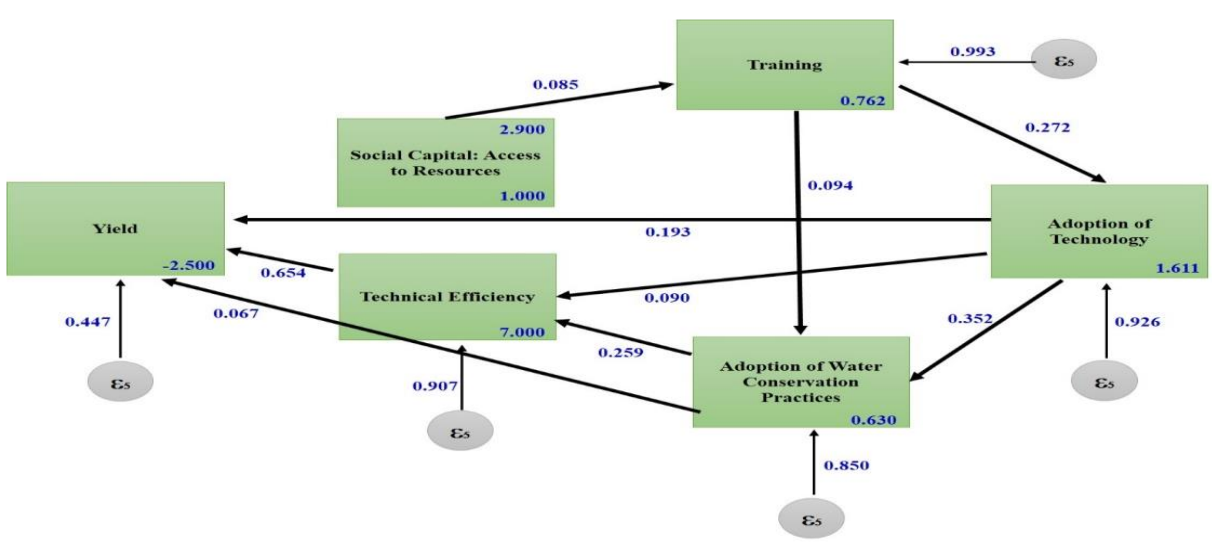
As presented in Table 4.12, social capital positively influences training, which in turn has a positive effect on technological adoption, which then leads to actual adoption of the practice engendering an increase in technical efficiency and yield per hectare. A one standard deviation increase in social capital will result to a total effect of 0.085 for training, 0.023 for technological adoption, 0.016 for water conservation practices, 0.006 for technical efficiency, and 0.010 for the yield. These findings are consistent with what Sidibe (2005) observed in Burkina Faso where social capital increases the adoption of soil and water conservation techniques. Correspondingly, in Ghana and Kenya, Nkegbe & Shankar (2014) and Nyangena (2008) respectively noted that soil and water conservation technology adoption increases with social capital. From Africa to Asia, the influence of social capital is very apparent. If producing more food with less water is the way forward, it is important to take into account the incorporation of social capital in the decision-making equation of water conservation especially in Central Luzon where almost 66 percent of the farmers are practicing it.

Support Towards Bioenergy Initiatives. In a paddy rice production system, there are usually several by-products or residues. The most common of these are the rice husks, also known as rice hulls, and the rice straws. Gummert (2013) estimated that 20 percent of rice paddy weight is husk. In an ongoing study on assessing the potential of rice husks as energy source in Panay Island, Philippines, Militar (2014) ascertained that rice straws make up 29 percent of rice paddy weight. These residues have been traditionally considered as waste products, and they have no commercial value (Launio, Asis Jr, Manalili, & Belizario, 2014). Due to its high calorific value, rice husks and straws, which consist mainly of ligno-cellulose and silica, have recently been identified to have great potential as a renewable energy source (Yerima & Isa, 2012; Cunha-Pereira et al., 2011; Prasara-A & Grant, 2011; Maiti, Dey, Purakayastha, & Ghosh, 2006; Summers et al., 2003).

Table 4.12: Standardized effects of access to social capital assets and resources on adoption of water conservation measures in tabulated and graphical formats.

Hypothesis on Adoption of Water Conservation Practices:
Access to social capital assets and resources positively influence the adoption of water conservation practices resulting to higher farmer efficiency and productivity.

