WESTERN SYDNEY UNIVERSITY

The Diversity of Smallholder Farmers and their Adoption of the Sustainable Intensification Practices in Malawi

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DEDICATION

I dedicate this work to my: three girls: Denise, Dolly, and Debbie; husband Dr M.A.R. Phiri; late grandparents Mr and Mrs C.Z. Mhango, for working tirelessly to be where I am today, may your souls rest in eternal peace.

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Conference and seminar presentations

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AUTHOR'S DECLARATION

This thesis is submitted to the Western Sydney University in accordance with the requirements of the WSU Policy DDS, Doctor of Philosophy Rules, September, 2009

STATEMENT OF AUTHENTICATION

This thesis contains no material which has been accepted for the award of any other degree in any University or other tertiary institution and, to the best of my knowledge, contains no material previously published or written by another person, except where due reference has been made in the text.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACIAR	Australian Centre for International Agricultural Research
CA	Conservation agriculture
CFA	Confirmatory Factory Analysis
CIMMYT	International Maize and Wheat Improvement Centre
CKA	Central Karonga
CR	Crop rotation
DARS	Department of Agricultural Research Services
EFA	Exploratory Factor Analysis
ESA	Eastern and Southern Africa
FAO	Food and Agriculture Organization
FEWSNET	Famine Early Warning Systems Network
FGD	Focus Group Discussion
FISP	Farm Input Subsidy Program
HU	Herbicide use
IARCs	International Agriculture Research Centers
IFPRI	The International Food Policy Research Institute
LUANAR	Lilongwe University of Agriculture and Natural Resources
LLTC	Limbe Leaf Tobacco Company
NARS	National Agriculture Research Systems
NSO	National Statistical Office
MoAFS	Ministry of Agriculture and Food Security
MSH	Middle Shire
MT	Minimum tillage
Ors	Ordinary ratios
PCA	Principal component analysis
PHA	Phalombe /Lower Chirwa Plain
PPS	Probability-Proportional-to-Size

RR	Residue retention
Ses	Standard Errors
SIMLESA	Sustainable Intensification of Maize and Legume in the Eastern and Southern Afric
SIPs	Sustainable Improved Practices
TCC	Tobacco Control Commission
WFP	World Food Program

ABSTRACT

Low agricultural productivity and the associated poverty caused by the rapid degradation of soil fertility have negatively affected agricultural based livelihoods in Malawi. As a result, sustainable improved practices (SIPs) such as improved maize and legume seeds and conservation agriculture packages, among others, have been developed and promoted as suitable options to reverse the issue of low food production. Although there have been strong-minded efforts by scientists and agriculture extension staff to improve the adoption of these technologies, questions remain regarding their uptake among smallholder farmers. Furthermore, even in places where the technologies have been in practice, this process has been very slow, with big variations of adoption across all smallholder farmers.

This study draws its empirical data from two sources: Firstly, from collaborative work between the International Maize and Wheat Improvement Centre (CIMMYT) and the Department of Agricultural Research Services (DARS)in Malawi. Secondly from the data collected by Western Sydney University in collaboration with assistance of Bunda College of Agriculture under the University of Malawi (now LUARNAR). Data collection was mainly through farmer household surveys and farmer focus group discussions conducted between 2011 and 2013. The research took place in 6 target districts on a total of 1293 (891 and 402) farmers in the north, central and southern Malawi.

Therefore, this study sought to address three main objectives by administering and evaluating a structured questionnaire specifically to capture farm household data on: a) the diversity that exist among the smallholder farmers which influences their use of

sustainable intensification practices, b) opportunities and constraints for the intensifications of improved maize-legume varieties among smallholder farmers for dietary intensification and ecological intensification, c) the stepwise adoption and factors that influence farmers decision to adopt the individual components of the adapted conservation agriculture package in Malawi. Three standalone empirical chapters are merged to form the core of this thesis which has been integrated and synthesised in the final chapter. Overall, this thesis contributes both to literature and methodology. Overall, this thesis contributes both to literature and methodology.

Results from principal component analysis (PCA) and cluster analysis (CA) technics consistently indicated that there is diversity among the smallholder farmers revealing four different farmer classes which influenced their adoption of the improved soil fertility technologies. These farm types were: a) type 1 farms (35.13%) were classed as ‘small subsistence-oriented family farms’ practiced crop residue retention and crop rotation, b) type 2 (31.43%) were ‘small semi-subsistence family farms’, type 3 (25.36%) were ‘survivalist’ (small, independent, semi-specialized family farms whose main objective was family sustenance) and, c) type 4 (7.52%) were ‘production-oriented, small, dependent, semi-specialized family farms’.

Farm typologies indicated that farm types 1 and 2 practiced crop residue retention and crop rotation by intercropping of maize–legumes improved varieties, potentially making them the possible adopters of improved farm technologies among the rest of the farm types. Minimum tillage adoptions remained sparse. Type 3 farms, in addition to being family sustenance-oriented, specialised in a cash crop such as tobacco, cotton, legume which made them party commercial, which had a negative impact on practicing of improved farm technology. Type 4 farms were like type 3 but different high level of specialization as tenants in tobacco growing largely dictated by their landlords, which limited their adoption of improved farm technology.

