ADOPTION FACTORS AND PERCEPTIONS OF GREEN MANURE AND COVER CROP TECHNOLOGIES AMONG PARAGUAYAN SMALLHOLDER FARMERS

A Thesis

by

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ABSTRACT

Adoption of green manures and cover crops among Paraguayan smallholder farmers may be more easily achieved if researchers, extensionists, and stakeholders understand social processes that drive farmers to adopt these conservation agriculture practices. The purpose of this study was to characterize Paraguayan smallholder farmer attributes, determine characteristic independent variables that significantly influence adoption of green manures and cover crops, evaluate participants' perceptions of the technologies, and characterize adoption-extent rates of green manures and cover crops among participants. The sample population (N = 76) consisted of southeastern Paraguayan smallholder farmers that participated in an oral survey with the researcher. The data were analyzed through descriptive statistics, analysis of variance (ANOVA), bivariate correlation, and regression analysis to complete the research objectives. Findings of this study indicate: demographic conditions, variation between sample groups, relationships among the dependent and independent variables, and the influence of independent variables on the cultivation of green manure and cover crop technologies (user status, measured as the dependent variable).

Decreased soil fertility is a significant constraint to production in fields, especially for smallholder farmers who lack access to inputs. The implementation of green manures and cover crops can be viewed as an erosion prevention tool for smallholder subsistence farmers. User participants are capable of managing green manures and cover crops for on-farm implementation or continued cultivation. Participants attributed the implementation of green manures and cover crops to increase crop production above all other potential benefits.

Participants did not consider the technologies as an economically viable practice. However, the cultivation of green manures and cover crops were perceived to decrease farmer labor requirements. Chemical fertilizers positively influence adoption of the technologies. The availability of information, training attendance, and technical assistance all positively influence adoption of green manures and cover crops. Finally, participation in social organizations positively conditions adoption of the technologies. Researchers and extensionists should continue working with Paraguayan farmers to implement or determine appropriate soil conservation practices meanwhile keeping the beneficiaries' input in consideration. Continued social research in green manure and cover crop technologies is warranted due to the lack of concise investigation efforts in a smallholder context.

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CHAPTER I

INTRODUCTION

Paraguay is a country with an agricultural economy located in the heart of South America. The commercial agriculture industry largely produces cattle, cotton, and soy for export. The overall formation of the agricultural industry significantly favors farmers with considerable capital and land and often neglects the rights and needs of low-income smallholder subsistence farmers. Much of the current situation in Paraguayan smallholder agriculture stems from decades of military dictatorship that funneled economic profits to political supporters and large landholders in agricultural production (COHA, 2012; Guereña, 2013). Rural, poor farmers received modest government support in their struggle to maintain livelihoods. Though Paraguay has practiced a democratic governing process for the past 25 years, inequality differences are easily recognized between urban rural settings.

Paraguayan smallholder farmers face daily challenges to maintain their livelihoods. Factors such as erosion, extreme climate conditions, migration, land inequality, and lack of education or available resources place farmers in a threatened outlook for the future. Paraguayan farmers are aware of agricultural and environmental interactions and the need to sustainably manage the land for future generations (Jarvis, 2002). However, lack of knowledge and available resources has hindered their advancement toward more sustainable agriculture practices.

Green manure and cover crop technologies have been promoted in Paraguay to smallholder farmers as a sustainable field conservation method for several decades. The conservation agriculture practice is promoted within the subtropical climate context for erosion control and organic matter buildup. Several organizations currently work in Paraguay to promote the practice at an agriculture extension level. Although green manures and cover crops have been promoted for decades, barriers to adoption exist. The success of green manure and cover crop promotion has been described as "limited" because of ignored social criteria in the selection of a green manure species (World Bank, 2009).

Studies within conservation agriculture conclude that user attributes toward a technology greatly influences the adoption-decision process (Alonge & Martin, 1995). Recent conservation agriculture adoption models include supplementary socio-economic factors and perceptions of innovations that lead to adoption (Knowler & Bradshaw, 2007). Adoption research of green manure and cover crop technologies has been conducted, but social scientists mention that literature is scant and scattered especially in the Latin American context (Anderson, Gündel, Pound, & Triomphe, 2001; Bunch, 2012).

One organization currently working with green manure and cover crop extension is the Peace Corps. A primary agricultural extension objective is to motivate small-scale farmers to optimize the use of human, material, and natural resources to raise standards of living and increase food security. A common practice among agriculture volunteers (in the Peace Corps) is the promotion of green manures and cover crops to communities as a method of conserving or rehabilitating the soil. Volunteers provide farmers with an initial seed establishment amount of green manures and cover crops for subsequent technology implementation within a two-year period. Based on personal experiences as Peace Corps Volunteers with small-asset based farmers promoting green manures and cover crop technologies, several counterparts rejected the idea for personal farming systems. It was evident to investigate and understand the adoption-decision process of green manure and cover crop technologies among Paraguayan smallholder farmers.

The research idea was initiated through personal experience working in a rural, poor, subsistence-based farming community in an area with some of the most degraded soils in the country. It became important to identify characteristics among farmers who would be most likely to adopt conservation agriculture practices such as green manures and cover crops. These results are to provide information to extension service agencies to improve future dissemination practices to meet the desires and needs of future potential adopters in green manure and cover crop technologies. This thesis describes perceptions of, and factors that influence adoption of green manure and cover crop technologies among rural, subsistence Paraguayan farmers.

CHAPTER II

BACKGROUND

Smallholder subsistence farmers in developing countries who seek to reduce household food security challenges are influenced to adopt conservation agriculture technologies. Factors such as intensive crop cultivation, land scarcity, soil degradation, and climate change influence farmers to efficiently utilize available natural resources and external inputs to maintain or improve farming conditions (Arellanes & Lee, 2003). Conservation agriculture technicians appeal for the continued discussion and focus of land degradation issues because of adverse effects on crop productivity, food security, and the environment (Barungi et al., 2013). Continuous land degradation undermines efforts to reduce poverty among farmers and threatens soil health sustainability (Barungi et al., 2013; Pretty, Morison, & Hine, 2003). Easily implemented, low-cost conservation agriculture technologies can assist poor farm households rehabilitate marginal soils, improve field management, and prevent land degradation (Arellanes & Lee, 2003). Governments, non-governmental organizations (NGOs), and other organizations promote green manure and cover crop technologies as low-input conservation practices supporting smallholder farmers around the world.

Green manures and cover crops are well established in agricultural systems. These technologies are promoted for sustainable land use with potential to improve marginal areas where smallholder farmers face productivity constraints. Application of the technologies in smallholder agriculture provides multiple benefits that may include nitrogen fixation, increased organic matter, weed suppression, disease and pest control, erosion control, and food sources (Anderson et al., 2001; Bunch, 2012; Florentín, Peñalva, Calegari, & Derpsch, 2010; Pretty et al., 2003). Although this practice is no panacea, it is a valuable, low-cost addition to technological options that integrate conservation and productivity considerations (Erenstein, 2003).

Interest in the development and dissemination of green manure and cover crop technologies among stakeholder organizations has been intense. However, projects promoting the practice have achieved limited impact because of ignored social elements for selecting suitable species to improve soil (World Bank, 2009). Though awareness of conventional agriculture consequences has increased, it has not translated to the adoption of sustainable practices among farmers (Alonge & Martin, 1995). The extent to which farmers are aware of green manure and cover crop concepts and their use in soil management decisions is poorly understood (Anderson et al., 2001). Arellanes and Lee (2003, p. 694) wrote, "relatively little work has formally examined socio-economic factors that influence adoption of these technologies." Unlike classic extension models that explain how a technology's relative advantage influences adoption; conservation agriculture models conclude adoption is considerably more influenced by farmers' attitudes and perceptions about the practice (Alonge & Martin, 1995; Rogers, 2003). Perspectives call attention to the quality of information disseminated, perceptions of innovations, and institutional and economic factors related to adoption (Alonge & Martin, 1995). Researchers in green manure and cover crop technologies advocate participatory, decentralized development and dissemination of the technologies (Cherr, Scholberg, & McSorley, 2006; Erenstein, 2003). The promotion of green manure and cover crop strategies depend on sharing concepts, information, and perceptions among extensionists, farmers, and stakeholders (Anderson et al., 2001).

Paraguayan agriculture faces significant challenges for the future of smallholder farming, especially in terms of land inequality (i.e., distribution of ownership) and the realities of rural poverty in the country. Paraguay is described as the most land inequitable country in Latin America (Guereña, 2013). Land inequality is a principal factor that perpetuates poverty in rural Paraguay (Guereña, 2013; World Bank, 2010). Recent agriculture census data conclude 79% of total arable land is owned by 1.6% of the total farm population (Dirección de Censos y Estadísticas Agropecuarias, 2009). On the other extreme, 4.3% of total farmland is owned by the majority 86% that constitute the total farm population (Dirección de Censos y Estadísticas Agropecuarias, 2009). A majority (51%) of small farms in Paraguay have 5 to 20 ha; a lesser proportion (42%) have farms of 1 to 5 ha, and 6% of farms have less than 1 ha (Dirección de Censos y Estadísticas Agropecuarias, 2009). About 35% of the total farm population owns less than the minimum 10 ha considered to be the basic unit to sustain a family's economy (Dirección de Censos y Estadísticas Agropecuarias, 2009; Guereña, 2013).

The future of rural smallholder poverty is a constraint for the Paraguayan agricultural industry. Rural areas continue to be the main contributors to poverty and extreme poverty in Paraguay (World Bank, 2010). Previous calculations of poverty have underestimated rates of extreme national poverty and poverty in rural settings (World Bank, 2010). Though national poverty rates decreased from 2004 to 2009, overall poverty and extreme poverty rates among rural areas were 50 to 70% higher than expected (World Bank, 2010). About 40% of the total Paraguayan population lives in rural areas and has a disproportional amount of poor and extreme poor compared to urban areas (World Bank, 2010). More than half of the total poor population and more than two-thirds of the extreme poor live in rural Paraguay (World Bank, 2010). According to World Bank (2010) statistics, two out of five Paraguayans are poor and one in five is classified as extremely poor. It is estimated that more than two million Paraguayan citizens are poor and over one million are extremely poor (World Bank, 2010). National census data conclude that 34% of the total rural population live in poverty and nearly half rely on agriculture as a basis for living (Dirección General de Estadística, Encuestas y Censos, 2013).

The rural poor and extreme poor often require additional assistance to maintain livelihoods or overcome barriers out of poverty (World Bank, 2010). Many rural poor families rely on government conditional cash transfer deposits through social welfare programs or remittances received from family members abroad. By 2009, the total beneficiaries of conditional cash transfer programs amounted to 100,000 (World Bank, 2010). It is well known that migration and remittances have increased as a source of income for rural households in Paraguay (World Bank, 2010). There is minimal reliable information about rural poor receipts in terms of financial assistance (Mössinger, Siebold, & Berger, 2015; World Bank, 2010). New poverty estimates indicate that resources allocated to fight poverty through social programs need to increase in favor of rural areas (World Bank, 2010).

Paraguay’s agricultural and environmental problems have escalated in the past 50 years. Inefficient agricultural management methods such as slash and burn, continuous or excessive tillage, and monoculture cropping have resulted in poor soil fertility that leads to continuous declines in crop production (Florentín et al., 2010; Jarvis, 2002). These methods leave large amounts of bare soil exposed to climatic agents that accelerate soil degradation and cause rapid erosion and nutrient leaching. Reduced income and increased poverty among rural farmers have been consequences of these processes (Florentín et al., 2010).

Paraguayan farmers are increasingly aware of the need to intensively manage the land (Jarvis, 2002). Green manures and cover crops have been promoted in Paraguay for nearly 70 years: however, these practices have not necessarily translated to widespread adoption of conservation technologies (Peace Corps Paraguay, 2008). One major constraint to green manure and cover crop adoption is the lack of affordable, high quality, locally available seed (Florentín et al., 2010). Other adoption constraints may include lack of knowledge, limited capital, competition for land, and misperceived benefits of the practice (Ali & Narciso, 1994; Anderson et al., 2001; Florentín et al., 2010). Critics argue the formation of smallholder agriculture strategies in Paraguay should be oriented toward maintenance of soil fertility through disseminating conservation agriculture practices such as green manures and cover crops (Florentín et al., 2010).