Variables	Path	Direct Effects	Indirect Effects	Total Effects
Training	←Social Capital: Access to Resources	0.085*	*no path*	0.085*
Yield	←Training	*no path*	0.113***	0.113***
	←Adoption of Water Conservation Practices	0.067**	0.169***	0.236***
	←Adoption of Technology	0.193***	0.142***	0.335***
	←Technical Efficiency	0.654***	*no path*	0.654***
	←Social Capital: Access to Resources	*no path*	0.010*	0.010*
Adoption of Water Conservation Practices	←Training	0.093**	0.096***	0.189***
	←Adoption of Technology	0.352***	*no path*	0.352***
	←Social Capital: Access to Resources	*no path*	0.016*	0.016*
Adoption of Technology	←Training	0.272***	*no path*	0.272***
	←Social Capital: Access to Resources	*no path*	0.023*	0.023*
Technical Efficiency	←Training	*no path*	0.073***	0.073***
	←Adoption of Water Conservation Practices	0.259***	*no path*	0.259***
	←Adoption of Technology	0.090**	0.091***	0.181***
	←Social Capital: Access to Resources	*no path*	0.006*	0.006*



Notes:
[a] *** significant at 1%, ** significant at 5%, * significant at 10%.
[b] Solid lines represent statistically significant paths.
[c] Model fit: $\chi^2 = 34.275$ $(prob = 0.000)$, $RMSEA = 0.110$, $CFI = 0.939$, $SRMR = 0.050$.

Amidst the Philippine Department of Energy's (DOE's) campaign for the development of an energy system that utilizes local sources of energy in support of the Philippine Energy Plan 2011–2030 and the Biofuels Act of 2006 (Republic Act 9367), the need to maximize the potential of rice for other purposes other than satisfying food security needs is very timely. In response to the country's renewable energy policy, the Philippine Rice Research Institute (PhilRice) has advocated the integration of energy generation into the rice production sector. The Institute has proposed the use of rice by-product biomass as an alternative energy source. PhilRice research scientists have estimated that, on average, the country produces 2.90 million metric tons of rice husks annually (Frediles, 2012). Based on a heating value of 14 gigajoules per ton as used in Orge and Abon (2012), the estimated rice husk residues translate to approximately 40.75 million gigajoules of energy or 1,083 million liters of oil.

If the food self-sufficiency target of producing 22.73 million metric tons of rice is achieved, there is a potential to produce 4.55 million metric tons of husks and 6.59 million metric tons of straws. At this level of by-product production, rice husks have the potential to produce 1,698 million liters of oil with a power and energy equivalent of 254 megawatts and 2,228 million kilowatt-hours, respectively. The utilization of rice straws as potential bioenergy resource can generate 260 megawatts of additional power with an energy equivalent of 2,275 million kilowatt-hours.

Despite the energy potential of rice by-products, its utilization for bioenergy production is hardly recognized in the Philippines. In Central Luzon, only 48 percent of the farmers reveal that they are aware that rice husks and straws can be used for energy production. Even with this level of awareness, almost 80 percent of the farmers in the region support rice by-product bioenergy initiatives.

Cognizant that social capital stimulates development in rural areas through information accumulation and transaction cost reduction (Woolcock & Narayan, 2000), this study explored the role that it plays in energy development in farming communities in Central Luzon. In particular, through the structural equation modeling this study analyzed how social capital influences awareness and support towards bioenergy initiatives within the rice sector in Central Luzon. This, to the author’s knowledge, is one of the pioneering attempts to link social capital with bioenergy programs specifically in using staple food by-products.

Contrary to expectations, the analysis revealed that social capital does not significantly influence the level of awareness on rice by-product utilization for bioenergy production. In the same way, it does not have an effect towards expressing support on bioenergy initiatives as shown in Table 4.13. Interestingly, results show that having an awareness about the value of rice by-products as energy sources and expression of support towards bioenergy initiatives positively influence technical efficiency and yield at the farm-level. A standard deviation increase in awareness of by-product utilization and support towards bioenergy initiatives can increase technical efficiency by 0.014 and 0.037 units, respectively. This indicates that when farmers are equipped with the necessary information in regards to rice by-products from a training, for instance, they can make informed decisions and courses of actions that can help them enhance their efficiency levels, which can then lead to increase in production.

This study, in general, demonstrated the direct and indirect connection of social relations to building a farmer's social capital stock, which in turn can help enhance efficiency and productivity. In terms of adopting sustainable management practices, the infancy of the concept of by-product utilization for energy production probably influenced the insignificant effect of social capital. Nevertheless, social capital has an overall positive effect on water conservation. If the policy objective were to influence the level of efficiency and production at the farm level as well as sustainable rice farming, it would be partial not to take into consideration the role of social networks and social capital. Decision makers should deliberately account for social capital as a valid direct or indirect component of the rice production process.

Table 4.13: Standardized effects of access to social capital assets and resources on support towards bioenergy initiatives in tabulated and graphical formats.

