Understanding farmer co-learning processes under the Learning Centre approach to promote uptake of soil fertility management technologies in Zimbabwe

by

Tinashe Charles Mashavave

A thesis submitted in partial fulfilment of the requirements of the Degree of Master of Philosophy

Department of Soil Science and Agricultural Engineering

Faculty of Agriculture
University of Zimbabwe

August 2014

ABSTRACT

The current low levels of technology adoption among smallholder farmers in southern Africa do not reflect the high investment levels in agro-technological research aimed at addressing perennial food insecurity challenges. A study was conducted in the context of established Soil Fertility Consortium for Southern Africa (SOFECSA) field-based Learning Centres (LCs) to assess the effectiveness of impact-oriented adaptive research in driving the benefits of integrated soil fertility management (ISFM) for improved livelihoods among smallholder farmers during the 2009/10 and 2010/11 cropping seasons. Specifically, the study sought to: i) identify determinants of farmer participation in knowledge sharing alliances around field-based learning centres; ii) explore interaction patterns that determine improved information and knowledge sharing among smallholder farmers participating in learning alliances; and iii) evaluate relative benefits of ISFM technology use by smallholder farmers participating in learning alliances. Data were collected through key informant interviews, focus group discussions, and direct observations. A questionnaire survey was also administered to a stratified random sample of 70 households drawn from learning alliance participant and non-participant groups clustered by resource-endowment. The main analytical tools used in this study were descriptive analysis, logistic regression, social network analysis and gross margin analysis. A major challenge encountered in this research was the number of farmers who volunteered to participate in learning alliances (68) which had the potential to compromise regression analysis due to small sample sizes. The time frame of the study could not effectively capture adoption of the promoted ISFM package as some potential adopters wait until they observe success from neighbouring farmers before integrating the practices in their cropping programmes. Gross margin analyses used in the study are point estimates, but in reality farmer production circumstances are not static. The study showed how farmers valued the attributes defining a LC with respect to its technical content, physical location and attitude of the host farmer, as a prerequisite for their participation in the learning alliance. A logistic regression analysis showed that socio-economic, physical and demographic attributes of the farming households influenced participation at varying scales. Specifically, farmer’s age, size of arable land, ownership of farming implements, household membership in learning alliances and social capital had a significant positive influence on participation. On the other hand, available active labour and number of cattle owned negatively influenced participation. Approximately 72% of farmers within learning alliances adopted components of the promoted ISFM package and these were often seen to be modified to suit particular farmer circumstances. To understand the potential of smallholder farmer social interactions in influencing the innovation-decision process, social network analysis was used. Results showed how exposure of farmers to field-based learning alliances altered their social interaction pattern producing a denser network structure implying access to more horizontal and vertical connections. Closeness centrality indices were generally higher for learning alliance participants than non-participants, suggesting higher communication efficiency in terms of sending and receiving ISFM information. While national extension dominated information dissemination within the network of non-participants, farmer-farmer interactions were the primary source of information for participant farmers. This suggested a digression from predominantly linear extension approaches to an innovation systems approach. There was a general indication that learning alliances enabled uptake of legume-cereal rotations by 42% of the farmers. Analysis of differential benefits of ISFM technologies showed that adoption of rotations led to higher maize grain yields and net benefits for both the 2009/10 and 2010/11 cropping seasons than conventional practices. Marginal returns to investment were close to 200% and 59% for 2009/10 and 2010/11, respectively. Resource-endowed farmers constantly had higher maize grain yields of >2 t ha^{-1}, than the intermediate and resource-constrained farmers who averaged ~ 1.6 t ha^{-1} and ~1.8 t ha^{-1}, respectively over the two seasons. However, adoption of rotations by the resource-constrained farmers resulted in maize grain yields 10-15%

higher than the intermediate group farmers. The rotations not only improved the cropping environment for the staple maize crop, but also provided a food security buffer in the poor rainfall season of 2010/11.These results suggested that research and development initiatives that empower smallholder farmers and their partners to participate along agricultural value-chains are essential to enhance the generation, dissemination and adoption of relevant and improved soil fertility management technologies. It was concluded that mobilisation of farmers into learning alliances can be an effective approach for promoting their uptake of technologies such as ISFM. Extension approaches should consider the use of participatory methodologies that empower target communities to actively participate in the research and scaling-up processes as co-learners with researchers, extensionists and other agro-stakeholders along input and output market chains.

ACKNOWLEDGMENTS

My sincere gratitude to RUFORUM for providing funding for the research through Grant No: RU 2009 GRG_05 "Translating integrated soil fertility management empirical knowledge into action through participatory learning and marketing with farmers in Zimbabwe" to Dr Florence Mtambanengwe from the University of Zimbabwe. The study was conducted in the context of broader research for development initiatives of the Soil Fertility Consortium for Southern Africa (SOFECSA). Additional funding and availing Integrated Soil Fertility Management (ISFM) technical materials in the study area by SOFECSA is also highly acknowledged.

Many thanks go to my main supervisor, Prof. P Mapfumo, for his professional guidance and constructive criticism during the course of the study. My heartfelt thanks also go to my co-supervisors Dr F Mtambanengwe and Dr S Siziba for their unwavering support, encouragement, professional supervision and co-ordination of field activities. To my fellow RUFORUM student, Tariro Gwandu, thank you for the moral support and cooperation.

I thank Hatirarami Nezomba, Jairos Rurinda, Grace Kanonge, Grace Manzeke, Tongai Mutangadura, Christopher Chagumaira and Natasha Kurwakumire for their assistance in field work. I would also want to express my gratitude to smallholder farmers from Nyahava Ward, Makoni District and extension officers from the Department of Agricultural and Technical Extension Services (AGRITEX) of the Ministry of Agriculture, Mechanisation and Irrigation Development, Zimbabwe for their cooperation.

DEDICATION

In memory of my late father Mr Joakim Mashavave.

All praise and honour goes to the Lord God Almighty for seeing me through this work.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

Introduction

1.1 Background

Decreasing per capita food production remains a major developmental challenge in sub-Saharan Africa (SSA) (FAO et al., 2012). Africa is estimated to have spent US$18.7 billion on food imports in the year 2000 alone, which rose by over two-fold to US$49 billion in 2008. In 2006, Africa received 3.8 million tonnes of food aid, which is over a quarter of the world total, indicating substantial external dependency (FAO, 2008). Projections for 2012-2022 show SSA to be the only region that will experience an increase (15.1%) in the number of food insecure people. This is despite global prediction that the proportion of individuals facing food insecurity will fall from 42% in 2012 to 38% in 2022 (USDA, 2012). Within the same period the food distribution gap is anticipated to grow by 19% suggesting considerable regional food insecurity (USDA, 2012). Sub-Saharan Africa's annual cereal imports are expected to rise to >30 million tonnes by the year 2020 due to a continued decline in the per-capita food production against a rapidly growing population estimated at 3% per annum (FAOSTATS, 2012).

The World Bank recognizes soil nutrient depletion as the single most critical biophysical constraint to food production and security in most smallholder farming systems of SSA (World Bank, 1995; TSBF, 2000). The declining soil fertility has resulted in low soil productivity, loss of agro-biodiversity, low soil water and nutrient use efficiencies in cropping systems, low returns to capital investments and soil loss (Odera et al., 2000; Mapfumo et al., 2013), which in turn deepen poverty. This implies that a commensurate increase in agricultural production to meet the demands of a growing population is inevitable. The concern for low yields has led to many attempts in the past decades to develop, test and disseminate several integrated soil fertility management (ISFM) technologies that could restore soil fertility and improve productivity (Hagmann et al., 1998; Mekuria and Siziba, 2003; Mapfumo, 2009). Mapfumo et al. (2013) defined ISFM as the application of a combination of proven concepts, principles and practices to the efficient use of available organic and inorganic resources, soil water and appropriate plant genotypes, and according to farmers' socio-ecological circumstances, to maintain/improve soil fertility leading to sustainable crop production for household food security, income benefits, environmental integrity and enhanced livelihoods.

Smallholders have widely adopted improved varieties including hybrids, but fall short on improved soil fertility management technologies (Stoorvogel and Smaling, 1998; Damisa and Igonoh, 2007). This poor adoption has often been linked to the lack of responsiveness of the new technologies to farmers' heterogeneous resource endowments and risk-return preferences (Chambers, 1993; Mekuria and Siziba, 2003). Mapfumo (2009) highlighted the existence of and the need to bridge glaring technical knowledge gaps between researchers and major players in the agricultural sector to stimulate adoption of improved technologies. This therefore suggests that innovative approaches which empower all actors in agricultural value chains; are a necessity and these could foster a shared understanding of the multi-faceted consequences of poor and declining soil productivity to generate appropriate solutions collectively (Mapfumo et al., 2013). However, there is still paucity of empirical evidence on effective approaches that can influence the adoption of improved soil fertility management options.

The applicability of participatory action research (PAR) approaches in complex social learning contexts (German et al., 2007) has revealed potential for influencing change processes. Participatory action research is viewed as a means of bringing together diverse stakeholders as co-learners and bringing the knowledge and skills of each player to bear on the problem and work collectively towards solutions (Pretty and Buck, 2002). The PAR approaches are perceived to improve efficiency, both in technology development and in building farmers' capacity for experimentation and collective learning (German et al., 2007). This has generated scope for evaluating how PAR can influence farmer learning and uptake of ISFM technologies.

In recent years, the Soil Fertility Consortium for Southern Africa (SOFECSA) has demonstrated the potential of field-based Learning Centres and innovation systems approaches in promoting agro-stakeholders to work together to identify technological options that respond to farmers' unique circumstances (Mapfumo, 2009; Gwandu et al., 2014). The consortium employs the Learning Centre (LC) concept to promote ISFM and climate change adaptation by smallholder farmers as entry points aimed at developing mechanisms for 'getting out of the maize poverty trap' (Mapfumo, 2007). Integrating these farmer-centred co-learning approaches with PAR was found to translate available empirical ISFM knowledge into increased crop yields and income benefits for smallholder farmers (Mapfumo et al., 2013; Gwandu et al., 2014). However, comprehensive empirical evaluation and harmonisation of the approaches towards co-learning is still required. The evaluation could include monitoring, process, cost-benefit and impact evaluation (Aldrich and Sayer, 2007). It may also encompass outcome mapping to observe transitional effects such as change of farmer perceptions (Valadez and Bamberger, 1994). Increasingly, there has been an appreciation that impact evaluation should focus on 'influence' more than 'impact', as impacts are often a product of a myriad of interacting factors.

1.2 Rationale

Despite cumulative gains in empirical knowledge over decades of soil fertility research, adoption rates of promising and improved technologies by target groups remain low and insignificant and yields have not changed either (Stoorvogel and Smaling, 1998). Grain yields of staple cereals, especially maize (*Zea mays* L.), in most parts of Southern Africa rarely exceed 1 tonne ha^{-1} among smallholder farmers (Mafongoya et al., 2006; Manzeke et al., 2012). The

Zimbabwe Vulnerability Assessment Committee (ZimVAC) in 2012 estimated that more than 1.6 million Zimbabweans will be unable to access sufficient food during the peak hunger period from January to March 2013. This has come in the wake of recurrent droughts, a string of poor crop yields, policy reforms within the agricultural sector and a high HIV/AIDS prevalence rate which have contributed to the upward spiral of vulnerability and acute food insecurity since 2001 (*http://www.wfp.org*). The challenge is thus to identify suitable approaches that can enhance uptake of improved soil fertility management technologies by farmers of diverse resources for sustainable agricultural production.

Emerging evidence suggests that lack of suitable mechanisms associated with the predominantly top-down models of dissemination of available knowledge and information to farmers by extension agencies and other agricultural service providers partly explains the low technology uptake (Hagmann et al., 1998; Nyikahadzoi et al., 2012; Mapfumo et al., 2013). The understanding that reality is socially-constructed and viewed in different ways by different actors in a system points to the need for researchers to be engaged in co-learning processes with those directly affected (Baum and Tolbert, 1985; German et al., 2007), in this case the smallholder farmers. This may yield appropriate mechanisms for addressing the highly complex problems in smallholder farming systems. Each stakeholder is likely to bring a distinctive problem perspective and contribute to development of options for enhanced adaptive capacity, through participatory experimentation, evaluation of outcomes and making appropriate adjustments (Colfer, 2005; Lebel et al., 2006).

The 'transfer of technology' (ToT) model (Hagmann et al., 1998) was the widespread practice for research and technology development initiatives prior to the emergence of participatory approaches. Through this approach, it was the researcher's task to identify, analyse and solve farmers' technical problems usually at research stations (Roling, 1994; Hagmann et al., 1998). In

Zimbabwe, for instance, the results were then disseminated as instructions and blueprint solutions to the farmers through the agricultural extension agent, who was the link between researchers and farmers (CTA, 1997). This top-down flow of information was disjointed; both institutionally and in terms of disciplines thus, discouraged the feed-back of information (Hagmann et al., 1998; Nyikahadzoi et al., 2012). The approaches often failed to address the diversity of farmers' socio-economic and institutional environments. Hence, there was little adoption of the new and improved technologies (Stoorvogel and Smaling, 1998). Participatory approaches developed in the 1990's, including participatory technology development (PTD), participatory extension approach (PEA), and participatory rural appraisal (PRA), were therefore designed to adapt technologies to farmers' conditions (Hagmann et al., 1998). However, the role played by farmers in the predominantly linear and non-participatory research and development processes has still remained low (Chambers, 2005) as there has not been significant emphasis on co-learning unlike innovation systems approaches designed to develop technologies together with farmers (Douthwaite et al., 2002).

There has been a growing advocacy that PAR, coupled with the new concept of field-based Learning Centres (LCs), has the potential to build the capacity of smallholder farmers for enhanced uptake of ISFM technologies but, this has still to be empirically evaluated (German et al., 2007; Mapfumo et al., 2013). Moreover few, if any, studies have attempted to evaluate the effectiveness of learning alliances in promoting adoption of soil fertility enhancing technologies. Therefore this study focussed on evaluating the potential of field-based learning alliances in promoting the adoption of ISFM technologies among smallholder farmers for improved yields and livelihood benefits in the context of LCs introduced by SOFECSA in eastern Zimbabwe. This study was also aimed at contributing to future innovation systems research and extension programmes in building adaptive capacities among smallholder farmers as opposed to providing pre-packaged recommendations which may not be applicable to different farmer circumstances.

Such an evaluation was meant to reinforce investment and stimulate interest from major players in agricultural input and output markets.

1.3 Hypotheses

The study was guided by the following hypotheses:

1. Farmers who have received training and are bound to a specific social group have a higher level of participation in knowledge sharing alliances around ISFM learning centres than non-participating farmers.
2. Interaction processes in field-based learning alliances lead to differential utilisation and benefits of ISFM technologies among smallholder farmers.
3. Farmers participating in co-learning and knowledge sharing alliances stand to benefit both socially and economically more than their non-participating counterparts.

1.4 Objectives

The overall objective of this study was to evaluate how mobilization of smallholder farmers and multi-stakeholders into learning alliances could influence their participation in collective processes that drive ISFM benefits for improved livelihoods.

The specific objectives of this study were to:

1. Determine main factors influencing farmer participation in knowledge sharing alliances around field-based LCs introduced by SOFECSA,
2. Investigate interaction patterns that determine improved information and knowledge sharing among smallholder farmers participating in field-based learning alliances,

3. Evaluate relative benefits of ISFM technology use by smallholder farmers participating in co-learning alliances around field-based LCs.

1.5 Thesis structure

Chapter 1 gives the problem statement and justification. A detailed literature review on evolvement of soil fertility management technologies and emergence of participatory approaches in adapting improved technologies to smallholder farmers' agro-ecological and socio-economic environments are given in Chapter 2. Literature on adoption is also critically reviewed in this chapter. A description of study sites and methodology used in the study are given in Chapter 3. Chapter 4 focuses on main factors influencing farmer participation in knowledge sharing processes around field-based learning centres. In Chapter 5, farmer interaction patterns that determine improved information and knowledge sharing among smallholder farmers are explored. Comparative analysis of differential economic benefits through the adoption of ISFM technologies between PAR and non-PAR participants is given in Chapter 6. A synthesis of the overall study findings including overall conclusions and recommendations is given in Chapter 7.

CHAPTER 2

Literature review

2.0 Introduction

This chapter gives an overview of low and declining soil fertility as an impediment to increased agricultural productivity in Africa culminating in the potential of integrated soil fertility management (ISFM) technologies to address these issues. A brief synopsis of the Soil Fertility Consortium for Southern Africa (SOFECSA) initiatives is also given and the applicability of participatory action research (PAR) in these initiatives to facilitate co-learning processes between farmers and other agro-stakeholders for co-innovation. Technology adoption literature is explored including the potential implications on the adoption of any new technologies among smallholder farmers. The chapter ends by giving a schematic presentation of the conceptual framework in the adoption of ISFM technologies within field-based learning alliances established by SOFECSA in eastern Zimbabwe.

2.1 Poor and declining soil fertility challenge in Africa

Poor and declining soil fertility has been identified as the most critical biophysical constraint to agricultural growth in most SSA farming systems including Zimbabwe (Sanchez et al., 1997; Sanchez et al., 2009). This has been exacerbated by poor adoption rates of improved soil fertility management technologies (Odendo et al., 2006). Smaling et al. (1997) reported that annual depletion rates of sub-Saharan soils stood at 22 kg ha^{-1} for nitrogen, 2.5 kg ha^{-1} for phosphorus and 15 kg ha^{-1} for potassium. Besides the low crop yields, declining soil fertility has been found to lead to a loss of agro-biodiversity, loss of livestock pastures, soil losses due to erosion and low water use efficiencies in cropping systems (Ajayi et al., 2007). Meaningful investments in soil fertility management technologies are therefore crucial in order to improve productivity levels in most African soils (FAO, 2004).

In some instances farmers have abandoned poor soils into more fertile ‘virgin’ lands thus further accelerating degradation of the natural resource base (Vlek et al., 2008). Research and development efforts to promote the adoption of technologies with a potential to redress the low soil fertility have often been futile as most farming communities have often failed to link poor crop yields to the rather less evident decline in soil fertility (Mapfumo et al., 2013). The use of improved soil fertility management technologies that place additional costs to production have remained a preserve for the more resource-endowed members of the community, as resource-constrained farmers are known to have little capacity to acquire requisite inputs. Smallholder farmers have generally maintained their traditional ways of farming with little or no meaningful investments to maintain the soil fertility base, resulting in continual declining agricultural productivity (Stoorvogel et al., 1993; Mtambanengwe and Mapfumo, 2005).

Farmers have responded to the decline in soil fertility by using locally derived nutrient sources and inorganic fertilisers in order to boost agricultural productivity (Palm et al., 2001b). However, efforts to enhance soil fertility especially among smallholder farmers are usually hampered by diverse biophysical, socio-economic and institutional challenges. Animal manure, cattle manure in particular, has been widely used as an organic ameliorant across most smallholder farming systems of SSA (Kuntashula et al., 2004; Nhamo et al., 2004). Nevertheless, most farmers cannot access the 10-20 ton ha^{-1} of manure required to fertilise their fields. The farmers generally have few animals to produce adequate manure quantities which are often of low quality due to poor handling and treatment (Mapfumo and Giller, 2001; Mugwira and Murwira, 1997). Other organic technologies that have been widely documented include crop residues, woodland litter and green manures (Campbell et al., 1998; Nzuma et al., 1998; Giller, 2001).

Several studies have shown that without the application of fertilisers, grain yields fall by at least three-quarters thus aggravating food insecurity challenges among many households (Mapfumo and Giller, 2001; Zingore et al., 2007). This is often coupled with a decline in incomes and inability to re-invest into soil fertility management. Conversely, inorganic fertiliser use in SSA has remained the lowest among the world's developing regions averaging < 20 kg ha^{-1} per annum (CAADP, 2006; Mapfumo et al., 2013). Exorbitant fertiliser costs coupled with poor access to fertiliser markets, depressed producer prices, in some instances non-availability of inorganic fertilisers on the market and the high risk of crop failure in low rainfall areas have been the major constraints to the use of synthetic fertilisers (Govereh et al., 2002; Honlonkou, 2004; Bationo et al., 2006; CAADP, 2006). The economic policy reforms adopted in the southern African region led to the removal of subsidies on inorganic fertilisers resulting in a significant reduction in the use of fertilisers by most smallholder farmers (World Bank, 1995; Mekuria and Waddington, 2004). Inorganic fertiliser cost is estimated at 2-6 times higher in the SSA region compared to Europe or North America (Sanchez, 2002). This further compounds the problem of inorganic fertiliser use among many smallholder farmers who usually operate at subsistence level. It is therefore imperative that research and development initiatives focus on developing techniques and effective mechanisms for enhancing soil fertility using the available inorganic and organic resources in smallholder farming systems for sustained agricultural production (NEPAD, 2003). This entails innovations that combine productivity growth of both food and cash crops and recognise the value of farmer participation, local adaptation, empowering both local and national institutions and players along agricultural value chains to enable farmers generate profits from surplus production (SSA CP, 2008).

2.2 Potential role of integrated soil fertility management (ISFM)

Increasingly, it is recognised that central to agricultural productivity enhancement is the use of inorganic fertiliser and its judicious use in combination with available organic options (Mapfumo, 2011). This is based on the argument that strategies promoting the use of organic ameliorants alone without the incorporation of inorganic fertilisers rarely do well under most smallholder farming systems because of the low effect of poor quality organic fertilisers on soils inherently low in fertility levels (Jama et al., 1999; Mtambanengwe et al., 2006; Vanlauwe et al., 2010). These nutrient resources vary in terms of chemical and physical properties, nutrient release efficiencies, positional availability and crop specificity and farmer acceptability (FAO, 1998). Mapfumo and Giller (2001) highlighted that organic fertilisers tend to be limited in quality and quantity, hence the need to supplement them with inorganic fertilisers to sustain crop yields.

The shift from traditional fertiliser response trials designed to come up with recommendations for simple production increases culminated into integrated soil fertility management (ISFM) (Mapfumo et al., 2008). Integrated soil fertility management involves integration of soil fertility enhancing methods such as improved crop management practices, integration of livestock, soil and water conservation measures and ways to maintain soil organic matter (FAO, 1998; Sanginga and Woomer, 2009). The soil fertility management package has components that include inorganic fertilisers, animal manure, crop residues, crop rotation, compost and green manures among many (Vanlauwe, 2004; Maatman et al., 2007).

The potential for ISFM technologies to address challenges of soil fertility decline and helping the low resource farmers mitigate problems of food insecurity as well as improve resilience of soil's productivity capacity has been widely documented (Bationo et al., 2003; Ajayi et al., 2007; Vanlauwe et al., 2010). Improved yields and profits provide farm households with greater food security and incomes and stimulate national economic growth. A study in the eastern districts of Zimbabwe showed that through the use of ISFM technologies, smallholder farmers across different resource-endowments realised average maize grain yields of approximately 3.2 t ha^{-1} (Mapfumo, 2009). However, the maize grain yields were consistently highest on learning centres (LCs) hosted by the more resource-endowed farmers and these were in the range 2.5 to 4.2 t ha^{-1}. Almost similar grain increases were observed in Mozambique and Malawi (Mapfumo, 2009). These productivity increases realised through the use of improved technologies suggest not only enhanced food security but improved income benefits for the smallholders thus giving them the ability to invest more in soil fertility management.

Economic analysis of ISFM technology options has been attempted in some past studies employing different analytical techniques such as cost-benefit analysis and gross margin analysis (Waddington and Karigwindi, 2001; Mekuria and Siziba, 2003; Waddington et al., 2007). Mekuria and Siziba (2003) used the Net Present Value (NPV) method to assess the financial effects of using green manure for soil fertility management on smallholder farms in Zimbabwe and Malawi. The study showed that NPVs were positive for farmers who fallow and those who cannot implying that there were positive pay-offs for investing in green manure technologies. A similar study by Nhemachena et al. (2003), on green manure legume options revealed that at a discount rate of 20%, NPV values for sunnhemp, crotalaria, maize without fertility inputs and *mucuna* were all negative benefits while cowpea had the highest positive overall benefit. Econometric analysis employed in the same study showed that determinants of groundnut productivity were land area, groundnut selling prices and labour availability. Elsewhere, discounted net benefits for maize-groundnut rotations were greater than those for continuous maize mono-cropping irrespective of whether or not inorganic fertiliser was used (Waddington and Karigwindi, 2001). However, in the same study, inclusion of labour costs resulted in better returns for continuous maize plus fertiliser than rotations, while returns for rotations and continuous maize without fertiliser were almost the same. Similar results were also reported for grain legume-maize intercrops on sandy soils in sub-humid North Central Zimbabwe (Waddington et al., 2007).

Despite evidence pointing towards positive livelihood and economic benefits, adoption of ISFM technologies by farmers has been low (Mekuria and Siziba, 2003; AGRA, 2009). Sanginga and Woomer (2009) highlighted that realisation of maximum benefits from ISFM technologies required an enabling context which entails well-organized service delivery institutions, progressive value chains, and favourable policies. Critics also maintain that only resource-endowed farmers stand to gain from ISFM initiatives, while poor farmers including women farmers do not have the capacity to adopt (IFDC, 2002). High uncertainty and lack of experience usually associated with the ISFM technologies increases the risk of implementation failure and reduces adoption among smallholder farmers (Vanlauwe, 2004; Damisa and Igonoh, 2007). Moreover, comprehension of ISFM principles and concepts is knowledge intensive and as such demands some level of literacy among farmers (Marenya and Barrett, 2007; Sanginga and Woomer, 2009). The farmer needs additional knowledge and experience in terms of the type of ameliorant, time of application and rate. Nonetheless, researchers and extensionists have largely attributed the low adoption to the lack of comprehension of the technologies, a factor exacerbated by the wide communication gaps among researchers, farmers and other development agents (Odendo et al., 2006; Gwandu et al., 2014). The challenge is thus to bridge this gap with suitable approaches capable of generating technologies that consider farmers' needs, interests and capacities (IFDC, 2002; Hawkins et al., 2009).

Basing on the strength of its proven potential to improve and restore soil fertility, enhance the biological and physical properties of the soil and contribute to reduced soil erosion, ISFM has been identified as an appropriate approach to develop technologies suitable for smallholder farmers of different resource categories (Mapfumo et al., 2013). Farmers are able to realise higher and more stable yields resulting from enhanced soil productivity combined with more resilient crop varieties leading to improved food security and incomes (Mapfumo et al., 2013). This may in turn push the uptake of improved soil fertility management technologies. However, given the trend in the adoption and diffusion of improved technologies which has generally lagged behind scientific and technological advances (Okuro et al., 2002; Ajayi et al., 2007), there is scope to integrate ISFM with farmer-centred innovation systems approaches to generate context specific innovations for impact (Mapfumo, 2009). The successful integration of PAR approaches in complex social learning contexts and institutional transformation in other areas of natural resources management (German et al., 2007) has generated possibility for their applicability to soil fertility management initiatives.