CHAPTER III

PERCEPTIONS OF GREEN MANURE AND COVER CROP TECHNOLOGIES AMONG PARAGUAYAN SMALLHOLDER FARMERS

Introduction

Preliminary agricultural economic models that were created to understand the commercialized agriculture process and describe adoption behavior based on relative advantages of innovations did not account for other variables that influence the adoption-decision process (Feder, Just, & Zilberman, 1982; Rogers, 2003). With increasing attractiveness of conservation agriculture practices in developing countries, critics argue classical models do not provide full explanation in these applications (Alonge & Martin, 1995). Agriculture adoption models include adopter perception paradigms, those of which have been the least quantitatively developed in the literature (Adesina & Zinnah, 1993). Adopter perceptions suggest that perceived attributes of innovations condition adoption or rejection among farmers based on the appropriateness or inappropriateness of a technology to the potential adopter (Adesina & Zinnah, 1993, Alonge & Martin, 1995). The omission of perception variables may bias results on factors that influence adoption of agricultural technologies (Adesina & Zinnah, 1993). The limited quantitative economic studies that consider farmers' perceptions implicitly take technological innovations as appropriate for the farmer and lack account for subjective preferences for technology characteristics (Adesina & Zinnah, 1993).

Farmers have unique attitudes and perceptions of technologies. The potential for a technology to be widely adopted depends on understanding farmers' perceptions of new technologies as they experiment with them on portions of their fields (Soule, 1997). According to Nyende and Delve (2004, pp. 78-79), “beyond agronomic evaluation, it is essential to identify the opportunities and constraints of each introduced technology, conduct assessments to understand farmers’ actual use and management of the technologies, perceived benefits, farmers’ ideas and perceptions, and innovations, and problems and solutions in the use of the technologies.” Several studies conclude the importance of farmer attitudes and perceptions toward conservation agriculture technologies; however, lack of literature in green manure and cover crop technologies warrants continued research in the concept (Adesina & Zinnah, 1993; Alonge & Martin, 1995; Odendo et al., 2000).

Effective refinement in the technology generation process is driven by farmers’ perceptions and preference feedback of green manure and cover crop technologies (Odendo et al., 2000). Incorporating attitude and perception data in the design of conservation agriculture systems is likely to be better than giving no consideration to farmers’ expressed preferences (Ahnström, Höckert, Bergea, Francis, Skelton, & Hallgren, 2008). A better understanding of farmer characteristics and perceptions may help policymakers develop strategies to increase adoption of conservation agriculture technologies (Adesina & Zinnah, 1993; Comer, Ekanem, Muhammad, Singh, & Tegegne, 1999).

Farmer feedback plays an important role in the process of generating conservation agriculture technologies. Technology recipients should have an active role in the entire process rather than being passive recipients of the technology (Odendo et al., 2000). Farmers believe that their knowledge about production and the environment should be considered important in the development and realization of farmland conservation (Ahnström et al., 2008). Farmers need to feel supported with advice and engagement about their production systems, not just with financial resources (Ahnström et al., 2008). Conflict between stakeholders in the technology development and dissemination process can lead to more inefficient and inequitable outcomes for all (Ali, 2011). Without appropriate research and policy support, extension efforts are likely to remain in a localized extent or simply wither away (Pretty et al., 2003).

Social empirical models developed through conservation agriculture studies may assist researchers in green manure and cover crop technologies develop appropriate instruments to survey a sample of the practice. Knowler and Bradshaw (2007) identified several perception variables in a 31-study meta-analysis of factors influencing conservation agriculture adoption.

Because certain conservation agriculture practices such as green manures and cover crops are promoted for soil erosion control, adoption is more likely to occur when farmers perceive or experience soil erosion problems. Studies conclude farmers' perceived soil problems often contribute to adoption of conservation agriculture and green manure technologies (Arellanes & Lee, 2003; Knowler & Bradshaw, 2007). Severe land degradation and productivity loss may convince farmers to cultivate green manures and covers crops where other economic alternatives in cultivation are limited (Erenstein, 2003). Farmers perceiving soil erosion problems are more inclined to adopt such practices, whereas farmers who do not perceive soil erosion problems are less likely to adopt. However, Barungi et al. (2013) concluded that farmers in Uganda who perceived soil infertility were less likely to adopt soil erosion control technologies than were participants who perceived good soil fertility.

Farmers' perceived management ability influences the adoption of conservation agriculture practices (Knowler & Bradshaw, 2007). Odendo et al. (2000) noted that farmers often practice management capabilities on experimental or demonstration plots before adoption of conservation agriculture practices to their personal plots. Perceived management ability may demonstrate effective comprehension among green manure and cover crop recipients, or may indicate the extent to which farmers practice their capabilities before on-farm implementation. Increased yields in the utilization of conservation agriculture technologies have been thoroughly investigated to positively influence adoption (Knowler & Bradshaw, 2007). Several studies of green manures and cover crops have measured farmers' perceptions of yield increases in the technology implementation (Anderson et al., 2001; Arellanes & Lee, 2003).

Study results suggest that key constraints to conservation agriculture adoption are caused from perceived risks, and extension practitioners play a key role in working with farmers to reduce these concerns (Bot & Benites, 2001). Subsistence farmers in developing countries are typically risk averse and bear more risk in technology adoption compared to non-subsistence farmers (Feder et al., 1982). Any small uncertainty related to a technology could make smallholder and risk averse farmers delay the decision to adopt a new agricultural technology (Barungi et al., 2013; Knowler & Bradshaw, 2007; Odendo et al., 2000). Commonly identified perceived risks in the cultivation of green manure and cover crop technologies include disease, extreme weather conditions, pests, and access to inputs (Ali, 2011; Anderson et al., 2001; Knowler & Bradshaw, 2007). Literature also concludes the lag-time to realize benefits of green manures and cover crops increases perceived risk that the benefits of the technology may not materialize (Erenstein, 2003).

Farming is an economic contributor to a society, and studies have reviewed the economic viability of conservation agriculture practices. Economic feasibility among green manure and cover crop technologies is normally evaluated from experimental data; however, social scientists note fundamental flaws in data such as testing in highly controlled conditions, improper documentation of costs, and the isolated measurement of crops without regard to effects on land use patterns or cropping systems (Ali & Narciso, 1994). There remains continued need to determine farmers' perceptions of economic viability among selected conservation agriculture practices (Alonge & Martin, 1995; Knowler & Bradshaw, 2007). Scientists note socio-economic conditions should prevail in green manure and cover crop viability assessment in smallholder conservation farming (Erenstein, 2003).

Perceived economic viability depends on numerous factors such as biophysical, technological, farm level, and institutional factors (Ali & Narciso, 1994; Erenstein, 2003). Factors contributing to adoption beyond a farm finance scheme need to be identified because perceived profitability of conservation agriculture practices vary geographically based on several factors (Knowler & Bradshaw, 2007). Green manure and cover cropping has the most adoption potential whenever its implementation is economically attractive to the user (Alonge & Martin, 1995; Erenstein, 2003). Perceived unfeasible practices will discourage adoption among farmers and is classified as a major barrier to adoption (Ali & Narciso, 1994; Soule, 1997). Socio-economic studies have produced both favorable and unfavorable results as farmers' perceptions of economic feasibility in the cultivation of green manure and cover crop technologies (Ali & Narciso, 1994; Alonge & Martin, 1995). Alonge and Martin (1995) concluded that research and educational efforts should be directed toward making conservation agriculture practices profitable and compatible to transition farmers toward more sustainable practices.

Farmers often consider more than one potential benefit of green manures and cover crops when selecting for cultivation and personally experiment with different species before making a final selection (Fischler & Wortmann, 1999). Extensive experimental data exist on advantages and disadvantages in the cultivation of green manures and cover crops. However, less research exists in smallholder farmers' perceived attributes of the technologies. Overlapping perceptions among study participants may reveal trends in perceived advantages and disadvantages of particular technologies. This may enhance relationships between extension and farmers through a comprehensive understanding of a technology (Ali, 2011). No literature was found that describes farmers' perceived attributes of these technologies in Paraguay.

The most common perceived advantages to green manure and cover crop production include weed suppression, improved soil fertility, decreased soil erosion, improved soil moisture content, and nitrogen fixation (Ali & Narciso, 1994; Buckles & Triomphe, 1999; Eilittä, Mureithi, & Derpsch, 2004; Erenstein, 2003; Fischler & Wortmann, 1999; Knowler & Bradshaw, 2007; Nyende & Delve, 2004; Snapp, Rohrbach, Simtowe, & Freeman, 2002). Other commonly reported perceived advantages include pest reduction, nutrient recycling effect, substitution for inorganic fertilizer, alimentary sources, organic matter accumulation, ability for intercropping with food or cash crops, and ease of land preparation after continuous cultivation (Buckles & Triomphe, 1999; Erenstein, 2003; Nyende & Delve; 2004; Odendo et al., 2000; Soule, 1997). Finally, less commonly noted advantages include disease resistance, increased crop management flexibility, less time to recuperate land compared to fallow systems, economic substitute for herbicides in weed control, fuel sources, preparation for direct seeding practices, drought resilience, soil buffer capacity, and high seed production for future self-sustainability (Ali & Narciso, 1994; Erenstein, 2003; Nyende & Delve, 2004; Soule, 1997).

Although green manure and cover crop technologies provide several advantages and are often adopted for their multiple benefits, disadvantages in cultivation do exist. The most common perceived disadvantages are the lack of availability or high cost of seed (Ali & Narciso, 1994; Eilittä et al., 2004; Nyende & Delve, 2004; Snapp et al., 2002). Other common reported disadvantages include incidence of rodents and snakes, opportunity costs of land or competition with other crops, and the limited potential of green manures and cover crops beyond soil recuperation purposes (Buckles & Triomphe, 1999; Eilittä et al., 2004; Erenstein, 2003; Nyende & Delve, 2004; Soule, 1997). Farmers also perceive green manures and cover crops as disadvantageous because of the time required for results to materialize (Ali & Narciso, 1994; Erenstein, 2003; Soule, 1997). Green manures and cover crops have been promoted for smallholder implementation with minimal machinery input. However, study participants have considered these technologies to require specialized planting equipment, which can hinder adoption of the practice (Ali & Narciso, 1994; Knowler & Bradshaw, 2007). Though pest control may be viewed as an advantage, other results conclude that farmers' perceived disadvantages of green manures and cover crops include pest problems due to cultivation (Knowler & Bradshaw, 2007; Snapp et al., 2002). Finally, farmers may perceive it is necessary to form or join farmer interest groups to receive technologies, therefore hindering adoption of the practice (Knowler & Bradshaw, 2007).

Perceived labor requirements of green manure and cover crop technologies significantly influence adoption and the extent to which farmers utilize the crops (Knowler & Bradshaw, 2007). Studies examine perceived and actual labor requirements in green manures and cover crops; however, conflicting results continue. Fischler and Wortmann (1999) posited that farmers could allocate labor to other farm efforts and increase net farm benefits through the easy establishment of green manures and subsequent weed suppression in the fields. Soule (1997) concluded that farmers often misperceive decreased labor requirements in green manure cultivation and actually spend more time in practice management than originally perceived. Fischler and Wortmann (1999) also indicated that farmers' subjective perceptions of labor requirements do not always correspond with measured labor input. Finally, Odendo et al. (2000) indicate farmers perceive increasing labor requirements in relation to increasing plot sizes in the management of green manures and cover crops. This is explained in the increased need for crop establishment and incorporation, especially in times when labor competition occurs to prepare other fields for planting. Adoption is more likely to occur when farmers perceive or experience decreased labor demands for cultivating the crops; however, they may not adopt if increased labor demands are perceived in the technology (Anderson et al., 2001; Eilittä et al., 2004; Erenstein, 2003; Florentín et al., 2010).

The continuation and expansion of perception research in green manure and cover crop technologies is warranted because of the lack of concise, updated studies; especially in the context of smallholder farmers in Latin America (Anderson et al., 2001; Bunch, 2005; Bunch, 2012). This continuation will assist researchers and extension agents to refine social-based issues in green manure and cover crop technology adoption in hopes of achieving wider adoption rates among smallholder farmers in developing countries.

Purpose and Objectives

The purpose of this research was to characterize Paraguayan smallholder farmers' perceptions of green manure and cover crop technologies. Specifically, the objectives of the study were to

1. Describe Paraguayan smallholder farmer characteristics;
2. Identify participants' perceptions of green manure and cover crop technologies;
3. Determine if differences in perceptions existed between users and non-users of the technologies;
4. Characterize the extent, or intensity, to which adopters of green manures and cover crops utilized the technologies; and,
5. Examine if significant differences existed between quantitative calculated adoption rates and participants' perceived adoption rates.