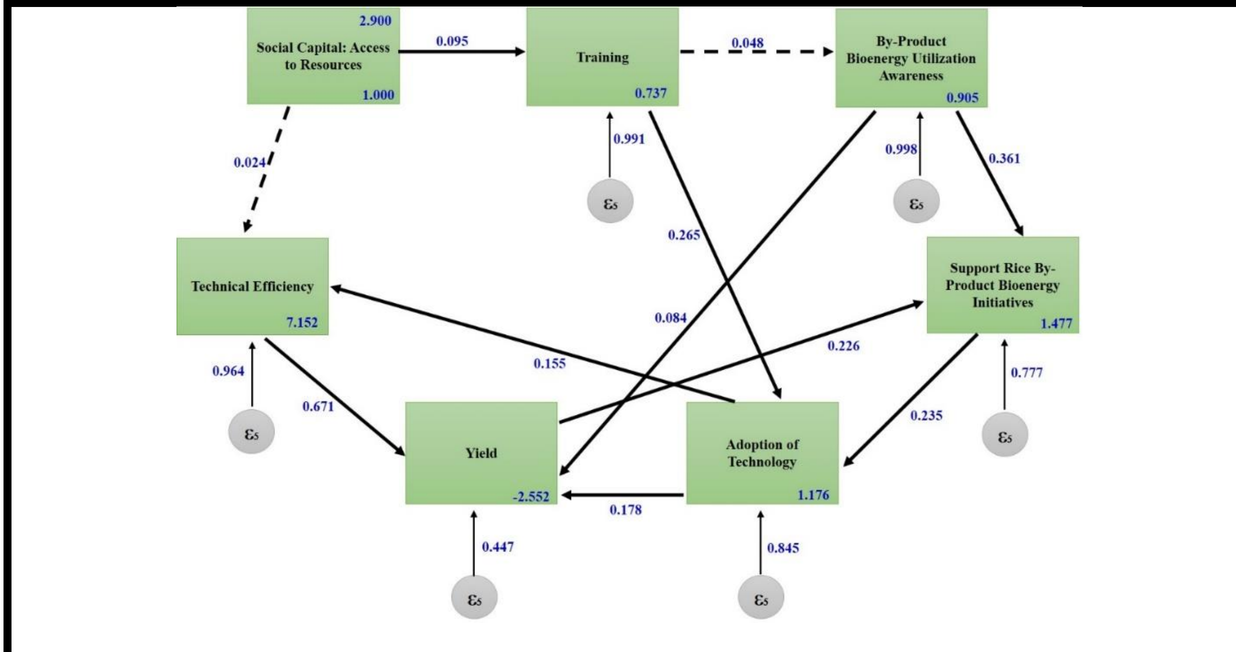
Hypothesis on Support Towards Bioenergy Initiatives:
Access to social capital assets and resources positively influences farmers' bioenergy awareness and support towards bioenergy initiatives leading to higher technical efficiency and productivity.

Variables	Path	Direct Effects	Indirect Effects	Total Effects
Training	←Social Capital: Access to Resources	0.095**	*no path*	0.095**
Support Rice By-Product	←Training	*no path*	0.036*	0.036*
	←Technical Efficiency	*no path*	0.154***	0.154***
	←Yield	0.226***	0.003***	0.230***

Hypothesis on Support Towards Bioenergy Initiatives: *Access to social capital assets and resources positively influences farmers' bioenergy awareness and support towards bioenergy initiatives leading to higher technical efficiency and productivity.*				
Variables	**Path**	**Direct Effects**	**Indirect Effects**	**Total Effects**
Bioenergy Initiatives	←Adoption of Technology	*no path*	0.065***	0.065***
	←By-Product Bioenergy Utilization Awareness	0.361***	0.025***	0.385***
	←Social Capital: Access to Resources	*no path*	0.007	0.007
Technical Efficiency	←Training	*no path*	0.042***	0.042***
	← Support Rice By-Product Bioenergy Initiatives	*no path*	0.037***	0.037***
	←Yield	*no path*	0.008***	0.008***
	←Adoption of Technology	0.155***	0.002***	0.157***
	←By-Product Bioenergy Utilization Awareness	*no path*	0.014***	0.014***
	← Social Capital: Access to Resources	0.024	0.004*	0.028
Yield	←Training	*no path*	0.081***	0.081***
	← Support Rice By-Product Bioenergy Initiatives	*no path*	0.067***	0.067***
	←Technical Efficiency	0.671***	0.010***	0.681***
	←Adoption of Technology	0.178***	0.108***	0.286***
	←By-Product Bioenergy Utilization Awareness	0.084***	0.026***	0.109***
	←Social Capital: Access to Resources	*no path*	0.024	0.024
Adoption of Technology	←Training	0.265***	0.008**	0.273***
	← Support Rice By-Product Bioenergy Initiatives	0.235***	0.004***	0.238***
	←Technical Efficiency	*no path*	0.036***	0.036***
	←Yield	*no path*	0.054***	0.054***
	←By-Product Bioenergy Utilization Awareness	*no path*	0.090***	0.090***
	←Social Capital: Access to Resources	*no path*	0.027***	0.027***
By-Product Bioenergy Utilization Awareness	←Training	0.048	*no path*	0.048
	←Social Capital: Access to Resources	*no path*	0.005	0.005