2.3 Soil Fertility Consortium for Southern Africa (SOFECSA) initiatives

The Soil Fertility Consortium for Southern Africa (SOFECSA) embarked on large scale initiatives under diverse southern African agro-ecosystems and socio-economic environments with ISFM and effective market linkages as fundamental entry points for developing mechanisms to enable smallholder farmers to *'exit the maize poverty trap'.* Based on a detailed analysis of the specific farming context, including household goals, aspirations and resources as well as the bio-physical environment, the initiatives are aimed at finding "best fit" options instead of the "one-size-fits-all" technologies (Mapfumo, 2009). SOFECSA has developed the Learning Centre (LC) concept, which is based on the premise that co-learning processes of concepts and principles of knowledge intensive technologies open wider opportunities for adoption and innovation. An effective innovation system is known as one where information flows among actors, allowing for new knowledge to be generated in the context of application

(Biggs and Matsaert, 2003). Under the SOFECSA initiatives, technologies are developed through a participatory process, combining a systems approach and local knowledge involving "on-farm" experimentation with farmers, researchers and public/private extensionists (Mapfumo et al., 2008).

The LC approach integrates field-based interactive and non-linear learning processes with PAR tools to drive innovation (Mapfumo et al., 2013). Learning centres generally take "learning-by-doing" approach and provide platforms for farmers, reseachers, extension agents and other diverse agro-stakeholders to exchange ideas and knowledge on new innovations (Gwandu et al., 2014; Mapfumo et al. 2013). Gwandu et al. (2014) characterised the LCs for a number of attributes: i) providing field-based platforms for farmers to actively evaluate traditional and new farming practices and technologies; ii) allowing joint testing of technologies and generation of new innovations; iii) allowing for interactions among farmers of diverse resource endowments, technical experts and policy makers thus generating scope for improving productivity and livelihoods among smallholder farmers; and iv) exposing agro-service providers and policy makers to field conditions that typify smallholder farmers' production circumstances. This particular focus on co-learning processes where information exchange for adaptive experimentation is the fundamental component makes LCs different from other participatory extension approaches developed in the past such as Farmer Field Schools (FFS) which place value on a particular commodity. While farmer groups within the framework of an FFS are not formed with the intention of creating a long-term organisation, action-learning with respect to LCs is an iterative cycle of planning-action-reflection (Pontius et al., 2002; Luther et al., 2005; Mapfumo et al., 2013).

Adaptive testing of ISFM technologies or components of technologies prioritised by farmers and other agro-stakeholders along value chains is done at LCs to generate context specific ISFM options (Mapfumo, 2007; Mapfumo et al., 2008). The promoted ISFM technology options consisted of legume-cereal rotations, different mineral fertiliser formulations, mineral fertilisation of rotations, sunnhemp (*Crotalaria juncea*) green manure-maize rotations among many applied solely or combined with chemical fertilisers (Nyikahadzoi et al., 2012). The practical integration of PAR approaches (Piercy and Thomas, 1998) in SOFECSA initiatives in eastern Zimbabwe targeted at revitalising lost faith in traditional social food safety nets such as the *Zunde raMambo*, recorded a sharp rise in maize grain yields from < 0.3 t ha^{-1} (under traditional farmer practices) to ~4 t ha^{-1} using improved ISFM techniques. The techniques involved the use of combinations of organic and inorganic nutrients to address severe phosphorus and nitrogen deficiencies on a medium range maturity maize cultivar for the 2009/10 cropping season (Mapfumo, 2009). Participants at the *Zunde raMambo* realised maize grain yields that were at least two and half times more than non-participants following ISFM-based fields established and managed by volunteer farmers drawing from their participation and learning experiences at the community learning centre (Mapfumo et al., 2013). This has generated scope for quantifying the effectiveness of field-based action learning processes in driving the benefits of ISFM for improved technology uptake and livelihoods.

2.4 Evolution of participatory action research process

Early research often assumed that farming communities within the same agro-ecosystem were homogenous before emerging evidence indicated that they varied and were stratified across many boundaries bound to influence their participation in any new innovation (Baum and Tolbert, 1985; Mtambanengwe and Mapfumo, 2005). Some studies have also shown that there is evidence that enhancing farmers' capacities to develop and disseminate improved technologies from farmer-to-farmer could significantly contribute to agricultural development (Hagmann et al., 1998; Hawkins et al., 2009). Active participation of target beneficiaries in new innovations enhances their chance of benefitting from the project and it also enables extension of the benefits to others (German and Stroud, 2007). The target group owns the process and should the course of action fail to bring the desired outcomes, the community still has the power and initiative to retry or modify innovations to suit their specific conditions (Flood, 2002).

Participatory action research (PAR) approaches evolved through the 1990s into the 21st century and have been applied to various fields of development, giving such approaches as plant breeding (PPB) and technology development (PTD) (Defoer and Budelman, 2000; Cromwell et al., 2003; FAO, 2008). Other research approaches related to PAR include participatory research, critical action research, action learning, action science and industrial action research (Kemmis and McTaggart, 2000). The process consists of iterative cycles of community-level action and reflection thereby reinforcing change processes by ensuring continuous learning, sharing and adjustment of actions to align them with agreed upon objectives, thereby empowering the actors themselves to learn and adapt (German et al., 2007). Participatory action research can strengthen understanding by building upon the complementarities of local and scientific knowledge (DeWalt, 1994), thus helping to stimulate local ownership of interventions (Ishida et al., 1998; German and Stroud, 2007).

Participatory action research unlike other research methods captures changes in reality. It embraces principles of participation, reflection, empowerment and emancipation of groups seeking to improve their social situation and thus has been criticized for lacking the methodological rigour and scientific soundness which is the main standard of most academic research (Kemmis and McTaggart, 2000; Lebel et al., 2006). Selener (1997) suggested that this weakness is an essential attribute for a more joint and adaptive research design. Other researchers emphasize that sacrificing some level of academic research principles is worthwhile given the practical impact generated through PAR approaches (Lebel et al., 2006). Basing on the ability of PAR to foster continuous learning and sharing of knowledge it may therefore be an effective tool in driving ISFM innovation-decision process among smallholder farmers. The systematic learning on the change process may in turn fill the methodological and institutional gap between research and action.

2.5 Application of PAR as a change management tool

Increasingly, there is realisation that despite the ability of biophysical soil fertility management research to generate good knowledge, it has to contend with social processes if that research is to be considered relevant among smallholders (Hagmann and Chuma, 2002). It is often assumed that PAR is a tool useful only for solving local-level problems and social issues. However, PAR may be carried out within research and development organizations as a process of institutional change, by policy makers interested in taking an adaptive approach to change, or by local communities as they seek context specific solutions to common problems (Hagmann and Chuma, 2002; German and Stroud, 2007). Participatory action research approaches recognise that communities are not homogenous but made up of diverse groups with conflicts and differences in interests, power and capacities. The aim is to achieve equitable and sustainable development through the negotiation of interests among these groups and by providing space for the marginalised in collective decision-making (Greenwood and Levin, 2007).

Participatory action research approaches have been successfully applied to address adaptive capacity challenges in complex socio-ecological systems such as natural resource management and climate change (Hagmann and Chuma, 2002; Colfer, 2005; Mapfumo et al., 2013) and facilitating institutional change processes (Hagmann, 1999; CIAT, 2010). Examples include building stakeholder partnerships in the Communal Areas Management Programme for Indigenous Resources (CAMPFIRE) and managing the Mafungautsi State Forest in Zimbabwe (German et al., 2008); watershed management in the African Highlands Initiative (German et al., 2007) and development of appropriate primary education mechanisms for marginalised children in Tanzania (Mkombozi, 2005). This suggests that the experiences and approaches may be readily applicable to ISFM adoption initiatives within smallholder farming systems.

However, PAR approaches have also been found to generate unanticipated challenges to local communities and PAR implementing agencies thus making anticipatory development of coping mechanisms inevitable. Common challenges have been found to revolve around coordination and harmonisation of institutional mandates; the need to instil a common understanding of PAR among research and development partners; power relations within target communities; sustaining stakeholder interest for participation as well as funding of the change process which tends to run over long periods (German et al., 2008; Mapfumo et al., 2013).

Current agricultural research and extension initiatives place value on technologies that are knowledge intensive and require management skills and effective learning (FAO et al., 2012; Gwandu et al., 2014). PAR characterised by iterative planning-action-reflection cycles has been widely recognised as a potential tool for enhancing participation of target communities in context specific change processes (Scoones et al., 2005; German and Stroud, 2007). Integration of PAR approaches in learning centre based ISFM initiatives may therefore encourage smallholder farmers to learn through experimentation, building on their own knowledge and practices, and blending them with new ideas from other agro-stakeholders along agricultural value chains (Mapfumo, 2007).

2.6 Determinants of new technology adoption in smallholder farming systems

Generally, literature on the factors affecting adoption of any new farm technology reveals four themes: (i) characteristics of the technology; (ii) prevailing institutional environment; (iii) socio-economic characteristics of the farmers; and (iv) familiarity with technology (Feder et al., 1985; Rogers, 1995; Abadi Ghadim et al., 1996; Sheikh et al., 2003). Farmer’s decision to adopt a new technology can be thought of as a two-stage process separating the decision of whether or not to adopt a technology and how much of the technology to use (Nichola, 1996; Shiferaw and Holden, 1998; Brett, 2004).

2.6.1 Adoption as influenced by characteristics of the technology

Rogers (1995) postulated that attributes of a technology such as complexity, consistency with existing values and needs, trialability and visibility of results tend to influence technology adoption decisions. This therefore implies that a particular innovation may be preferred by an adopter in a particular situation while this may not be that case for another potential adopter facing different circumstances. Adoption of technology may not offer equal utility for everyone due to disparities in access to resources, preferences and societal values (Hillbur, 1998). A study in Burkina Faso and Guinea showed that the characteristics of new sorghum and rice varieties such as yield, food quality and tillering capacity had a significant influence on the adoption of the varieties promoted (Adesina and Baidu-Forson, 1995). The study concluded that varieties that were perceived to give better yields than local varieties had a better chance of being adopted. This suggests that good characteristics promote positive farmer perception of a technology which can enhance diffusion from farmer-to-farmer.

Leathers and Smale (1991) noted that agricultural innovations are often promoted as a package. Many farmers have shown incremental technology adoption patterns through modifying the package and adopting components of the package. This is mainly because of capital scarcity and risk considerations as farmers try to learn more about the entire technology (Smale et al., 1995; Mazvimavi et al., 2008). Thus, different households have different patterns of adoption of a given technological package (Morales and Perfecto, 2000). Complementarity of new technologies with existing ones has been shown to influence adoption decisions in West Africa.

Despite mechanised processors having been developed long before the introduction of improved cassava varieties in Nigeria, farmers only became aware of the profitability of using the processors when the two technologies were used together leading to enhanced adoption (Johnson and Masters, 2004). Doss and Morris (2001) suggest that gender has an indirect effect on adoption rates through the ability to access sufficient complementary inputs. Women farmers have been found to give priority to food crops than cash crops based on their productive role as providers of food (Valdivia, 2001).

A study by Quinn et al., (2003) has shown that the probability of adoption of soil fertility management technologies is enhanced if they contribute directly to immediate livelihood requirements. Studies on legume-based soil fertility technologies revealed that some nitrogen-fixing trees were less preferred by farmers since the grain could not be consumed or sold whilst in some places farmers perceived that the trees took out land which could be used for cultivating food or cash crops (Schulz et al., 2003). However, dual purpose grain legumes were readily accepted as they provided food as a vegetable or pulse crop besides improving soil fertility (Schulz et al., 2003; Mtambanengwe and Mapfumo, 2005). These grain legumes are usually rotated or intercropped with cereals due to their significance in supplementing household dietary needs (Rusinamhodzi et al., 2006). The successful introduction of conservation agriculture (CA) to cotton production systems in Zambia led to a significant adoption of the technology among many farmers (Tschirley et al., 2004). This implies the inclusion of high valued crops in promoting soil fertility enhancing technologies may widen the applicability of ISFM technologies to different farming scenarios thus enhancing adoption.

2.6.2 Adoption as influenced by the prevailing institutional environment

Institutions are normally defined as mechanisms of social order governing the behaviour of a group of individuals within a specific community. Provision of infrastructure such as roads, physical markets and effective communication services reduces transaction costs and enables farmers' access to markets. This implies that the policy and institutional environment in which farmers operate has a bearing on their decisions with regards to adoption of improved technologies (Ajayi et al., 2007). The relative profitability and net returns of soil fertility technologies may be compromised by national and international trade policies thus influencing their adoption (Mekuria and Waddington, 2004). Generally, prevailing producer prices, interest rates on capital, cost and level of subsidies on fertiliser determine the relative returns to investment and adoptability of soil fertility enhancing technologies (Ajayi et al., 2007). Having the appropriate agricultural equipment or inputs timely and at affordable prices has always been a challenge to most smallholder farmers due to high transaction costs and risks that characterise agricultural research and development (SSA CP, 2008).

Access to markets and credits has been identified as a major constraint on the technology supply side. Smallholder farmers often face difficulties in accessing agricultural credits as financial institutions are generally reluctant to lend due to poor collateral and lack of information on the creditworthiness of the borrower (Croppenstedt et al., 2003). Women farmers are at a greater disadvantage than their male counterparts as they usually have very limited access to financial and social capital, market information and productive resources such as land (FAO et al., 2012). In Western Kenya, distance to markets had a significant negative influence on the adoption of inorganic fertilisers (Alene et al., 2008). The study concluded that this could be related to relative transaction costs that increase in the acquisition of inputs and marketing of produce.

Adequate and timely extension services expose farmers to new technologies and their potential benefits (Abdulai and Huffman, 2005). Extension services augment the deficiencies in the farmers' formal education thus enhancing their knowledge on certain agricultural issues and enabling them to make informed decisions with regards to the available technologies and improved practices. Farmers are advised on how to undertake soil fertility improvement technologies that require precision in terms of time of application, rate, type of fertiliser and method of application (Singh, 1988). However, Pannell (1999) argues that extension advice is never a substitute for personal trialling and the heterogeneity of smallholder farming systems consistently makes the use of blanket extension recommendations difficult. Other studies also assert that the integrity of extension advice might also suffer in situations where recommendations are out of context with farmers' circumstances (Oluoch-Kosura et al., 2001). This literature seems to suggest that an enabling policy and institutional environment is fundamental if any new innovation has to generate context-specific solutions for impact.

2.6.3 Adoption as influenced by the farmers' socio-economic characteristics

Household and farm attributes such as gender, age, education level of household head, active labour, farm size, number of livestock, food security among many other factors have been widely documented as major determinants of the decision to adopt agricultural practices (Neupane et al., 2002; Chianu and Tsujii, 2004; Mugwe et al., 2009). More education enhances farmers' comprehension of concepts and principles of improved technologies and allows them to effectively weigh the benefits and risks of adopting such technologies (Nkonya et al., 1997; Rahman, 2003). There are contrasting views about the effect of age on the adoption of improved technologies as different studies have shown age to influence adoption both positively and negatively (Odera et al., 2000; Gockowski and Ndoumbe, 2004; Farouque and Takeya, 2007; Mugwe et al., 2009). The positive influence has been attributed to the knowledge, resources and skills acquired by older farmers that might enhance their perception and adoption capacity (Farouque and Takeya, 2007). On the other hand older farmers may not be willing to invest in completely new innovations that might expose them to greater risks (Khanna, 2001).

Family size can provide a pool for active labour but, a large family may also imply insufficient resources to finance adoption of new techniques. Labour was found to have a positive influence of improved fallows of leguminous trees for soil fertility improvement in Zambia (Keil et al., 2005). The ability of farmers to hire additional labour was also found to promote the adoption of ISFM practices in the central Highlands of Kenya (Mugwe et al., 2009).These results were consistent with findings by Oluoch-Kosura et al., (2001) who observed that availability of full-time labour positively influenced the use of manure and fertiliser technologies. However, within the same study a bigger family negatively influenced investment in soil fertility management by constraining disposable incomes and resource allocation behaviour.

Farmers are often reluctant to adopt technologies that expose them to greater risks and must also be convinced that the new technology will address their socio-economic and livelihood needs (Napier et al., 1991; Pannell, 1999). Reviews on the diffusion of new technologies show varying technology adoption abilities that decrease with an increase in the farmer's socio-economic constraints (Bationo et al., 2004). Soil fertility technologies that require substantial levels of external inputs and farm-level investment remain a preserve for the more resource-endowed, as community members who are resource-constrained have little capacity to adapt (Mtambanengwe and Mapfumo, 2005). In Botswana, the availability of income enhanced a household's capacity to adopt improved technologies but, higher incomes were also found to promote off-farm instead of on-farm investments (Reardon et al., 2000).

There is also strong evidence that even for innovations oriented towards resource conservation, economic considerations are the most important determinants of actual adoption decisions (Napier et al., 1991; Cary and Wilkinson, 1997). Risk aversion in farmer's soil fertility management decisions tends to override decision making processes regarding crop mix and soil fertility management practices (Rogers, 1995; Marra et al., 2001). African farming systems are highly heterogeneous: between agro-ecological and socio-economic environments, in the wide variability in farmers' resource endowments and in farm management (Giller et al., 2011). This means that single solutions (or 'silver bullets') for improving sustainable food security and livelihood options do not necessarily exist. Subsequently, this has generated scope for evaluating differential technology impacts on households participating within field-based learning alliances with a particular focus on how smallholders are heterogeneous and resource-constrained.

Social perceptions, which are a function of personality and culture, are mostly based on experiences and knowledge and play a significant role in the adoption of new technologies (Islam, 1990; Gurung, 2003). Generally, people are selective and tend to readily accept messages consistent with their pre-existing attitudes and beliefs (Gurung, 2003). For example, in Mozambique, customary arrangements with respect to the planting of trees often selected against certain groups such as women, tenants and migrants, who found no value in adopting trees for long-term investments in soil fertility management. This was because trees symbolised evidence for claiming ownership of land under such customs (Unruh, 2001).

Although spatial proximity among smallholders can facilitate copying the neighbour's ways (Shampine, 1998), several studies have considered the influence of social capital on the adoption of technologies (Swinton, 2000; Isham, 2002; Bandiera and Rasul, 2006). Lule et al., (2007) defines social capital as the ties, networks and linkages between individuals, groups and communities that bind and bridge society. Social capital enables farmers to co-operate, co-ordinate, share information and resources, and act collectively (Swinton, 2000). Farmers may update their own prior perceptions and attitudes basing on successes observed from neighbouring farmers (Conley and Udry, 2001). Pomp and Burger (1995) demonstrated that the peer group effect was significant in influencing the dissemination of new technologies for cocoa production in Indonesia as other farmers copied early adopters within their network. Elsewhere, a study to analyse whether individual adoption decisions on new sunflower production techniques were dependent on the choices of neighbouring farmers in the same social network, showed that the network effect was only stronger among farmers who regularly shared information with others (Bandiera and Rasul, 2006). However, these social interactions can generate both positive and/or negative attitudes toward an innovation (Nkamleu, 2007).

However, there is yet to be consensus over some variables which have a positive influence on adoption in one study at the same time observed to yield a negative influence elsewhere. The general pattern of most adoption studies is the focus on factors that enhance or impede eventual adoption and not the actual mechanisms involved in adoption process *per se*. This generates scope for understanding the dynamic adoption process through the actual mechanisms that drive innovation among farmers rather than only focussing on individual household and farm characteristics.

2.6.4 Adoption as influenced by familiarity with technology

Rogers (1995) asserts that farmers have to be first aware of the existence of an innovation before they can actually seek to know how much of the technology to use, its correct use and how it operates. This implies that adoption of an improved technology requires that farmers have adequate knowledge of what it is, how it is done as well as their perception of consistency with already existing practices (Pannell, 1999). However, the acquisition of knowledge is a social process that involves sourcing and sharing information (Rogers, 1995). Farmers become aware of technologies as information is disseminated from the point of origin to end-users through a medium such as news media, extension advice on-farm or on-station demonstrations and farmers' field days (Rogers, 1995; Conley and Udry, 2001). Ultimately, this information will lead to the formation of positive or negative attitudes which play a critical role in influencing the adoption of a particular technology.

An emerging school of thought is that farmers' innovation decisions do not only hinge on economic or personal benefits, but are also influenced by the level of social interactions they maintain among themselves, or with other farmers and other players along agricultural value-chains (Hartwich and Scheidegger, 2010; Mashavave et al., 2013). It is through group sessions such as field days, farmers' workshops, exchange visits among many that farmers are able to acquire information and knowledge on improved innovations as they exchange views and share their own experiences with others (Hagmann et al., 1998; Bandiera and Rasul, 2006; Mashavave et al., 2013). The action of farmers and their decision-making abilities given the level of knowledge and information that is available to them sustains agricultural innovation (Rahman, 2003; Boz and Ozcatalbas, 2010).

Interrelationships among stakeholders have been shown to be central in addressing problems associated with natural resource management (Krishna, 2001; Pretty and Ward, 2001; Adler and Kwon, 2002). The introduction of a new innovation may result in a change to the existing social network structure of farmers or the formation of entirely new networks (Barley, 1990). Social networks can be built on similar attributes or affiliations, social relations, interactions and/or resource/information flows (Borgatti et al., 2009; Grosser et al., 2010; Mashavave et al., 2013). Interaction between players can be intended and purposeful or can be unintended and more or less constrained by factors external to the actors (Brass, 1995a; Dunne et al., 2002). The strength of these social connections is a function of time, intimacy, emotional intensity and reciprocity (Granovetter, 1973; Estrada, 2007). There has been little or no research that has attempted exploring how smallholder social networks can influence ISFM technology uptake in sub-Saharan Africa.

Familiarity with a technology may not necessarily lead to its adoption especially when target beneficiaries do not consider it relevant to their situation. The uncertainty created by the introduction of an innovation usually diminishes when the information about the technique is made available giving possibilities to solve an individual's perceived problems (Rogers, 1995). Some farmers rely on their own experiences as a source of knowledge and information but, some variation is likely to occur between farmers who have had an experience with a technology versus those seeing it for the first time (Boz and Ozcatalbas, 2010). A study in Uganda found out that farmers who had been involved in agroforestry for longer periods had more knowledge of Alnus pest which influenced their choice of species to cultivate (Nyeko et al., 2002). This suggests that farmers who have practical experience on ISFM technologies from own experimentation or through observing nearby farmers will exhibit different adoption behaviour than their peers.

Experimentation through trial-and-error enables the farmers to assess the value of innovations while improving their ability to make informed decisions (Marra et al., 2001; Kosgei and Jewitt, 2006). Kaliba et al. (2000) also advocates for research and extension policies that promote farmer participation in research processes and participatory evaluation of on-farm field trials and demonstrations. However, smallholder framers are usually unwilling to absorb the costs of practical experimentation and base their adoption decisions on experiences from early adopters (Bardhan and Udry, 1999). On the other hand, some studies concluded that information gained from own experience maybe more valuable than that gained from others given heterogeneity in skills and resources across farmers and the incomplete transmission of information (Foster and Rosenzweig, 1995; Munshi, 2004). This implies that exposing smallholder farmers to field-based co-learning processes may enhance their awareness on ISFM technologies and the likelihood of adoption.

2.7 How current literature on adoption informs ISFM technology development

Researchers in disciplines such as sociology, geography and anthropology may be required to analyze additional factors conducive to the dissemination and uptake of improved ISFM technologies. There may be a need to integrate both qualitative and quantitative methodologies of research. There has been limited work on trying to understand the soil fertility management problem from the perspective of the smallholder farmers hence, researchers and extensionists are often faced with the challenge on how to promote widespread adoption of new and improved technologies. Much of the literature seems to suggest a need to enhance farmers' capacities to participate in research, experimentation and evaluate innovations as applicable to their context. The literature also suggests that adoption is a collective process consisting of embedded networks of interdependent stakeholders. This entails strengthening partnerships between researchers, extension agencies, farmers and other agricultural service providers as co-learners and co-researchers, in ways that promote innovation and sustainable adoption. It is in this context that SOFECSA's field-based learning centres are justified for wider evaluation. By the same reasoning, PAR may also be an appropriate tool to empower smallholder farmers and enhancing their critical analysis skills for improved adoption of ISFM technologies. However, there is paucity of empirical research on the effectiveness of collective action learning processes in promoting social learning among key agro-stakeholders. This knowledge gap is especially wider with respect to understanding of soil fertility management technology adoption among smallholder farmers.

2.9 Analysis of technology adoption in literature

Farmer's adoption decisions of new technologies are normally built on the assumption that adoption of a technology will maximise their expected utility (Rahm and Huffman, 1984). By implication, smallholder farmers adopt ISFM innovations if the expected value of benefits from introduced technologies exceeds value of benefits from current practices. The dependent variable is a binary choice: to adopt (= *1*) or not adopt (= *0*) a technology. A number of empirical models have been suggested to explain farmers' choices with regards to adoption of technologies. Examples of such models used in rational adoption-decision models include, but not limited to Linear Probability Models (LPM), binary logistic and probit models (Aldrich and Nelson, 1984; Maddala, 1993; Baidu-Forson, 1999). Linear probability models generally use Ordinary Least Squares (OLS) estimates for making predictions hence are not suitable for limited values of dependent variable (Maddala, 1993).Gujarati (1996) also asserted that LPM is not a good option in modelling rational decision choices as the models are affected by a number of problems including heteroscedasticity, lower R^2 values in general and possibility of the predicted value lying outside the acceptable probability range (0-1).

The logistic and probit models use maximum likelihood estimation (MLE) procedures to give unbiased and efficient estimates of the probability that the dependent variable will take on the discrete values (Agresti, 1996; Tiwari et al., 2008; Mugwe et al., 2009). Generally, MLE finds the function that maximises the ability to predict the probability of the dependent variable based on what is known about the independent variables (Amemiya, 1981). A major limitation with logistic and probit regression models is that they tend to overestimate beta-coefficients when the sample size is less than about 500. However, in a single study, this overestimation might not have any relevance on interpretation of results since it is much lower than the standard error of the estimate (Agresti, 1996). Maddala (1993) argue that there is no single theory of causation that can fully capture the different dimensions of farmer decision-making processes. This therefore implies that the choice of the model depends largely on the nature of study.