Methods

The descriptive, cross-sectional research design utilized quantitative dichotomous, categorical, and continuous data. The target population of this study consisted of southeastern Paraguayan smallholder farmers. The sample population (*N*=76) consisted of farmers who were purposively selected to participate. Some 17-study locations were selected within seven departments in Paraguay to collect a diverse set of data and to reflect evidence on a regional scale. The sample groups were split between users and non-users of green manure and cover crop technologies. Users (*n*=40), or adopters of green manures were defined as participants who had been cultivating green manures or cover crops within the previous one-year period at the time of data collection. Non-users (*n*=36) were defined as participants who were non-adopters or those who did not cultivate green manures or cover crops within the previous one-year period at the time of data collection. One research goal intended to maintain an equal ratio of participants among sample groups to allow for objective data analysis. The research team also surveyed equal ratios of participants with similar characteristics in each study location to limit data collection bias.

The survey instrument was adapted from Knowler and Bradshaw's (2007) meta-analysis of variables that significantly influence the adoption of conservation agriculture practices. The selection of variables focused on farmer characteristics and perceptions of conservation agriculture technologies. In total, 13 variables from the meta-analysis were selected for survey implementation. Five additional variables for a total of 18 variables were included in the study because of recommendations recognized through the literature review.

First, the dependent variable classified participants into two subgroups of green manure and cover crop technologies (1= user, 0= non-user). Continuous data within farmer characteristic independent variables included age, education, farming experience, and cultivation length of green manures and cover crops, in years. Farm size and cultivation size were collected through continuous data in number of hectares. Dichotomous data scales included: participant gender (1= male, 0= female), previous soil erosion (1= yes, 0= no), and perception data (1= yes, 0= no). These measures included perceived soil problems and current erosion, management abilities or skills, yield effect, risks, economic viability, advantages and disadvantages, and labor requirements. In addition, perceived risks, advantages, and disadvantages included categorical information in which participants noted attributes of the technologies.

The five new variables included in the instrument were: cultivation time period of green manures, perceived economic viability, perceived advantages and disadvantages, and adoption-extent rate. Perceived economic viability was added to the instrument due to the recommended need for future data collection and analysis within conservation agriculture adoption studies (Knowler & Bradshaw, 2007). The perception variables in the cultivation of green manure and cover crop technologies were to reflect evidence for Paraguay.

Feder et al. (1982) previously argued adoption studies should not simply be composed of dichotomous variables, and the extent in which farmers adopt technologies should also be analyzed. Strictly dichotomous variables are not sufficient in determining the extent, or intensity of adoption. Sufficient instrumentation may be attained in which a dichotomous adoption variable is explained in a calculation for percentage of adoption (Feder et al., 1982). This variable was the final addition to the instrument to characterize adoption-extent rates among participants. The adoption-extent rate first quantitatively calculated the amount of green manures and cover crops cultivated (number of ha) compared to total land cultivated (number of ha) among user participants. Participants were then asked to estimate or calculate the percentage (0 – 100) of their cropland on which they have adopted green manures and cover crops.

Participants had the opportunity to expand their responses narratively by explaining their experiences. This allowed for expansion upon quantitative data and for previously unidentified information in the green manure and cover crop adoption process to be recognized. Recent Paraguayan census data conclude illiteracy rates among rural populations at 10%; therefore, the survey was administered orally to allow participation of illiterate farmers (Dirección General de Estadística, Encuestas y Censos, 2013). Paraguay is officially recognized as a bilingual country. The survey was implemented through Spanish and Guaraní languages. The instrument was parallel translated and verified for translational correctness with a certified language instructor (Stoop & Harrison, 2012).

Data were analyzed through descriptive statistics (frequencies, means, and standard deviations). Analysis of variance (ANOVA) was conducted to determine if significant differences existed between the sample groups. ANOVA data were analyzed at the .05 level for significance.

Results and Discussion

Participants (*N*=76) included smallholder farmers from seven departments in southeast Paraguay. A plurality of participants (*n*=30) resided in the Itapúa department. Other participants were located in Paraguarí (*n*=14), Misiones (*n*=10), Caazapá (*n*=8), Caaguazú (*n*=7), Guairá (*n*=5), and Ñeembucú (*n*=2) (Figure 3.1).

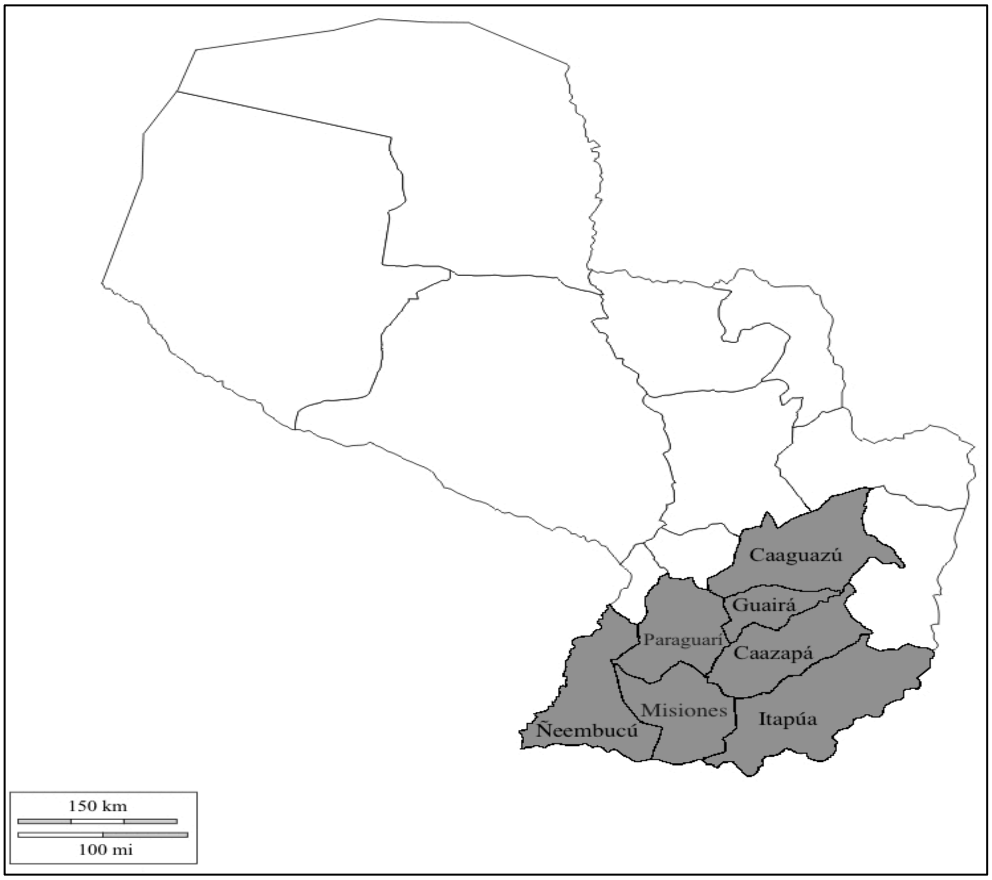

Figure 3.1. Study Location Map by Departments. Adapted from "Paraguay Departments Outline," by D. Dalet, 2016. Retrieved from http:// http://d-maps.com/carte.php?num_car=25075&lang=en. Copyright 2007-2016 Daniel Dalet.

Descriptive sample groups and population demographic information is presented in Table 3.1.

Table 3.1

Description of Sample Population

Characteristics	Users (*n* = 40)		Non-users (*n* = 36)		Sample population (*N* = 76)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Time (years)						
Age	52.58	10.80	54.14	9.88	53.31	10.15
Education	6.38	3.25	6.69	3.98	6.53	3.59
Agricultural experience	35.80	15.42	34.69	14.65	35.28	14.97
Green manure and cover crop experience	5.93	4.96	2.94	6.93	4.51	6.12
Land (ha)						
Farm size	9.30	7.46	7.92	5.72	8.65	6.68
Cultivated land size	3.90	3.28	2.99	2.48	3.47	2.95

The user group had 33 males and 7 females, while the non-user group had 32 males and 4 females. The user group age (*M* = 52.58, *SD* = 10.80) was younger compared to non-users (*M* = 54.14, *SD* = 9.88). The mean age for the sample (*M* = 53.31, *SD* = 10.15) was much higher than expected. The evidence supports a need to identify extension methods to target younger populations to succeed an aging subsistence farming population.

The sample had education of a mean of 6.53 years and with a standard deviation of 3.59. Within participant groups, non-users completed more years (*M* = 6.69, *SD* = 3.98) of formal education compared to users (*M* = 6.38, *SD* = 3.25). Users had slightly more mean years' experience in agriculture (*M* = 35.80, *SD* = 15.42) compared to non-users (*M* = 34.69, *SD* = 14.65). The sample reported higher land holdings (*M* = 8.65ha, *SD* = 6.68) compared to census data. Users reported larger farm sizes (*M* = 9.30ha, *SD* = 7.46) and land cultivation sizes (*M* = 3.90ha, *SD* = 3.28) compared to non-users' farm size (*M* = 7.92ha, *SD* = 5.72) and cultivated land size (*M* = 2.99ha, *SD* = 2.48).

The sample cultivated less area (*M* = 3.47ha, *SD* = 2.95) than the majority of the smallholder farmer population. Users of green manures had more years (*M* = 5.93, *SD* = 4.96) cultivating, or experience with the technologies than did non-users (*M* = 2.94, *SD* = 6.93). There were non-user participants (*n* = 12) with numerous years' experience with the technology, however, 67% (*n* = 24) of non-users had no experience (0 years) with the technology. The results indicate the implementation of the technology in the study locations is relatively new, and further research may enhance data by surveying areas where the technologies have been implemented for a longer period of time.

Next, participants' perceptions of green manure and cover crop technologies were identified. Only 17% of the sample population perceived risks in the cultivation of green manure and cover crop technologies. More non-users (*M* = 0.22, *SD* = 0.42) perceived associated risks in green manure cultivation compared to users (*M* = 0.13, *SD* = 0.34). Participants were asked to identify perceived risks in green manure and cover crop cultivation. The responses are presented in Table 3.2. Non-users indicated a common perceived risk of pest attacks to the crops (*f* = 6). Other participants' perceived risks were drought intolerance, disease, extreme weather conditions, limited production in poor soils, and the increased risk due to uncertainty that the lag time to notice benefits may not materialize. The higher frequency of perceived risks among non-users indicates an opportunity to delay the decision in the adoption-decision process, or even reject if farmers were previously utilizing the technologies. The data demonstrate the importance of extensionists' need to work with farmers to reduce potential risks in the adoption of green manure and cover crop technologies.

Table 3.2

Perceived Risks of Green Manure and Cover Crop Cultivation

	User *f*	Non-user *f*	Total *f*
Pests	2	6	8
Drought intolerance	1	1	2
Disease	1	0	1
Lag time	1	0	1
Limited production in poor soils	1	0	1
Extreme weather	0	1	1

Further analysis of descriptive data revealed mixed perceptions toward green manure and cover crop technologies. Most notably, all participants perceived an increased yield effect from the cultivation of green manures and cover crops. Continued investigation is needed to identify why non-users may be disinclined toward adoption even though they positively identify green manure and cover crops with yield increases.

The perceived ability to manage the crops produced varied results between the groups. A majority of green manure users (n = 38) perceived the ability to manage the crops, whereas non-users (n = 12) were less likely to perceive management capabilities in the practice. These data support that participants may have practiced management capabilities on various plots before personal implementation, or that the participants effectively demonstrate comprehension of the technologies from receiving technical assistance, trainings, or peer-to-peer interactions.

Next, participants (M = 0.76, SD = 0.43) identified similarly between groups regarding participants' perceived soil problems. Fewer users of green manures and cover crops (*M* = 75%, *SD* = 0.44) perceived soil problems compared to non-users (*M* = 78%, *SD* = 0.42).

The trend of similar results revealed that almost half (*M* = 49%, *n* = 37) of the sample considered green manure and cover cropping as an economically viable farming practice in terms of financial costs and returns. Additional economic viability factors beyond a financial scheme were not presented to the participants. A majority of non-user respondents (*M* = 0.56, *SD* = 0.50) reported a perceived economic viability in cultivation, whereas fewer user respondents (*M* = 0.41, *SD* = 0.50) perceived the cultivation of green manure and cover crop technologies as an economically viable practice. Because participants may consider green manure and cover cropping as economically unfeasible, this may deter a large portion of subsistence farmers from adopting the conservation agriculture practice, or cause them to discontinue the practice.