Hypothesis on Support Towards Bioenergy Initiatives:
Access to social capital assets and resources positively influences farmers' bioenergy awareness and support towards bioenergy initiatives leading to higher technical efficiency and productivity.

Variables	Path	Direct Effects	Indirect Effects	Total Effects



Notes:
[a] *** significant at 1%, ** significant at 5%, * significant at 10%.
[b] – – –► refers to a path that is statistically not significant. Solid lines represent statistically significant paths.
[c] Model fit: $\chi^2 = 60.073$ ($prob = 0.000$), $RMSEA = 0.106$ $CFI = 0.916$, $SRMR = 0.055$.

Conclusion and Recommendations

The concept of social capital has been widely investigated in the agricultural production sector. Unlike previous research that assessed social capital in terms of participation or membership in organizations or clubs, this study took a different approach by looking at social capital from the resource or asset acquisition perspective. With this approach, the study went beyond the conventional method and offered a nascent view on the concept.

With the adapted measure for social capital, this research through the application of structural equation modeling (SEM) empirically show that ego (personal) network of farmers positively influences the acquisition of social capital in the form of access to resources such as technology, information, financing, and production materials among others. Through intermediary variables such as training and adoption of technology, the study demonstrated that increased in technical efficiency and productivity of rice farms in Central Luzon is positively related to access to social capital assets and resources. The sustainable management practices models exhibited mixed results with social capital positively influencing adoption of water conservation practices resulting in increased yield and efficiency, and having no impact at all on the level of awareness and support towards the utilization of rice by-products as alternative sources of energy.

Given the results of the study, the results offer a different frame of reference for farmers and decision makers who are finding ways to make rice production sustainable and at the same time profitable. Farmers and decision-makers may have to consider social capital as a source of strategic farm-level enhancement in efficiency and production. Incorporating social capital in the planning and decision-making process is possibly the new paradigm and it is no longer an option but a required component. If the conventional factors of production are leveraged with social capital assets and resources, there is a likelihood that rice self-sufficiency may be attainable. Therefore, training programs offered to farmers must be planned strategically to allow the promotion of not only strong relationships among farmer but also a venue to strengthen farmer-to-farmer resource sharing and exchange that builds up their social capital stock.

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Appendices

Appendix A. Tabulation of characteristics of social connections of farmers in Central Luzon.

Variables	Description	Location	Guimba (n=294)		Tarlac City (n=150)	
			Mean	Standard Deviation	Mean	Standard Deviation
Generic Issues or Topics						
Family/ Relatives	Number of family members or relatives regularly talked to and approached regardless of issue or topic (at least once a month)	Within Village	17	19.73	17	17.41
		Outside Village	6	9.97	7	9.25
Friends	Number of people considered as friends regularly talked to and approached regardless of issue or topic (at least once a month)	Within Village	26	37.62	24	28.09
		Outside Village	13	17.65	14	17.68
Total	Total number of people talked to and approached regardless of issue or topic (at least once a month)	Within Village	43	52.28	41	40.87
		Outside Village	20	23.99	21	23.00
Agricultural Issues or Topics						
Family/ Relatives	Number of family members or relatives regularly talked to and approached regarding agricultural issues (at least once a month)	Within Village	8	10.03	10	11.06
		Outside Village	4	8.36	4	6.87
Friends	Number of people considered as friends regularly talked to and approached regarding agricultural issues (at least once a month)	Within Village	13	20.91	14	23.27
		Outside Village	7	11.19	8	12.08
Total	Total number of people talked to and approached regarding agricultural issues (at least once a month)	Within Village	21	27.38	24	31.97
		Outside Village	11	17.90	12	16.71

Note: The difference in the means of all variables is considered to be not statistically for the two study sites.

Appendix B. Tabulation of sociodemographic composition of the ego (personal) networks of farmers in Central Luzon.