2.8 Conceptual framework

The conceptual framework of this study (Figure 2.1) was guided by the innovation-decision process as postulated by Rogers (1995). As farmers access and share available empirical information and knowledge on promoted ISFM technology options, they become more knowledgeable about the new techniques (Pannell, 1999). Evaluation of the risks and benefits of the new technologies will subsequently lead to the formation of attitudes towards the technologies and these can either be positive or negative. Ultimately, the farmers end up deciding on whether or not to adopt the technology (Rogers, 1995). However, this dissemination process from the source to potential end-users is to a large extent influenced by the socio-economic and demographic attributes of the user (Neupane et al., 2002). Other similar studies on adoption decision behaviour by farmers generally indicate that the pattern can be modelled through the use of binary choice (discrete or dichotomous) models (Tiwari et al., 2008; Mugwe et al., 2009). These are generally used to assess the presence or absence of a variable of interest. The binary logistic model has been widely used in different adoption studies (for example Chianu and Tsujii, 2004; Mugwe et al., 2009) and thus was adopted in this study.

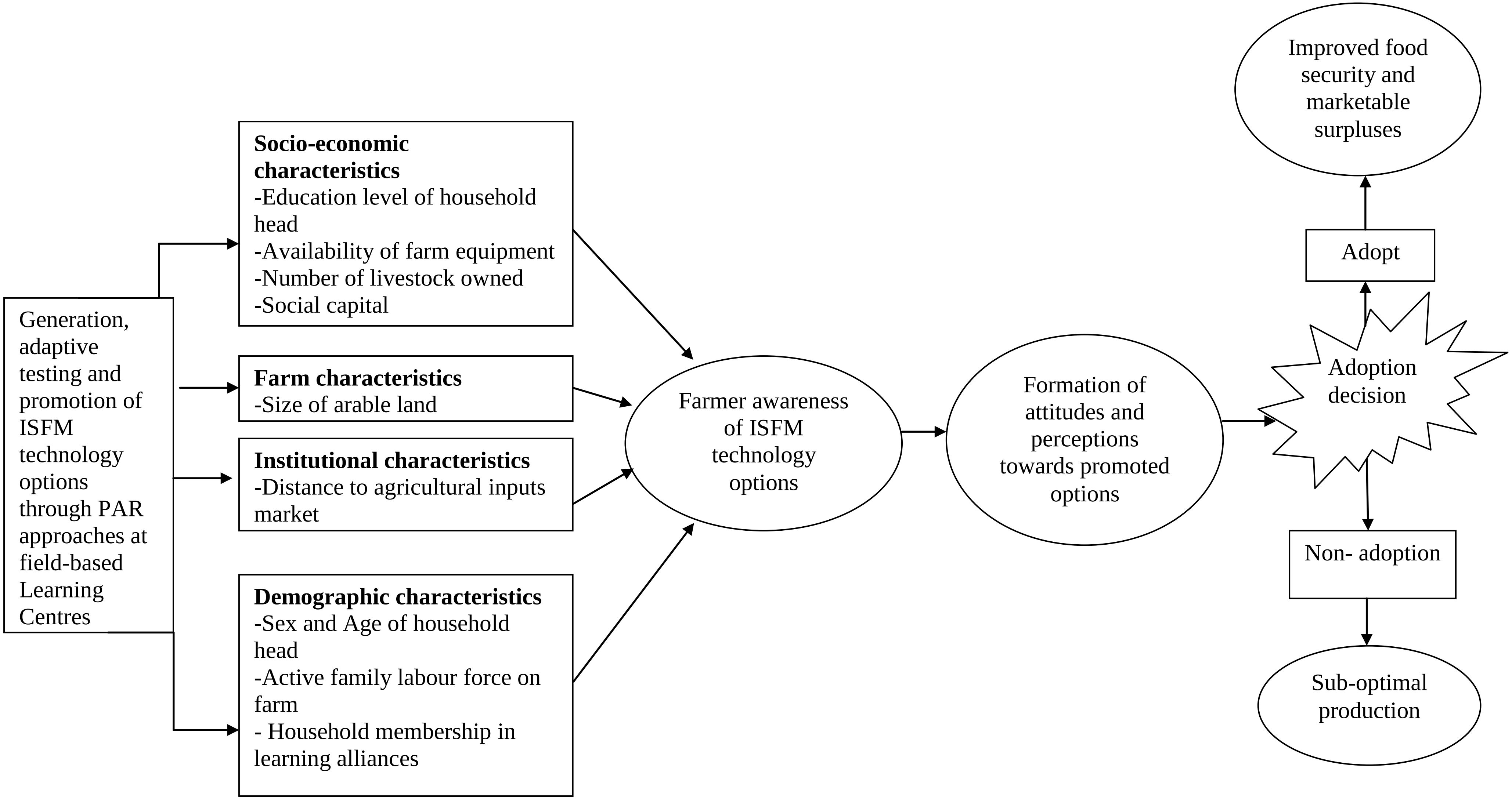


Figure 2.1 Diagrammatic Presentation of the Conceptual Framework for Understanding the Influence of Co-learning Processes on Innovation-decision Cycle at Field-based Learning Centres in Nyahava Community, Eastern Zimbabwe. Adapted from Neupane et al. (2002)

CHAPTER 3

Methodology

3.0 Introduction

A brief description of the study area including the current agricultural production practices is given in this chapter. Selection of target villages as well as establishment of learning alliances around field-based integrated soil fertility management (ISFM) learning centres is deliberated on. A concise description of sampling procedures is also described culminating into an outline of data collection methods used in this study. The chapter ends by giving an analytical framework with respect to each of the specific objectives as highlighted in Chapter 1 of this study.

3.1 Site description

This study was conducted under the auspices of ongoing SOFECSA ISFM initiatives in Chinyika smallholder farming community, eastern Zimbabwe since the year 2007.

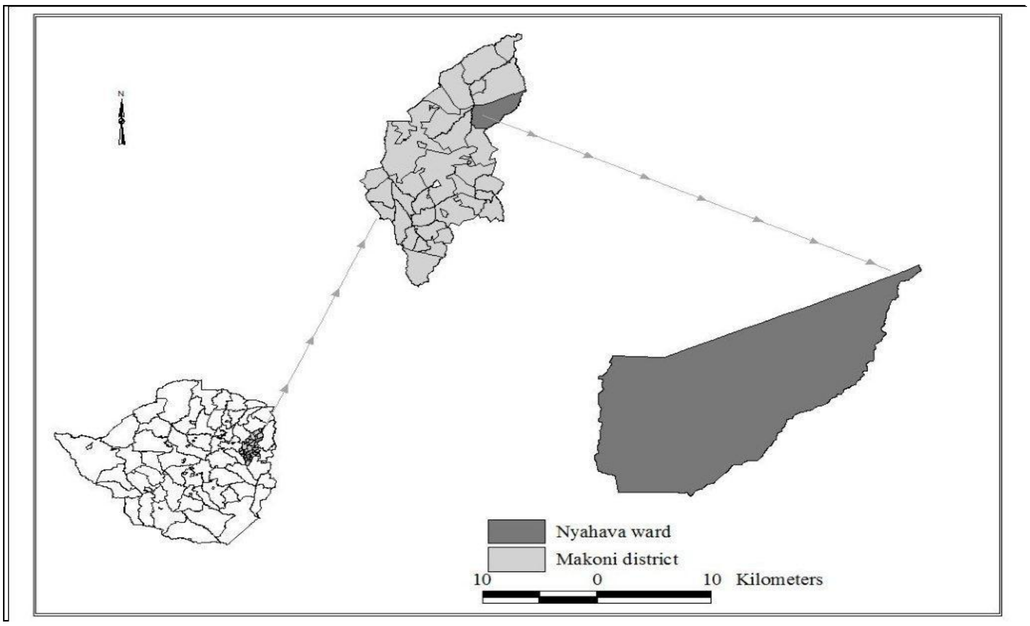


Figure 3.1 Map Showing the Location of Nyahava Ward of Makoni District, Eastern Zimbabwe

The study was conducted in the smallholder farming community of Nyahava ward located in Chinyika East (18°12`S 32°24`E) of Makoni district, in eastern Zimbabwe (Figure 3.1). The area was opened by the Government of Zimbabwe in 1983 using what was called Model A of resettlement (Bratton, 1994). The model was characterised by individual settlement in nucleated villages with individual land allocation and communal grazing. Each settler was allocated 6 ha of arable land and a grazing right to de-pasture 4-10 livestock units depending on agro-ecological region (Chisora, 2006). The settlers were drawn from areas as far as Dorowa, Buhera, Romsley, Chivhu in Manicaland and Mashonaland East provinces among others typically characterised by high population densities, erratic rainfall and poor soil fertility. Makoni district, in Manicaland province, is about 170 km east of Harare, and covers the country's agro-ecological regions or Natural regions (NR) II to NR IV. Natural Region II receives mean annual rainfall of ~800 mm while NR IV receives the least precipitation averaging 450-600mm (Sayce, 1987). The soils are predominantly granitic sands (Lixisols and Arenosols) with challenges of low soil organic carbon and inherently poor nutrient supply capacity (Nyamapfene, 1991; FAO, 1998).

Agricultural production in the study area

Years before the resettlement programme, the area had a large-scale commercial farming system dominated by extensive livestock and tobacco farming. Currently, dominant crops include maize (*Zea mays* L.) and grain legumes that include groundnuts (*Arachis hypogaea* L.), cowpea (*Vigna unguiculata* [L.] Walp) and Bambara groundnuts (*Vigna subterranea* [L.] Verdc.) with a strong livestock component, particularly cattle. Tobacco (*Nicotiana tobacum* L.) is the main cash crop grown in the area mostly under contract farming (Mtambanengwe and Mapfumo, 2005).

3.2 Selection of villages and formation of farmer learning alliances

Villages 19, 20 and 38 of Nyahava ward were deliberately targeted for the study. The average number of farming households per village was 45. Village selection was primarily based on existing background information on farmer groups, production trends of the staple maize, as well as on institutions and organisations supporting farmers on markets. Local leaders, extension agents, and other key informants came up with further criteria for village selection that included: (i) previous interaction with SOFECSA including existence of ISFM-based learning centres; (ii) accessibility in terms of road infrastructure and proximity to community members; and (iii) evidence of some level of commercial orientation to agricultural production.

During the initial implementation phases of PAR, field-based ISFM farmer Learning Centres were established for participatory experimentation, evaluation and co-learning among farmers and stakeholders. These learning centres were established with the facilitation of SOFECSA lead researchers with the involvement of national extension agents; Agricultural, Technical and Extension Services (AGRITEX). However, following training of extension agents and farmers on principles and concepts of ISFM, local committees took over the role of establishing more learning centres whilst the researchers played a catalytic role (Mtambanengwe and Mapfumo, 2009). The underlying assumption was that translation of ISFM empirical knowledge into action through PAR approaches, would lead to enhanced uptake of the technologies subsequently leading to higher crop yields and marketable surpluses among smallholder farmers. Joint visioning exercises and participatory action planning (PAP) meetings were held in each of the targeted villages, prior to the 2009/10 cropping season. These activities were meant to identify and establish shared vision among farmers and various agro-stakeholders across disciplines on the underlying causes of declining agricultural productivity and how this was linked to low and declining soil fertility.

This led to the formation of farmer groups on a voluntary basis to participate in ISFM field-based learning alliances (PAR participants). Sixty-eight (68) farmers volunteered to participate in the established learning alliances. Farm-level adaptive testing and evaluation of the promoted ISFM technologies/innovations were conducted at selected learning centres in the 2009/10 and 2010/11 cropping seasons within each of the villages, in comparison to traditional farmer practices. Separation of the groups in the learning alliances was by resource endowment following criteria developed by Mtambanengwe and Mapfumo (2005). The farmers were categorised according to resource group (RG) as shown in Table 3.1.

Table 3.1 Descriptive criteria for smallholder farmer resource group classification in Nyahava, Zimbabwe

Resource Category	Major attributes
Resource-endowed (RG 1)	• Owners of basic farming implements (e.g. a plough, ox-cart) • High livestock ownership with >10 cattle and at least 2 oxen • Relatively high capacity to secure inputs • Most of the farmers have regular contact with extension • Often have access to credit facilities
Intermediate (RG 2)	• Varying but limited resource base • Limited access to credit • No regular pattern of hiring-in or hiring-out labour • Seek to enhance their production through collective social arrangements and active involvement with extension services
Resource-constrained (RG 3)	• Relatively low resource base and have difficulties in conducting general farming activities • Lack of draught power (0-3 cattle) and lack of cash to buy inputs • Usually not a member of social groups and often shy away from community meetings • Often hire-out labour to the other two groups • Dominated by women

Adapted from Mtambanengwe and Mapfumo (2005)

A counterfactual group of 70 non-PAR participant farmers was drawn from some villages in Maire ward situated approximately 30 kilometres from Nyahava where no SOFECSA innovations had been tested. Prior to the interventions, the two places generally shared a number of characteristics and the farmers operated under similar circumstances. These non-participant farmers were also clustered by resource endowments. This counterfactual group provided for the sampling frame from which the random sample of non-participants was drawn for questionnaire administration in 2011.

3.3 Random sampling method

The sample size was largely limited by the number of farmers who had volunteered to participate in the established field-based learning alliances (68). Name lists for the PAR and non-PAR participants were entered in the computer using Microsoft Office Excel 2007 on separate spreadsheets (Rossi et al., 2004). Six spreadsheets were used: three for learning alliance participants grouped as RG 1, RG 2 or RG 3 and three for non-participants also clustered by resource groups. By entering =RAND() command on the column adjacent to the name list on each of the working sheet, random numbers were generated for each entry between 0-1. Applying the sort function the names and the generated numbers were randomly sorted (Rossi et al., 2004). This was meant to produce statistically representative samples from the learning alliance participant and non-participant farmer groups. Random samples were then drawn for each sub-stratum from each of the sorted lists as shown in Table 3.2 below:

Table 3.2 Composition of stratified random samples for questionnaire administration in Chinyika, eastern Zimbabwe 2011

Farmer resource group	Learning alliance participants (n=30)	Non-participants (n=40)
RG 1	9	9
RG 2	11	14
RG 3	10	17

The community generally had few farmers in the resource-endowed category hence the smaller numbers in the sample. The other two groups (RG 2 and RG 3) had more farmers hence more individuals in the sample. Smaller samples have the effect of reducing the efficiency of logistic models. However, a minimum of ten cases per variable are acceptable (Agresti, 1996).

3.4 Primary data collection

Both qualitative and quantitative assessments (Bamberger, 2000; Bellon, 2001) were used to establish factors likely to influence participation of farmers in field-based learning alliances as well as their uptake of soil fertility technologies under promotion. Key methods used for qualitative assessments included focus group discussions, key informant interviews, informal interviews and direct observations. Information gathered from these sources included farmer perceptions on agricultural production trends and possible reasons for observed trends; perceptions on field-based Learning Centres introduced by SOFECSA; interaction patterns for access and sharing ISFM knowledge and information; perceptions on promoted ISFM technology options; general agricultural issues among many other issues.

For quantitative assessments, a questionnaire (Appendice 3) was administered in 2011 to the stratified random sample of 70 smallholder farmers drawn from the learning alliance participants (n=30) and a counterfactual sample of non-participants (n=40). Issues addressed in the questionnaire included general household explanatory variables, crop production, social capital, food security, income levels, information/knowledge access and sharing pathways, and use of ISFM technology options. Pre-testing of the questionnaire was done with a team of selected enumerators to ensure accuracy and precision in the administration of questions. To ensure reliability and minimise bias of the data, questionnaire interviews were targeted at the household head or his/her proxy mature enough to provide the relevant information. Administered questionnaires were checked for any missing information or ambiguous responses, including making follow-ups where necessary, before leaving the study area and commencement of data entry into the Statistical Package for Social Science (SPSS version 16.0 of 2007) software.

3.5 Analytical framework

Data were analysed by first generating descriptive statistics of interviewees and secondly logistic regression analysis for factors influencing farmer participation in learning alliances. The Pearson Chi-square statistic was used to test for association between categorical variables while paired T-test was applied for testing differences in the means of quantitative variables between the two groups of respondents (learning alliance participants and non-participants) (Gujarati, 1996). To assess farmer interaction patterns with regards to access and sharing of ISFM information and knowledge UCINET 6 software for social network analysis was employed (Borgatti et al., 2002). Differential ISFM benefits were assessed using gross margin analysis.

3.5.1 Determinants of farmer participation in knowledge sharing alliances

Local extension agents and key informants came up with criteria for distinguishing ISFM learning alliance participants from non-participants. Participants were found to be: (i) using combinations of inorganic and organic fertilisers; (ii) increasing use of locally available nutrient sources such as woodland litter and termitaria soil; (iii) appreciating legume-cereal rotations; (iv) matching plot sizes to the available soil nutrient resources; (v) making particular selection of crop cultivars/varieties and (vi) staggering planting of crop varieties as well as crop diversification. By inference, the participants satisfying these criteria were viewed as adopters of ISFM technologies.

The catalogue of promoted ISFM technology options by SOFECSA in Nyahava since the year 2007 comprised of: animal manure, compost (sole or in combination with organic fertilisers), legume-cereal rotations, legume-cereal intercrops and Rhizobia inoculation of legume seed. Woodland litter and legume green manure were also considered important sources of organic matter, while termitaria soil was a common amendment (Nyikahadzoi et al., 2012). In this study the logistic regression model was adopted to determine the factors likely to influence the different ISFM technology options promoted. Technology adopters were defined as: 1) ISFM adopter as that farmer found to be using at least four catalogue components singly or in combination; 2) termitaria adopter using termite mound soil; 3) organic fertiliser adopter as that farmer using at least two components from animal manure, woodland litter or compost; and 4) legume adopter as that farmer using at least two components from legume-cereal rotations, legume-cereal intercrops, Rhizobia inoculation of legume seed or green manuring with sunnhemp (*Crotalaria juncea* L.) in their main fields.

According to Agresti (1996), the functional form of logistic model was specified as:

$$\text{In}\ [P_x / (1-P_x)] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\ldots\ldots\ldots\ldots\ \beta_k X_{ki}$$

Where:

- P_x is the probability of an event occurring for an observed set of variables X_i, that is, the probability that the farmer participates in ISFM learning alliances and $(1-P_x)$ is the probability of non-participation.
- β_o is the intercept term, and β_1, β_2 ……β_k are the coefficients of the independent variables X_1, X_2........X_k.
- the subscript *i* is the i^{th} observation in the sample

The choice of independent variables for the logistic models was informed by working hypotheses suggested by general economic theory and empirical findings from similar studies.

Household variables (including respective codes used in this study) hypothesised to influence smallholder farmers' participation in field-based learning alliances are outlined and briefly described in Table 3.3.

Sex of household head (*code* = Gender) implicitly suggests decision-maker of the household. Research suggests that male-headed households in developing countries have relatively higher access to resources and information than female-headed households thus giving them greater capacity to adopt technologies (Kaliba et al., 2000). This implies male-headed households are likely to have a higher probability of adopting ISFM practices than the female-headed households.

Age (Age) generally implies farming knowledge and experience gained with years of farming practice and as farmers acquire more experience, their ability to process and utilise new information improves (Feder et al., 1985; Adesina et al., 2001). Generally, it is believed that higher education (Educ) influences a farmer's ability to perceive, interpret and quickly respond to new information (Nkonya et al., 1997; Rahman, 2003). Adoption of knowledge-intensive concepts and principles of technologies such as ISFM requires precision in the application of different fertiliser options in terms of timing and quantities (Mapfumo et al., 2013). Education level is therefore expected to have positive influence on farmer uptake of introduced technologies.

Family labour (Labour) has been identified as one of the most important inputs in smallholder farming systems (Elad and Houston, 2002) herein calculated as the number of household members aged between 16 to 58 years. This age group consists of family members who can actively contribute to farm activities. Some ISFM technologies such as the use of woodland litter, cattle manure and termitaria soil are labour intensive (Pali et al., 2003), thus it is hypothesised that insufficient labour will most certainly limit adoption of labour-demanding technologies.

Table 3.3 Household factors hypothesised to influence adoption of ISFM technology options by smallholder farmers in Chinyika, eastern Zimbabwe

Independent Variables	Code	Measure	Rationale
Sex of household head	Gender	1=male, 0=female	Female farmers tend to have limited access to requisite information and resources
Age of household head	Age	Years	Farmer's experience increases the likelihood of understanding ISFM benefits
Level of Education	Educ	1=formal education, 0=informal	Education enhances understanding of new ISFM concepts and principles
Labour availability	Labour	Active labour force (16-58 years)	Availability of labour enhances capacity to adopt ISFM technologies
Arable land	Arable	Hectares	Large farm size increase the probability of adoption of ISFM
Ownership of farming implements	Oxplough	Number of ox-ploughs owned	Availability of farming equipment enables timely operations
Livestock ownership	Livest	Number of cattle owned	Livestock availability improves manure availability, draught power and provides an alternative income source for the acquisition of inorganic fertilisers
Membership in learning alliances	Colearn	1= participant, 0= non-participant	Trained farmers apply acquired knowledge and skills in their farms
Social capital	Scap	Social capital	Social capital enhances access and sharing of ISFM information
Distance to input market	Fertdist	Kilometres	Large distance to input markets reduces the likelihood of adoption of ISFM

Larger arable land size (Arable) avails opportunity to the farmer to maintain their traditional way of farming whilst experimenting with new options on other land portions hence expected to enhance the likelihood of adoption of ISFM technologies (Feder et al., 1985). There is a general decrease in adoption capacities with an increase in resource constraints (Mtambanengwe and Mapfumo, 2005), hence it is anticipated that the more resource endowments (Assets) a household has the higher the probability of ISFM technology uptake.

Livestock (Livest), especially cattle, are an important source of manure and draught power among smallholder farming communities. Farmers who own livestock can sell some and use proceeds to procure inorganic fertilisers which can be used singly or in combination with locally available nutrient sources. Expectations are that livestock ownership has a positive influence on farmer uptake of ISFM innovations promoted.

Household membership in an ISFM knowledge-sharing alliance (Colearn) is a dummy showing the treatment effect of mobilising farmers into alliances formed around ISFM field-based learning centres. Expectations are that as smallholder farmers access and share available empirical ISFM information and knowledge in learning alliances, there would be a positive change of perceptions and attitudes leading to enhanced technology uptake.

Social capital (Scap) is a proxy (computed by summing frequency ratings of interactions between the farmer and other local farmers and outside community including service providers) signifying farmer interactions with peers or external agencies. This exposes them to a wide range of ideas and information which may force them to form positive or negative attitudes towards an innovation (Bandiera and Rasul, 2006; Mashavave et al., 2013). Thus direction of influence on technology adoption is uncertain.

Distance to major market for inorganic fertiliser (Fertdist) was used as a proxy for access to input markets. Transaction costs increase with distance of a household from market (Abdulai and Huffman, 2005); hence distance to market is expected to impact negatively the uptake of

ISFM technologies involving use of inorganic fertilisers used singly or in combination with organic resources.

3.5.2 Smallholder farmer interaction patterns for information sharing

In order to explore the potential of smallholder farmer social networks in enhancing access and sharing of ISFM information and knowledge, Social Network Analysis (SNA) was adopted in this study. The SNA framework and data collection was guided by social network literature (Borgatti et al., 2002; Borgatti, 2006). Most researchers prefer using resource flows to explain the impact of social networks (Podolny, 2001) by employing proxies such as frequency and/or intensity of interactions as actual transfers within networks are rarely measured (Borgatti and Cross, 2003). In the pre-SOFECSA phase, access to agricultural information by smallholders in the study area was predominantly through national extension agents, regarded the major source of post-1980 agricultural information being used currently by most farmers (Mashavave et al., 2013). Linked ISFM information sources and platforms from both participant and non-participant farmers were tracked using snowballing methods with the farmer as the focal actor (*ego* in network analysis) and his/her *alters* (other actors with whom *ego* has direct relationships) (Borgatti, 2006). Full network methods were not employed in this study because of the cost implications in tracking every actor in the network and also the problem of isolated actors (pendants) who may not be beneficial to the whole network (Borgatti, 2006; Kilduff and Brass, 2010). While snowballing techniques may not reveal all the stakeholders within the network they are affordable and sociometric measures can be applied with ease to identify central players (Borgatti, 2006). Generation of additional qualitative information was done using techniques such as participatory observation of recurrent interactions, group discussions, document analysis, and key informant interviews particularly with all regular participants in the field-based learning alliances (Bernard et al., 1984; Sasovova et al., 2010). Typical data collected included perceived information pathways among the smallholder farmers, their level of participation at Learning Centre activities, and limitations to successful information access and sharing among many other issues.

Sources and platforms for access and sharing of ISFM information and knowledge among both farmer groups were identified by capturing their horizontal and vertical social connections (Scott, 2000). Only ‘human’ sources of information and knowledge were asked to identify their ties whilst other ‘non-human’ sources were recorded as given by the farmer (ego) (Mashavave et al., 2013). The sample of non-participants (counterfactual group) was drawn from where no SOFECSA activities had been conducted to counter contamination in the interaction map for non-participants. This ego-network survey was meant to capture the changes, if any, in the interaction patterns and players in the presence or absence of a new innovation.

Social network analysis (SNA) was then used to analyse the collected data for both groups using UCINET 6 software firstly by constructing typical interaction maps (socio-grams) for both farmer groups using NetDraw in UCINET (Borgatti et al., 2002). Sociometric measures were then applied to the observed network structures in order to identify key players as well as assessing the level of connectedness of the smallholder farmers. Centrality indices are generally used to quantify the importance of actors within a social network and this is based on the notion that all actors are not equally important for dynamics and stability of the system (De Nooy et al., 2005; Estrada and Bodin, 2008). Social network analysts have developed a variety of sociometric measures of centrality among them degree centrality, betweenness centrality, closeness centrality to assess the importance of an actor within a particular network (Namba et al., 2008). Degree centrality index determines an actor’s connectivity to other network partners; betweenness centrality measures an actor’s influence whilst closeness centrality measures the ability of a player to quickly send and receive information (communication efficiency)

(Freeman, 1979). Thus closeness centrality indices were used for this study to assess the communication efficiencies of observed farmer networks and as a proxy to the role of farmer social networks in the adoption decision process of improved ISFM options (Brass, 1995a; Kilduff and Brass, 2010).

Closeness centrality (CC) measures the rate of spread of information from a central actor *i* to all other actors within the network sequentially (Mashavave et al., 2013). Closeness centrality of *i* is calculated as:

$$\mathrm{CC}_i = \sum_{j=1; i \neq j}^{n} \left(\frac{\mathrm{d}_{ij}}{n-1} \right)$$

Where

- n is number of actors, and
- d_{ij} is the shortest distance (geodesic distance) between actors *i* and *j* measured in number of connections/ties.

Closeness centrality is calculated as the inverse of the sum of the shortest distances between each actor and every other member in the social network (Freeman, 1979; De Nooy et al., 2005). The underlying assumption here is that whatsoever flows through the network only moves along the shortest available paths. In essence, the implication is that actors with low CC values generally have the least potential to affect other actors within the network and the reverse is true (Borgatti, 1995). For the purposes of comparison the CC assessments in this study were mostly limited to common information sources and platforms between learning alliance participants and non-participants (Mashavave et al., 2013).