Data indicate and support previous literature of soil problems throughout Paraguay. A majority of the sample (*n* = 61) experienced past soil erosion problems. Users reported a high incidence (*M* = 0.87, *SD* = 0.34) of previous soil erosion problems. In addition, a majority of non-users (*M* = 0.75, *SD* = 0.44) reported similar past erosion problems in fields. Noticeable differences existed when participants were asked about current soil erosion problems. Users noted smaller proportions (*M* = 0.23, *SD* = 0.42) of current soil erosion problems compared to non-users (*M* = 0.58, *SD* = 0.50). Users of green manures and cover crops reported a 65% reduction in soil erosion problems between past and current conditions. Meanwhile, non-users reported a 17% reduction within the same category.

A majority of the sample population (*M* = 0.81, *SD* = 0.39) reported a perceived reduction in labor requirements when utilizing green manures and cover crops. Users reported a high rate (*M* = 0.90, *SD* = 0.30) of reduced labor requirements, whereas non-users reported a lower (*M* = 0.71, *SD* = 0.46) perceived labor reduction rate. Participants were only asked about their perceived labor reduction, and did not consider other factors that may contribute to the total labor in green manure and cover crop application.

All users (*M* = 1.00) of green manures and cover crops responded affirmatively to perceived advantages in the cultivation of the practice. However, non-user respondents (*M* = 0.97, *SD* = 0.17) had a slight deviation from a purely perceived advantageous practice. Table 3.3 presents respondents' dictated perceived advantages in the cultivation of green manures and cover crops.

Table 3.3

Perceived Advantages of Green Manure and Cover Crop Cultivation

	User *f*	Non-user *f*	Total *f*
Increased production	20	20	40
Improved soil quality	7	10	17
Provision of soil amendments/nutrients	8	6	14
Less hoeing	9	3	12
Soil cover	8	1	9
Weed suppression	7	2	9
Improved quality of subsequent crop	5	3	8
Soil humidity	7	1	8
Ability to sell seeds	6	0	6
Natural/organic technology	1	4	5
Self-sufficient technology	4	0	4

Note. Other reported advantages: direct seeding, soil recuperation, income generation source, drought resistance, improved plant growth, increased crop germination, ability to associate crops, alimentary sources, decreased pests, erosion control, soil acidity buffer, easier tilling of the soil, and less cost.

Participants commonly noted more than one advantage of green manure and cover crop technologies in their responses, which supports the idea that farmers tend to analyze various benefits of green manures and cover crops before selecting an appropriate species to cultivate. The most common dictated advantage was increased crop production ($f = 40$). These findings indicate that Paraguayan smallholder farmers are more likely to consider the potential crop production increase above all other advantages, and at a higher magnitude compared to other dictated advantages. The following most commonly noted perceived attribute in the conservation technology was improved soil quality ($f = 17$), followed by provision of nutrients and amendments to the soil ($f = 14$). These two attributes were the only characteristics that corresponded to the mostly commonly noted benefit in published literature. These two attributes are related to the agronomic conditions of highly degraded soils that exist in Paraguay.

Other mentioned perceived advantages in green manure and cover crop technologies confirm previous literature about the practice. However, a few participants did note the ability of green manures and cover crops as a potential income generation source by selling seeds ($f = 6$); that which has not previously been reported in conservation agriculture studies. These data help enhance relationships between extension and farmers through a comprehensive understanding of the technology. This information may assist extensionists for promoting the conservation agriculture technologies to potential adopters, and which benefits may be more likely to influence adoption among these beneficiaries.

A smaller proportion of the sample population ($M = 0.28$, $SD = 0.45$) noted perceived disadvantages in the cultivation of green manures and cover crops compared to perceived advantages. User respondents had lower ($M = 0.26$, $SD = 0.45$) reported perceived disadvantages compared to non-user respondents (*M* = 0.29, *SD* = 0.46). Table 3.4 notes respondents' dictated perceived disadvantages in the cultivation of green manures and cover crops. The most commonly reported disadvantage was the high cost of seed (*f* = 6), which supports the literature. Other reported perceived disadvantages include: the lag time to realize benefits (*f* = 3), susceptibility to pest attacks (*f* = 3), and more work during cultivation (*f* = 2) or for establishment (*f* = 2). Other minimally (*f* = 1) reported disadvantages included: lack of proper implements for crop management, lack of seed markets available, and large amounts of seed required for establishment.

One participant mentioned a disadvantage that little importance is placed on the technology. This may be to blame on the part of extension, which shows the need to place more importance on the conservation technology. Finally, other participants noted that green manures and cover crops have a disadvantage that users continually need to purchase seeds for cultivation. This demonstrates improper comprehension of the practice, in which a majority of species are able to reseed as a sustainable practice. It is important for extension educators to properly inform users or potential adopters of proper techniques when implementing or utilizing the practice so that misperceived information is not shared among peers throughout a farming region.

Table 3.4

Perceived Disadvantages of Green Manure and Cover Crop Cultivation

	User *f*	Non user *f*	Total *f*
Seed price	3	3	6
Lag time to realize benefits	2	1	3
Pests	1	2	3
More work	0	2	2
More work for initial establishment	2	0	2

Note. Other reported disadvantages by a participant (n = 1): labor constraints among other crops, land competition, little importance placed on the technology, lack of seed source, need to continue purchasing seeds, large seed amount required for establishment, disease, lack of implements to properly manage green manures, and lack of perennial green manure crops.

Next, data were analyzed through a one-way ANOVA at the .05 level to determine if significant differences existed between sample groups. Demographic data revealed no significant differences existed between the sample groups. Within perception variables, the ANOVA failed to detect any significant differences between groups in regard to perceived risks, increased yield effect, soil problems, economic viability, past soil erosion, advantages, and disadvantages.

Only three perception variables produced significant results in the ANOVA. First, users of green manures and cover crops perceived their ability to manage the conservation practice significantly different than non-users of the technologies. The perceived management ability ANOVA produced an F-ratio of 53.858, suggesting that users of green manures and cover crops are confident in their ability to successfully manage the crops. This confidence may arise from practiced management capabilities on various plots before personal implementation, or that the participants effectively demonstrate comprehension of the technologies from receiving technical assistance, trainings, or peer-to-peer interactions. The data are presented in Table 3.5.

Table 3.5

Perceived Management Ability Analysis of Variance (ANOVA)

	SS	*df*	*MS*	*F*	*p*
Between groups	7.205	1	7.205	53.86	0.05
Within groups	9.9	74	0.134		
Total	17.105	75			

Next, significant differences existed between users' perceived current soil erosion problems compared to non-users. The ANOVA produced an F-ratio of 11.449. The ANOVA data is presented in Table 3.6. The differences in data indicate that users noted positive effects on soil erosion when implementing green manure and cover crop technologies. The difference between previous and current soil erosion conditions among users shows an effective educational method that extensionists may use when promoting green manure and cover crop technologies. However, results do not indicate that reduction of soil erosion is caused solely from the implementation of green manure and cover crop technologies. These data may be useful in future promotion of green manure and cover crop technologies.

Table 3.6

Perceived Current Soil Erosion ANOVA

	SS	*df*	*MS*	*F*	*p*
Between groups	2.433	1	2.433	11.45	0.05
Within groups	15.725	73	0.213		
Total	18.158	74			

Finally, significant differences existed in participants' perceived decreased labor requirements in the implementation of green manure and cover crop technologies. Users of the technologies perceived decreased labor requirements among other crops compared to non-users of the technologies. The ANOVA information is presented in Table 3.7. An *F*-ratio of 4.678 signifies that the reduction in labor may positively influence adoption of the technologies. The promotion of reduced labor requirements in the implementation of green manures and cover crops may assist extensionists in achieving wider adoption of the technologies.

Table 3.7

Perceived Decreased Labor Requirements ANOVA

	SS	*df*	*MS*	*F*	*p*
Between groups	0.693	1	0.693	4.68	0.05
Within groups	10.659	72	0.148		
Total	11.351	73			

Next, the study characterized the extent, or intensity in which users of green manure and cover crop technologies utilized the practice, and identified participants' perceived adoption-extent rates. Users cultivated a total 48.70 ha of green manures and cover crops during the data collection period. At the same time, the users cultivated a total of 157.25 ha cropland. Mean green manure and cover crop cultivation among users was 1.22 ha. Mean cultivation among participants was 3.93 ha. The weight calculated mean extent rate was 30.97% of green manure and cover crop utilization on the croplands used in the data collection process.

Users reported a mean 46.74% perceived adoption utilization when asked about cultivation extent rates. Further analysis of the results indicated that of the total respondents (n = 38), over half (n = 20) underestimated the actual calculated adoption extent-rates by 28% (SD = 0.19). Other respondents (n = 13) overestimated adoption extent-rates by 31% (SD = 0.30). Finally, fewer respondents (n = 4) correctly estimated their perceived adoption extent-rates compared to calculated rates. A weighted ANOVA was performed to determine if significant differences existed between quantitative and perceived calculated adoption rates among users of the technologies.

The weighted ANOVA indicated that Paraguayan smallholder farmers significantly differ in their perceived adoption-extent rates compared to calculated adoption-extent rates in the utilization of green manure and cover crop technologies. The ANOVA information is presented in Table 3.8.

Table 3.8

Perceived Adoption-Extent Rates and Calculated Rates ANOVA

	SS	*df*	*MS*	*F*	*p*
Between groups	0.993	1	0.993	12.40	0.05
Within groups	2.880	36	0.080		
Total	3.873	37			

Because of significant differences between participants' perceived and calculated rates adoption rates, a Paraguayan smallholder farmer's ability to estimate their adoption-extent may not accurately reflect their current, actual situation compared to calculated adoption-extent rates.

Conclusions and Recommendations

Paraguayan subsistence farmers are aging with limited policy discussion of replacing the population. It is pertinent for government and extension communities to adopt policies that introduce, involve, and train younger populations to succeed this practice as the smallholder farmer population continues to age. Several non-user participants in the study had numerous years of experience with green manures and cover crops, however, were disinclined to utilize the conservation agriculture practice. Further research should examine how, or why smallholder farmers are disinclined to adopt the practice even though they may be aware of various benefits in the technology implementation. Additionally, future research should examine why previous users have decided to forgo current production of the conservation agriculture technology.

Perceived risks in green manure and cover crop cultivation may cause farmers to delay or forgo adoption (Barungi et al., 2013; Knowler & Bradshaw, 2007; Odendo et al., 2000). Extension agents should work with farmers to reduce perceived risks (Knowler & Bradshaw, 2007). In turn, this may assist in achieving higher rates of green manure and cover crop technology adoption. Participants perceived the implementation of green manures and cover crops leads to an increased yield among other crops. However, the lack of difference between the two groups suggests that the perception of increased yield may not influence increased adoption of the technologies. More importantly, researchers should investigate why non-users are disinclined to adopt though their perceptions indicate a perceived advantage in the implementation of the practice.

The perceived ability to manage green manures and cover crops demonstrates the extent to which farmers practice their abilities on demonstration plots, or effective comprehension of management techniques learned from capacity-building events such as trainings or technical assistance visits (Odendo et al., 2000). Significant differences existed between users' perceived management ability of green manures and cover crops compared to non-users. These findings suggest that the ability to properly manage the conservation agriculture practice may influence adoption of the technologies (Knowler & Bradshaw, 2007). Extension agents should capacitate potential adopters with the focus of hands-on, practical applications that help build farmers' confidence to properly manage the technologies. Further research could determine which type of capacitation (i.e., farmer field day, 1:1 visit, farmer interest group meetings) is more effective in achieving wider adoption rates of green manure and cover crop technologies.

Soil degradation is a production constraint in fields. Because of the high incidence of soil degradation reported among participants, this may not accurately indicate a variable that influences adoption of green manures and cover crops. However, the data suggest that researchers and extensionists continue working with Paraguayan farmers to implement or determine appropriate soil conservation and rehabilitation practices, meanwhile keeping the beneficiaries' knowledge and input in consideration.

Green manure and cover cropping technologies are not viewed as an economically viable practice. Researchers, governments, and extensionists should prioritize efforts to reduce costs to entry in the implementation of the cropping systems, or provide practical methods for users or potential adopters to improve the sustainability of the technology. Research should examine practical, economical applications of green manure and cover cropping systems that entice smallholder farmers to invest financial resources wisely; or for potential adopters to realize the initial investment may yield long-term, economic results in the sustainable practice. Further educational efforts are needed to make conservation agriculture practices profitable and compatible to transition farmers toward more sustainable practices.