Ego (Personal) Network Sociodemographic Variables	All Sites (n=444)	Nueva Ecija (n=294)	Tarlac (n=150)
Alters			
Key Members of the Ego Network (Total)	2119	1372	747
Age			
Mean (in years)	48.89	48.52	49.60
Standard Deviation (in years)	7.46	7.84	6.61
Gender			
Male (%)	94	92	98
Female (%)	6	8	2
Education			
Grade School (%)	43	34	58
High School (%)	47	53	36
College (%)	10	12	6
Holding Position in Community			
Yes (%)	87	86	89
No (%)	13	14	11
Active in Village or Community Organizations			
Yes (%)	68	71	63
No (%)	32	29	37
Proximity(1)			
Mean (kilometers)	0.66	0.76	0.45
Standard Deviation (kilometers)	2.01	2.42	0.68
Length of Time Known(1)			
Mean (in years)	30.96	31.63	29.63
Standard Deviation (in years)	12.41	12.64	11.88

Note: The means of all variables are statistically different at 95% confidence level for the two study sites with the exception of the age of the ego (personal) networks.

Appendix C. Tabulation of relational dimension of social capital among farmers in Central Luzon.

Measures of Relational Dimension[a]	All Sites (n=444)	Nueva Ecija (n=294)	Tarlac (n=150)
Alters			
Key Members of the Ego Network (Total)	2119	1372	747
Social Relationship			
Family/Relative (%)	40	36	47
Farm Plot Neighbor (%)	3	2	3
Friend (%)	47	47	48
Residential Neighbor (%)	7	9	2
Other[b] (%)	3	6	0
Sociability: Frequency of Contact[c]			
Mean (in days per month)	26.35	26.41	26.25
Standard Deviation (in days per month)	6.68	6.36	7.28
Social Cohesion: Level of Closeness			
Very close (%)	94	92	99
Quite close (%)	3	4	0
Fairly close (%)	3	4	1
Very little closeness (%)	0	0	0
Not close at all (%)	0	0	0
Trust in Relationship: Level of Trust			
Very well (%)	87	81	97
Quite well (%)	4	6	0
Fairly well (%)	6	9	2
Very little (%)	0	1	0
Not at all (%)	2	3	1
Social Support: Help from Ego (Personal) Network in Time of Crisis			
Yes (%)	97	97	98
No (%)	3	3	2

Notes:

[a] The measures of relational dimension are adapted from Acquaah, Amoako-Gyampah, & Nyathi (2014).

[b] Other includes agricultural extension worker, co-worker, fellow church member, and fellow member in the same community organization.

[c] The mean frequency of contact between farmers and alters in Nueva Ecija and Tarlac is not statistically significant at the 95% confidence level. The most common mode of contact is face-to-face. Nueva Ecija farmers exhibit this form of contact to 96 percent of the members of their ego (personal) network. In Tarlac, face-to-face interaction is the only form of contact of farmers with the members of their ego (personal) network.

Appendix D. Tabulation of social capital assessment in terms of access to resources.

Social Capital Measures in Terms of Access to Various Forms of Assets or Resources	All Sites (n=444)	Nueva Ecija (n=294)	Tarlac (n=150)
Alters			
Key Members of the Ego Network (Total)	2119	1372	747
Types of Resources Accessed through the Ego (Personal) Network			
Market information (%)	5	6	3
Rice production materials (%)	3	5	0
Technology (%)	6	9	1
Financing and market information (%)	8	4	14
Financing and rice production materials (%)	3	4	0
Market information and technology (%)	9	10	9
Materials and market information (%)	4	6	0
Materials and technology (%)	3	4	0
Financing, materials, and market information (%)	9	5	16
Financing, materials, and technology (%)	34	27	46
Financing, market information, and technology (%)	8	10	4
Market information, materials, and technology (%)	7	9	4
Others (%)	2	1	3

Note: The basis of this assessment is the social capital measurement proposed by (Van der Gaag & Webber, 2008).

Chapter 5. Bottom-line, Implications, and Prospects

This study has examined the possibility of achieving rice self-sufficiency in the Philippines. In particular, this dissertation demonstrated the viability of attaining domestic self-sufficiency without maximizing biophysical (land) resource expansion if production and technical efficiency levels of farmers are enhanced. Through social capital assessment, this body of research showed that the components comprising the social capital of rice farmers are essential if sustainability in rice self-sufficiency is to be attained and maintained.

Conclusions

The apparent and potential risks of food shortage at various sectoral levels have engaged many governments, including the Philippines, to seek adoption of food self-sufficiency policies. Even if this policy strategy is known to have an elusive success rate and doubts have been cast over its feasibility, the Philippines remains optimistic that food self-sufficiency is a viable goal. In 2012, the Philippine government launched the Food Staples Sufficiency Program (FSSP) with a target to increase rice supply by nearly 50 percent in 2016 given production levels in 2010. Through the FSSP, the Philippine government espoused for the expansion of rice plantation and irrigation areas to complement the introduction of high yielding varieties and widespread mechanization of the rice industry.