3.5.3 Assessing differential integrated soil fertility management benefits

Partial budget analyses were employed to assess the viability of adopting legume-cereal rotations compared to conventional farming practices. This was informed by the observation that among the number of technologies promoted, the adoption pattern tended towards legume-cereal rotations with groundnuts being the dominating grain legume. Non-widespread production of cowpeas was mainly due to: (i) non-availability of seed; (ii) susceptibility to insect pests such as aphids and (iii) poor storageability of the grain due to weevils. This made the inclusion of cowpeas in the analysis impossible as a very insignificant proportion of farmers planted the crop for the 2010/11 cropping season.

The underlying assumption for this study was that the expected net benefits from using components or whole ISFM package promoted exceeds the expected value of benefits from use of current practices or not using it (Rahm and Huffman, 1984; Pannell, 1999). Another assumption made was that any observed variation was a result of the new innovation though in reality, differences may arise from diverse farmer socio-economic circumstances, agricultural management practices among many other factors (CIMMYT, 1988). Partial budget analysis was employed for this study to analyse the viability of legume-cereal rotations. Groundnut-maize rotations were used for the analysis of differential benefits since the adoption pattern among participant farmers tended towards this option. Non-participant farmers maintained their maize mono-cropping practices methods.

Partial budgets have been widely used to analyse farm business changes especially to estimate the financial effect of incremental changes. However, a major limitation with partial budgeting is that this tool only estimates possible financial impacts but does not assure them. Moreover, gross margin analysis does not indicate how much profit a farmer will be making as overhead production costs are not included in the analysis (CIMMYT, 1988). The analysis considered two cropping seasons 2009/10 and 2010/11 using averaged data for each of the groups (learning alliance participants and non-participants). In this context, the term ‘partial budget’ referred to only those costs associated with the new innovation and not all production costs. Specifically, only costs related to the groundnut enterprise were included in the analysis. The difference in labour requirements between the two options (mono-cropping versus rotation) was primarily due to demands in planting, weeding and harvesting of the groundnut crop. Farmers generally do not attach a monetary value to family labour but for this study the opportunity cost for family labour was estimated at the local daily wage rate for hired labour (labour day) plus the value of non-monetary payments normally offered such as maize grain or grocery items (CIMMYT, 1988).

For this study, all maize and groundnut grain produced (consisting of grain retained for family consumption, sold, retained for seed and/or given out) was valued at the prevailing market prices: US\$ 275 tonne^{-1} for 2009/10 and US\$ 285 tonne^{-1} for the 2010/11 cropping seasons. Shelled groundnut grain was valued at US\$ 400 tonne^{-1} and US\$ 450 tonne^{-1} for the two respective seasons. A sensitivity analysis was carried out to assess the changes in viability of cereal-legume rotations when the farmers disposed their maize grain through informal traders (locally called ‘*makorokoza*’). The informal traders were offering the farmers between US\$150 and US\$200 cash tonne^{-1} of maize grain, *ceteris paribus*, for the two seasons, respectively. The inability of the Grain Marketing Board to pay cash for maize grain deliveries usually left the farmers with no option, but to dispose their surplus grain through the informal channel in order to get the desperately needed cash. A tonne of maize grain was exchanged for 5 X 50 kg bags of Compound D fertiliser, 5 X 50 kg bags of ammonium nitrate fertiliser and 10 kg maize seed. Collection of data for the analysis was through a questionnaire survey (Appendice 3) and secondary data that included input and product prices for maize and groundnut grain.

CHAPTER 4

Determinants of smallholder farmer participation in learning alliances

4.1 Introduction

Addressing challenges of low and declining soil fertility in smallholder farming systems remains a priority for agricultural research and development initiatives by both national and international institutions in sub-Saharan Africa (Mapfumo et al., 2008). Active engagement between farmers and external agents has been shown to improve their knowledge capital on new and improved technologies, thus enhancing capacity to adopt (FAO, 2001). The potential for innovation systems approaches in promoting stakeholder participation in adapting technologies on Integrated Soil Fertility Management (ISFM) and climate change adaptation measures has been demonstrated at field-based Learning Centres (LCs) established by the Soil Fertility Consortium for Southern Africa (SOFECSA) under diverse southern African agro-ecosystems and socio-economic circumstances (Mapfumo, 2007). Application of PAR approaches in these initiatives has, however, revealed major demands to quantify farmer- and market-driven ISFM innovations at process level in order to stimulate interest from major players in agricultural input-output markets.

Information on factors influencing farmer participation in knowledge sharing processes around established field-based ISFM LCs is only emerging since this is a new concept. This chapter, therefore, gives findings following co-learning initiatives with smallholder farmers under the auspices of SOFECSA's ISFM initiatives in eastern Zimbabwe.

[§]Preliminary findings of this Chapter were published as: Mashavave T, Mapfumo P, Mtambanengwe F, Chikowo R, Gwandu T, Nezomba H and Siziba S, (2011). Factors influencing participation of smallholder farmers in knowledge sharing alliances around SOFECSA field-based Learning Centres. *African Crop Science Proceedings* 10: 331-334

[§]Consolidated version of the Chapter subsequently submitted for publication as: Mashavave T, Mtambanengwe F, Mapfumo P, Gwandu T, Nezomba H and Siziba S. Factors influencing participation of smallholder farmers in knowledge sharing alliances around field-based learning centres in eastern Zimbabwe. *African Crop Science Journal*

Using PAR approaches, smallholder farmers were mobilised into learning alliances to enable access, and sharing of information and knowledge on ISFM. The main objectives were to determine: (i) the main factors influencing farmer participation within ISFM field-based learning alliances and (ii) the effectiveness of learning alliances in promoting uptake of ISFM practices.

4.2 Results and discussion

4.2.1 Characteristics of interviewed households

The general characteristics of smallholder farming households in the study area are given in Table 4.1. Results indicated that 43% of the interviewed households participated at field-based learning centres (learning alliance participants) in one way or the other whilst the remaining 57% could be largely classified as non-participants. The proportion of female-headed households of 27% was consistent with the 20-30% reported in other surveys (Ahmed et al., 1997; Twomlow and Ncube, 2001), with male-headed households constituting the remaining 73% of respondents. Mean ages between participants and non-participants were significantly different ($p = 0.012$). The average age of 58 years among participant farmers (Table 4.1) implied a wealth of farming experience and thus the potential to sustain smooth flow of information and knowledge within established learning alliances. Non-participant farmers (61%) had relatively more formal education than participant farmers (39%) though over 50% of farmers had attained formal education within the participant cluster. There exists a significant relationship between the education level of the household head and their participation in learning alliances ($p = 0.035$) implying that education level enhanced the likelihood of participation within learning alliances. Though the number of household members actively engaged in farming activities ranged from 0 to 10 people the average active labour was 3-4 people suggesting a general labour shortage across farming households.

Table 4.1 Socio-economic characteristics for smallholder farming households in Chinyika East, eastern Zimbabwe 2011

Characteristic	**Learning Alliance Participant (n=30)**	**Non-Participant (n=40)**	**Paired T-test; Chi-squre *p*-values**
Education level of household head			
No. with no formal education	14 (48%)	15 (52%)	0.035*
No. with formal education	16 (39%)	25 (61%)	
Mean available labour (people)	3.6 (2.2)	3.2 (1.8)	0.124
Mean arable land size (hectares)	5.2 (1.3)	5.4 (1.3)	0.334
Mean number of ox-ploughs	1.2 (0.6)	1.0 (0.5)	0.549
Mean social capital scores	29.5 (7.4)	32.1 (4.4)	0.320
Sex of household head			
No. of female	7 (37%)	12 (63%)	0.389
No. of male	23 (45%)	28 (55%)	
Mean age of household head (years)	58 (16.8)	53 (19.0)	0.012*
Mean distance to nearest input market (kilometres)	51.3 (30.0)	34.5 (18.9)	0.042*
Mean number of cattle	8.5 (9.1)	6.0 (4.7)	0.023*

*Values in parenthesis for continuous variables are standard deviations; * Significance at $p<0.05$*

Total arable land holding averaged 5.3 hectares though the total land allocation in this settlement was historically fixed at 6 hectares per household (Chisora, 2006). The high level of ownership of ox-ploughs by approximately 90% of households did not tally with the low level of cattle ownership within the community which varied significantly according to the resource group of the respondent. The farmers usually perceived that ownership of implements such as ox-drawn ploughs enabled them to carry out timely operations of farming activities. However, the mean number of cattle was significantly different between the participant and non-participant farmers (p = 0.023).

Non-participant farmers were relatively well-networked to fellow farmers, outside communities and external agro-service providers with average ratings of 32.1 than learning alliance participants (29.5). Nevertheless, participant farmers were generally prepared to travel greater distances to the input/output markets than non-participants as implied by the significant difference between the mean distances to the nearest input market (p = 0.042). The visits were mostly undertaken to procure certified agricultural inputs, mainly inorganic fertilisers and seed, from larger towns where they are not limited on the choice of suppliers and/or products.

4.2.2 Socio-economic characteristics of learning alliance participants

Overall, the results indicated that men and women attended village meetings in almost equal proportions of 51% and 49% respectively (Figure 4.1). However, disparities were evident when it came to the newly established action learning groups which generally had male dominance of more than 60%. This observed trend of male dominance, which is the opposite of the usual trends of female dominance in most smallholder communities in sub-Saharan Africa (FAO, 2006; Ogunlela and Mukhtar, 2009), may partly be explained by the history of the origins of the Chinyika communities. Chinyika was established in the post-independence era by the Government of Zimbabwe in the early 1980’s to ease congestion of old communal areas around the country. Despite the farmers having diverse backgrounds, they were brought together by the passion for farming which is the primary source of livelihood for family and for which men have the prime responsibility (Mapfumo et al., 2010). The area is commercially oriented in terms of availability of road infrastructure; existence of farmer supporting institutions and generally lies in a moderate-high potential agro-ecological zone (NR 2) receiving mean annual rainfall of 650-750mm.

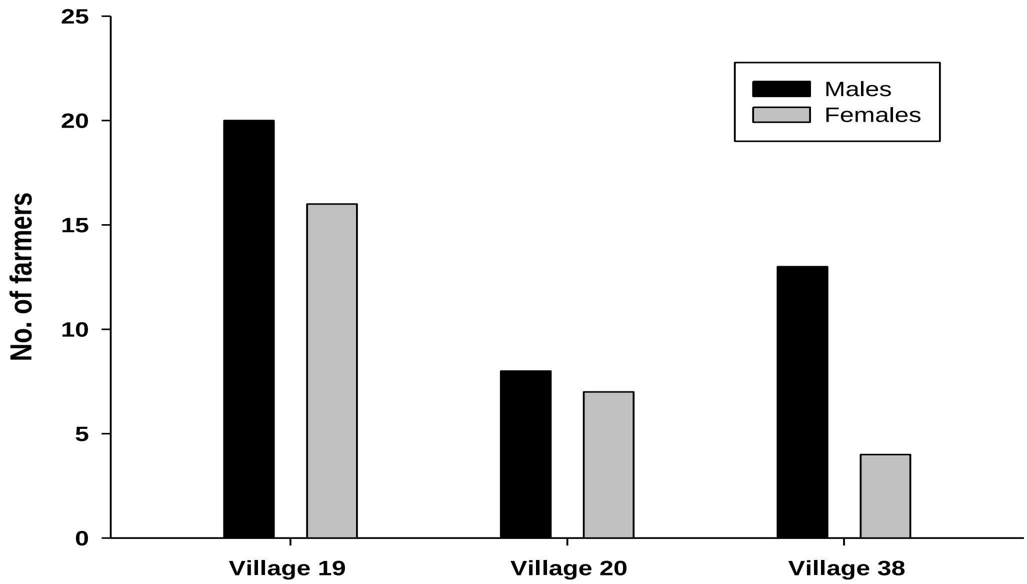


Figure 4.1 Composition of Farmer Action Learning Groups in Three Villages in Nyahava Community, Eastern Zimbabwe

Composition of the newly established action learning groups did not differ much in numbers between males and females. However, in one village (Village 38), the number of men was three-times more than their female counterparts (Figure 4.1). This was attributed to improved information access and positive experiences with SOFECSA interventions in the past. Farmers with better access to quality information have often been found to show a clear change of attitude towards innovation (Geran, 1996). On the other hand, despite women farmers being responsible for most agricultural activities in Southern Africa(Ogunlela and Mukhtar, 2009) , women's active participation in agricultural research initiatives is somehow constrained by their active role in the domestic or the reproductive sphere and their preference to engage in other home-economic activities where they can control their income (Bastidas, 1999).

Ranking of perceived characteristics of a co-learning alliance revealed marked differences between the male-dominated group (Village 38) and those which had almost equal proportions of males and females (Villages 19 and 20). While unity among members ranked highly among the other two similar groups, having a common goal and a working constitution were ranked highly by the male-dominated group (Table 4.2). This seems to suggest the interest of men in issues of governance (Ogunlela and Mukhtar, 2009).

Table 4.2 Perceived characteristics of learning alliances around field-based learning centres by smallholder farmers in Nyahava, eastern Zimbabwe

	Village 19 (M=20; F=16)	Village 20 (M=8; F=7)	Village 38 (M=13; F=4)
1.	Members must be united	Members must be united	Members should have a common goal
2.	Activities must be carried out collectively	Share unmarketed produce equally	Have a working constitution
3.	Share produce equally	Collectively market produce	Group must be large enough to attain a critical production target
4.	The agricultural extension worker (AEW) should represent all	Activities must be carried out collectively particularly accessing inputs	Unity among members important
5.	Collectively identify a buyer if there are surpluses	Target high yields to generate marketable surplus	Produce must have guaranteed buyers well before production starts

In the two female-dominated groups (Villages 19 and 20), sharing of produce was prioritised as a pre-condition for participation, (Table 4.2), but was lowly ranked by the other group which only had 4 females versus 13 males (Figure 4.1). This gave a reflection of how female members prioritise household food self-sufficiency before issues of marketing are considered (Valdivia, 2001). Studies from other developing countries often report that male members of farming households often take a leading role in decision-making process regarding agricultural development, and have a higher access to resources and information of improved technologies (Geran, 1996; Kaliba et al., 2000).

Resource-constrained and intermediate group farmers constituted more than 80% of the farmers in the ISFM co-learning alliance whilst only 16% of the farmers belonged to RG1 (Figure 4.2), and it was interesting to note that this group had a male dominance with only one female member (Figure 4.3).

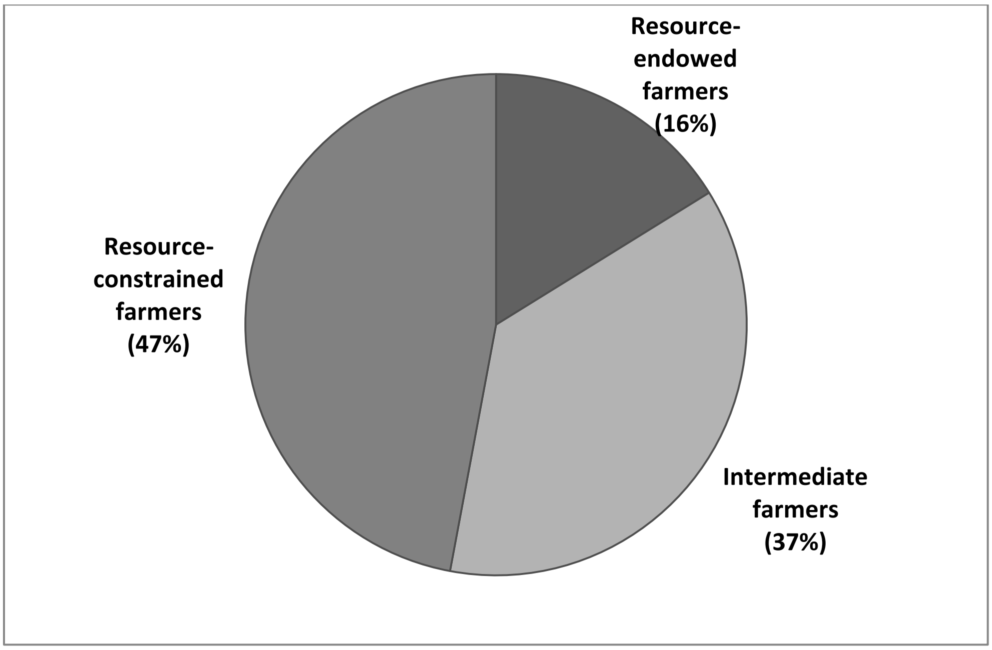


Figure 4.2 Relative Distribution of Farmers in Co-learning Alliances by Resource Endowment in Nyahava Community, Eastern Zimbabwe (n=68)

There was generally an increase in the number of female farmers with an increase in the resource constraints and these actually dominated the resource-constrained group (Figure 4.3). Several studies have indicated that the socio-economic characteristics of farmers, among other factors, play a key role in decision-making in agricultural activities (Mtambanengwe and Mapfumo, 2005; Zingore et al., 2007). Working in the same community during the drought years of the 2000s, Mapfumo et al. (2010) observed an increased presence at meetings and ISFM LC activities of resource-constrained (RG3 farmers) households relating to agriculture or general livelihood initiatives in the area. The observed high proportion of RG3 farmers (close to 50% representation) in learning alliances (Figure 4.2) supports this observation of a group previously known to 'shy-away' from research and development initiatives (Mtambanengwe and Mapfumo, 2005).

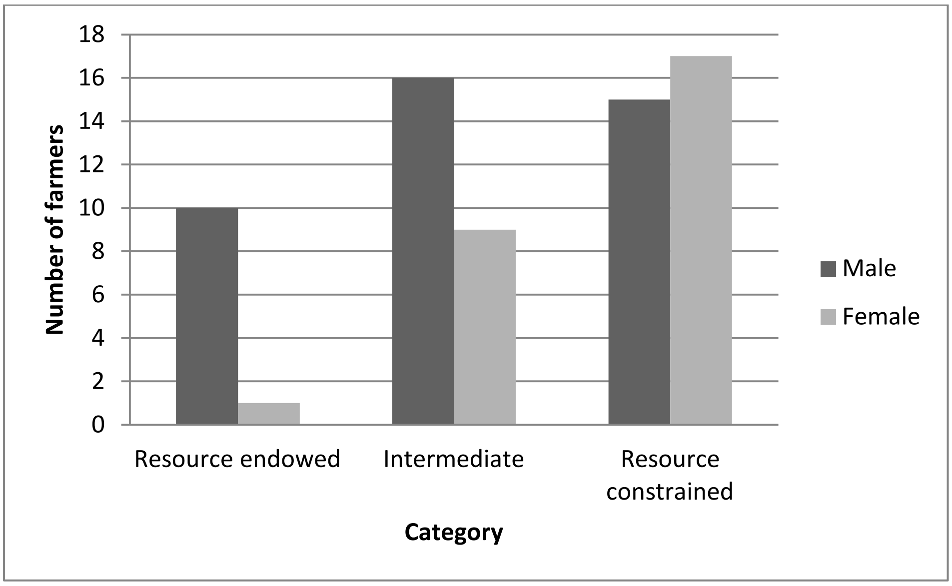


Figure 4.3 Distribution of Male and Female Farmers in Co-learning Alliances by Resource Endowments in Nyahava, Eastern Zimbabwe (n = 68)

From the farmers' perspective, participation in knowledge sharing alliances around LCs was enhanced by several factors, among them:

(i) accessibility and visibility of the LC;

(ii) experience of the learning centre host farmer;

(iii) history of contact with SOFECSA researchers as well as the championing on SOFECSA ISFM options and climate change adaptation measures by the host;

(iv) the host being a natural-born leader able to mobilise and impart acquired knowledge to others, including encouraging participation of everyone within the community and;

(v) the realisation of high yields on small land areas at LCs as opposed to extensification.

Learning Centres were viewed by the farmers as knowledge and information processing centres through the creation of a more effective context for discussing issues related to climate change and ISFM thereby building capabilities of these farmers. Field-based LCs also enabled the farmers to discuss ISFM issues on the level of personal experiences rather than on the level of blueprint solutions generated elsewhere. Most of the interviewed farmers hailed the technologies being promoted as well as the new information on climate change adaptation as positive move towards enhancing crop productivity and general livelihoods in a cash economy.

Smallholder farmers and other agro-stakeholders participating in the field-based learning alliances shared information on agronomic practices, use of organic soil fertility amendments, chemical fertiliser application techniques, use of termitaria soil and legume-based technologies. Approximately 72% of participating farmers who had successfully attended LC activities were found to have adopted components and modified some components of the ISFM package promoted, consistent with findings by Smale et al. (1995) that farmers tend to have incremental technology adoption patterns. These were found to be increasingly using chemical and organic fertilisers in combination; split application of chemical fertilisers; woodland litter; crop diversification; legume-cereal rotations/intercrops; termitaria soil and matching land sizes to available nutrient sources. Woodland litter was first put in cattle pens only to be taken out later and spread on main fields after it had well decomposed. The increased innovation maybe related to the social dynamic created in the course of recurrent learning and knowledge-sharing within the context of learning alliances. This may be an indication that empowering farmers through frequent interactions with their peers and other agro-stakeholders from outside the community boundaries influenced their adoption decisions.

4.2.3 Factors driving uptake of ISFM technologies by farmers

The integrated soil fertility management options promoted in field-based learning alliances and subsequently used by smallholder farmers in their main fields are presented in Table 4.3. There was generally good adoption of the promoted ISFM package being taken up by 77 % of the smallholder farmers. Using the mother-baby approach, Mugwe et al. (2009) found that only 46 % of the farmers had adopted ISFM technologies promoted in the central highlands of Kenya.

Table 4.3 Adoption of promoted ISFM technologies by smallholder farmers in Chinyika, eastern Zimbabwe 2011

Technology	**Adopters**	**Non-adopters**	$\chi 2$ ***p* value**
Organic ameliorants	43 (61%)	27 (39%)	0.478
Legume-based	41 (59%)	29 (41%)	0.779
Termitaria soil	12 (17%)	58 (83%)	0.013**
ISFM	54 (77%)	16 (23%)	0.285

**Association significant at 5% level

Adoption of technologies by farmers is generally voluntary. However, there are cases where adoption was not voluntary. For example, adoption of conservation farming (CF) technology in Zimbabwe, upon the inception phase, was not in most cases voluntary as the target farmers of vulnerable households were provided with agricultural inputs and appropriate extension support as incentives to adopt the CF technology (Twomlow et al., 2008a). Though some spontaneous adoption by less vulnerable households has been reported, some farmers who originally participated in the CF promotions opted out due to various reasons (PRP, 2005). This suggests that the field-based learning alliance approach used in this study was effective in promoting uptake of soil fertility management technologies. Farmers who adopted organic ameliorants and legume-based technologies were in almost similar proportions of 61 % and 59 % respectively.

Termitaria soil was the least adopted technology with 83 % non-adoption and this was significant at 5 % level (p = 0.013). This widespread non-adoption could be attributed to the demand of the technology on labour required to collect sufficient amounts of the soil. The variation in the uptake of the different ISFM practices promoted was consistent with some previous studies which showed that farmers generally adopt components of an innovation in order to learn more about the whole technological package (Smale et al., 1995; Morales and Perfecto, 2000).

Table 4.4 shows the results of the adoption models of the promoted ISFM package and its components. Generally the models had good explanatory power and the legume technology adoption model correctly predicted 64% of adopters and non-adopters. The implication therefore, is that the variation not explained in the model (36%) can be accounted for by other factors not included in the model. There was low correlation between the independent variables signifying some level of independence between the factors.

Binary logistical regression models revealed the age of the household head had a significant positive influence on the adoption of termitaria soil technology at 10% probability level implying that younger households had less probability of using termite mound soil than older households. This was in contrast to studies in Kenya and elsewhere which showed that farmer's age tends to decrease the probability of adopting soil fertility management technologies (Baidu-Forson, 1999; Odera et al., 2000; Mugwe et al., 2009). A study on the adoption of soil conservation technologies in the Phillipine uplands showed that age had both positive and negative influence on adoption decisions of contour hedgerows in Cebu and Chivera respectively (Lapar and Pandey, 1999). In this current study, a plausible explanation for the positive influence of age on adoption of termitaria soil among older farmers could be due to the accumulated wealth of knowledge and resources thus, giving them relatively high capacity of adopting improved technologies than younger farmers.

Table 4.4 Binary logistic regression analysis results of the factors influencing adoption of ISFM practices for 70 households surveyed in Chinyika East, Zimbabwe 2011

Variable	**Organic ameliorants**	**Legume technologies**	**Termitaria soil**	**ISFM**
GENDER	-0.295(0.673)	-0.896(0.717)	-1.063(1.702)	-1.128(0.904)
AGE	0.010(0.020)	0.021(0.020)	0.064(0.036)***	0.007(0.021)
EDUC	0.363(0.770)	0.582(0.764)	0.937(1.214)	-0.751(0.919)
LABOUR	0.164(0.150)	-0.201(0.144)	-0.634(0.345)***	0.012(0.170)
ARABLE	0.118(0.219)	0.365(0.220)***	-0.301(0.324)	0.247(0.235)
OXPLOUGH	1.824(0.802)**	1.688(0.799)**	-1.219(1.142)	0.429(0.838)
LIVEST	-0.094(0.055)***	-0.052(0.053)	-0.159(0.108)	-0.060(0.064)
FERTDIST	0.000(0.012)	-0.016(0.012)	-0.007(0.017)	0.001(0.014)
COLEARN	-0.296(0.642)	-0.033(0.626)	2.941(1.070)*	1.137(0.797)
SCAP	0.086(0.056)	-0.036(0.052)	0.103(0.088)	0.119(0.070)***
Constant	-4.888(2.200)**	-1.344(2.045)	-3.982(2.817)	-3.248(2.551)
Log-likelihood	-76.824	-81.547	-43.445	-63.903
Total variation explained in model	67%	64%	86%	76%

Values in parenthesis are standard errors

*, ** and *** indicate significance at 0.01, 0.05 and 0.1 level respectively

The number of household members who could contribute actively to farming activities, which averaged 3-4 people in this study (see Table 4.1), negatively influenced the adoption of termitaria at 10% significance level implying that households with insufficient labour had less probability of adopting this technology. This could be explained by the interaction between labour and the collection of sufficient amounts of termitaria soil which were in most instances inadequate to fertilise large land portions. Use of termitaria soil involves digging up the dry hard termite mounds, heaping the collected rich soil, and then transporting it to target field portions, all of which requires a lot of labour inputs. This suggests that pooling of labour among the smallholder farmers or hiring additional labour in the collection of termite mound soil may ease the labour constraint. Hiring of additional labour positively influenced the probability of adoption of integrated use of manure and chemical fertilisers in central Kenya (Okuro et al., 2002). On the other hand, Bogale (2009) concluded that as household size increased, the number of mouths to feed also increases and may actually compromise allocation of resources towards agricultural production.