The implementation of green manures and cover crops can be viewed as a soil erosion prevention tool for smallholder subsistence farmers (Arellanes & Lee, 2003; Erenstein, 2003; Knowler & Bradshaw, 2007). Significant differences between the sample groups indicate the implementation of these technologies has the potential to protect precious field resources and nutrients in which smallholder subsistence farmers depend on production. The reduction in erosion among green manure and cover crop users indicates an effective promotional technique to entice future adopters to utilize the conservation agriculture practice (Knowler & Bradshaw, 2007). Future research should examine if the sole implementation of green manure and cover crop technologies acts as a soil erosion prevention tool for on-farm implementation. Additionally, agronomic research should determine the extent to which the implementation of green manures and cover crops reduces erosion in a Paraguayan context. Enhanced data about reduction in soil erosion may further assist in achieving wider adoption rates among Paraguayan smallholder farmers.

The cultivation of these conservation agriculture technologies leads to decreased labor among other field crops in production and may influence adoption of the practice (Knowler & Bradshaw, 2007). Significant differences between the sample groups support this idea. This may lead to additional productivity time for other work constraints outside of the field, and lead to a more productive rural Paraguayan farm population that brings production-dependent farmers out of poverty. The research asked participants only about perceived labor reduction, and did not quantifiably calculate the decreased labor rates. Further research should calculate decreased labor rates among green manure and cover crop users in accordance with Soule (1997) and Fischler and Wortmann (1999) to accurately determine if green manures and cover crops contribute to reduced field labor.

Paraguayan smallholder subsistence farmers consider the implementation of green manures and cover crops to increase crop production above all other potential benefits. Other commonly identified advantages in green manure and cover crop production included improved soil amendments, nutrients, and quality, which support previous studies' findings (Anderson et al., 2001; Eilittä, Mureithi, & Derpsch, 2004; Erenstein, 2003; Knowler & Bradshaw, 2007). Future promotional efforts in Paraguay should concentrate on educating potential adopters about potential benefits when implementing green manure and cover crop technologies.

Access to affordable, high quality green manure and cover crop seed is important for continued promotion in efforts to achieve increased adoption rates among smallholder subsistence farmers. These findings support literature in which lack of access to affordable, high quality seed is mentioned as a disadvantage, or adoption barrier in green manure and cover crop technologies (Eilittä et al., 2004; Nyende & Delve, 2004). Researchers, governments, and stakeholders must continue efforts to ensure sufficient access, reduce input costs, and effectively communicate the benefits of investment to potential adopters. This is especially important in the Paraguayan smallholder farm context, in which high rates of poverty and extreme poverty exist in rural areas where lives are dependent on agricultural production (World Bank, 2010).

Users of green manures and cover crops cultivated less than one-third of the total cultivated land utilizing the technologies. At the same rate, participants overestimated their perceived adoption-extent rate by more than 10% compared to quantitative measures. These data demonstrate that farmer estimation of technology adoption-extent is not an accurate indicator to replace quantifiable measures. Further sociological research on this topic could examine various factors farmers contemplate to estimate their perceived adoption-extent of a particular technology. In addition, further agronomic and extension research should focus on factors that limit green manure and cover crop technology adoption, and how to increase adoption-extent rates among users of the technologies.

The continuation of social research in green manure and cover crop technologies is warranted due to the lack of concise, concentrated efforts that have existed in this century, especially in a smallholder subsistence context. The future of smallholder agriculture in Paraguay depends on concentrated efforts in soil conservation or rehabilitation to provide future generations the opportunity of leading a productive, prosperous lifestyle for years to come.

CHAPTER IV

ADOPTION FACTORS OF GREEN MANURE AND COVER CROP TECHNOLOGIES AMONG PARAGUAYAN SMALLHOLDER FARMERS

Introduction

Decades of agricultural research in adoption theory have refined models from a purely economic standpoint to a more farmer-based, sociological approach. Conservation agriculture adoption studies have emphasized and assisted in the transition of these models to a farmer standpoint (Comer et al., 1999). Adequate conservation agriculture adoption studies exist, however, green manure and cover crop researchers mention scant literature on factors influencing adoption in tropical and subtropical agricultural regions (Anderson et al., 2001; Eilittä et al., 2004; Erenstein, 2003; Florentín et al., 2010). Green manure and cover crop adoption studies conclude factors influencing adoption are often non-technical issues; therefore, researchers should examine social aspects in the adoption of the practice (Anderson et al., 2001; Ojiem et al., 2006). Social factor studies help provide a better understanding of specific processes that govern adoption (Cherr et al., 2006). Though researchers lobby for continued examination of social aspects in green manure and cover crop technologies, measuring adoption is cited as a challenge to researchers who attempt to model soil management decisions (Odendo et al., 2000).

Social empirical models developed through conservation agriculture studies may assist researchers in green manure and cover crop technologies develop appropriate instruments to survey a sample of the practice. Knowler and Bradshaw (2007) examined 31 studies in conservation agriculture practice adoption and determined several significant variables that influence adoption. The meta-analysis concluded four major themes: farmer, biophysical farm, financial/management, and exogenous characteristics significantly influence a farmer to adopt a conservation agriculture practice.

The meta-analysis concluded certain farmer characteristic variables such as age, gender, education level, and years of experience may affect the adoption-decision process (Knowler & Bradshaw, 2007). Factors such as gender and age of participants within studies have been examined, but have not produced significant results (Knowler & Bradshaw, 2007). However, it is important to note that only one of the 31 studies examined included an age variable within a Latin America context (Knowler & Bradshaw, 2007). Continued research of these variables may assist in producing more conclusive results for the future. No census data is available for the age of Paraguay's farmer population.

Paraguay faces significant generational challenges in the agriculture industry, which few young individuals remain, or desire to enter the subsistence farming practice. The country faces a dual-migration problem of nationals moving to urban settings, or immigrating to neighboring Argentina (Oddone & Guidini, 2013). Census data from 2010 conclude that more than 500,000 Paraguayan-born people (8.5% of the Paraguayan population) were residing in Argentina (Oddone & Guidini, 2013). Within this group, 52% were between 20 and 29 years old. In addition, 60% of Paraguayan nationals who emigrated between 2003 and 2008 were between 20 and 34 years old (Oddone & Guidini, 2013).

Farmers' education levels may influence adoption of conservation agriculture technologies. For example, education level within green manure and cover crop studies has produced both significant and insignificant results as a factor influencing adoption (Anderson et al., 200l; Arellanes & Lee, 2003). Current Paraguayan rural educational rates are estimated at 6.6 years compared to 9.6 years in urban areas (Dirección General de Estadística, Encuestas y Censos, 2013). Only 9% of the total rural Paraguayan workforce has a high school education, and less than 25% has even attended high school (Correa, Traxler, & Hite, 2007). National agriculture statistics conclude a majority (47.9%) of the farm population (*N*=287,967) completed between 4 and 6 years of education (Dirección de Censos y Estadísticas Agropecuarias, 2009). Knowler and Bradshaw (2007) concluded that many conservation agriculture studies have produced positive, negative, and insignificant results that education level influences adoption. Therefore, it is difficult to assert that education levels condition adoption. Participants' years of experience has produced both positive and insignificant results; therefore, justification exists to continue research to determine whether this variable significantly conditions adoption of conservation agriculture technologies (Knowler & Bradshaw, 2007).

Biophysical farm characteristics have been identified as significant variables that influence adoption of conservation agriculture practices (Knowler & Bradshaw, 2007). Green manure and cover crop adoption studies attribute farm and cultivated land size as significant in adoption of the practice (Anderson et al., 2001; Florentín et al., 2010). Small landholders may place higher priorities on food security, income growth, and land allocation to other crops in the adoption-decision process (Snapp et al., 2002). However, Knowler and Bradshaw (2007) concluded participants' farm size, and/or land cultivation size was inconclusive because of conflicting positive, negative, and insignificant results (Knowler & Bradshaw, 2007). Agriculture census data conclude smallholder farmers (*N*=241,956) with 0 to 20 ha of land have a mean 5.54 ha (Dirección de Censos y Estadísticas Agropecuarias, 2009). The total Paraguayan farm population (N=249,989) cultivated 855,029 ha (Dirección de Censos y Estadísticas Agropecuarias, 2009). A majority (32.55%) cultivated 5 to 9.99 ha, and a smaller portion (23.6%) cultivated 3 to 4.99 ha (Dirección de Censos y Estadísticas Agropecuarias, 2009). Continued research may assist in determining a more conclusive result as to whether these variables influence adoption of conservation agriculture technologies.

Farm financial and management characteristics are significant in the adoption of conservation agriculture technologies (Knowler & Bradshaw, 2007). Land tenure constitutes a factor that is statistically significant in conservation agriculture and green manure and cover crop technology adoption (Anderson et al., 2001; Knowler & Bradshaw, 2007; Snapp et al., 2002). Land continues to be the most important asset in rural areas in Paraguay (World Bank, 2010). Landless, or renting farmers are less likely to consider long-term soil management practices for fear of eviction once soil conditions improve (Anderson et al., 2001; Erenstein, 2003; Pretty, et al., 2003). Access to land and financial markets in Paraguay affect the probability of a household being poor (World Bank, 2010). Because of high land ownership inequality levels in Paraguay, land is a likely determinant of equal opportunity in rural areas through the link of human capital investment (World Bank, 2010). Recent census data conclude that 24% of the agriculture population practices land occupation as a method of cultivation (Dirección de Censos y Estadísticas Agropecuarias, 2009). No formal research has examined social effects associated with land occupation among Paraguayan farmers. More secure and unambiguous property rights could increase the overall productivity of the agriculture sector, especially within rural settings (World Bank, 2010).

The ownership, or importance of livestock was found to significantly influence farmers to adopt conservation agriculture technologies (Knowler & Bradshaw, 2007).

Knowler and Bradshaw (2007) identified land-use intensity and crop rotation also significantly influenced adoption of conservation agriculture practices. Farmers who have available land to fallow or recuperate are more likely to adopt practices, whereas farmers who continuously cultivate land may be less likely to adopt because of land and crop competition reasons (Knowler & Bradshaw, 2007). Additionally, farmers who implement crop rotation are also more likely to adopt conservation practices because of increased knowledge of nutrient requirements among different crops (Knowler & Bradshaw, 2007). The external input of chemicals (i.e. fertilizers, herbicides, and pesticides) is also statistically significant in the adoption of these practices (Knowler & Bradshaw, 2007).

Though Knowler and Bradshaw (2007) positively identified access to credit as a significant influence to adoption in conservation agriculture, green manure and cover crop studies have found significant and insignificant influences of this variable (Anderson et al., 2001; Arellanes & Lee, 2003; Soule, 1997). For rural areas, access to credit is just as important as access to land (World Bank, 2010). The government currently offers farm credit with an 18% interest rate; however, farmers report difficulties in accessing this credit and often resort to credit from private enterprises with a 30% interest rate (Mössinger et al., 2015). Landless and land-poor rural poor Paraguayans need access to financial services to improve their livelihoods and compete in agricultural markets (World Bank, 2010). Improved access to formal financial services, especially through credit, would allow opportunities for more efficient technology adoption and resource allocation (World Bank, 2010). Innovative policies to improve access to formal credit in rural areas are needed (World Bank, 2010).

Access to non-farm income has produced mixed results among studies; however, has been found overall to be a significant variable in adoption of conservation agriculture practices. Knowler and Bradshaw (2007) describe the mixed results within non-farm income as a provision for more financial resources to adopt the practice, or conversely, the diminished priority of agriculture in the household, therefore reducing interest to adopt. Research throughout Latin America shows that rural non-farm income represents a large share of total income of rural households (Correa et al., 2007). The importance of rural labor markets and non-farm economy in Paraguay has increased in the past decade (World Bank, 2010). Income studies conclude non-farm income is an important method to overcome poverty (Correa et al., 2007). Rural poverty alleviation strategies require support for both increased agricultural productivity and improved access to non-farm income (Correa et al., 2007).

The final theme in Knowler and Bradshaw's (2007) meta-analysis of adoption factors in conservation agriculture is exogenous characteristics. Knowler and Bradshaw (2007) conclude available sources of information also significantly influence conservation agriculture technology adoption. In addition to extension sources, farmers may receive green manure and cover crop information from other farmers, NGOs, foreign government assistance, or local agriculture enterprises (Anderson et al., 2001; Eilittä et al., 2004). Exposure to training and technical assistance also positively influences farmers to adopt conservation agriculture practices (Knowler & Bradshaw, 2007). Because of complexity, versatility, and specificity, risks to adopting green manure and cover crop technologies may be greater where farmers need to learn new, more sophisticated techniques and adapt them to on-farm conditions (Bot & Benites, 2001; Graff-Zivin & Lipper, 2008).