Given the specific strategies identified in the FSSP, this dissertation examined the food self-sufficiency issue from a tri-dimensional sustainability lens—biophysical (environmental), economic, and social perspectives. This study employed a multi-criteria spatial land suitability assessment using geographic information system (GIS) to determine the extent of areas that may be suitable for rice production and expansion as well as the associated possible rice yields. Cognizant that expanding land area is only one way to increase production, the stochastic production frontier analysis was performed to assess areas for possible enhancement of technical efficiency to stimulate an upward shift in the rice production function. In terms of capturing the social dimension, this study assessed social capital from the resource or asset acquisition perspective. With this approach and through the application of structural equation modeling, the study went beyond the conventional method of investigating social capital in an agrarian setting, which is usually through investigation of individuals' participation or membership in organizations and clubs.

Based on the combination of multi-criteria evaluation (MCE) methods with geographic information system (GIS), suitability analysis showed that at the national scale, the Philippines has about 2.06 million hectares of land that can be allocated to rice expansion. At a region-specific level, Central Luzon can still accommodate expanded rice production to about 94,085 hectares of land in the region. With this potential for expansion, the necessary yield per hectare to attain the FSSP target is between 3.54 and 4.53 metric tons.

With geospatial analysis, it became possible to determine the production intensity per hectare to achieve the FSSP target. The results clearly emphasized the spatial extent of potentially suitable areas, of which the majority are largely already under rice cultivation. From an applied standpoint, the information from the suitability assessment demonstrates the capabilities and limitations of certain areas in supporting rice production.

Given that only 20 percent of the necessary increase in production can be expected from land expansion, the remaining 80 percent must be generated through increased productivity. Stochastic production frontier analysis revealed that the average technical efficiency of farms in Central Luzon, Philippines, ranged from 0.76 to 0.82 in the wet season and from 0.80 to 0.92 in the dry season, respectively. Increasing average farm efficiency by 13 percent and 22 percent, respectively, in the two Central Luzon provinces can help attain the FSSP target by potentially increasing yield per hectare to 7.32 and 5.63 metric tons per hectare at the maximum correspondingly in the dry and wet seasons in Guimba, and 4.78 and 3.90 metric tons, respectively, in the dry and wet cropping seasons in Tarlac.

With the average regional technical efficiency of 0.827 as representative of rice farm performance across the country, it is possible to increase average yield nationally above 3.89 metric tons per hectare. At this rate and with the amount of land devoted to rice in 2010 (*i.e.,* 4.3 million hectares), it is possible to surpass the FSSP target of 22.73 million metric tons per year. At this level, achieving the FSSP target does not require expansion of land areas devoted to rice and the desired increase will be possible with an increase in machinery expenditures, per unit utilization of fertilizer per hectare, and use of hybrid seeds.

In Guimba, a 10 percent increase in machinery expenditure results in a 0.98 percent yield increase per hectare during the dry season and by 0.76 percent in the wet season, *ceteris paribus*.

For the same level of increase in machinery expenditure, per hectare production in Tarlac increases by 3.65 and 3.75 percent respectively in the dry and wet seasons, *ceteris paribus*. For Guimba, a 10 percent increase in the use of hybrid rice cultivars can result in a 0.71 percent increase in yield per hectare in the dry season and 0.62 percent increase in yield per hectare in the wet season, *ceteris paribus*.

The potential options for increased production require additional expenses on the part of the rice producers. The government, through the programs of the Department of Agriculture, however, plans to provide affordable access to appropriate farm machinery through distribution of farm machinery to qualified beneficiaries as well as establishment of service centers that would allow pooling of farm machinery and equipment where farmers can go to loan machinery, equipment, and implements. Further, in terms of having access to high quality seeds, the national government plans to partner with the local government units, private seed growers, and farmers' organizations to establish community seed banks that will promote the informal system of high quality seed exchange among farmers.

The combined results from the stochastic production frontier and spatial econometric analyses suggest that under these scenarios – without a spatial component or with a spatial effect – farmers can increase the level of production given current input allocations and achieve the FSSP target. In the no spatial effect scenario for the dry season, results demonstrate that for statistically significant production variables such as seeds, fertilizer, pesticides, machinery, and animals, yield per hectare can increase between 0.56 and 1.37 percent in Guimba and between 0.22 and 4.18 percent in Tarlac for every ten percent increase in input utilization. Incorporating spatial component using the spatial error model shows that for the same level of input utilization, yield in Guimba can increase by 0.57 to 1.38 percent, whereas yield in Tarlac can increase by 2.15 to 3.74 percent. These levels of increases in input utilization maybe possible on a seasonal basis especially for farmers in Tarlac since they disclosed that they have several sources of capital for production with 12 percent using their own capital and 86 percent outsourcing capital through various forms of formal and informal credit lines.