Arable land size had a significant positive ($p<0.10$) influence on the adoption of legume based technologies, an implication that those households with relatively large pieces of land had a higher probability of adopting legume-based technologies. This could be explained by the fact that larger land sizes avail the smallholder farmers the opportunity to experiment with the new technologies and are able to spread the risks associated with early technology adoption (Feder and Slade, 1984). In a study to promote the adoption of conservation farming practices in some districts of Zimbabwe, the first cropping season saw a number of farmers trying out the new technology on relatively poor fields as a way of minimising the risk of food production shortfalls. Observations were that the farmers simply maintained their conventional farming methods on better quality soils (Mazvimavi and Twomlow, 2009).

The availability of farming equipment had a significant positive influence on the adoption of organic ameliorants and legume based technologies at 5% significance level, an implication that resource-endowed smallholder farmers had a higher probability of taking up these technologies. The availability of farming equipment enhanced the likelihood of adoption of organic ameliorants and legume-based technologies possibly due to the ability of resource-endowed farmers to carry out timely operations. This was consistent with findings by Mtambanengwe and Mapfumo (2005) that resource-endowments give farmers a relative capacity to adopt new and improved soil fertility. On the other hand, resource-constrained and the more food insecure households tend to be preoccupied with survival or coping strategies leaving them with less time to manage their own fields (Tchale et al., 2004; Mapfumo et al., 2013).

Contrary to expectations, the number of cattle had somewhat a negative influence on the adoption of all the ISFM practices analysed though this was only significant for uptake of organic technologies. This implied that households with fewer cattle had a higher probability of adopting the promoted technologies than farmers with many cattle. Despite livestock (especially cattle) being a store of wealth and an important source of manure and draught power, the higher probability of adoption of organic technologies among those with fewer cattle could be attributed to the definition of an adopter of organic technologies in this study which required use of any organic manure plus any other organic nutrient source. Possibly the predominant number of cattle owners just use cattle manure alone because the quantities are relatively adequate whilst those without cattle literally scavenge for any organic alternatives such as woodland litter and compost. In order to enhance nutrient supply and generate sufficient quantities, farmers with fewer cattle usually put woodland litter in cattle pens which would be taken out later and applied on main fields. However, other adoption studies showed that livestock ownership influenced adoption of soil fertility enhancing technologies positively as a source of manure which could be used in combinations with inorganic fertilisers (Kristjanson et al., 2005; Marenya and Barrett, 2007). Observations were also that those with more livestock usually sold some to raise income to address mostly non-agricultural obligations such as sending children to school and medical expenses, consistent with findings by Reardon et al. (2000) who showed that higher incomes tend to encourage off-farm activities.

Membership into learning alliances had a significant positive influence on the adoption of termitaria soil use at 1% level and the magnitude of its coefficient was indicative of its importance in influencing adoption. Household membership in field-based ISFM knowledge sharing alliances exposed them to information and knowledge on new and improved soil fertility management options, hence the significant influence on the adoption of termitaria soil technology. The positive influence could be attributed to the increased knowledge on the alternative use of termite mound soil to augment the limited quantities of cattle manure regarded as the most important organic ameliorant (Nhamo et al., 2004; Mapfumo, 2009).

Social networks positively influenced the uptake of the promoted ISFM package at 10% probability level suggesting that farmers with more social interactions had a higher chance of adopting the catalogue of promoted technologies. The positive influence of social capital on the adoption of ISFM implied that social networks exposed smallholder farmers to diverse information sources and platforms for access and utilisation of available empirical knowledge on ISFM. Bandiera and Rasul (2006) found that social capital could yield a "synergistic effect" by fostering combination of different ideas and skills, and a "realisability effect" due to enhanced access to different resources; thus contributing to enhanced adoption of improved technologies. Key informants indicated that the negative influence on legume technologies could be explained by the indirect and less visible contribution of sunnhemp to food security; unavailability of legume seed and inoculant at local shops hence the non-widespread adoption (see Table 4.3).

4.3 Conclusions

Smallholder farmers perceived that attributes of the Learning Centre and host farmer were a prerequisite for participation in field-based learning alliances. Conversely, binary logistic regression analysis showed that factors that significantly influenced participation within learning alliances (analysed as uptake of promoted ISFM components in this study) varied with the practices surveyed. Different farming households had different capacities and preferences in the decision to participate or not in established field-based learning alliances. Farmer's age, size of arable land, ownership of farming equipment, household membership in learning alliances and social capital had a positive and significant influence on participation, whilst available active labour and number of cattle owned influenced participation negatively. These results suggest that action-learning alliances could enhance participation and uptake of improved ISFM technologies through targeting of appropriate technologies within smallholder farming communities.

CHAPTER 5

Smallholder farmer interaction patterns for information sharing

5.1 Introduction

More and more, trans-disciplinary research has been identified as appropriate fora of research in search for context-specific solutions within highly complex smallholder farming systems (Hurni and Wiesmann, 2004; Mapfumo et al., 2013). This generated scope for understanding technology adoption from a social network perspective with a particular insight into the inter-relationships among agro-stakeholders (Mashavave et al., 2013) rather than the attributes of the actors which has been the focus of most previous studies on technology adoption (e.g. Rogers, 1993; Kaliba et al., 2000; Abdulai and Huffman, 2005). The network perspective presupposes that social networks among agro-stakeholders create opportunities or constraints that may in turn drive or impede technology uptake (Borgatti et al., 2009; Halgin, 2009). These social interactions play a critical role in the formation of attitudes as individuals relate their own experiences to those of others facing similar circumstances (Galaskiewicz and Burt, 1991).

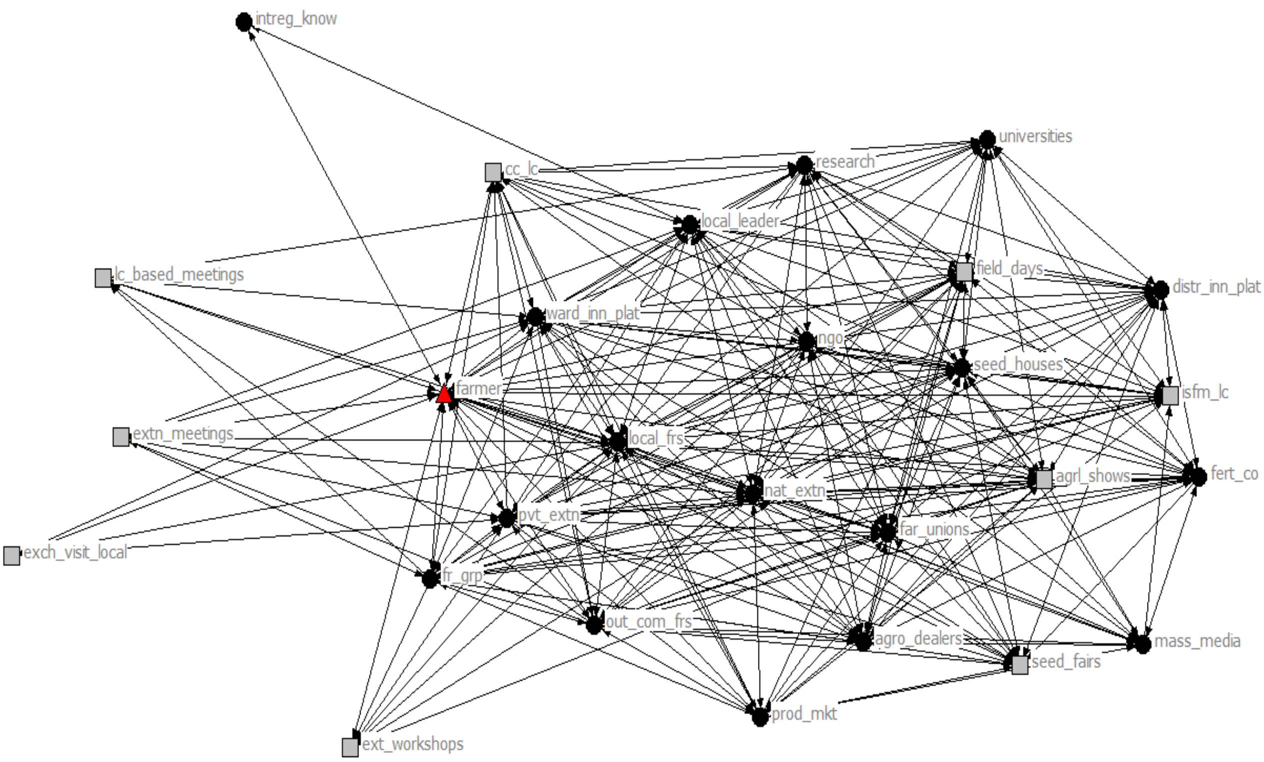
The potential value of smallholder farmer social networks in enhancing access and sharing of integrated soil fertility management (ISFM) information and knowledge was explored, in the context of field-based learning alliances in the eastern district of Zimbabwe. The specific objectives were to: a) assess the changes in social network structure of smallholder farmers participating in field-based learning alliances; b) investigate changes in central value chain players with the introduction of a new innovation, and c) quantify the communication efficiencies of farmer social networks in the dissemination of ISFM technologies.

[§]This Chapter has been published as: Mashavave T, Mapfumo P, Mtambanengwe F, Gwandu T and Siziba S (2013). Interaction patterns determining improved information and knowledge sharing among smallholder farmers. *African Journal of Agricultural and Resource Economics* Volume 8 Number 1 pages 1-12

5.2 Results and Discussion

5.2.1 Perceived farmer social network structures

The interaction map of farmers participating in field-based learning alliances had a dense network structure (Fig 5.1) suggesting that these smallholders had access to a wide range of information sources and platforms (Mashavave et al., 2013).



(Black circles represent ISFM information and knowledge sources while grey squares represent platforms for access and sharing ISFM information)

Figure 5.1 Social Network Structural Configuration for Learning Alliance Participant Farmers in Chinyika, Makoni District, Zimbabwe (Adapted from Mashavave et al., 2013)

The most isolated source of ISFM knowledge and information was inter-generational knowledge (intreg_know). This was defined by the farmers as that information which is passed as ‘folk’ knowledge from previous generations. Despite the less reliance on the knowledge from this source which is often characterised by incomplete transmission of information, farmer's knowledge and innovations within this network were integrated for adaptive learning and testing at field-based Learning Centres (LCs). Other sources of information identified by the farmers included farmer groups (fr_grp); farmers from outside the community (out_com_frs); fertiliser companies (fert_co); seed houses, universities, research institutions among many.

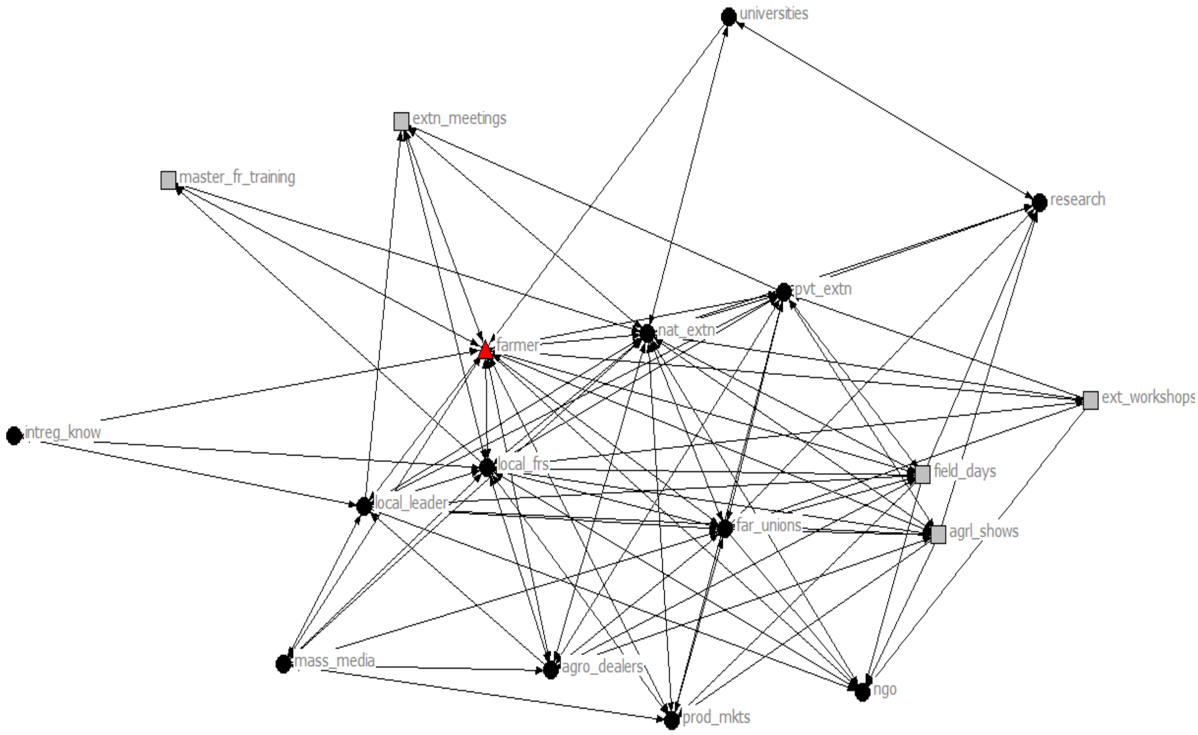
Farmers also accessed ISFM information and knowledge through district innovation platforms (DIP) and ward innovation platforms (WIP) established by SOFECSA in Makoni district. Mapfumo (2009) defines an innovation platform (IP) as a multi-sectoral, multi-institutional coalition of actors working together within a value chain system. District innovation platforms were comprised of members in the banking sector, ministry of agriculture and other external agro-service providers including farmer associations. However, there were variations in the composition of the IPs which was largely determined by the representation of a particular institution/organisation. This suggests that there exists scope for enhancing information and knowledge sharing as more organisations and actors are established especially at the micro-level (ward level) creating a potential to further increase the density of interactions (Mashavave et al., 2013). The network configuration suggested a high potential for continuous feedback among the different actors (Hall, 2005) and enhanced opportunities to access resources and services as IPs quickly hook up to new developments which can be shared with the farmers. Cross et al. (2003) found that enhanced bonding and bridging ties provide new information and diverse perceptions which can lead to creativity and innovation. Bouma et al. (2008) also concluded that proper development of bridging capital can link the smallholders for a different level of power and social status.

Platforms that were less preferred by the farmers included exchange visits with local farmers (exch_visit_local); external workshops (ext_workshops) and extension facilitated meetings (extn_meetings) as evidenced by their pronounced outward orientation. Participatory action planning (PAP) meetings were the common form of Learning Centre based meetings (lc_based_meetings) conducted during the pre-season months of September or early October for joint learning on ISFM and climate change. The meetings were subsequently followed by implementation of planned activities as the season commenced while mid-season and post-season joint monitoring and evaluation were done in January and July/August, respectively (Mashavave et al., 2013). These activities generally progressed through an iterative cycle of planning - action – reflection as recommended by Hagmann et al. (1998).

Timely interaction and learning is a vehicle for strengthening social coherence and trust within organised groups (Borgatti and Cross, 2003). Hagmann et al., (1998) suggests that group extension and training is more economic than individual farmer extension. The farmers also interacted at platforms such as field days, learning centres, seed fairs, exchange visits with local farmers and agricultural shows. Sharing of information at these platforms led to increased perception about new technologies by early adopters who would also share their experiences with fellow farmers leading to improved diffusion of innovations. Frequent interactions of smallholders at field-based learning alliances established by SOFECSA were also found to foster broader understanding of key ISFM principles and concepts, improved collaboration for generation of context-specific solutions as well as promoting market-oriented production among farmers (Mashavave et al., 2013). These social interactions of the smallholders within their locality as well as with farmers and agro-stakeholders from outside their community boundaries were also cited as responsible for the improved uptake of promoted ISFM options by approximately 72% of farmers in eastern Zimbabwe tailor-made to suit the farmers' particular circumstances (Mashavave et al., 2011). Collective action enhances farmers bargaining power, provides an opportunity for the farmers to pool scarce resources as well as reduce transaction costs in the purchase of essential ISFM inputs by removing opportunistic behaviour from the value chain (Nyikahadzoi et al., 2012). In essence, these results suggested that innovations that empower smallholder farmers have a potential to generate positive impact on their livelihoods.

The sociogram for non-participant farmers (Fig 5.2) suggested poor linkages among agricultural value chain actors as evidenced by the less dense connections (ties) compared to that of participant farmers. Intergenerational knowledge was the least preferred source of information due to its pronounced outward projection. Farmers' knowledge in this type of network was regarded of less value by scientific research standards (Hagmann et al., 1998) and thus could not be integrated into research initiatives. Universities and direct research were other less common sources of information as evidenced by their outward orientation and few ties. There were no direct links between farmers and research institutions providing evidence that extension agents still dominated the transmission of research-based knowledge to farmers (Gwandu et al., 2014). Agricultural value chain players had few spaces where they could regularly meet to collectively generate and share new knowledge and strategies. The weak collaboration within the social network could not permit the farmers to develop stable relationships with agro-service providers hence they were limited from realising economies of scale (Mashavave et al., 2013).

Generally, information exchange was mostly incidental and consisted of informal dialogues characterised by lack of sufficient information to form 'focused discussions'. Farmer-to-farmer interactions were mostly along socio-cultural dimensions such as gender, age, and religion a characteristic known as homophily in social network analysis (McPheson et al., 2001; Leonard et al., 2008). These results suggest that weak social interactions are not suitable for supporting self organisation and co-learning processes among smallholder farmers and service providers thus may discourage uptake of technologies.



(Black circles represent ISFM information and knowledge sources while grey squares represent platforms for access and sharing ISFM information)

Figure 5.2 Social Network Structural Configuration for Non-Participant Smallholder Farmers in Chinyika, Makoni District, Zimbabwe (Adapted from Mashavave et al., 2013)

Master Farmer Training Programmes run by national extension service, AGRITEX, were the most isolated platform for accessing and sharing of information and knowledge. Other identified platforms for accessing and sharing information included extension meetings, field days, agricultural shows, and external workshops. Farmers were notified on extension meetings through village chairpersons using media such as verbal communication, mobile phones, and/or school children. Unlike field days held in the villages with field-based learning alliances which attracted diverse agro-stakeholders, the field days within non-participant communities had very few outsiders; hence such activities were rarely conducted in this particular area (Mashavave et al., 2013). Production and marketing issues were mostly conducted on an individual farmer basis hence the farmers could not organise themselves for collective scaling-up of production.

5.2.2 Smallholder farmer social network impact on innovation learning cycle

Connectedness (closeness centrality) indices were generally higher for learning alliance participants than their counterparts implying relative communication efficiency of their network (Table 5.1). Higher communication efficiency within a social network implies that the players are able to convey information timely and accurately as information travels over short distances (Freeman 1979). Opsahl et al. (2010) asserts that low closeness indices imply that information transmission is slow and this raises the likelihood of incomplete transmission of information. National extension still dominated information dissemination within the network of non-participants as evidenced by a more pronounced index for national extension (nat_extn) of 94.4 than that of learning alliance participants (81.8).

Information and knowledge from national extension agents had less preference within the network of participants indicative of an innovation systems approach where farmers take the lead in research initiatives and outsiders take a facilitatory role. This suggested superiority of contextualised practical experimentation as opposed to transfer of technology approaches (Hagmann et al., 1998) which tend to inhibit feedback loops among agro-stakeholders. The two networks had lowest closeness values for intergenerational knowledge (intreg_know) suggesting that information from this source had the least potential to influence these networks.

Exposure to field-based learning alliances also enabled approximately 73% of the participating farmers to access crucial marketing information. This information was very useful in their decision-making with regards to choice of cropping as well as the production methods to maximise productivity. These results suggest a strong relationship between improved information flows and farmers' decision-making capacities. A closer look into the non-participant network revealed a rather strong attachment to non-governmental organisations

(NGOs) and produce markets (prod_mkts). This could have been influenced by the anticipation of perceived benefits such as free handouts or primarily as a source of food supplements, especially maize grain in the event of grain shortages (Mashavave et al., 2013). Farmer participation in action learning alliances enhanced their proximity to and from research initiatives as evidenced by a more pronounced research index of 67.5 among participants against 58.6 for non-participants.

Table 5.1 Closeness centrality indices for participant and non-participant farmers social networks in Chinyika

	Learning alliance participant (n=30)	**Non-participant (n=40)**
Information Sources	*Closeness centrality*	
Local Farmers	96.4	85.0
Farmer's Experience	93.1	89.5
National Extension	81.8	94.4
Farmers' Unions	81.8	73.9
Private Extension	75.0	70.8
Agro-dealers	73.0	65.4
Local Leader	69.2	70.8
Research	67.5	58.6
Universities	67.5	51.5
Mass Media	62.8	56.7
NGO	62.8	65.4
Produce Markets	61.4	63.0
Intergenerational Knowledge	50.9	50.0
Platforms		
Field Days	73.0	63.0
Agricultural Shows	73.0	63.0
Extension Meetings	58.7	58.6
External Workshops	56.3	54.8

Note: *Detailed closeness centrality indices are given in Appendices 1 and 2*

Higher closeness indices for highly interactive platforms such as field days (field_days) and agricultural shows (agrl_shows) among participants than their counterparts implied that these platforms were important in promoting sharing of experiences and ideas with other farmers and agro-stakeholders outside the community boundaries. Key informants revealed that such functions had become non-existent prior to the introduction of SOFECSA initiatives in 2007 due to depressed agricultural productivity, mainly attributed to declining soil fertility. This was characterised by maize grain yields which usually revolved under less than 2 t ha^{-1}. These field days were attended by diverse groups within and outside the community. Climate change and ISFM information and knowledge were shared through poetry, songs and drama at these events. Fellow group members usually passed on advice and training to their peers who would have failed to attend such gatherings. Information received through extension facilitated meetings (extn_meetings) had almost equal importance in both networks of participants (58.7) and non-participants (58.6). The less preference of these meetings by participants could be further evidence that the interaction pattern (see Fig 5.1) is a digression from traditional models of technology transfer from research. The least important platforms of access and sharing of information within the networks were external workshops (ext_workshops). This was because of the cost implications involved in organising external workshops which was inhibitive to most smallholder farmers. In most cases, such workshops were only financed by NGOs.

5.3 Conclusions

Exposure of smallholder farmers to field-based learning alliances alters their network structure of social interactions to a denser pattern suggesting proximity to more information sources. An expanded social network transforms the information dissemination pathway from a predominantly linear model, dominated by national extension, towards an innovation systems approach. Communication efficiencies within a network of social interactions are enhanced by the presence of more players within the network. Social networks are therefore an important mechanism that can drive innovation by empowering smallholders to easily access and share information and knowledge on improved technologies thus shortening their technology adoption cycle.

CHAPTER 6

Differential benefits of integrated soil fertility management practices

6.1 Introduction

Improving agricultural productivity for enhanced food security and production of marketable surpluses for income generation remains a major challenge in smallholder farming systems of sub-Saharan Africa (SSA) (Kiptot, 2008; World Bank, 2008). Soil fertility related research has generated various promising technology options such as integrated soil fertility management (ISFM), but the impact of the promoted technologies on farmers' productivity and livelihoods has not matched the potential (Mekuria and Siziba, 2003; Hobbs et al., 2007). Studies have suggested that adoption is poor because most research and development initiatives were promoted in ways that smallholders did not perceive to be relevant to their immediate livelihood options and risk-return preferences (Heisey and Waddington, 1993; Stoorvogel and Smaling, 1998; Quinn et al., 2003). Farmers are generally reluctant to adopt technologies that expose them to greater risks and must be convinced that a new technology will bring greater benefits than existing practices (Napier et al., 1991).

This chapter is an assessment of how mobilisation of smallholder communities in ISFM field-based learning alliances with key agro-stakeholders within cereal value chains would translate into improved ISFM adoption and subsequently enhance impact on livelihoods. The specific objectives were to: (i) evaluate the differential benefits of ISFM technology options among smallholder farmers participating in learning centre processes and; (ii) evaluate profitability of ISFM innovations under varying price scenarios.

6.2 Results and discussion

6.2.1 Adoption as influenced by household characteristics

Results showed that approximately 67% of the farmers within learning alliances had integrated legume-based technologies in their farming systems. However, only 42% of the farmers practiced legume-cereal rotations following what they had seen demonstrated at field-based LCs. This adoption rate suggests that there is still scope to increase adoption.

Table 6.1 Distribution of farmers who adopted legume-cereal rotations by farmer resource category in Chinyika, Zimbabwe 2011

Resource Category	**Legume-cereal Adopter (%)** (n = 13)	**Non-adopter (%)** (n = 17)
Resource-endowed (RG1)	50	50
Intermediate (RG2)	56	44
Resource-constrained (RG3)	20	80

Only 20% of the resource-constrained farmers had taken up legume-cereal rotations in their main fields (Table 6.1). Crop rotations in most cases were not feasible due to the general shortage of legume seed and that staple cereals tend to be given priority over other crops including legumes (Mtambanengwe and Mapfumo, 2009). In a separate study to evaluate uptake of conservation farming in Zimbabwe, less than 30% of the farmers practised crop rotation in the first three years primarily due to limited access to legume seed and lack of awareness on the need to rotate crops (Mazvimavi and Twomlow, 2009). This therefore, entails that complementary mechanisms should be put in place to enable access to the requisite inputs if the initiative is to record early successes. These may include provision of the inputs or engaging the smallholders for practical experimentation and adaptive testing of technologies in order to raise awareness on the potential of improved technologies. From the farmers' point of view, non-monetary benefits of ISFM technologies included good crop stands, improved yields, breaking of pest life cycles, and improved soil fertility among many.

6.2.2 Viability analysis of legume-cereal rotation

Farmers practising legume-cereal rotations had higher maize grain yields than those using conventional methods leading to high gross field benefits for each of the corresponding season (Table 6.2). Despite the 2010/11 cropping season receiving poor rainfall, average maize yields for those who practiced rotations were 2054 kg ha^{-1} whilst those who maintained conventional farming methods attained an average of 1794 kg ha^{-1} signifying a marginal yield increase of about 260 kg ha^{-1}. The average yields under conventional farming were consistent with the 0 - 1.5 t ha^{-1} reported by key informants who largely attributed this to the continuous mining of nutrients with little or no replenishment. Maize grain harvest or the 2009/10 cropping season for crop rotation adopters, which were twice those of non-adopters, lasted an average of 12 months whilst that of their counterparts lasted an average of 11 months.