Extension practitioners play a key role assisting farmers throughout the decision-adoption process in green manure and cover crop technologies (Bot & Benites, 2001).

Farmers often report limited availability, and inadequate or inaccurate information among extension agents. These constraints are problematic in technology adoption (Ojiem et al., 2006). Programs introducing green manures and cover crops teach farmers how to utilize these species to improve the soil, but lack consideration in educating farmers about other uses of the crops (Bunch, 2005).

More extensive training and technical assistance on multiple uses of green manure and cover crop technologies may influence the rates of adoption among smallholder farmers. Finally, social participation has been identified as a significant variable influencing conservation agriculture practice adoption (Knowler & Bradshaw, 2007). Farmers involved in community organizations, interest groups, or leadership positions demonstrate positive influence to adopt conservation practices.

A range of factors influencing the adoption of green manure and cover crop technologies exist. The neglect of farmer-centered research and extension has overlooked many potential barriers that occur in the application of the technologies among rural smallholder farmers (World Bank, 2009). Future research must focus on farmers sharing their individual experiences for researchers and extensionists to adapt conservation agriculture technologies to ensure widespread, sustained adoption of this practice. The lack of concise formal examination of adoption factors of green manure and cover crop technologies warrants continued research on the topic (Anderson et al., 2001; Arellanes & Lee, 2003; Bunch, 2005, Erenstein, 2003). Wider adoption could be achieved if these variables of green manure and cover crop technologies are better understood (Anderson et al., 2001). Researchers conclude "any effective conservation policy will have to rely on a thorough understanding of that factors that lead farmers to adopt conservation practices" (Traoré et al., 1998, p. 114).

Purpose and Objectives

The purpose of this study was to examine adoption of green manure and cover crop technologies among Paraguayan smallholder farmers. The study objectives were to

1. Describe Paraguayan smallholder farmer characteristics;
2. Identify relationships between the adoption of green manure and cover crop technologies and characteristic variables; and
3. Determine if characteristic variables (farmer, biophysical, farm financial/management, and exogenous characteristics) significantly influence adoption among sample groups.

Methods

The descriptive, cross-sectional research design utilized quantitative dichotomous and continuous data methods. The target population of this study consisted of southeastern Paraguayan smallholder farmers. The sample population (N=*76*) consisted of farmers that were purposively selected to participate. Some 17-study locations were selected within seven departments in Paraguay to collect a diverse set of data and to reflect evidence on a national scale.

The sample groups were split between users and non-users of green manure and cover crop technologies. Users (n=40), or adopters of green manures were defined as participants who had been cultivating green manures or cover crops within the previous one-year period at the time of data collection. Non-users (n=36) were defined as participants who were non-adopters or those who did not cultivate green manures or cover crops with the previous one-year period at the time of data collection. One research goal intended to maintain an equal ratio of participants among sample groups to allow for objective quantitative data analysis. The research team also surveyed equal ratios of participants with similar characteristics in each study location to limit data collection bias.

The research instrument (Appendix A) was adapted from Knowler and Bradshaw's (2007) conservation agriculture meta-analysis that identified major themes and independent binary variables that are significant in the adoption of a practice. Knowler and Bradshaw (2007) originally examined 46 variables that influence adoption of conservation agriculture practices. The analysis indicated only 33 of the total 46 variables were significant in the adoption of the technologies. The remaining 13 inconclusive variables were argued for continued research because of the varied positive, negative, and insignificant results that were produced during the meta-analysis (Knowler & Bradshaw, 2007).

The selection of variables for instrumentation focused on farmer, farm, financial, and exogenous characteristics that pertain to green manure and cover crop technologies. In total, 19 variables were selected for survey implementation. The dependent variable classified participants into two subgroups of green manure and cover crop technologies (1= user, 0= non-user). The instrument contained themes of farmer, biophysical, financial/management, and exogenous independent characteristic variables.

Continuous data within farmer characteristic variables included age, education, and farming experience, in the number of years. Participant gender (1= male, 0= female) was collected on a dichotomous scale.

Biophysical farm characteristic variables were measured through continuous data about farm size and cultivation size (number of ha). Farm financial and management characteristic variables were collected through dichotomous data. The measures included were: rented land (1= yes, 0= no) livestock ownership (1= yes, 0= no), land-use intensity (1= continuous system, 0= fallow system), crop rotation (1= yes, 0= no), chemical fertilizers (1= yes, 0= no), pesticides (1= yes, 0= no), access to credit (1= yes, 0= no), and non-farm income (1=yes, 0= no) were also collected through dichotomous measures.

Finally, dichotomous data in the exogenous theme included measures of access to an information source about green manure and cover crop technologies (1= yes, 0= no), training attendance on green manures and cover crops (1= yes, 0= no), receive technical assistance (1=yes, 0= no), and social participation in an organization (1= yes, 0= no). The definitions of instrumentation variables can be found in Table 4.1.

Participants had the opportunity to expand their responses narratively by explaining their experiences. This allowed for expansion upon quantitative data and allow for previously unidentified information in the green manure and cover crop adoption process to be recognized. Recent Paraguayan census data conclude illiteracy rates among rural populations about 10%, therefore requiring data collection instruments to be orally administered to allow objective participation (Dirección General de Estadística, Encuestas y Censos, 2013). Paraguay is officially recognized as a bilingual country. The survey design was implemented through Spanish and Guaraní languages. The instrument was parallel translated and verified for translational correctness with a certified language instructor (Stoop & Harrison, 2012).

All data were analyzed using descriptive statistics. A bivariate correlation was conducted through a Pearson's r first to determine relationships between the adoption of green manure and cover crop technologies and other characteristics. The data were analyzed at the .05 significance level. Next, a regression analysis was conducted to determine factors influencing adoption of the technologies. First, a linear regression was conducted to examine non-binary data responses. A logistic (logit) regression was then utilized to examine the binary data. The regression data were analyzed at the .05 significance level.

Table 4.1

Definition of Dependent and Independent Variables

Dependent variable	
Green Manure/Cover Crop User Status	1= User, 0= Non-user, of green manures and cover crop technologies within the previous one-year period leading up to data collection
Independent variables	
Age	Age of participant, measured in years
Gender	Gender of participant, 1= male, 0= female
Education	Participant years of education, measured in years
Experience	Participant years working experience in agriculture, measured in years
Farm size	Farm size, measured in hectares
Cultivation size	Size of land cultivated, measured in hectares
Rented land	Rented land, 1= yes, 0= no
Livestock	Ownership of livestock, 1= yes, 0= no
Land use intensity	Intensity of cultivation, 1= continuous, 0= fallow system
Crop rotation	Crop rotation practice, 1= yes, 0= no
Chemical fertilizer	Use of chemical fertilizers, 1= yes, 0= no
Natural fertilizer	Use of natural (manure) fertilizers, 1= yes, 0= no
Pesticides	Use of pesticides, 1= yes, 0= no
Credit	Access to credit, 1= yes, 0= no
Non-farm income	Access to non-farm income, 1= yes, 0 = no
Information source	Access to information about green manures, 1= yes, 0= no
Training	Attendance at green manure training, 1= yes, 0= no
Technical assistance	Receive technical assistance, 1= yes, 0= no
Social participation	Membership in a social organization, 1= yes, 0= no

Results and Discussion

Participants (*N*=76) included smallholder farmers from seven departments in southeast Paraguay. The majority (*n*=30) of participants resided in Itapúa department. Other study locations included participants in Paraguarí (*n*=14), Misiones (*n*=10), Caazapá (*n*=8), Caaguazú (*n*=7), Guairá (*n*=5), and Ñeembucú (*n*=2) departments (Figure 4.1).

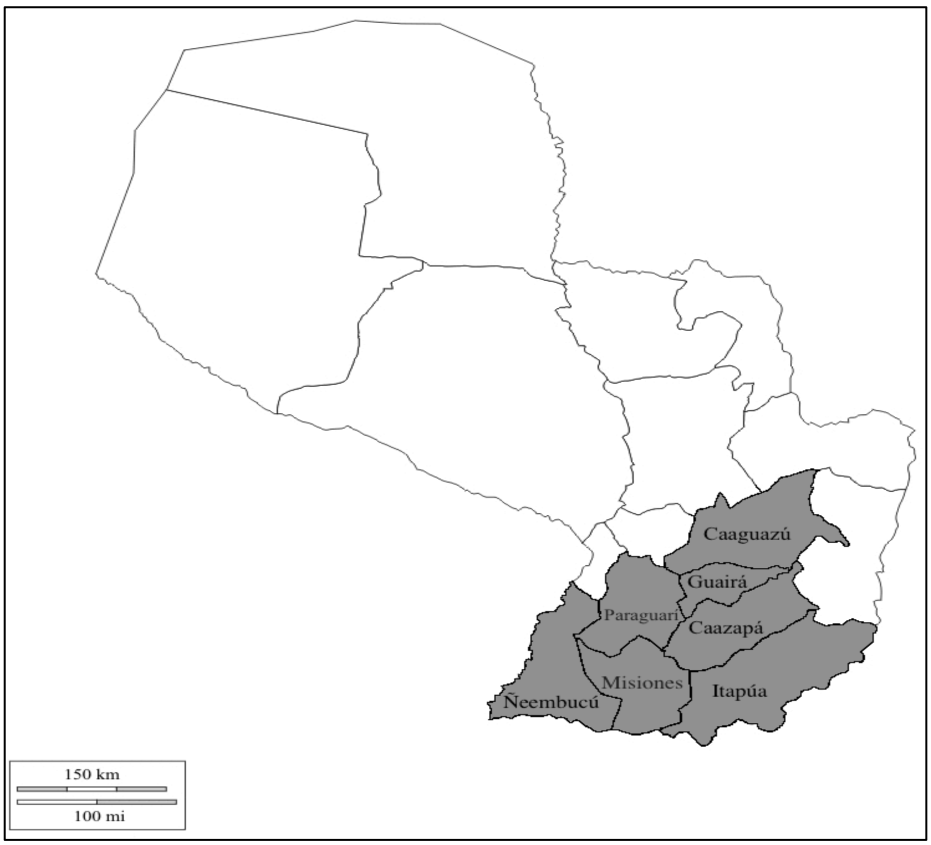

Figure 4.1. Study Location Map per Departments. Adapted from "Paraguay Departments Outline," by D. Dalet, 2016. Retrieved from http:// http://d-maps.com/carte.php?num_car=25075&lang=en. Copyright 2007-2016 Daniel Dalet.

From the sample population, 40 participants were considered users and 36 were considered non-users. Table 4.2 refers to descriptive statistic data in the sample population demographics.

Table 4.2

Sample Population Descriptive Statistics of Independent Variables

Influencing variables	Users (n = 40)		Non-users (n = 36)		Sample population (n = 76)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Age	52.58	10.80	54.14	9.88	53.31	10.15
Gender	0.83	0.38	0.89	0.32	0.88	0.34
Education	6.38	3.25	6.69	3.98	6.53	3.59
Experience	35.80	15.42	34.69	14.65	35.28	14.97
Farm size	9.30	7.46	7.92	5.72	8.65	6.68
Cultivation size	3.90	3.28	2.99	2.48	3.47	2.95
Rented land	0.13	0.33	0.11	0.32	0.12	0.33
Livestock	0.98	0.16	1.00	0.00	0.99	0.11
Land use intensity	0.73	0.45	0.58	0.50	0.66	0.48
Crop rotation	0.95	0.22	0.88	0.32	0.92	0.27
Chemical fertilizer	0.65	0.48	0.39	0.49	0.53	0.50
Pesticides	0.80	0.41	0.67	0.48	0.74	0.44
Credit	0.75	0.44	0.64	0.49	0.70	0.46
Non-farm income	0.43	0.50	0.56	0.51	0.49	0.50
Info source	0.85	0.36	0.50	0.51	0.68	0.47
Training	0.80	0.41	0.36	0.49	0.59	0.49
Technical assistance	0.50	0.51	0.25	0.44	0.38	0.49
Social participation	0.75	0.44	0.50	0.51	0.63	0.49

The user group had 33 males and 7 females, while the non-user group had 32 males and 4 females. The user group age (*M* = 52.58, *SD* = 10.80) was younger compared to non-users (*M* = 54.14, *SD* = 9.88). The results support that younger farmers may be more disposed to adopting conservation agriculture practices compared to older, more traditional farmers. The mean age for the sample population (*M* = 53.31, *SD* = 10.15) was much higher than expected.