Through structural equation modeling, results showed the direct and indirect contribution of social relations to building a farmer's social capital stock. These relationships influence efficiency and productivity providing insight into how social dynamics of farmers influence rice sustainability in the Philippines. Ego (personal) network of farmers positively influences the acquisition of social capital in the form of access to resources such as technology, information, financing, and production materials among others. Through intermediary variables such as training and adoption of technology, increases in technical efficiency and productivity of rice farms are positively related to access to social capital assets and resources. In terms of adopting sustainable management practices, social capital has an overall positive effect on the adoption of water conservation practices.

While social network information and social capital are rarely considered in sustainable development projects, this dissertation validates the role that these variables play in enhancing productivity and therefore potential sustainability. As demonstrated, social capital is a potential source of strategic farm-level enhancement in efficiency and production. If the conventional factors of production are leveraged with social capital assets and resources, achieving rice self-sufficiency can be sustained.

Policy Recommendations

To view rice merely as a food staple is to view rice myopically. Rice production, as demonstrated by this study and several other research works, transcends the food self-sufficiency issues. Based on various land area expansion scenarios together with historical yields per hectare, this study estimated the spillover effects from achieving the FSSP target on agricultural water and energy sectors. It is imperative that water remains available for use in rice production and by-products become feasible energy supply sources. One way to ensure sustainability in the rice production sector is to employ policy mechanisms that promote conservation of the water supply while maintaining if not increasing rice yield and farmers' income. Further, it is important to develop an energy-relevant policy in sync with the rice self-sufficiency target.

The stochastic production frontier and technical efficiency/inefficiency analyses generate useful information for agricultural planners and policymakers. For instance, the stochastic frontier analysis showed that the use of machinery at various stages of rice cultivation from land prepartion to crop establishment, care, and harvest significantly influences yields across locations and seasons. The lower rate of machinery utilization in Tarlac than in Guimba provides agricultural planners information on prioritizing the deployment of government-provided machineries to farmers. In addition, the production frontier analysis demonstrated that other than machinery, the use of fertilizer and hybrid seeds are statistically significant with positive coefficients for both the dry and wet cropping seasons in Guimba implying that an increase in the use of these two inputs would generate an increase in production. With these information, agricultural planners as well as policymakers can design a program whereby farmers would have an easier access to fertilizer and hybrid seeds, both physically and financially. An example of such program can be the “use now, pay later” scheme, where farmers will be allowed to get fertilizer and hybrid seed inputs from a designated agent and the government is the guarantor that payment will be made after the harvest season.

With the addition of spatial dependency to the production and inefficiency models, the resulting analysis demonstrates clustering of field-level yields and efficiency estimates. Accounting for spatial effects on the production and inefficiency models lowers coefficients for the production and technical inefficiency models as compared to their classical counterparts. This suggests to agricultural decision-makers that location-specific strategies are probably more appropriate. For instance, in Tarlac spatial interaction at the farm and dwelling locations exist in rice farming communities. By taking into account the spatial aspect of rice production, agricultural planners and stakeholders may be able to identify specific geographical locations at the village level where enhanced production (e.g., through better connection to the national irrigation system during the dry season, greater access to fertilizers during the wet season, and year-round access to machinery) is possible without increasing resource allocation.

Findings from the spatial regression models convey the necessity of spatial components in the unbiased assessment of how to attain the FSSP target. This makes a compelling case for policies aimed at enhancing both yield and production efficiency to take into account the appropriate geographical planning level. Policies need not necessarily be all-encompassing strategies that are implementable from national-scale instead farm- or village-specific interventions might be more pertinent. For instance, analysis showed that in Guimba, the villages of Balingog East, Santa Cruz, and Tampac I are consistently registering high incidence of inefficiencies considering both the dwelling and farm locations of the rice producers in the dry and wet seasons. In Tarlac, the villages of Sapang Maragul and Tibagan are the areas with high incidence of production inefficiencies regardless of farm and dwelling locations. If the goal is to maximize the use of limited funds and make the greatest impact at the village level, initiatives that target areas of low farm efficiency may have the greatest potential for increasing rice yields.