However, for 2010/11 a season considered poor in terms of erratic rainfall the maize produce lasted an average of 12.5 and 9.5 months for adopters and non-adopters, respectively. Adoption of different ISFM options was shown to increase maize yields at varying scales in other related studies. For example adoption of different cropping sequences by farmers in Ghana resulted in maize yield benefits ranging from 25-125%. In Zimbabwe, initiatives by SOFECSA to revive traditional social safety nets known as *Zunde raMambo* using ISFM as an entry point gave a 10-fold increase in maize yields relative to conventional farmer practices (Mapfumo et al., 2013). Success stories were also reported from studies in other countries such as Malawi and Kenya (e.g. Kanyama-Phiri et al., 2000; Kangai et al., 2003; Ajayi et al., 2007; Mugwe et al., 2009). These results suggest that those farmers who had adopted improved soil fertility management practices were generally more food secure than those using conventional farming practices.

Table 6.2 Partial budget analysis for legume-cereal rotation and maize mono-cropping practices for the 2009/10 and 2010/11 cropping seasons for Chinyika East, Zimbabwe (n=30)

Item	**Quantity**	**Unit**	**Legume-cereal rotation**		**Maize mono-cropping**	
			2009/10	2010/11	2009/10	2010/11
A. Benefits						
Average maize yield		kg ha^{-1}	2297.51	2053.66	1613.04	1793.59
Average groundnut yield		kg ha^{-1}	694.44	491.76	0	0
Gross field benefits, maize		\$ ha^{-1}	**631.82**	**585.29**	**443.59**	**511.17**
Gross field benefits, groundnut		\$ ha^{-1}	**277.78**	**221.29**	**0**	**0**
Total gross field benefits		\$ ha^{-1}	**909.60**	**806.58**	**443.59**	**511.17**
Less:						
B. Costs that vary						
Cost of groundnut seed	120kg ha^{-1}	\$ ha^{-1}	32.40	31.68	0	0
Cost of labour for planting groundnut	12.22 *ld ha^{-1}	\$ ha^{-1}	48.88	61.10	0	0
Cost of hand weeding groundnut	10 ld ha^{-1}	\$ ha^{-1}	40.00	50.00	0	0
Cost of labour for harvesting groundnut	8.66 ld ha^{-1}	\$ ha^{-1}	34.64	43.30	0	0
Total costs that vary		\$ ha^{-1}	**155.92**	**186.08**	**0**	**0**
Net benefits		\$ ha^{-1}	**753.68**	**620.50**	**443.59**	**511.17**

Note:

- *ld ha^{-1} = labour days per hectare (each labour day valued at US\$4.00 and US\$5.00 for 2009/10 and 2010/11 cropping season respectively)
- Shelled groundnuts were valued at US\$400.00 and US\$450.00 $tonne^{-1}$ for 2009/10 and 2010/11 season, respectively.
- Maize grain was valued at US\$275.00 and US\$285.00 $tonne^{-1}$ for 2009/10 and 2010/11 season, respectively.

The yield gains realised from adoption of rotation practices also offset the production costs and as a result, total gross field benefits for adopters were more than twice that of their counterparts for the 2009/10 season whilst those of the 2010/11 season were approximately one and half times higher. Through rotation, a farmer would increase his net benefits by approximately between 20-70% for the 2009/10 cropping season. Marginal returns to investment, calculated as a ratio of the change in net benefits to a change in net costs, for the good and poor season were approximately 200% and 59%, respectively. These results suggest that smallholder farmers stand to benefit from the adoption of ISFM technologies such as legume-cereal rotations which enable them to achieve some positive marginal returns even in the event of crop failure.

Resource endowed farmers constantly attained higher maize grain yields of >2 t ha^{-1} than their less-endowed counterparts in both of the seasons under consideration (Table 6.3). This is consistent with a previous research by Mtambanengwe and Mapfumo (2009) who reported that LCs hosted by this group always realised high maize grain yields than the intermediate and resource-constrained groups. In a season considered poor (2010/11), RG1 farmers had average yields of close to 3 t ha^{-1}. Despite the poor season, resource endowed farmers were the only group that realised a marginal increase in maize grain yield of 13.7% whilst the other two groups had marginal losses of approximately between 8-12%. On average, maize harvest for the resource-constrained group from the 2010/11 season lasted approximately 8 months while that of RG1 and RG2 farmers lasted 13.5 and 10.7 months, respectively. The observed results suggested that there are reduced farmer capacities with an increase in their resource constraints (IFDC, 2002; Mtambanengwe and Mapfumo, 2009). This therefore implies that the more resource endowed farmers have a relative advantage in terms of achieving food security through the adoption of improved soil fertility management technologies.

Table 6.3 Partial budget analysis for legume-cereal rotation practices for the 2009/10 and 2010/11 cropping seasons by farmer resource groups for Chinyika East, Zimbabwe (n=30)

Item	**Quantity**	**Unit**	**2009/10 Season**			**2010/11 Season**		
			RG1	RG2	RG3	RG1	RG2	RG3
A. Benefits								
Average maize yield		kg ha^{-1}	2486.56	1687.45	1850.67	2827.38	1476.61	1695.45
Average groundnut yield		kg ha^{-1}	295.67	94.63	177.69	244.14	323.62	284.65
Gross field benefits, maize		\$ ha^{-1}	**683.80**	**464.05**	**508.93**	**805.80**	**420.83**	**483.20**
Gross field benefits, groundnut		\$ ha^{-1}	**118.27**	**37.85**	**71.08**	**109.86**	**145.63**	**128.09**
Total gross field benefits		\$ ha^{-1}	**802.07**	**501.90**	**580.01**	**915.66**	**566.46**	**611.29**
Less:								
B. Costs that vary								
Total costs that vary		\$ ha^{-1}	**193.34**	**185.85**	**116.94**	**213.25**	**217.06**	**167.55**
Net benefits		\$ ha^{-1}	**608.73**	**316.05**	**463.07**	**702.41**	**349.40**	**443.74**

Notes:

- *ld ha^{-1} = labour days per hectare (each labour day valued at US$4.00 and US$5.00 for 2009/10 and 2010/11 cropping season, respectively)
- Shelled groundnuts were valued at US$400.00 and US$450.00 $tonne^{-1}$ for 2009/10 and 2010/11 season, respectively.
- Maize grain was valued at US$275.00 and US$285.00 $tonne^{-1}$ for 2009/10 and 2010/11 season, respectively.

On the other hand, it was interesting to note that adoption of legume-cereal rotations by the resource-constrained farmers gave them maize grain yields of between 10-15% higher than their counterparts in the intermediate group despite more RG2 (56%) farmers having adopted rotations. In the poor season (2010/11), RG2 and RG3 farmers actually had more net benefits from their groundnut crop than RG1 farmers. These results suggest that there is scope for influencing adoption decisions of low-cost technology options by resource constrained farmers as it gives them an opportunity to enhance their food security. Consequently, RG3 farmers had higher net income benefits than RG2 farmers in both of the seasons.

While the high grain yields for RG1 farmers could be related to their relative ability to access requisite resources such as certified inputs, farming implements and/or hired labour, the more stable yields for the RG2 and RG3 farmers could be an indicator of the superiority of collective learning processes in enhancing access to resources and services that would otherwise not be readily available to them. This may also be attributed to increased awareness on the use of locally available nutrient sources to enhance soil productivity. However, the ratio of net income benefits for the RG2 and RG3 farmers was approximately one to one while that of RG1 farmers to any of the other group was almost twice in both seasons (Table 6.3). These findings suggest that adoption of ISFM technologies not only benefits the resource-endowed farmers, but also enhances the capacity of the more or less resource-constrained smallholders to improve their food security and income benefits thus providing an opportunity for them to diversify their livelihood options.

6.2.3 Marginal returns as influenced by low maize grain producer prices

When smallholder farmers disposed their surplus grain through the informal channel, their gross field benefits for maize were almost halved (Table 6.4). Nevertheless, net benefits for farmers practicing crop rotations were higher than their counterparts in each of the corresponding seasons.

Table 6.4 Sensitivity analysis for legume-cereal rotation and conventional farming practices for the 2009/10 and 2010/11 cropping seasons for Chinyika East, Zimbabwe

Item	**Unit**	**Legume-cereal rotation**		**Maize mono-cropping**	
		2009/10	2010/11	2009/10	2010/11
A. Benefits					
Average maize yield	kg ha^{-1}	2297.51	2053.66	1613.04	1793.59
Average groundnut yield	kg ha^{-1}	694.44	491.76	0	0
Gross field benefits, maize	\$ ha^{-1}	**344.63**	**410.73**	**241.96**	**358.72**
Gross field benefits, groundnut	\$ ha^{-1}	**277.78**	**221.29**	**0**	**0**
Total gross field benefits	\$ ha^{-1}	**622.41**	**632.02**	**241.96**	**358.72**
Less:					
B. Costs that vary					
Total costs that vary	\$ ha^{-1}	**155.92**	**186.08**	**0**	**0**
Net benefits	\$ ha^{-1}	**466.49**	**445.94**	**241.96**	**358.72**

Marginal rates of return under the low field price scenario for the 2009/10 and 2010/11 cropping seasons were between 47-144%. The implication therefore is that higher produce prices coupled with improved soil fertility management practices can ensure the realisation of higher profits and enhanced livelihoods for the smallholder farmers. The results suggest that there exists a relationship between the adoption of ISFM technologies and climate variability. The positive returns in a season considered poor (2010/11) by many maybe evidence that uptake of legume-cereal crop rotations provided a food security buffer against the climatic shock. In a related study, adoption of conservation farming (CF) in different agro-ecological regions of Zimbabwe (low-high rainfall areas) showed that CF practices remained more profitable than traditional farming practices (Mazvimavi and Twomlow, 2009). This therefore implies that any efforts to address soil fertility challenges should also consider enhancing adaptive capacity to climate variations (Mapfumo et al., 2013).

6.2.4 Farmer perceptions on benefits of ISFM field-based learning alliances

Smallholder farmers in Nyahava perceived that non-monetary benefits of ISFM field-based learning alliances included: (i) providing channels for information dissemination; (ii) increased knowledge on use of locally available nutrient sources; (iii) strengthening farmers to pool demand for 'external' inputs; (iv) providing opportunity for members to pool together scarce resources such as labour for labour demanding technologies and timely farming operations (v) enhanced food self-sufficiency due to increased productivity among many others. These were consistent with the characterisation of collective learning processes by smallholder farmers in Wedza district, south-eastern Zimbabwe (Gwandu et al., 2014).

6.3 Conclusions

Exposure of smallholders to field-based learning alliances led to increased adoption of legume-cereal rotations. The farmers realised higher maize grain yields and income benefits than their non-participating counterparts. The high marginal returns for rotations provided an incentive for ISFM adoption for smallholder farmers. Farmers practicing legume-cereal rotations were generally food secure and realised income benefits approximately 1.5-2 times higher than those using conventional farming methods. There is potential to boost productivity among the resource-constrained groups through enhancing their access to requisite resources. Legume-cereal rotations provided smallholder farmers within learning alliances with an income and food security buffer from low produce prices (for the two seasons) and climatic shock in the poor season (2010/11). These results suggest superiority of ISFM technologies under varying pricing, farmer capacities and climatic variability scenarios. Hence, smallholder farmers stand to gain from cumulative economic benefits through uptake of improved soil fertility management practices.

CHAPTER 7

Overall conclusions and recommendations

7.0 Introduction

This chapter gives overall conclusions around the three main themes pursued in this research study. Recommendations emanating from these main conclusions are also given. The chapter ends by highlighting areas for further research.

7.1 Conclusions

Smallholder farmers value attributes defining a learning centre with respect to its technical content, physical location and attitude of the host farmer as a prerequisite for participation in field-based learning alliances. Socio-economic, physical and demographic attributes of the farming households influence their decision to participate in any new innovation and the degree of influence varies with the particular technology being promoted. Participation of farmers within learning alliances and uptake of improved soil fertility management technologies can be enhanced through targeting of appropriate technologies to households with characteristics that favour them. Research initiatives should promote technology adoption by exploring ways of addressing labour constraints within smallholder farming systems through the development of cost effective ways of handling technology options that have hitherto remained labour-intensive.

Exposure of smallholder farmers to new innovations such as learning alliances alters their social interaction pattern and opens up more vertical and horizontal connections. Communication efficiency in terms of sending and receiving information on new technologies is enhanced with an increase in the number of actors within the network. As the number of players within a network diminishes, information is conveyed through longer paths thus increase the probability of distortion and/or incomplete transmission of information. Collective learning processes between smallholder farmers and agro-stakeholders along value chains transforms information dissemination pathways from predominantly linear models to innovation systems approaches. Extension approaches that empower farmers through co-learning processes have a potential to shorten the innovation diffusion process and thus, increases the likelihood of technology uptake among smallholders. Adoption can also be enhanced through developing policies and institutional mechanisms that encourage collective participation and enhance ability of smallholders to integrate improved technologies in their farming systems.

Farmers' heterogeneity in socio-economic circumstances invariably leads to differential impacts of promoted technologies on smallholder households. Research and development initiatives should take cognisance of these variations if new innovations are to generate impact at scale. While the resource-endowed farmers generally have a relative advantage and capacity to adopt new technologies, adoption of improved soil fertility management options by the less endowed farmer groups enhances their food security and income benefits. Adoption of these soil fertility enhancing technologies by resource-constrained farmers may be improved through establishing complementary mechanisms such as localising markets for enhanced access to requisite inputs or provision of agricultural credits.

Facilitation of action-learning processes in the initial stages had their own limitations especially in trying to harmonise and co-ordinate institutional mandates. This was so because some institutions were not represented at the micro-levels and the lack of a shared vision even amongst the represented organisations. The formation of innovation platforms (IPs) established at national (NIP), district (DIP) to ward (WIP) levels then provided for technical backstopping through linkages with the relevant players. Another challenge was that of power relations within the community which had the potential to stall innovations. However, to circumvent this, consultations were first done through local leaders to seek their approval. Moreover, existing social structures of communication were used for the established learning alliances as opposed to the formation of new ones. Instilling a common understanding of participatory action research (PAR) among farmers, researchers and development partners was also a major issue. A series of trainings on the principles and concepts of PAR were first given to the diverse stakeholders through the lead researchers (SOFECSA) prior to the initiation of adaptive experimentation initiatives at field-based learning centres.

7.2 Recommendations

- Dissemination of soil fertility management technologies should be targeted for wide scale impact of new innovations within diverse smallholder farming systems.
- Research and development initiatives should empower smallholder farmers and their partners along agricultural value-chains to enhance information sharing for the generation, dissemination and adoption of relevant and improved soil fertility management technologies.
- Efforts to promote agricultural productivity in smallholder farming systems should consider putting in place mechanisms that enhance access to requisite soil fertility management resources by the farmers.

7.3Areas for further research

This study has shown that there is scope for promoting uptake of ISFM technologies through participatory action research approaches across diverse resource endowed farmers where conventional research approaches have often failed to stimulate adoption of soil fertility management technologies. Future research work can include the following:

- Enhancing market linkages for smallholder farmers to participate in competitive markets with a particular focus on collective action in the marketing of produce and procurement of ISFM inputs.
- Exploration of more mechanisms that drive innovation rather than focussing on individual farmer attributes which have been shown to yield both positive and negative influence on adoption of improved technologies in different studies resulting in inconsistent conclusions about their actual effect on uptake of technologies.
- Evaluation of tradeoffs among different ISFM options in the longer term as some technology options take time before farmers begin to realise benefits, and factoring in climate change variability.
- Exploration of the effect of social networks on the adoption cycle with a special focus on smallholder farmer resource categories

REFERENCES

Abadi Ghadim AK, Pannell DJ, Bennett A and Stewart V, (1996). Farmers' risk perspective on adoption of legume crops. In: M. Asghar (ed.), *Proceedings of the 8th Australian Agronomy Conference 1996*, Toowoomba, Queensland, 30 January - 2 February, 1996, *Australian Society of Agronomy* pp. 56-59.

Abdulai A and Huffman WE, (2005). The diffusion of new agricultural technologies: the case of crossbred-cow technology in Tanzania. *Journal of Agricultural Economics* 87: 645-659.

Adesina AA and Baidu-Forson J, (1995). Farmers' Perceptions and Adoption of New Agricultural Technology: Evidence from Analysis in Burkina Faso and Guinea, West Africa. *Agricultural Economics*, 13: 1-9.

Adesina AA, Mbila D, Nkamleu GB and Endamana D, (2001). Econometric analysis of the determinants of adoption of alley farming by farmers in the forest zone of Southwest Cameroon. *Agricultural Ecosystems and Environment* 80: 225-265.

Adler PS and Kwon S, (2002). Social capital: Prospects for a new concept. *Academy of Management Review*, 27: 17-40

AGRA, (2009). Restoring soil health in Africa. http://www.agra-alliances/section/work/soils

Agresti A, (1996). An introduction to categorical data analysis. Wiley and Sons Inc. New York, USA.

Ahmed MM, Rohrbach DD, Gono L, Mazhangara E, Mugwira L, Masendeke DD and Alibaba S, (1997). Soil Fertility Management in Communal Areas of Zimbabwe: Current Practices, ICRISAT Southern and Eastern Africa Region P.O. Box 776, Bulawayo, Zimbabwe. Working Paper No. 6

Ajayi OC, Akinnifesi FK, Sileshi G and Chakeredza S, (2007). Adoption of renewable soil fertility replenishment technologies in the southern African region: Lessons learnt and the way forward. *Natural Resources Forum* 31: 306-317

Aldrich JN and Nelson FD, (1984). Linear probability, logit and probit models. Sage University Paper Series on Quantitative Applications in Social Sciences. Newbury Park: Sage Publications Inc., California.

Aldrich M and Sayer J, (2007) In Practice: Landscape Outcomes Assessment Methodology “LOAM”. WWF Forests for Life Programme, Gland, Switzerland.

Alene AD, Manyong VM, Omanya G, Mignouna HD, Bokanga M and Odhiambo G, (2008). Smallholder market participation under transactions costs: Maize supply and fertilizer demand in Kenya. *Food Policy* 33: 318–328.

Amemiya T, (1981). Qualitative response models: A survey. *Economic Journal* 19: 1483-1536.

Baidu-Forson J, (1999). Factors influencing adoption of land-enhancing technology in the Sahel: lessons from a case study in Niger. *Agricultural Economics* 20 (3): 231–239.

Bamberger M, (2000). Integrating Quantitative and Qualitative Methods in Development Research. Washington, D.C.: World Bank.

Bandiera O and Rasul I, (2006). "Social networks and technology adoption in Northern Mozambique." *Economic Journal* 116(514): 869-902.

Bardhan P and Udry C, (1999). Development Microeconomics. Oxford University Press. Oxford.

Barley SR, (1990). The alignment of technology and structure through roles and networks. *Administrative Science Quarterly* 35: 61-103.

Bastidas EP, (1999). Gender issues and women’s participation in irrigated agriculture: The case of two private irrigation canals in Carchi, Ecuador. Research report 31, International Water Management Institute (IWMI).

Bationo A, Mokwunye U, Vlek PLG, Koala S and Shapiro I, (2003). Soil fertility management for sustainable land use in the West African Sudano-Sahelian zone. In: *Grain Legumes and Green Manures for Soil Fertility in Southern Africa: Taking Stock Of Progress,* *Proceedings of a Conference (8–11 October, 2002), Leopard Rock Hotel, Vumba, Zimbabwe*, 253–292. Soil fertility Network and CIMMYT, Harare, Zimbabwe

Bationo A, Kimetu J, Ikerra S, Kimani S, Mugendi D, Odendo M, Silver M, Swift MJ and Sanginga N, (2004). The African Network for Soil Biology and Fertility: New Challenges and Opportunities. In: A. Bationo (Ed.). *Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa*. Academy Science Publishers/TSBF-CIAT, Nairobi, Kenya. pp 1-23.

Bationo A, Hartemink A, Lungu O, Naimi M, Okoth P, Smaling E and Thiombiano L, (2006). African Soils: Their Productivity and Profitability for Fertilizer Use. Background paper for the Africa Fertilizer Summit. 9-13 June 2006 in Abuja, Nigeria.

Baum WC and Tolbert SM, (1985). Investing in Development: Lessons of World Bank Experience, Oxford University Press, USA (pp. 474-494)

Bellon MR, (2001). Participatory research methods for technology evaluation: A manual for scientists working with farmers. Mexico, D.F.: CIMMYT, Mexico

Bernard HR, Killworth P, Kronenfeld D and Sailer L, (1984). The problem of informant accuracy: The validity of retrospective data. *Annual Review of Anthropology* 13: 495-517.

Biggs S and Matsaert H, (2003). Strengthening Poverty Reduction Programmes Using An Actor Oriented Approach: Examples from Natural Resources Innovation Systems. ODI, AGren Network Paper Series 134. London.

Bogale A, (2009). Household level determinants of food security in rural areas of Dire Dawa, Eastern Ethiopia. *African Journal of Food, Agriculture Nutrition and Development* 9(9): 1914-1926

Borgatti SP, (1995). Centrality and AIDS. *Connections* 18 (1): 112–114.

Borgatti SP, (2006). E-NET Software for the analysis of ego-network data. Needham, MA: Analytic Technologies

Borgatti SP and Cross R, (2003). A relational view of information seeking and learning in social networks. *Management Science,* 49: 432-445.

Borgatti SP, Everett MG and Freeman LC, (2002). UCINET for Windows: *Software for Social Network Analysis.* Harvard, MA: Analytic Technologies.

Borgatti SP, Mehra A, Brass DJ and Labianca G, (2009). Network analysis in the social sciences. *Science* 323: 892-895.

Bouma JE, Bulte E and van Soest D, (2008). Trust and cooperation: social capital and community resources management. *Journal of Environmental Economics and Management* 56(2): 155–166.

Boz I and Ozcatalbas O, (2010). Determining information sources used by crop producers: A case study of Gaziantep province in Turkey. *African Journal of Agricultural Research* 5(10): 980-987.

Brass DJ, (1995a). A social network perspective on human resources management. In G. R. Ferris (Ed.), *Research in personnel and human resources management* (Vol. 13, pp. 39-79). Greenwich, CT: JAI Press.

Bratton M, (1994). Land redistribution 1980-1990, Chapter 4 in Rukuni M and Eicher CK (eds) Zimbabwe's Agricultural Revolution. Harare: University of Zimbabwe Publications.

Brett C, (2004). Farm level adoption decisions of soil water management technologies in Semi-Arid Eastern Kenya, In: *Contributed Paper Presented at the 48th Annual Conference of the Australian Agricultural and Resource Economics Society,* 11–13th February, 2004, Melbourne, Victoria.

CAADP, (2006). The Abuja Declaration on Fertilisers for an Africa Green Revolution- Status of implementation at regional and national levels. African Union Special Summit of the Heads of State and Government.

Campbell BM, Frost PGH, Kirchmann H and Swift MJ, (1998). A survey of soil fertility management in small-scale farming systems on north-eastern Zimbabwe. *Journal of Sustainable Agriculture* 11: 19-39.

Cary JW and Wilkinson RL, (1997). Perceived profitability and farmers' conservation behaviour. *Journal of Agricultural Economics* 48: 13-21.

Chambers R, (1993). Challenging the professions. Frontiers for rural Development. IT publications. London.

Chambers R, (2005). Ideas for Development. IDS: UK

Chianu JN and Tsujii H, (2004). Determinants of farmers' decision to adopt or not adopt inorganic fertilizer in the savannas of northern Nigeria. *Nutrient Cycling in Agroecosystems* 70: 293–301.

Chisora J, (2006). Microeconomics of soil nutrient resource allocation under Zimbabwe's smallholder farming systems. Msc Thesis. Department of Agricultural Economic and Extension. University of Zimbabwe, Harare. 110 pp.

CIAT, (2010). New dimensions in participatory plant breeding for eco-efficient agriculture. In: CIAT brief No. 3. CIAT, Cali

CIMMYT, (1988). From agronomic data to farmer recommendations: An Economics Training Manual. Completely revised edition. Mexico, D.F.

Colfer CJP, (2005). The Complex Forest: Communities, Uncertainty and Adaptive Collaborative Management. Washington, D.C.: Resources for the Future.

Conley T and Udry C, (2001). Social learning through networks: The adoption of new agricultural technologies in Ghana. *American Journal of Agricultural Economics* 83: 668-673.

Cromwell E, Cooper D and Mulvany P, (2003). Defining agricultural biodiversity. In: CIP, Upward (Eds.), Conservation and sustainable use of agricultural biodiversity: A sourcebook. *Users' perspectives with agricultural research and development*, 1: 5–12.

Croppenstedt A, Demeke M and Meschi M, (2003). Technology adoption in the presence of constraints: The case of fertilizer demand in Ethiopia. *Review of Development Economics* 7: 58–70.

Cross R, Parker A and Sasson L, (2003). Networks in the knowledge economy. New York: Oxford University Press.

CTA, (1997). Extension services: Masters or Servants; *Spore Newsletter* 68: 16

Damisa MA and Igonoh E, (2007). An evaluation of the adoption of integrated soil fertility management practices among women farmers in Danja, Nigeria. *Journal of Agricultural Education and Extension* 13(2): 107-116.

Defoer T and Budelman A, (2000). Managing Soil Fertility in the Tropics. A Resource Guide for Participatory Learning and Action Research. KIT Publishers, The Netherlands.

De Nooy W, Mrvar A and Batagelj V, (2005). Exploratory social network analysis with Pajek. Cambridge University Press, New York, p. 334.

DeWalt BJ, (1994). Using indigenous knowledge to improve agriculture and natural resource management. *Human Organization* 53(2):123–131.

Doss C and Morris M, (2001). How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. *Agricultural Economics* 25: 27–39.

Douthwaite B, Manyong VM, Keatinge JDH and Chianu J, (2002). The adoption of alley farming and *Mucuna:* Lessons for research, development and extension from a social constructivist perspective. *Agroforestry Systems* 56: 193-202

Dunne JA, Williams RJ and Martinez ND, (2002). Network structure and biodiversity loss in food webs: robustness increases with connectance. *Ecology Letters* 5: 558–567.

Elad RL and Houston JE, (2002). Seasonal labour constraints and intra-household dynamics in the female fields of southern Cameroon. *Agricultural Economics* 55:337–351.

Estrada E, (2007). Characterization of topological keystone species local, global and ‘‘meso-scale’’ centralities in food webs. *Ecological Complexity* 4: 48–57.

Estrada E and Bodin O, (2008). Using network centrality measures to manage landscape connectivity. A short path for assessing habitat patch importance. *Ecological Applications* 18: 1810–1825.

FAO, (2001). The Economics of Conservation Agriculture. Food and Agriculture organisation of the United Nations, Rome, Italy.

FAO, (2004). Tropical Livestock Units (TLU). Virtual Livestock Centre, Livestock and Environment Toolbox. Rome. *[http://lead.virtualcentre.org/en/dec/toolbox/Mixed1/TLU.htm]*, Accessed 20 April 2012

Food and Agriculture Organizations of the United Nations, (1998). Guide to efficient plant nutrient management. Rome, Italy: FAO Land and Water Development Division.