The sample population's education was higher (*M* = 6.53, *SD* = 3.59) compared to national farmer education rates. Within participant groups, non-users completed more years (*M* = 6.69, *SD* = 3.98) of formal education compared to users (*M* = 6.38, *SD* = 3.25). These results do not support previous studies' conclusions that more years of education influences adoption of green manures and cover crops.

Users had a slightly higher mean years of experience in agriculture (*M* = 35.80, *SD* = 15.42) compared to non-users (*M* = 34.69, *SD* = 14.65). The results support that more experience among farmers may signify a diversified knowledge of available practices to implement, which may include conservation agriculture technologies such as green manures and cover crops.

The sample population reported higher land holdings (*M* = 8.65ha, *SD* = 6.68) compared to census data. Users reported larger farm sizes (*M* = 9.30ha, *SD* = 7.46) and land cultivation sizes (*M* = 3.90ha, *SD* = 3.28) compared to non-users' farm size (*M* = 7.92ha, *SD* = 5.72) and cultivated land size (*M* = 2.99ha, *SD* = 2.48).

The sample population cultivated less area (*M* = 3.47ha, *SD* = 2.95) than the majority of the Paraguayan smallholder farmer population. The results conclude that users of green manure and cover crop technologies cultivate more land compared to non-users; however, there is minimal supporting evidence to conclude any relationship that more cultivation of land influences the utilization of the technologies.

A small portion of the sample population (*M* = 0.12, *SD* = 0.33) identified as land renters. Between the sample groups, users reported *M* = 0.13, *SD* = 0.33 and non-users *M* =

0.11, *SD* = 0.32 as land renters for agricultural production. Few differences existed between the sample groups in regard to livestock ownership. Ninety-eight percent of users (*SD* = 0.16) were livestock owners, while the entire non-user sample (*M* = 1.00) were livestock owners.

A majority of participants (*n* = 50) continuously cultivate their parcels of land, however; more non-users (*M* = 0.42, *SD* = 0.50) reported fallow systems to allow the land to recuperate compared to the user group (*M* = 0.28, *SD* = 0.45). A majority of participants (*n* = 70) noted the practice of crop rotation, however, fewer non-users (*M* = 0.89, *SD* = 0.32) practice this technique compared to users (*M* = 0.95, *SD* = 0.22).

Differences existed in the utilization of chemical fertilizers between the sample groups, in which users (*M* = 0.65, *SD* = 0.48) reported higher usage rates compared to non-users (*M* = 0.39, *SD* = 0.49). A majority of the sample population (*M* = 0.74, *SD* = 0.44) noted the use of pesticides. Eighty percent (*SD* = 0.41) of users utilized pesticides, meanwhile 67% (*SD* = 0.48) of non-users utilized pesticides for crop application.

A majority of participants (*M* = 0.70, *SD* = 0.46) noted access to credit. Within sample groups, users (*M* = 0.75, *SD* = 0.44) noted higher access to credit compared to non-users (*M* = 0.64, *SD* = 0.49). Exactly one-half (*M* = 0.50, *SD* = 0.50) of each sample group noted the use of hired labor in their agriculture systems. A majority of non-user participants (*M* = 0.56, *SD* = 0.50) noted incidences of non-farm income, whereas a majority of user participants (*M* = 0.58, *SD* = 0.50) noted reliance on farm income as the main cash source for the residence.

Within the exogenous characteristic theme, users of the technologies reported higher incidences in access to the variables. Users had a higher reported incidence (*M* = 0.85, *SD* = 0.36) of available information sources for green manures and cover crops compared to non-users (*M* = 0.50, *SD* = 0.51). In addition, users reported higher rates (*M* = 0.80, *SD* = 0.41) of attendance at green manure and cover crop training events compared to non-users (*M* = 0.36, *SD* = 0.49). Users (*M* = 0.50, *SD* = 0.51) also reported higher incidences of technical assistance reception compared to non-users (*M* = 0.25, *SD* = 0.44). Finally, users (*M* = 0.75, *SD* = 0.44) of green manures and cover crops reported higher rates of membership within a social organization compared to non-users (*M* = 0.50, *SD* = 0.51).

A Pearson's *r* was conducted to determine if relationships existed between the dependent variable and independent variables before conducting the regression analysis. The bivariate correlation produced relationships among five variables and the dependent variable of cultivating green manures and cover crops. Only two characteristic themes produced relationships within the study. The highest relationship was training attendance ($r = 0.45$, $p < .05$), which produced a moderate relationship in the utilization of green manure and cover crop technologies. Next, access to green manure and cover crop information ($r = 0.38$, $p < .05$) produced a moderate relationship to the adoption of the technologies. Two variables within exogenous characteristic theme also produced weak relationships. Social participation ($r = 0.26$, $p < .05$) and the ability to receive extension ($r = 0.26$, $p < .05$) were concluded as weakly related to the adoption of green manures and cover crops. Within the farm financial/management theme, the utilization of chemical fertilizer produced a weak relationship ($r = 0.26$, $p < .05$) between the two variables. The data are reported in Table 4.3.

Table 4.3

Bivariate Correlation of Independent Variables

Variable	*r* coefficient	*p*-value	Significant
Training attendance	0.45	0.001	$p < .05, p < .01$
Access to information	0.38	0.001	$p < .05, p < .01$
Technical assistance	0.26	0.003	$p < .05$
Social participation	0.26	0.002	$p < .05$
Chemical fertilizer	0.26	0.002	$p < .05$

Next, two regression models were conducted to determine the effect in which each variable influences adoption of green manure and cover crop technologies. No significant variables were determined from the linear regression of non-binary data. The logit regression model concluded the previous five correlated variables as factors influencing the adoption of green manure and cover crop technologies. The results are presented in Table 4.4.

Table 4.4

Regression of Dependent Variable on Independent Variables

Influencing Variables	Multiple R	R^2	Total Variance	F-Value Prob.	Sign of influence
Training attendance**	0.446	0.199	18.35	18.37	+
Access to information**	0.376	0.141	16.42	12.18	+
Chemical fertilizer*	0.261	0.068	18.95	5.41	+
Social participation*	0.259	0.067	17.68	5.31	+
Technical assistance*	0.257	0.066	17.93	5.23	+

* - significant at the .05 level
** - significant at the .01 level

First, the training attendance equation was found (F (1,74) = 18.37, $p < .05$), with an R^2 of 0.199, to influence farmers to adopt the conservation agriculture practice. Farmer training events are vital for potential adopters to recognize benefits in the implementation of the technologies. In addition, events such as farmer field days allow users, and potential adopters, to view and practice management abilities, therefore, receiving more influence to adopt the technologies.

Secondly, the information source regression equation was found (F (1,74) = 12.18, $p < .05$), with an R^2 of 0.141, to weakly influence adoption of the technologies. These sources may include government extension, NGOs, peer farmers, or other educational institutions within Paraguay.

Next, the chemical fertilizer regression equation was found (F (1,74) = 5.41, $p < .05$), with an R^2 of 0.068, to weakly influence the adoption of green manure and cover crop technologies. Anecdotal evidence suggests farmers receiving technology packages of green manures and cover crops often include chemical fertilizers, which may provide reasoning why this variable influences adoption.

Next, the social participation regression equation was found (F (1,74) = 5.31, $p < .05$), with an R^2 of 0.067 to weakly influence adoption of green manure and cover crop technologies. Many participants noted membership within a farmer-interest organization. Such organizations in Paraguay receive concentrated extension efforts such as agent visits or technology packages for on-farm implementation. In addition, organizational meetings allow for peer farmers to discuss current agricultural practices and share knowledge for future production enhancement or adoption of new agricultural practices.

Finally, the technical assistance regression equation was found (F (1,74) = 5.23, $p < .05$), with an R^2 of 0.066, to weakly influence adoption of green manures and cover crops. Extension in Paraguay should focus efforts on targeting larger populations of potential adopters to maximize efficiency of limited human extension resources available in country. Training events (i.e. farmer field days) have larger adoption potential rates compared to classic one-to-one agent-farmer ratio visits. Finally, participation within a social organization significantly influences adoption of green manure and cover crop technologies.

Conclusions and Recommendations

The results of the study indicate the following conclusions. The majority of the variables analyzed through the first model indicated little relationship between the utilization of green manure and cover crop technologies and the selected variable. Among the five variables identified as related to the adoption of the technologies, three variables were only weakly related, and the remaining two were moderately related. Further analysis in the logit regression emphasized the weak relationships and influence of variables on the adoption of green manure and cover crop technologies. It is important to note that each of the five characteristic variables only produced weak or moderate relationships and influences overall. Therefore, it can be concluded that conservation agriculture adoption models may not be worthy in measuring factors that influence adoption of green manure and cover crop technologies among Paraguayan smallholder farmers.

It is still important to recognize the five characteristic variables and how each may have a small effect on Paraguayan smallholder farmers' decisions to utilize green manures and cover crops. All results were identified to positively influence adoption. A majority of the factors that did influence adoption were exogenous characteristic variables. These results may indicate the importance of extension services to Paraguayan smallholder farmers. The availability of information sources, trainings, and technical assistance all positively influenced adoption of green manures and cover crops. These exogenous characteristics justify the need for, and expansion of continued extension efforts in promotion of these conservation agriculture practices to achieve widespread adoption.

In addition, the participation in social organizations positively conditions adoption of the technologies. The promotion of social participation among Paraguayan smallholder farmers presents opportunities for extension to capacitate potential adopters in soil conservation methods. Finally, the external input of chemical (inorganic) fertilizers positively influences adoption of the technologies. Future extension efforts should promote the combination of these inputs alongside the implementation of the technologies.

A majority of the variables analyzed indicated non-statistically significant results that influence adoption of green manure and cover crop technologies. Only five of the total 19 variables produced statistically significant results. There could be many reasons to explain why so many variables produced insignificant results. The survey instrument was adapted from a meta-analysis that measured adoption of a wide range of conservation agriculture technologies. Within this wide range of conservation agriculture technologies, each of the studies analyzed in the meta-analysis had differences in study sample populations and statistical analyses to aggregate and determine in one sole model that would determine influences in adoption of the technologies. Knowler and Bradshaw (2007) even noted that specificity, environmental, and other social conditions create complex situations that make social agricultural modeling difficult. The lack of finite, quantifiable measures in the study may also have an effect to explain how the abstract data did not produce significant results.

The results of this study support further research to effectively refine agricultural adoption modeling, especially in the context of conservation agriculture in smallholder, subsistence farming. Further examination into social, or exogenous characteristics, may have the most potential to be identified to influence adoption of conservation agriculture technologies such as green manures and cover crops.

Researchers and extensionists should continue working with Paraguayan farmers to implement or determine appropriate soil conservation and rehabilitation practices, meanwhile keeping the beneficiaries' knowledge and input in consideration. The continuation of social research in green manure and cover crop technologies is warranted due to the lack of concise, concentrated efforts that have existed in this century, especially in a smallholder subsistence context. The future of smallholder agriculture in Paraguay depends on concentrated efforts in soil conservation or rehabilitation to provide future generations the opportunity of leading a productive, prosperous lifestyle for years to come.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Green manure and cover crop technologies are versatile, beneficial, low-cost conservation agriculture technologies that assist farmers in maintaining or rehabilitating soil conditions for continued cultivation of subsistence and cash crop systems. Though the technologies have been promoted in Paraguay for decades, barriers to adoption exist. Promotional efforts have ignored social criteria, such as attributes and perceptions of these technologies. The neglect of examining attributes and perceptions within conservation agriculture studies may bias results on factors that influence adoption. Lack of knowledge and of available resources have also hindered widespread rates of green manure and cover crop technology adoption. Refinement and future extension promotion depends on participatory, decentralized development and dissemination of the technologies among researchers, extensionists, and farmers.

Paraguayan smallholder subsistence farmers face significant challenges for the future. Poor soil fertility and land distribution inequalities are principal constraints that perpetuate smallholder poverty and threaten Paraguay's future agriculture industry. Future extension strategies should be directed toward improvement of soil fertility through conservation agriculture practice utilization such as green manures and cover crops, meanwhile considering beneficiaries' attributes and their perceptions toward innovations as important.

This study examined Paraguayan smallholder farm characteristics and determined perceptions and factors that influence green manure and cover crop technology adoption. The results are important for researchers and extensionists to consider. Paraguay has an aging subsistence farmer population with few policy considerations to target younger populations to enter the practice. Government and extension communities should identify promotional efforts to prevent rural youth migration and entice entry or takeover of family smallholder farm systems.