Evaluation of the opportunities and constraints for maize-legume intensification among the smallholder farmers for dietary fortification and ecological intensification was done by comparing results of three random effects regression models using multilevel logistic analysis. Two different methods - first multivariate and second econometric technics were applied to correct for potential bias in estimating the factors that influenced adoption of maize-legume intensification. The results of the models indicated that farmers who had a shorter distance to walk to the farm inputs market and village market, had a higher participation in the intensification of maize-legume by 72 % of the farmers.

The thesis indicated that farmers decision to adopt or not to adopt each component combination from the adapted CA package (residue retention, minimum tillage, crop rotation and use of herbicides) was considered to be sequential and incremental. The results also revealed that the households' decision to adopt the individual component depended on farmers experience in growing cowpeas, soil depth and the households' food availability throughout the year. However, crop residue retention was the highest adopted (85%), followed by minimum tillage ate 70% and use of herbicide at 69%, with crop rotation the least at 30%.

PART I: OVERVIEW

CHAPTER ONE

Introduction

Section 1.1 looks at the available sustainable intensification (SIPs) practices for soil fertility improvement. The remainder of the chapter is organised as follows: Section 1.2 provides background information to agriculture production, farming systems and agricultural technologies in Malawi.

The problem statement (section 1.3) forms the next section, and this is followed by the objectives of the study (section 1.4). The main methods used in the study are outlined in section 1.5. Section 1.6 presents a justification of the study. This is then followed by the structure of the thesis in section 1.7. Finally, a summary concludes the chapter in section 1.8

1.1 Sustainable intensification practices (SIPs)

Sustainable intensification practices (SIPs) aim to enhance the productivity and resilience of agricultural production systems while conserving the natural resource base (Godfray, Beddington, et al., 2010; Godfray, Crute, et al., 2010; Pretty et al., 2011). Recent empirical evidence (Teklewold, Kassie, & Shiferaw, 2013) shows that combinations of SIPs provide higher net maize income and either reduce the input use or keep it constant, compared to cases where only single SIPs are promoted and adopted.

For decades, the extensive adoption of high-yielding varieties and fertilizers, accompanied by public support for irrigation were the core pillars for Asia's green revolution. However, these core technologies are not adequate to sustain agricultural productivity by themselves. Without a doubt, such agricultural intensification may generate negative environmental externalities such as the depletion of groundwater, environmental degradation, and chemical runoff (Pingali, 2012; Pingali & Rosegrant, 1994).

Accordingly, ‘sustainable intensification of agriculture’ is defined as producing more food from existing farm land in a way that conserves natural resources and does not compromise future food production (Conway, Waage, & Delaney, 2010; Garnett & Godfray, 2012; Pretty, 2008; Pretty, Toulmin, & Williams, 2011; Simons, 2015). One method that has enabled farmers to increase food outputs through sustainable intensification (SIPs) is by combining the use of new and improved varieties with changes to agronomic and agro-ecological management such as conservation agriculture (Pretty et al., 2011).

Therefore, agriculture production in Malawi should intensify sustainably to achieve food security requirements at household level throughout the country. Hence our investigation of SIPs includes analysing the following three main objectives:

a) understanding the diversity that exists among the smallholder farming systems for targeting of improved farm technologies
b) evaluating the opportunities and constraints for the intensifications of improved maize–legume varieties among smallholder farmers for dietary fortification and ecological intensification

c) assessing the stepwise adoption of an adapted CA package and the appropriateness of blanket recommendation of the CA package to all smallholder farmers in Malawi.

1.2 Background information to agriculture in Malawi

1.2.1 Diversity and production among farming systems

Malawi is a landlocked country located in southeast of Africa. The climate is sub-tropical; rainy season (November to May); dry season (May to November). Over 80% of the population still lives in the rural areas where agriculture is the main source of livelihood (Mulwafu & Msosa, 2005). The agricultural sector is the backbone of Malawi’s economy and this accounts for about 93% of total export earnings, and provides more than 80% of the total employment. The sector has, over the past 11 years, contributed an average of about 34% of the country's Gross Domestic Product (GDP) (M.A.R. Phiri, 2011) and contributes to national and household food sovereignty and security.

The agricultural sector in Malawi is dualistic, consisting of small-scale farmers and the commercial or estate sub-sector and this categorization is mainly based on the size of the landholding and crops grown, not necessarily their livelihoods. Malawi has 7.7 million hectares of arable land of which 6.2 million hectares are already under cultivation by both smallholders and estate farmers.