Food and Agriculture Organisation, (2006). Agriculture, trade negotiations and gender. FAO Corporate Document Repository, Rome

FAO, (2008). Report of 25th FAO Regional Conference for Africa 2008. (*www.fao.org/africa*-Accessed 20 July 2012)

FAO, (2008). Farmer field schools on land and water management in Africa. In: Proceedings of an International Workshop in Jinja, Uganda. April 24–29, 2006. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

FAO, WFP and IFAD, (2012). The state of food insecurity in the world 2012: Economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition. Rome, FAO.

FAOSTATS, (2012). Statistical databases and data-sets of the Food and Agriculture

Organisation of the United Nations. http://faostat.fao.org/default.aspx. Accessed 3 June 2013.

Farouque G and Takeya H, (2007). Farmers’ perception of integrated soil fertility and nutrient management for sustainable crop production: a study of rural areas in Bangladesh. *Journal of Agricultural Education.* 48(3):111 – 122

Feder GR and Slade R, (1984). The acquisition of information and the adoption of new technology. *American Journal of Agricultural Economics.* 17:110-120

Feder G, Just RE and Zilberman D, (1985). Adoption of agricultural innovations in developing countries: A survey. University of Chicago Press. Volume 33.

Flood RL, (2002). The Relationship of ‘systems thinking’ to Action Research. In Reason P and Bradbury, H (eds), *Handbook of action research: participative inquiry and Practice*. Sage. London.

Foster A and Rosenzweig M, (1995). Learning by doing and learning from others: human capital and technical change in agriculture. *Journal of Political Economy*, 103: 1176–209.

Freeman LC, (1979). Centrality in social networks: Conceptual clarification. *Social Networks* 1(3): 215-239

Galaskiewicz J and Burt RS, (1991). Inter-organisational contagion in corporate philanthropy. *Administrative Science Quartely* 36: 88-105.

Geran JM, (1996). Effect of group formation on rural women’s access to services in Western Province, Zambia. Sustainable development department, FAO, Rome.

German L and Stroud A, (2007). A framework for the integration of diverse learning approaches: operationalizing Agricultural Research and Development (R&D) linkages in Eastern Africa. *World Development* 35(5):792-814.

German LA, Mazengia W, Charamila S, Taye H, Nyangas S, Tanui J, Ayele S and Stroud A (2007). Action Research: An approach for generating methodological innovations for improved impact from agricultural development and natural resource management. *AHI Methods Guide* E1.

German LA, Tiani AM, Maravanyika TM, Chuma E, Jum C, Nemarundwe N, Daoudi A, Ontita E, Yitamben G, Orindi V and Beaulieu N, (2008). The application of PAR to climate change adaptation: A reference guide. IDRC and CIFOR, Canada.

Giller KE, (2001). Nitrogen fixation in tropical cropping systems, 2nd ed. CAB International, Wallingford, UK.

Giller KE, Corbeels M, Nyamangara J, Triomphe B, Affholder F, Scopel E, Tittonell P, (2011). A research agenda to explore Conservation agriculture in African smallholder farming system, Field crop research. www.elsevier.com/locate/fcr. Accessed 20 April 2013

Gockowski J and Ndoumbe J, (2004). The adoption of intensive horticulture in Southern Cameroon. *Agricultural Economics* 30: 195-202.

Govereh J, Jayne TS, Nijhoff JJ, Shawa JJ, Haantuba H, Belemu A, Ngulube E, Zulu B and Banda AK, (2002). Developments in fertiliser marketing in Zambia: Commercial trading, government programs and the smallholder farmer. *Policy Synthesis No 3*, MSU/ Food Security Research Project, Lusaka, Zambia

Granovetter MS, (1973). The strength of weak ties. *American Journal of Sociology,* 110: 1360-1380.

Greenwood D and Levin M, (2007). Introduction to action research: Social research for social change (2nd ed). Thousand Oaks, CA.

Grosser TJ, Lopez-Kidwell V and Labianca G, (2010). A social network analysis of gossip in organisational life. *Group and Organisation Management,* 35: 177-212.

Gujarati DN, (1996). Basic Econometrics. McGraw Hill Inc.

Gurung AB, (2003). Insects - A mistake in God’s creation? Tharu farmers’ perception and knowledge of insects: A case study of Gobardiha Village Development Committee, Dang-Deukhuri, Nepal. *Agriculture and Human Values*, 20: 337-370.

Gwandu T, Mtambanengwe F, Mapfumo P, Mashavave TC, Chikowo R and Nezomba H, (2014). Factors Influencing Access to Integrated Soil Fertility Management Information and Knowledge and its Uptake among Smallholder Farmers in Zimbabwe. *Journal of Agricultural Education and Extension*, 20 (1): 79-93

Hagmann J, (1999). Learning Together for Change: Facilitating Innovation in Natural Resource Management through Learning Process Approaches in Rural Livelihoods in Zimbabwe. Weikersheim: Margraf Verlag.

Hagmann J and Chuma E, (2002). Enhancing the adaptive capacity of the resource users in natural resource management. *Agricultural Systems* 73: 23–39.

Hagmann J, Chuma E, Murwira K and Conolly M, (1998). Learning together through participatory extension: A guide to an approach developed in Zimbabwe. Harare: Department of Agriculture, Technical and Extension Services, GTZ and ITDG.

Halgin DS, (2009). The effects of social identity on career progression: A study of NCAA basketball coaches. Best Paper Proceedings, *Academy of Management meetings*, Chicago

Hall A, (2005). Embedding agricultural research in a system of innovation, Consultative Group on International Agricultural Research, Science forum, strengthening research-for-development capacities.

Hartwich FS and Scheidegger U, (2010). Fostering innovation networks: The missing piece in rural development. *Rural development news* No.1

Hawkins R, Heemskerk W, Booth R, Daane J, Maatman A and Adekunle AA, (2009). Integrated Agricultural Research for Development (IAR4D). A concept paper for the Forum for Agricultural Research in Africa (FARA) Sub-Saharan Africa Challenge Programme (SSA CP). FARA, Accra, Ghana. 92 pp

Heisey P and Waddington S, (1993). Impacts of on-farm research. Proceedings of a networkshop on impacts of on-farm research in Eastern and Southern Africa. Lilongwe and Harare, CIMMYT

Hillbur P, (1998). The knowledge arena: Approaching agroforestry and competing knowledge systems- A challenge for agricultural extension. Lund, Sweden: Lund University Press.

Hobbs PR, Sayre K, and Gupta R, (2007). The role of conservation agriculture in sustainable agriculture. *Philosophical Transactions of the Royal Society Biological Sciences* 363: 543–555

Honlonkou AN, (2004). Modelling of natural resource management technologies: The case of fallow systems. *Environment and Development Economics* 9: 289-314

Hurni H and Wiesmann U, (2004). Towards transdisciplinarity in sustainability-oriented research for development. In Hurni H, Wiesmann U and Schertenleib R (eds.), *Research for Mitigating Syndromes of Global Change*. Geogaphica Bernensia, Bern, p 31–41.

IFDC, (2002). IFDC Innovations Report: IFDC innovative technology increases farmers' agricultural productivity, maintains resource base. *World Climate Report* 8 (8): 10-12

IFDC, (2010). About ISFM. *http://www.ifdc.org*, Accessed 20 April 2012

Isham J, (2002). The effect of social capital on fertiliser adoption: Evidence from rural Tanzania. *Journal of African Economies* 11: 39–60

Ishida F, Kamidouzono A and Wakatsuki T, (1998). Indigenous rice-based lowland farming systems of Nupe, Nigeria. *Tropical Agriculture* 42(1):18-28

Islam MA, (1990). Environmental perception and agriculture: Environmental aspects of agricultural development in Bangladesh. Dhaka, Bangladesh: University Press Limited.

Jama BA, Niang IA, Amadalo B, De-Wolf J, Rao MR, and Buresh RJ, (1999). The potential of improved fallows to improve and conserve the fertility of nutrient depleted soils of western Kenya In: *Proceedings of the 6th Biennial KARI Scientific Conference* (KARI) pp.133–144.

Johnson M and Masters W, (2004). Complementarity and sequencing of innovations: New varieties and mechanized processing for cassava in West Africa. *Economics of Innovation and New Technology* 13: 19–31.

Kaliba A, Verkuijl H and Mwangi W, (2000). Factors affecting adoption of improved maize seeds and use of inorganic fertilizer for maize production in the intermediate and lowland zones of Tanzania. *Journal of Agricultural and Applied Economics* 32: 35–47.

Kangai RA, Mugendi DN, Mucheru MW, Otor SCJ, Waswa BS and Kung'u J, (2003). Trends in adoption of soil fertility improvement strategies in Chuka, Eastern Kenya. *African Crop Science Conference Proceedings* 6: 661-667

Kanyama-Phiri G, Snapp S, Kamanga B and Wellard K, (2000). Towards integrated soil fertility management in Malawi: incorporating participatory approaches in agricultural research. Managing Africa's Soils No. 11. Russell Press, Nottingham

Keil A, Zeller M and Franzel S, (2005). Improved tree fallows in smallholder maize production in Zambia: Do initial testers adopt the technology? *Agroforestry Systems* 64: 225-236

Kemmis S and McTaggart R, (2000). Participatory action research. In Denzin NK and Lincoln YS (Eds.), *Handbook of Qualitative Research* (2nd ed., pp. 567-605). Thousand Oaks, CA: Sage.

Khanna M, (2001). Sequential adoption of site-specific technologies and its implications for nitrogen productivity: a double selectivity model. *American Journal of Agricultural Economics* 83(1): 35-51

Kilduff M and Brass DJ, (2010). Organisational social network research : Core ideas and key debates. In J. P. Walsh and A. P. Brief (Eds.), *Academy of Management Annuals* (Vol. 4, pp. 317-357). London: Routledge.

Kiptot E, (2008). Adoption dynamics of Tithonia Diversifolia for soil fertility management in pilot villages of western Kenya. *Experimental Agriculture* 44: 473–484.

Kosgei JR and Jewitt G (2006). Realizing Food Security in Semi-Arid Agro-ecosystems of Southern Africa: Does the Potential Lie in Upgrading Rainfed Agriculture? *Proceedings of the 10th Annual Searnet conference*, 4th-6th December 2006; Mombasa, Kenya

Krishna A, (2001). Moving from the stock of social capital to the flow of benefits: the role of agency. *World Development*, 29(6): 925-943.

Kristjanson P, Okike I, Tarawali S, Singh BB, and Manyong VM, (2005). Farmers' perceptions of benefits and factors affecting the adoption of dual purpose cow pea in dry savannas of Nigeria. *Agricultural Systems* 32: 195-210.

Kuntashula E, Mafongoya PL, Sileshi G and Lungu S, (2004). Potential of biomass transfer technologies in sustaining vegetable production in the wetlands (*dambos*) of eastern Zambia. *Experimental Agriculture* 40: 37-51

Lapar MLA and Pandey S, (1999). Adoption of soil conservation: The case of the Philippines uplands. *Agricultural Economics* 21:241–256.

Leathers H and Smale M, (1991). A Bayesian approach to explaining sequential adoption of components of a technological package. *American Journal of Agricultural Economics* 73: 734–742.

Lebel L, Anderies JM, Campbell B, Folke C, Hatfield-Dodds S, Hughes TP and Wilson J, (2006). Governance and the Capacity to Manage Resilience in Regional Social-Ecological Systems. *Ecology and Society* 11(1): 1-19.

Leonard SA, Mehra A and Katerberg R, (2008). The social identity and social networks of ethnic minority groups in organisations: A crucial test of distinctiveness theory. *Journal of Organisational Behaviour*, 29: 573-589.

Lule A, Mangheni NM, Sanginga PC, Delve RJ, Mastiko F and Miiro R, (2007). Social capital and adoption of soil fertility management technologies in Tororo district, Uganda: In:

Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities. Springer Publishers, Netherlands, pp. 947-954

Luther GC, Harris C, Sherwood S, Gallagher K, Mangan J and Touré Gamby K, (2005). Developments and Innovations in Farmer Field Schools and Training of Trainers. In: Norton, G.W., E.A. Heinrichs, G. C. Luther and M.E. Irwin. Globalizing Integrated Pest Management - A Participatory Research Process. Blackwell Publishing, Iowa, USA. pp. 159-190.

Maatman A, Wopereis MCS, Debrah KS, Groot JJR, (2007). From thousands to millions: Accelerating agricultural intensification and economic growth in sub-Saharan Africa: In: *Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities*. Springer Publishers, Netherlands, pp. 75-84.

Maddala GS, (1993). Limited-dependent and Qualitative Variables in Econometrics, Cambridge University Press, Cambridge, UK.

Mafongoya PL, Bationo A, Kihara J and Waswa BS, (2006). Appropriate technologies to replenish soil fertility in southern Africa. *Nutrient Cycling in Agroecosystems* 76: 137-151.

Manzeke G, Mapfumo P, Mtambanengwe F, Chikowo R, Tendayi T and Cakmak I, (2012). Soil fertility management effects on maize productivity and grain zinc content in smallholder farming systems of Zimbabwe. *Plant and Soil* 361 (1) 57-69.

Mapfumo P, (2007). Enhancing regional capacity for a green revolution in Southern Africa: SOFECSA's strategic direction and experiences. Paper presented at the AfNET-SOFECSA Green Revolution Symposium, 17-21 September, 2007. Arusha, Tanzania

Mapfumo P, (2009). Integrating sustainable soil fertility management innovations in staple cereal systems and other value chains to enhance livelihoods and environmental systems in Southern Africa. A SOFECSA Technical Annual Report for SSA-CP and Forum for Agricultural Research in Africa (FARA). SOFECSA, CIMMYT-Zimbabwe, Harare, Zimbabwe.

Mapfumo P, (2011). Comparative Analysis of the Current and Potential Role of Legumes in Integrated Soil Fertility Management in Southern Africa. Chapter 8 In: Bationo A, Waswa B, Okeyo JM, Maina F, Kihara J and Mokwunye U (Eds.) *Fighting Poverty in Sub-Saharan Africa: The Multiple Roles of Legumes in Integrated Soil Fertility Management.* (1st Ed.). Springer, NY, USA. pp. 175–200.

Mapfumo P, Adjei-Nsiah S, Mtambanengwe F, Chikowo R and Giller K, (2013). Participatory action research (PAR) as an entry point for supporting climate change adaptation by smallholder farmers in Africa. *Environmental Development* 5:6-22.

Mapfumo P and Giller KE, (2001). Soil Fertility Management Strategies and Practices by Smallholder Farmers in Semi-Arid Areas of Zimbabwe. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) with permission from the Food and Agriculture Organization of the United Nations (FAO). Bulawayo, Zimbabwe. 60 pp.

Mapfumo P, Chikowo R, Mtambanengwe F, Adjei-Nsiah S, Baijukya F, Maria R, Mvula A and Giller K, (2008). Farmers' perceptions lead to experimentation and learning. Agricultures Network, *LEISA Magazine* 24:4

Mapfumo P, Chikowo R and Mtambanengwe F, (2010). Lack of resilience in African smallholder farming: Exploring measures to enhance the adaptive capacity of local to climate change. *Final Technical Report to the IDRC-DfID Climate Change Adaptation in Africa (CCAA) program.* University of Zimbabwe Publications, Harare, Zimbabwe.

Marenya P and Barrett CB, (2007). Household-level determinants of adoption of improved natural resources management practices among smallholder farmers in western Kenya. *Food Policy* 32: 515–536.

Marra M, Pannell DJ and Abadi Ghadim A, (2001). The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: Where are we on the learning curve? *Agricultural Systems* 75: 215–235.

Mashavave T, Mapfumo P, Mtambanengwe F, Chikowo R, Gwandu T, Nezomba H and

Siziba S, (2011). Factors influencing participation of smallholder farmers in knowledge sharing alliances around SOFECSA field-based learning centres. *African Crop Science Proceedings* 10: 331-334

Mashavave T, Mapfumo P, Mtambanengwe F, Gwandu T and Siziba S, (2013). Interaction patterns determining improved information and knowledge sharing among smallholder farmers. *African Journal of Agricultural and Resource Economics* 8 (1):1-12

Mazvimavi K and Twomlow S, (2009). Socioeconomic and institutional factors influencing adoption of conservation farming by vulnerable households in Zimbabwe. *Agricultural Systems* 101: 20-29

Mazvimavi K, Twomlow S, Belder P and Hove L, (2008). An assessment of the sustainable uptake of conservation farming in Zimbabwe. Global Theme on Agro-ecosystems Report No. 39. P.O. Box 776, International Crops Research Institute for the Semi-Arid Tropics, Bulawayo, Zimbabwe. p. 60.

McPherson JM, Smith-Lovin L and Cook JM, (2001). Birds of a feather: Homophily in social networks. *Annual Review of Sociology*, 27: 415-444.

Mekuria M and Siziba S, (2003). Financial and risk analysis to assess the potential adoption of green manure technology in Zimbabwe and Malawi. In: S. Waddington (Ed.). *Grain Legumes and Green Manures for Soil Fertility in Southern Africa: Taking Stock of Progress.* Soil Fert Net and CIMMYT-Zimbabwe, Harare. pp. 215-221.

Mekuria M and Waddington S, (2004). Institutional and policy support is essential to promote the adoption of soil fertility technologies on maize-based smallholder farms in Southern Africa. *4th International Crop Science Congress*, Brisbane, Australia, 26 September - 1 October 2004

Mkombozi, (2005). Participatory Action Research: Local causation of primary school drop-outs and exclusions in Kilimanjaro Region. Mkombozi Centre for Street Children, Tanzania.

Morales H & Perfecto I, (2000). Traditional knowledge and pest management in the Guatemalan highlands. *Agriculture and Human Values* 17: 49–63.

Mtambanengwe F and Mapfumo P, (2005). Organic matter management as an underlying cause for soil fertility gradients on smallholder farms in Zimbabwe. *Nutrient Cycling in Agro-ecosystems* 73:227-243

Mtambanengwe F and Mapfumo P, (2009). Combating food insecurity of sandy soils in Zimbabwe: The legume challenge. *Symbiosis* 8: 25-36

Mtambanengwe F, Mapfumo P and Vanlauwe B, (2006). Comparative short-term effects of different quality organic resources on maize productivity under two different environments in Zimbabwe. *Nutrient Cycling in Agroecosystems* 76: 271-284.

Mugwe J, Mugendi D, Mucheru-Muna M, Merckx R, Chianu J and Vanlauwe B, (2009). Determinants of the decision to adopt integrated soil fertility management practices by small holder farmers in the Central Highlands of Kenya. *Experimental Agriculture* 45:72-73.

Mugwira, L.M. and Murwira H.K. 1997. *Use of Cattle Manure to Improve Soil Fertility in Zimbabwe: Past and Current Research and Future Research Needs*. Network Working Paper No. 2. Soil Fertility Network for Maize-Based Cropping Systems in Zimbabwe and Malawi. CIMMYT, Harare, Zimbabwe. 33 pp.

Munshi, K. 2004. Social learning in a heterogeneous population: social learning in the Indian Green Revolution. *Journal of Development Economics,* 73: 185-213

Namba T, Tanabe K and Maeda N, (2008). Omnivory and stability of food webs. *Ecological Complexity* 3: 73–85.

Napier TL, Napier AS, and Tucker MA, (1991). The social, economic and institutional factors affecting adoption of soil conservation practices: Asian experiences. *Soil Tillage Research* 20: 365–382.

NEPAD, (2003). Comprehensive African Agriculture Development Programme. New

Partnership for African Development (NEPAD). *http://www.nepad.org*, Accessed 12 May 2012

Neupane RP, Sharma KR and Thapa GP, (2002). Adoption of agro-forestry in the hills of Nepal: a logistic regression analysis. *Agricultural Systems* 72:177–196.

Nhemachena C, Murwira HK, Mutiro K and Chivenge P, (2003). A socio-economic analysis of legume production motives and productivity variation among smallholder farmers of Shurugwi Communal area, Zimbabwe. In: Waddington SR (ed), Grain legumes and green manures for soil fertility in Southern Africa- Taking stock of progress. *Proceedings of a conference held 8-11 October 2002 at the Leopard Rock Hotel, Vumba, Zimbabwe*. Soil Fert Net and CIMMYT- Harare, Zimbabwe, p 223-226

Nichola T, (1996). The decision to adopt and the intensity of adoption of technology: A double hurdle model application in the adoption of a sorghum hybrid. *Journal for Studies in Economics and Econometrics* 20: 49–57.

Nhamo N, Murwira HK and Giller KE, (2004). The Relationship Between Nitrogen Mineralization Patterns and Quality Indices of Cattle Manures from Different Smallholder Farms in Zimbabwe. In: A. Bationo (Ed.). *Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa*. Academy Science Publishers/TSBF-CIAT, Nairobi, Kenya. pp 299-315.

Nkamleu GB, (2007). Modelling farmers' decisions on integrated soil nutrient management in sub-Saharan Africa: A multinomial logit analysis in Cameroon. In: Bationo (ed). *Advances in integrated soil fertility management in sub-Saharan Africa: Challenges and opportunities*. Springer Publishers, Netherlands pp. 891-903.

Nkonya EM, Schroeder T and Norman D, (1997). Factors affecting adoption of improved maize seed and fertilizer in northern Tanzania. *American Journal of Agricultural Economics.* 48(1): 1-12

Nyamapfene K, (1991). The Soils of Zimbabwe. Nehanda Publishers, Harare, Zimbabwe

Nyeko P, Edward-Jones G, Day RK and Raussen T, (2002). Farmers' Knowledge and

Perceptions of pests in Agroforestry with Particular reference to Alnus species in Kabale District, Uganda. *Crop Protection*, 21: 929-941

Nyikahadzoi K, Siziba S, Mango N, Mapfumo P, Adekunhle A and Fatunbi O, (2012). Creating food self reliance among the smallholder farmers of eastern Zimbabwe: exploring the role of integrated agricultural research for development. *Food Security* 4: 647-656.

Nzuma, J.K., Murwira, H.K. and Mpepereki, S. (1998). Cattle manure management options for reducing nutrient losses: Farmer perceptions and solutions in Mangwende, Zimbabwe. In: S.R Waddington, H.K. Murwira, J.D.T. Kumwenda, D. Hikwa and F. Tagwira (Eds.). *Soil Fertility Research for Maize-Based Farming Systems in Malawi and Zimbabwe*. SoilFertNet/CIMMYT, Harare, Zimbabwe. pp 183-190.

Odendo M, Ojiem J, Bationo A and Mudeheri M, (2006). On-farm evaluation and scaling-up of soil fertility management technologies in western Kenya. *Nutrient Cycling in Agro-ecosystems* 76: 369–381.

Odera MM, Kimani SK and Musembi F, (2000). Factors influencing adoption of integrated use of manure and inorganic fertilizer in central highlands of Kenya. In: *Collaborative and Participatory Research for Sustainably Improved Livelihoods, Proceedings of the 7th Biennial Scientific conference*. Kenya Agricultural Research Institute (KARI) Nairobi, Kenya, 58–64.

Ogunlela YI and Mukhtar AA, (2009). Gender issues in agriculture and rural development in Nigeria: The role of women. *Human & Social Sciences Journal* 4 (1): 19-30

Okuro JO, Muriithi FM, Mwangi W, Verjuikl H, Gethi M and Groote H, (2002). Adoption of maize seed and fertilizer technologies in Embu district, Kenya. *Mexico, DF: CIMMYT and Kenya Agricultural Research Institute (KARI).*

Oluoch-Kosura WA, Marenya PP and Nzuma MJ, (2001). Soil fertility management in maize-based production systems in Kenya. Current options and future strategies. In: *Seventh Eastern and Southern Africa Regional Maize Conference 11–15th February*. pg 350–355

Opsahl T, Agneessens F and Skvoretz J, (2010). "Node centrality in weighted networks: Generalizing degree and shortest paths". *Social Networks* 32 (3): 245.

Pali PN, Delve R and Nkonya E, (2003). Using linear programming to optimize the use of biomass transfer and improved fallow species in eastern Uganda. In: *Harnessing Crop Technologies to Alleviate Hunger and Poverty in Africa*. *African Crop Science Conference Proceedings* 6: 339–447.

Palm CA, Gachengo CN, Delve RJ, Cadisch G and Giller KE, (2001b). Organic inputs for soil fertility management in tropical agroecosystems: Application of an organic resource database. *Agricultural Ecosystems and Environment* 83: 27–42.

Pannell D, (1999). Economics, extension and the adoption of land conservation innovations in agriculture. *International Journal of Social Economics* 26: 999–1012.

Piercy FP and Thomas V, (1998). Participatory evaluation research: An introduction for family therapists. *Journal of Marital and Family Therapy,* 24(2): 165-176.

Podolny JM, (2001). Networks as the pipes and prisms of the market. *American Journal of Sociology,* 107: 33-60

Pomp M and Burger K, (1995). Innovation and imitation: Adoption of cocoa by Indonesian smallholders. *World Development* 23: 423–31.

Pontius J, Dilts R and Bartlett A, (2002). Ten Years of IPM Training in Asia - From Farmer Field School to Community IPM. FAO, Bangkok. 106 pp.

Pretty J and Buck LE, (2002). Social capital and social learning in the process of natural resource management. In: C.B. Barrett, F. Place and A.A. Aboud (eds.) *Natural Resources Management in African Agriculture.* Nairobi: ICRAF and CABI Publishing.

Pretty J and Ward H, (2001). Social capital and the environment. *World Development,* 29(2): 209-227

Protracted Relief Program (PRP), (2005). CF for Vulnerable Households. Guidelines for PRP

Partners, No. 1 DFID and ICRISAT. Available from: *www.prpzim.info.* Accessed 15 April 2013

Quinn CH, Huby M, Kiwasila H, and Lovett JC, (2003). Local perceptions of risk to livelihood in semi-arid Tanzania. *Journal of Environmental Management* 68: 111-119.

Rahm MR and Huffman WE, (1984). The Adoption of Reduced Tillage: The Role of human capital and other variables: *American Journal of Agricultural Economics* 66: 405-413.

Rahman S, (2003). Environmental impact of modern agricultural technology diffusion in Bangladesh: An analysis of farmers' perceptions and their determinants. *Journal of Environmental Management*, 68: 183-191.

Reardon T, Taylor JE, Stamoulis K, Lanjouw P, and Balisacan A, (2000). Effects of non-farm employment on rural income inequality in developing countries: an investment perspective. *Journal of Agricultural Economics* 51 (2): 266–288.

Rogers E, (1993). Diffusion of Innovations. New York: Free Press.

Rogers EM, (1995). Diffusion of Innovations 4th Edition. New York, USA: The Free Press.