Considerable evidence supports that soil problems are a production constraint, and future efforts should maintain a course of action to work with farmers in the implementation of soil conservation practices to improve soil quality. Green manures and cover crops are considered an effective soil erosion prevention tool for Paraguayan smallholder farmers. The significant decreases and lack of erosion among green manure users indicates a potential outcome of adoption, and demonstrates a promotional benefit to potential adopters of the technologies. The perceived ability to manage green manures and cover crops may indicate another necessity for adoption and demonstrates effective comprehension of the technologies from receiving technical assistance, training, or farmer-to-farmer interactions.

Perceived risk of green manure and cover crop cultivation may constrain or delay the adoption-decision process among potential adopters. Extension must work with potential adopters to reduce perceived risks in the technology adoption-decision process. Smallholder farmer participants do not consider the technologies as an economically viable practice. This may deter smallholder farmers from adopting the technologies. Efforts should be prioritized to reduce entry costs in the implementation of the system and examine methods to improve the sustainability of the technology. Examples may include the examination of economical applications that entice potential adopters to invest financial resources wisely or the realization of long-term benefits after initial investment. Efforts are needed to make conservation agriculture practices profitable and compatible to transition farmers toward sustainability.

Farmers consider multiple benefits of green manure and cover crop technologies before selecting appropriate species to cultivate. Paraguayan smallholder farmers are more likely to consider the potential crop production increase above all other advantages, and at a higher magnitude compared to other advantages. Further research should examine how, or why smallholder farmers are disinclined to adopt the practice even though they may be aware of various benefits in the technology implementation. The most common reported disadvantage was high seed cost.

Perceived decreased labor requirements in the implementation of green manures may indicate a potential outcome in adoption of the practice. Promotion of reduced labor requirements in the implementation of the technology may assist extensionists achieve wider adoption rates.

Measuring adoption-extent rates is a challenge for the future of conservation agriculture research. Farmers may not be able to accurately estimate their perceived use. In addition, mathematical calculations may not be sufficient in measuring the intensity which a farmer utilizes a conservation agriculture technology. Further research must examine factorial analyses that include factors of: long-term effects on land use, production costs, and environmental considerations in order to refine the measurement of adoption intensity of conservation agriculture technologies.

Many characteristic variables that may influence adoption of conservation agriculture technologies were not found to influence adoption of green manures and cover crops among Paraguayan smallholder farmers. A majority of the variables analyzed through the first model indicated little relationship between the utilization of green manure and cover crop technologies and the selected variable. However, relationships in green manure and cover crop cultivation were indicated with training attendance, information sources, chemical fertilizer, social participation, and technical assistance.

Training attendance was found to positively influence adoption of green manure and cover crop technologies. Training events, such as farmer field days, are vital for potential adopters to recognize benefits in the implementation of the technologies. In addition, these events allow potential adopters to view and practice management abilities, therefore, receiving more influence to adopt the technologies. These type of training events allow extension practitioners to focus efforts on targeting larger populations of potential adopters to maximize efficiency of limited human extension resources available in country. Sources of information from farmer interest groups, NGOs, government extension, and educational institutions are also influential in the adoption of green manure and cover crop technologies. These educational sources have potential to investigate the most effective materials or methods needed to promote widespread adoption of conservation agriculture technologies such as green manures and cover crops.

Chemical fertilizer inputs also significantly influence adoption of green manure and cover crop technologies. Extension should continue promoting green manures and chemical fertilizers in a crop package to entice farmers to adopt the technologies. Participation within a social organization significantly influences adoption of green manure and cover crop technologies. Social promotional efforts should encourage smallholder farmer participation in these organizations in order to maximize limited extension resources. Finally, access to technical assistance was found to influence the adoption of green manure and cover crop technologies.

Because of the majority insignificant and weak significant variables, it can be concluded that conservation agriculture adoption models may not be effective in measuring factors that influence adoption of green manure and cover crop technologies among Paraguayan smallholder farmers. Specificity, environmental, and other social conditions create complex situations that make agricultural modeling difficult. Refinement within agricultural adoption modeling is necessary in conservation agriculture adoption, especially in the green manure and cover crop context. Further examination into social, or exogenous characteristics may have the most potential to be identified to influence adoption of conservation agriculture technologies such as green manures and cover crops.

Researchers and extensionists should continue working with Paraguayan farmers to implement or determine appropriate soil conservation and rehabilitation practices, meanwhile keeping the beneficiaries' knowledge and feedback in consideration. The continuation of social research in green manure and cover crop technologies is warranted due to the lack of concise, concentrated efforts that have existed in this century, especially in a smallholder subsistence context. The future of smallholder agriculture in Paraguay depends on concentrated efforts in soil conservation or rehabilitation to provide this and future generations the opportunity of leading productive, prosperous, sustainable lifestyles in production agriculture.

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APPENDIX A

LETTER OF CULTURAL UNDERSTANDING

To: Texas A&M University IRB
From: Gloria Aquino, Peace Corps/Paraguay
Date: January 26, 2015
Re: Letter of Cultural Understanding

I am writing in regard to an agriculture volunteer, Orry Pratt (researcher), and his thesis research while in Paraguay. I am the Associate Peace Corps Director (APCD) for the Agriculture program, and I have held this position for seven and a half years now. I am a native Paraguayan that understands the cultural, language, and demographical concepts that are important in formulating culturally appropriate research. In addition, I received my master's degree in 1995 from Kansas State University, and understand the processes that drive research. I have discussed the proposed research several times with the researcher, and understand the objectives in data collection. I also assisted the researcher in the survey translation to the Guaraní language for accuracy.

Based on the review of subject recruitment methods with the researcher, I affirm that the use of phone calls and personal visits are culturally appropriate based on the demographics of the research locations. Because of distance issues for the researcher, in addition to the rural aspects of the locations, these measures will be taken in order to ease the data collection process. The use of digital materials (with exception to cell phones) and public flyers are not socially acceptable for subject recruitment. This study does not offer any compensation; therefore, participants will not be coerced in any form.

The utilization of a bilingual, understandable, information is important when working in Paraguay. The researcher has developed accurate; understandable consent forms and surveys for data collection. Participants will not be intimidated, or confused with the consent forms or surveys. The consent process does allow for adequate privacy among the participants; no names or phone numbers shall be published. No other personal information shall be collected.

There is no perceived risk in conducting this study. No safeguards shall be needed to protect the rights or welfare of the subjects. Because there is no risk involved for the participants, no procedures are needed to reduce participant risk.

I recommend this study to be culturally appropriate based on the terms and conditions previously discussed with the researcher. This research may assist the extension officials that work in this country, and around the world for the future. I look forward hearing the results of this topic very soon. This is not an official endorsement from Peace Corps Paraguay but based on my personal knowledge of Orry Pratt.

Regards,

Gloria Aquino
ACPD – Agriculture
Peace Corps/Paraguay
gaquino@py.peacecorps.gov
+595.21.600.155 x1873

APPENDIX B

PARTICIPANT RECRUITMENT DIALOGUE

Hello, my name is Orry Pratt, and I am a Peace Corps volunteer. I work in the agriculture sector and I live near San Pedro del Paraná. I work with many farmers in my community and I enjoy working in Paraguay. I am conducting research about agriculture as a part of my service. I would like to ask if you would participate in my study to understand agriculture in this country. I can visit your house to conduct the survey if you wish. Please let me know if you would like to participate in the study.

Affirmative response: Great, when is a good time to meet?
Negative response: Okay, thank you for your time.

APPENDIX C

PARTICIPANT INFORMED CONSENT

Name of study: Adoption factors and perceptions of green manure and cover crop technologies among Paraguayan smallholder farmers

First, I will say each phrase in Spanish, and then I shall translate each phrase into Guaraní so that you understand this consent form well, as well as the study questions. I would like to ask you to participate in an academic study. You do not have to participate in the study if you do not wish. If you say yes, you may stop your participation in the study at any moment. Please, use all the time you need to make your decision.

I would like to know more about how to help Paraguayan smallholder farmers. This study will help me learn more about green manures and cover crops. I am asking people like you, who have agricultural experience, to help me. If you say "yes," I will administer a survey with questions in which you will respond. I will ask you about family information, your farm, your finances, and your social participation. I will read you the questions in a clear voice, and will write your responses in the survey form. These questions do not have right or wrong answers. You can skip any question if you do not wish to answer. There is no benefit, nor penalty for you to participate or not participate, but your responses can assist other farmers globally in the future. Participation is free and does not imply any commitment. Nobody will treat you in a different manner. The only authorized people allowed to view your responses are those who work with this study. The study will take about 15 minutes of your time.

Personal information will be confidential, and nobody will know that you participate. When I share the study results, especially with my professors and academic journals, no personal information will be included. I will do everything possible so that nobody outside of the study will know you participate. There may be questions that might make you feel uncomfortable, but you do not have to respond if you feel bad. You understand that you do not have to respond to questions if you do not wish to do so. You may end the survey at any moment and nothing will happen to you.

For questions about your rights as a research participant; or if you have questions, complaints, or concerns about the research, you may contact the Texas A&M University Human Subjects Protection Program at 979.458.4067, toll-free at 1.855.795.8636, or email at irb@tamu.edu. If you have questions, concerns, or complaints about the study, please let me know now. Also, you may contact me at 0984.656.188 or email at orrypratt@gmail.com. You must sign this document in order to participate. Upon signing this document, you are saying that you are agreeing to participate in this study. I have explained to you the information of this study in Spanish, and have translated it into Guaraní so that you may fully understand the information in this form.

____
Name

_________________________________ __________
Signature Date

APPENDIX D

RESEARCH INSTRUMENT

Farmer characteristics	
Do you cultivate green manures or cover crops?	1=yes, 0=no (Dependent variable)
What is your gender?	1=male, 0=female (Independent variables)
What is your age?	Farmers age, in years
How many years of education did you receive?	Number of years of education
How many years have you been farming?	Number of years farming
Do soil problems exist on your farm?	1=yes, 0=no
Do you know how to manage green manures and cover crops?	1=yes, 0=no
Do green manures and cover crops increase the yield of other crops?	1=yes, 0=no
Is risk involved with cultivating green manures?	1=yes, 0=no
If so, please tell me the different risks in cultivating green manures	
Is cultivating green manures economically feasible?	1=yes, 0=no
Do advantages exist in cultivating green manures?	1=yes, 0=no
If so, please tell me the different advantages in cultivating green manures	
Do disadvantages exist in cultivating green manures?	1=yes, 0=no
If so, please tell me the different disadvantages in cultivating green manures	
Biophysical farm characteristics	
How many total hectares is your farm?	Number of total hectares
How many total hectares do you cultivate?	Number of hectares in cultivation
Do you rent land?	1=yes, 0=no If yes, number of hectares __________
How many years has your land been cultivated?	Number of years under cultivation
How many years experience do you have with green manures and cover crops?	Number of years experience
Have you experienced erosion problems on this land in the past?	1=yes, 0=no
Do you currently experience soil erosion problems on this land?	1=yes, 0=no
How do you work your land?	1=continuous cultivation, 0=cultivation/fallow system
How many hectares do you cultivate utilizing green manures on property you own?	Number of hectares
How many hectares do you utilize green manures on rented property?	Number of hectares
Do you practice crop rotation?	1=yes, 0=no
Do green manures and cover crops require more labor?	1=yes, 0=no
Do you feel green manures and cover crops require less labor?	1=yes, 0=no
What percent (out of 100) do you feel you have adopted green manures and cover crops on your farm?	Perceived adoption-extent rate (0-100)
Financial management characteristics	
Please describe your land tenure situation.	0=all rented land, 1=owned/rented land, 2=all owned land 3=family-shared 4= land occupant
Do you own livestock?	1=yes, 0=no
Do you have access to receive credit?	1=yes, 0=no
Do you have sources of income that are non-farm related?	1=yes, 0=no
Do you apply chemical fertilizer?	1=yes, 0=no
Do you apply natural fertilizer?	1=yes, 0=no
Do you hire labor?	1=yes, 0=no
Do you use pesticides?	1=yes, 0=no
Exogenous characteristics	
Do you receive extension or technical assistance?	1=yes, 0=no
Have you ever attended a class, training, or workshop in green manures and cover crops?	1=yes, 0=no
Do you participate in any social organizations?	1=yes, 0=no
Do you have available sources of information about green manures and cover crops?	1=yes, 0=no
Do you have an available market to purchase green manure and cover crop seeds?	1=yes, 0=no