The results from social capital assessment and the structural equation modeling offer a different frame of reference for farmers and decision makers who are finding ways to make rice production sustainable and at the same time profitable.[133] Farmers and decision-makers may have to consider social capital as a source of strategic farm-level enhancement in efficiency and production. Incorporating social capital in the planning and decision-making process is possibly the new paradigm and it is no longer an option but a required component. If the conventional factors of production are leveraged with social capital assets and resources, there is a likelihood that rice self-sufficiency may be attainable. Therefore, training programs offered to farmers must be planned strategically to allow the promotion of not only strong relationships among farmers but also a venue to strengthen farmer-to-farmer resource sharing and exchange that builds up their social capital stock. This would mean that social capital needs of the farmers are assessed accordingly and that programs are tailored according to the specific needs and priorities of the farmers in different communities. A one-size fits all type of program may not be the most strategic approach to enhance social capital assets and resources.

An example of a training program component may include incorporation of social exercises or experiments where trust among farmers can be further strengthened since only 87 percent of the farmers in Guimba and Tarlac revealed that they highly trust that their fellow farmers can be relied on during times of personal or farm-related crises. It is highly possible that this level of social trust specifically in terms of mutual financial and labor exchange can be enhanced since 72 and 57 percent of the farmers in the two provinces disclosed that there is reciprocal exchange of financial favor and labor, respectively, within the villages. In government-led training programs, farmers from communities with extremely high level of trust and resource reciprocity can be tapped as social farm experts to share and demonstrate their experience on how trust and reciprocity have added value in their production and how sharing information can be beneficial in rice production. The programs can also engage farmers who have overcome inter-community trust issues. These farmers who have broken barriers in terms of

[133] In meeting the rice self-sufficiency target, the expected level of production will generally increase the supply of domestically-produced rice. With this increase in local supply, the likelihood of falling rice prices is apparent. To enhance economic incentives for farmers to support domestic rice production, the national government, through the programs of the Department of Agriculture's National Food Authority, is implementing price support system and procurement policies. Although the government is allowing market forces a greater role in setting retail prices, it continues to conduct price monitoring to ensure that farmers receive the guaranteed prices.

networking and placing trust to farm members outside their own communities may be able to impart the challenges they faced, the lessons they learned, and the advantages towards their farm practices of reaching out to other communities.

The Road Ahead

Decision-makers can use the maps as a guide to channel investment plans and enhance rice expansion initiatives across the Philippines. However, in future studies, more detailed climatic attributes and socioeconomic characteristics, which largely influence land use decisions should be added into the geospatial analysis. Further, since the intimate link between energy resources, food self-sufficiency, and water security is seldom thought of together in the food self-sufficiency equation, it may be necessary to tie the food self-sufficiency program with the water and energy security initiatives at various spectrum of policy, planning, design, and operation. If the Philippine government is serious in its campaign to attain domestic food self-sufficiency, it is crucial to strengthen synergies and policy coherence between agriculture, energy, and the environmental sectors. This can be achieved through the institutionalization of a sound policy coordination and integration strategy by introducing multi- and inter-sectoral processes and means that support transformation of structural conditions between and among these sectors.

At the national level, the government can create a permanent task force with representatives from the agriculture, energy, and the environment sectors. The task force will oversee the institutionalization of coherent policies in the three sectors. The task force can review existing policies such as the Biofuels Act of 2006 (Republic Act No. 9367) and the Renewable Energy Act of 2008 (Republic Act No. 9513) to ensure that these policies do not endanger but rather enhance food security by raising staple food production and incomes. At the same time, the task force can oversee the balance integration of policies by providing an enabling mechanism that provides agricultural, energy, and environmental stakeholders green development opportunities that promote agricultural growth, job creation, enhance livelihoods, and promotion of renewable energy utilization in rural areas. The task force can also serve as a policy and monitoring body to critically examine that the implementation of existing policies and the development of new ones do not grant preferential bias towards a particular sector, but rather espouse for even integration of sustainability across the three sectors.

This study recognizes the importance of accounting for spatial effects in the production and inefficiency models. Because it is not a common practice to incorporate the spatial effect in a one-step stochastic production model, this study applied the two-step approach in order to assess the spatial effects. This study, however, attempted the one-step procedure incorporating spatial effects as conducted in a handful of studies but it resulted in a mathematical non-convergence in the solution. For future research, simultaneous addition of parameters that measure spatial dependence in the analysis should be examined.

To ensure sustainability of progress made in attaining food self-sufficiency, social, economic, and environmental dimensions should be considered in every step of the planning horizon. Relevant agencies should envisage horizon-planning tools including future modeling and foresight development to incorporate policy incentives and mechanisms that provide target groups such as farmers, irrigators, or maybe electric cooperatives, to enhance each dimension in support of sustainable staple food production, more specifically the overlooked social aspect. Long-term implementation mechanisms, which include active awareness-raising campaigns, should complement socially-sensitive policies together with strong financial and institutional commitments.