Roling NG, (1994). Innovation and the Agricultural Knowledge and Innovation system. In: *The setting, Background Material to the Multimedia Package: Discoveries on the Farmers' Track- Point and Pictures on Agricultural Innovation*. Peter Linde Productions, Wageningen

Rossi PH, Lipsey MW and Freeman HE, (2004). Evaluation: A systematic approach (7th Ed.). Thousand Oaks, CA: Sage

Rusinamhodzi L, Murwira HK and Nyamangara J, (2006). Cotton-cowpea intercropping and its N_2-fixation improves yield of a subsequent maize crop under Zimbabwean rain-fed conditions. *Plant and Soil* 287: 327-336.

Sanchez PA, (2002). Soil fertility and hunger in Africa. *Science* 295: 2019-2020

Sanchez PA, Denning GL, and Nziguheba G, (2009). The African green revolution moves forward. *Food Security* 1: 37–44.

Sanchez PA, Shephard KD, Soule MJ, Place FM, Buresh RJ, Izac AN, Mokunye AU, Kwesiga FR, Ndiritu CG and Woomer PL, (1997). Soil fertility replenishment in Africa: an investment in natural resource capital. In: JR Buresh, PA Sanchez and F Calhoun (Eds.). *Replenishing soil fertility in Africa*. SSSA Special Publication 51: 1–46, SSSA, Madison, Wisconsin USA.

Sanginga N and Woomer PL, (2009). Integrated Soil Fertility Management in Africa: Principles, Practices and Developmental Process. Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture. Nairobi. pp 263.

Sasovova Z, Mehra A, Borgatti SP and Schippers MC, (2010). Network churn: The effects of self-monitoring personality on brokerage dynamics. *Administrative Science Quarterly, 55,* 639-670

Sayce K, (1987). Tabex Encyclopedia Zimbabwe. Quest Publishing (Pvt) Limited, Moffat Street, Harare, Zimbabwe.

Schulz S, Honlonkou AN, Carsky RJ, Manyong VM and Oyewole BD, (2003). Alternatives to *mucuna* for soil fertility management in southern Benin: Farmer perception and use of traditional and exotic grain legumes. *Experimental Agriculture* 39: 267-278

Scoones I, Devereux S, and Haddad L, (2005). Introduction: New directions for African agriculture. *IDS Bulletin* 36 (2): 109-114

Scott J, (2000). Social network analysis: *A handbook*. London: Sage.

Selener D, (1997) Participatory Action Research and Social Change. New York, USA: Cornell University. The Cornell Participatory Action Research Network.

Shampine A, (1998). Compensating for information externalities in technology diffusion models. *American Journal of Agricultural Economics* 80: 337–346.

Sheikh AD, Rehman T and Yates CM, (2003). Logit models for identifying the factors that influence the uptake of new 'No-Tillage' technologies by farmers in the rice-wheat and the cotton-wheat farming systems of Pakistan's Punjab. *Agricultural Systems* 75: 79–95.

Shiferaw B and Holden S, (1998). Resource degradation and adoption of land conservation technologies in the Ethiopian highlands: A case study in Andit Tid, North Shewa. *Agricultural Economics* 18: 233–247.

Singh HS, (1988) Economics of dry farming and socioeconomic constraints in the adoption of improved dryland farming. Dryland Farming and Wasteland Development Report of the International workshop Part II. Jaopur, India. Pp 110-117.

Smale M, Heisey PW and Leathers DW, (1995). Maize of the ancestors and modern varieties: The microeconomics of high yielding variety adoption in Malawi. *Economic Development and Cultural Change* 43(2): 351-368.

Smaling EMA, Nandwa SM and Janssen BH, (1997). Soil fertility in Africa is at stake. In: Buresh RJ, Sanchez PA and Calhoun F (Eds) *Replenishing soil fertility in Africa. SSSA special publication* 51: 47-62

Stoorvogel JJ and Smaling EMA, (1998). Research on soil fertility decline in tropical environments: integration of spatial scales. *Nutrient Cycling in Agro-ecosystems* 50 (1-3), pp 151-158.

Stoorvegel JJ, Smaling EMA and Janssen BH, (1993). Calculating soil nutrient balances in Africa at different scales. I. Supranational scale. *Fertilizer Research* 35, 227–235.

Sub Saharan Africa Challenge Program (SSA CP), (2008). Mid Term Plan 2009 – 2010. Accra: Forum for Agricultural Research in Africa.

Swinton SM, (2000). More social capital, less erosion: evidence from Peru's Antiplano. Department of Agricultural Economics, Michigan State University, East Lansing

Tchale H, Wobst P, and Frohberg K, (2004). Soil fertility management choice in the maize-based smallholder farming system in Malawi. Proceedings of the inaugural symposium, 6 to 8 Dec. 2004, Grand Regency Hotel, Nairobi, Kenya.

Tiwari KR, Bishal K, Sitaula Ingrid LPN, and Paudel GS, (2008). Determinants of farmers' adoption of improved soil conservation technology in a Middle Mountain Watershed of Central Nepal. *Environmental Management* 42:210–222.

TSBF, (2000). The biology and fertility of tropical soils. Tropical Biology and Fertility Program report 1997-1998, TSBF, Nairobi, Kenya

Tschirley D, Zulu B and Shaffer J, (2004). Cotton in Zambia: An assessment of its organisation, performance, current policy initiatives, and challenges for the future. *Michigan State University Food Security Research project working paper no 10*, Lusaka, Zambia

Twomlow SJ and Ncube B (Eds.), (2001). Improving soil management options for women *DFID-Supported Project 'Will Women Farmers Invest in Improving their Soil Fertility Management?' Experimentation in a Risky Environment*, 13–15th September, 2000, ICRISAT Bulawayo, Zimbabwe, p. 150

Twomlow S, Urolov JC, Jenrich M, and Oldrieve B, (2008a). Lessons from the field – Zimbabwe's Conservation Agriculture Task Force. *Journal of SAT Agricultural Research* 6: 1-11

United States Department of Agriculture (USDA), (2012). International food security assessment, 2012-2022. A report from the Economic Research Service Outlook/GFA-23 Available at *http://www.ers.usda.gov,* Accessed 15 April 2013

Unruh JD, (2001). Land dispute resolution in Mozambique: Institutions and evidence of agroforestry technology adoption. *CAPRI Working Paper No 12*, IFPRI, Washington

Valadez J and Bamberger M, (1994). "Monitoring and Evaluating Social Programs in Developing Countries." Economic Development Institute of the World Bank Series, World Bank, Washington, D.C

Valdivia C, (2001). Gender, livestock assets, resource management, and food security: Lessons from the SR-CRSP, *Agriculture and Human Values*, 18: 27-39.

Vanlauwe B, (2004). Integrated soil fertility management research at TSBF: The framework, the principles and their application. In: Bationo A. (ed). *Managing nutrient cycles to sustain soil fertility in sub-Saharan Africa.* Academy Science Publishers, Nairobi.

Vanlauwe B, Bationo A, Chianu J, Giller KE, Merckx R, Mokwunye U, Ohiokpehai O, Pypers P, Tabo R, Shepherd KD,Smaling EMA, Woomer PL and Sanginga N, (2010). Integrated soil fertility management: Operational definition and consequences for implementation and dissemination. *Outlook on Agriculture* 39: 17–24.

Vlek P, Le QB and TameneL, (2008). Land decline in land rich Africa — A creeping disaster in the making. CGIAR Science Council Secretariat, Rome, Italy pp 55.

Waddington SR and Karigwindi J, (2001). Productivity and profitability of maize + groundnut rotations compared with continuous maize on smallholder farms in Zimbabwe. *Expl. Agric* 37: 83-98

Waddington SR, Mekuria M, Siziba S and Karigwindi J, (2007). Long-term yield sustainability and financial returns from grain legume-maize intercrops on a sandy soil in sub-humid North Central Zimbabwe. *Expl. Agric* 43: 489-503

World Bank, (1995). Towards environmentally sustainable development in sub-Saharan Africa: A World Bank agenda. Rep. No. 15111-AFR. World Bank, Washington DC

World Bank, (2008). World Development Report 2008: Agriculture for development – response from a slow trade – sound farming perspective. The World Bank, Washington DC

World Food Programme (WFP), 2012. *http://www.wfp.org*, (Accessed 5 February 2013)

Zingore S, Murwira HK, Delve RJ, Giller KE, (2007). Soil type, historical management and current resource allocation: three dimensions regulating variability of maize yields and nutrient use efficiencies on African smallholder farms. *Field Crops Research* 101: 296-305.

APPENDICES

Appendix1: Geodesic path closeness centrality for a learning alliance participant farmer in Chinyika east, Zimbabwe

Closeness Centrality Measures

		1 inFarness	2 outFarness	3 inCloseness	4 outCloseness
6	local_frs	28.000	32.000	96.429	84.375
1	farmer_exp	29.000	30.000	93.103	90.000
2	nat_extn	33.000	31.000	81.818	87.097
10	far_unions	33.000	33.000	81.818	81.818
28	ward_inn_plat	34.000	32.000	79.412	84.375
17	pvt_extn	36.000	39.000	75.000	69.231
19	field_days	37.000	38.000	72.973	71.053
8	seed_houses	37.000	34.000	72.973	79.412
22	agrl_shows	37.000	37.000	72.973	72.973
13	agro_dealers	37.000	38.000	72.973	71.053
7	out_com_frs	37.000	38.000	72.973	71.053
4	distr_inn_plat	38.000	37.000	71.053	72.973
9	fert_co	39.000	39.000	69.231	69.231
20	isfm_lc	39.000	46.000	69.231	58.696
26	seed_fairs	39.000	43.000	69.231	62.791
15	local_leader	39.000	34.000	69.231	79.412
3	research	40.000	36.000	67.500	75.000
21	cc_lc	40.000	46.000	67.500	58.696
16	universities	40.000	41.000	67.500	65.854
18	fr_grp	41.000	35.000	65.854	77.143
11	mass_media	43.000	43.000	62.791	62.791
14	ngo	43.000	38.000	62.791	71.053
12	prod_mkt	44.000	40.000	61.364	67.500
24	extn_meetings	46.000	47.000	58.696	57.447
23	ext_workshops	48.000	49.000	56.250	55.102
25	lc_based_meetings	48.000	50.000	56.250	54.000
27	exch_visit_local	51.000	50.000	52.941	54.000
5	intreg_know	53.000	53.000	50.943	50.943

Statistics

		1 inFarness	2 outFarness	3 inCloseness	4 outCloseness
1	Mean	39.607	39.607	69.671	69.824
2	Std Dev	5.833	6.247	10.427	10.621
3	Sum	1109.000	1109.000	1950.800	1955.068
4	Variance	34.024	39.024	108.727	112.804
5	SSQ	44877.000	45017.000	138959.328	139668.891
6	MCSSQ	952.679	1092.679	3044.352	3158.510
7	Euc Norm	211.842	212.172	372.772	373.723
8	Minimum	28.000	30.000	50.943	50.943
9	Maximum	53.000	53.000	96.429	90.000
10	N of Obs	28.000	28.000	28.000	28.000

Network in-Centralization = 56.56%
Network out-Centralization = 42.65%

Appendix 2: Geodesic path closeness centrality for a non-participant farmer in Chinyika east, Zimbabwe

Closeness Centrality Measures

		1 inFarness	2 outFarness	3 inCloseness	4 outCloseness
2	nat_extn	18.000	19.000	94.444	89.474
1	farmer_exp	19.000	19.000	89.474	89.474
8	local_frs	20.000	20.000	85.000	85.000
4	far_unions	23.000	23.000	73.913	73.913
18	local_leader	24.000	23.000	70.833	73.913
10	pvt_extn	24.000	24.000	70.833	70.833
17	agro_dealers	26.000	25.000	65.385	68.000
9	ngo	26.000	33.000	65.385	51.515
16	field_days	27.000	24.000	62.963	70.833
11	prod_mkts	27.000	28.000	62.963	60.714
15	agrl_shows	27.000	24.000	62.963	70.833
3	research	29.000	34.000	58.621	50.000
14	extn_meetings	29.000	31.000	58.621	54.839
5	mass_media	30.000	27.000	56.667	62.963
13	master_fr_training	31.000	32.000	54.839	53.125
12	ext_workshops	31.000	28.000	54.839	60.714
6	universities	33.000	31.000	51.515	54.839
7	intreg_know	34.000	33.000	50.000	51.515

Statistics

		1 inFarness	2 outFarness	3 inCloseness	4 outCloseness
1	Mean	26.556	26.556	66.070	66.250
2	Std Dev	4.475	4.810	12.405	12.510
3	Sum	478.000	478.000	1189.257	1192.498
4	Variance	20.025	23.136	153.875	156.492
5	SSQ	13054.000	13110.000	81343.711	81819.680
6	MCSSQ	360.444	416.444	2769.758	2816.857
7	Euc Norm	114.254	114.499	285.208	286.041
8	Minimum	18.000	19.000	50.000	50.000
9	Maximum	34.000	34.000	94.444	89.474
10	N of Obs	18.000	18.000	18.000	18.000

Network in-Centralization = 61.97%
Network out-Centralization = 50.72%

Appendix 3: Questionnaire

Household ID [ ]

Evaluating potential benefits of co-learning processes in promoting use of soil fertility management technologies by smallholder farmers

NB: This interview must be conducted with the head of the household or his/her adult proxy in a sampled household. The person selected should be informed about the purpose and nature of the study and that the information collected will be treated as confidential and must also give verbal consent to be interviewed.

IDENTIFYING INFORMATION

1	Name of Enumerator	
2	Date of interview	
3	Country	Zimbabwe
4	District	Makoni
5	Province	Manicaland
6	Ward	
7	Village	
8	Name of household head	
9	Is respondent household head? *1=Yes, 0=No*	
10	If no, relationship of respondent to household head *1=Wife, 2=Child, 3= relative, 4=n/a*	

GENERAL HOUSEHOLD INFORMATION

	Demographic data	Response	Codes
1	Gender of household head		*1=Male 0=Female*
2	Age of household head in years		
3	Highest level of education attained by household head		*1=no formal education, 2=primary incomplete, 3=primary complete, 4=secondary incomplete, 5=secondary complete, 6=adult education, 7=vocational training incomplete, 8=vocational training complete, 9=college/university incomplete, 10=college/university complete*
4	Highest level of education attained by any household member		
5	Number of members aged 16 and 58 years		
6	Number of members aged below 16 years		
7	Number of members aged 59years and above		
8	De-facto residence of household head		*1=Local village, 2=Distant town, 99=Other (specify)*
9	Position of household head in community?		*1=ordinary citizen, 2=head man, 3= religious leader, 4=teacher, 5=health worker,6 = extension worker, 99=other(specify)*
10	How long has the household head been farming in the village?		*Number of years*

LAND OWNERSHIP

C (1). What is your landholding?

	Holdings	Hectarage
1	What is the size of your arable land holdings?	
2	How much land did you cultivate in the 2009/10 cropping season?	
3	How much land did you cultivate in the 2010/11 cropping season?	

1 hectare=2.471acres   1 acre =0.405 hectares

C (2). How did you acquire your land? *1=received from local head; 2=government resettlement programme; 3=inherited from parents; 4=bought, 99=other (specify)………………*

HOUSEHOLD ASSET BASE

D (1). How many of the following assets does this household own now?

Row	Asset	Do you own? 1=Yes; 0=No	(b) If yes, number owned
	Livestock		
1	Cattle		
2	Goats		
3	Chicken		
4	Pigs		
5	Turkeys		
6	Guinea fowl		
	Implements/machinery		
7	Wheel barrow		
8	Ox-plough		
9	Ox-cart		
10	Cultivator		
11	Motor car		

HOUSEHOLD CROP PRODUCTION AND PRODUCE MARKETING

E (1). What crops did you grow in the 2009/10 cropping season?

		PRODUCE DETAILS										PRODUCTION COSTS ($)									
	CROP	Did you grow? 1=Y, 0=N	Area (acres)	Qty harvested (kg)	Qty saved for seed (kg)	Qty sold (kg)	Sell price $	Type of market?	In what form?	Qty for food (kg	Qty given out (kg)	Tillage	Seed	Hired labour	Basal fert	Top dressing fert	Manure	Pesticides	Transport in	Packaging	Transport out
1	Maize																				
2	Groundnuts																				
3	Sugar beans																				
4	Soyabeans																				
5	Cowpeas																				
6	Tobacco																				
7	Bambara nuts																				
8	Sorghum																				
9	Millet																				
10	Other (Specify)…….																				

Type of market: 1=on-farm to consumers; 2=on-farm to middlemen; 3=local/village market; 4=district town; 5=distant market; 99=Other (specify)………….
In what form: 1=fresh/as harvested; 2=shelled; 3=processed (milled, cooked e.t.c); 99=other (specify)………………

1 hectare=2.471acres 1 acre =0.405 hectares

E (2). What crops did you grow in the 2010/11 cropping season?

		PRODUCE DETAILS										PRODUCTION COSTS ($)									
	CROP	Did you grow? 1=Y, 0=N	Area (acres)	Qty harvested (kg)	Qty saved for seed (kg)	Qty sold (kg)	Sell price $	Type of market?	In what form?	Qty for food (kg	Qty given out (kg)	Tillage	Seed	Hired labour	Basal fert	Top dressing fert	Manure	Pesticides	Transport in	Packaging	Transport out
1	Maize																				
2	Groundnuts																				
3	Sugar beans																				
4	Soyabeans																				
5	Cowpeas																				
6	Tobacco																				
7	Bambara nuts																				
8	Sorghum																				
9	Millet																				
10	Other (Specify)…….																				

Type of market: 1=on-farm to consumers; 2=on-farm to middlemen; 3=local/village market; 4=district town; 5=distant market; 99=Other (specify)………….
In what form: 1=fresh/as harvested; 2=shelled; 3=processed (milled, cooked e.t.c); 99=other (specify)………………

1 hectare=2.471acres 1 acre =0.405 hectares

E (3). Did you sell your produce collectively? *1=Yes, 0=No*............................ (If no, proceed to E. 8)

E (4). If you sold produce collectively with other farmers, may you please give the following information?

Row	Attribute	Response
1	What is the name of the collective group?	
2	How many members are in the group?	
3	What are the main activities of the group?	
4	How many times does the group meet per year?	
5	Who initiated this group?	
6	Who sets the produce prices?	

***Main activity**: 1 = Production; 2 = Processing; 3 = Marketing; 4 = Production & processing; 5 = Production and marketing; 6 = Processing and marketing; 7 = Production, processing and marketing; 99=Other (specify)…………….*
***Who initiated formation of this group?** : 1 = Farmer group; 2 = trader group; 3 = individual trader; 4 =NGO; 5 =SOFECSA; 6 =Village/local government leaders; 99 = Other (specify)……………*
***Who sets prices?:** 1=Farmers as a group 2=Traders 3=Farmers in consultation with traders 99=Other (specify)….*

E (5). What did you perceive to be the benefits of collective marketing? ....………………………
…………………………………………………………………………………………………
………………………………………………………………………………………...

E (6). What were the challenges you faced in collective marketing? ....
....
....

E (7). In your opinion, how can these challenges of collective marketing be addressed?.................
....
....

E (8). If no to collective marketing, why you do not participate in group marketing? .... *1=Lack of time, 2=Lack of resources, 3=Prefer to work alone, 99=Other (specify*..................

E (9). What are your major constraints to marketing of crop produce? ....
....
....

E (10). Do you have access to the following marketing information?

Row	Information	Do you have access? *1=Yes, 0=No*	What is your major source of information?
1	Crop prices		
2	Crops on demand		
3	When crops are demanded		
4	Supplies in different markets		
5	Availability of transport		

Source of information: *1=relatives/friends e.t.c, 2=other farmers, 3=government extension workers, 4=mass media, 5=NGOs/research agents e.g. SOFECSA, 6=traders, 99=other (specify)……………*

ACCESS TO AGRICULTURAL INPUTS

F (1). How would you assess your access to agricultural inputs in the 2010/11 farming season?

Row	Type of inputs	(a) Common source	(b) Distance to common source
1	Inorganic Fertilizer		
2	Crop chemicals		
3	Animal Manure		
4	Certified seed		
5	Post harvest insect control chemicals		

Common source of inputs: *1=purchased from market; 2=purchased from stockists; 3=purchased from other farmers; 4=received from government; 5=received from NGOs; 99=other (specify)…*

F (2). Did you face any constraints in the previous seasons in accessing inputs? *1=Yes, 0=No…*

F (3). If yes, what were your major constraints to access of agricultural inputs?..……………………………………………………………………
…………………………….……………………………………………………………………………
……………………………...

KNOWLEDGE & USE OF SOIL FERTILITY MANAGEMENT TECHNOLOGIES

G (1). What soil fertility management technologies are you familiar with?

Row	Technology/ Management Practice	(a) Do you know this technology? *1=Yes, 0=No*	(b)Where did you learn about the technology? (see codes)	(c) Are you using this technology in your main fields? *1=Yes, 0=No*	(d)When did you first use this technology?
1	Cattle manure				
2	Compost				
3	Legume-cereal rotation				
4	Legume-Cereal intercrops				
5	Rhizobia inoculation				
6	Combinations of inorganic and organic fertilizers				
7	Termitaria soil				
8	Leaf litter				
9	Sunnhemp				

Source of information on technologies: 1=Government extension workers, 2=SOFECSA meetings, 3=NGO (specify), 4=Other farmers, 5=Mass media, 99=Other (specify)

HOUSEHOLD INCOME SOURCES

H (1). How much income did your household receive in the past 12 months? (Ask for each source one at a time and if the household does not get income from that source, move to the next)

	Sources of Income	Do you get income from this source? 1=Yes, 0=No	Estimated income in the past 12 months (USD)
1	Remittances		
2	Crop sales		
3	Vegetable sales		
4	Livestock sales and products		
5	Hiring labour out *(Maricho)*		
6	Self employment		
7	Formal employment (non-agric)		
8	Beer brewing		
9	Credit received (in cash and kind)		
10	Petty trading		
11	Crafts		
	Other(specify)		

HOUSEHOLD ACCESS TO CREDIT

I (1). Have you ever accessed credits for your agricultural activities in the past 12 months? *1=Yes, 0=No*…............

I (2). If yes, did you access the following inputs on credit?

Row	Type of credit	Did you access? *1=Yes, 0=No*
1	Seeds	
2	Inorganic Fertiliser	
3	Crop chemicals	
4	Working capital (cash)	

ACCESS TO AGRICULTURAL INFORMATION AND KNOWLEDGE

J (1). What are your major sources of agricultural information and knowledge? ....
………………………………………………………………………………………………………
……………………………………………………………………………………….........................

J (2). What are your major platforms for accessing agricultural information and knowledge? ....
……………………………………………………………………………………………...................
……………………………………………………………………………………………................

J (3). Have you ever visited a SOFECSA learning centre? *1=Yes; 0=No* ……………….

J (4). If yes, what did you learn at the learning centre(s)? …………………………………….....................
………………………………………………………………………………………………………
…………………………………………………………………………………….......................................

J (5). If no, are there any reasons why you have never visited a learning centre? ………………..............
………………………………………………………………………………………………………
…………………………………………………………………………………......................................

J (6). Have you adopted any of the technologies demonstrated? *1=Yes; 0=No* ……………………

J (7). If yes, which technologies have you adopted specifically? …………………………………..........
……………………………………………………………………………………………………..………
……………………………………………………………………………………......................................

J (8). If no, are there any reasons why you have not adopted any technology? ……………………
………………………………………………………………………………………………..……………
……………………………………………………………………………………...............

J (9). What benefits have you observed through the use of these technologies you have adopted?
………
………

J (10). What are your major limitations to effectively share and access agricultural knowledge and information? ……………………………………………………...……………………….................
………

J (11). What can be done to make more people want to learn at SOFECSA learning centres? ....
………
………

J (12). How would you rate the methods/approaches of research / advisory / training services that you have received from various agro-stakeholders (e.g. SOFECSA) in the past two years? (not more than four)

	Perception on				
(a) Which organization have you been receiving agricultural services (information, technologies, training etc) from?	(b) Methods / approaches used	(c) Usefulness of advice/ research	(d) Timeliness of service provision	(e) Collaboration with farmers	(f) Frequency of interactions with farmers

Perception on methods: 1=Very Poor, 2=Poor, 3=Good, 4=Very Good
Perception on usefulness of advice: 1= Not useful, 2= Somehow useful, 3= Useful, 4= Very useful
Timeliness of service provision: 1= Untimely, 2= Always provided late, 3= Not always timely, 4= Timely
Collaboration: 1 = Very poor 2 = Poor, 3 = Good, 4 = Very good
Frequency of interaction: 1= Very infrequent 2= Occasional 3= Regular 4= Very Regular

SOCIAL CAPITAL (Interaction with other farmers, farmer groups, institutions, NGOs e.t.c)

K (1). In the past 12 months, how often has a member of your household participated in the following?

Row	Aspect	Rating of occurrence
1	Participated in a community development activity.	
2	Made financial contribution for community activity or collective problem.	
3	Been involved in settling conflicts or disputes among people.	
4	Visited other farmers within this community to learn about agriculture.	

5	Visited others farmers outside this community to learn about agriculture.	
6	Visited a community demonstration site to learn about agriculture.	
7	Visited an extension office to learn about agriculture.	

Rating of occurrence: 0=never happens, 1=poor, 2=average, 3=very good, 4=excellent

HOUSEHOLD FOOD SECURITY

L (1). How long did your harvest of the main cereal crop from the 2009/10 season last (in months)? ....

L (2). In the past 12 months were there months in which you did not have enough food to meet your family's needs *1=Yes, 0=No* …………

L (3). If yes, what coping strategies did you use? ....
....

L (4). How long do you think your harvest will last this time (2010/11 season) in months? ....

L (5). Household dietary diversity

In the last 24hours has your household consumed any of the following foods?

Row	Food	Types of foods	Has your household consumed? (*1=Yes, 0=No*)	How many days in the past 7days have you consumed this food?
1	Cereals	Foods made from maize, sorghum, millet, or other local grains		
2	Vitamin rich vegetables & tubers	Carrots, sweet potatoes, or pumpkins that are yellow or orange inside		
3	White tubers & roots	White potatoes, yams, cassava, or foods made from roots		
4	Dark green leafy vegetables	Sweet pepper, dark green/leafy vegetables including wild ones		
5	Vitamin A rich fruits	Ripe mangoes, papayas or other Vitamin A-rich fruits (incl wild)		
6	Meat	Beef, pork, goat, chicken, wild game or blood-based foods		
7	Eggs	Eggs		
8	Legumes, nuts & seeds	Beans, peas, lentils, nuts, seeds of foods made from these		
9	Milk &products	Milk, cheese or milk products		
10	Oils & fats	Oil, fats or butter added to food or used for cooking		
11	Sweets	Sugar, honey or sugary foods		
12	Caffeine or alcoholic beverages	Coffee, tea, alcoholic beverages or local examples		
13	Fish	Fresh or dried fish		