The commercial subsector comprises 30,000 estates cultivating 1.1 million hectares, with an average landholding of between 10 to 500 hectares. This subsector contributes only about 20% total national agricultural production, but provides over 80% of the agricultural exports. The estate subsector focuses on high-value cash crops for export, such as tobacco, tea, sugar, coffee and macadamia. On the other hand, smallholders mainly cultivate food crops such as maize, beans, rice, cassava, or sweet potatoes to meet subsistence requirements. Over 70% of the cultivated area in Malawi is under the customary land tenure system and is used by about 3.5 million smallholder farming families with landholdings ranging from 0.5 to 2.5 hectares, based on the 2011 data from the Ministry of Agriculture and Food Security (MoAFS, 2011).

However, crop yields have been too low and stagnant to provide significant development opportunities for the smallholder agricultural sector and to significantly contribute to the national growth. Agriculture growth has varied since independence (1964), with the first 15 years registering some gains and later declining. The growth was narrowly confined to the estate subsector and to smallholders with larger landholdings. Explanations for this include:

- over-dependency on rain-fed agriculture
- limited use of improved seeds
- poor adoption of alternative soil fertility technologies like conservation agriculture
- impoverished soils
- an inadequately resourced agricultural extension system.

This is worsened by weak market linkages high transportation costs, few and weak farmer organisations, poor quality control and inadequate information on markets and prices by smallholder farmers. Investment and re-investment in agricultural production have been poor due to high risks related to climate variability, among others, and poor access to credit, particularly for smallholder farmers.

1.2.2 The evolution of CA practices in Malawi

Agricultural production in Malawi during the pre-colonial period was based mainly on traditional technologies such as fallow systems to regenerate soil fertility (Mlay, Turuka, Kowero, & Kachule, 2003). During the colonial period (1891–1964), there existed some form of soil conservation practices in Malawi that farmers were expected to adopt (Derpsch, 2004). It was compulsory for all farmers to construct and align all the ridges along the contour bunds, especially for all farmers that were in areas considered prone to soil erosion. In addition, it was a must for all crops to be planted on ridges in all areas including those with low terrain and not on mounds as was the practice with cassava in many parts of the lakeshore and on the flat as in the Shire Valley areas.

All these soil and water conservation measures including graded bunds, waterways, ridges, storm drains and contour bunds were to be implemented by force and backed by legislation coerced by the then Prime Ministers, including Roy Welensky (HR Mloza-Banda & Nanthambwe, 2010). Farmers who failed to follow these practices were subject to heavy punishments such as imprisonment and fines (Mandala 1990). However, most farmers were not keen to undertake ridge realignment cultivation, water ways, storm drains and contour bund construction for three main reasons. Firstly, it was very tiresome to labour demanding using hand tools since the colonial government mainly constructed these structures with equipment such as ox-drawn ploughs (Derpsch, 2004) and farmers were expected to maintain them regularly with their hand hoe (HR Mloza-Banda & Nanthambwe, 2010). Secondly, farmers could not see the immediate benefits to their crop yields; and lastly, farmers were against the use of force which sometimes led to imprisonment (Kabuye, 2006).

Especially, during the period between 1950 and 1960, when the National Soil and Water Conservation Programme was established and implemented, is considered to be the darkest era in the history of agricultural extension service in Malawi. However, compulsory implementation of soil and water conservation programmes came to an end in 1961 after attaining self-government. From then onwards, extension staff adopted persuasion instead of coercion methods in advising farmers by explaining the long-term benefits of soil conservation measures to their farming systems. Eventually, most farmers appreciated the benefits of the messages and adopted these technologies to the extent that ridge cultivation became a common practice throughout Malawi (Kabuye, 2006).

However, the technology spread widely among farmers, with many finding it difficult to change to new technologies like conservation agriculture because farmers find it hard to believe that one can farm without using a hand hoe , also hand weeding is very laborious (Banda, 2007) even though this lead to severe soil erosion because of continuous soil disturbance by moving ridges from one point to another (Douglas, 1997.; Douglas, Mughogho, Shaxston, & and Evers, 1999).

1.2.3 Previous government Initiatives to enhance improved farm technology adoption

After independence, the approach to soil and water conservation saw some significant improvement as low cost technologies were used for pegging, and this involved mobilizing farmer communities to make marker ridges and other conservation measures through annual conservation campaigns (Henry Mloza-Banda, 2006). In particular, the agricultural extension system promoted conventional land preparation practices (G. S. Phiri, 2007) such as:

- the construction of ridges on contours every growing season
- covering soil with crop residues
- intercropping of improved maize with legume
- the making of compost manure (Henry Mloza-Banda, 2006; HR Mloza-Banda & Nanthambwe, 2010).

On a large scale, the implementation of CA programmes started in 1998 when Sasakawa, an International NGO in collaboration with the agricultural development divisions (ADDs), implemented a programme dubbed the Sasakawa Global 2000 (SG 2000) programme. The Malawian government was introducing the targeted input program (TIP) supported by the European Union and other international donor organizations where over 1.8 million smallholder farmers, were provided with a small package of inputs, free of charge called the ‘starter pack’. This consisted of 2.5 kg of hybrid maize seed, 7.5 kg of NPK fertilizer, 7.5 kg of urea plus 2.5 kg of legume seed to cover 0.1 ha of land (Planning Division, 1998). However, SG 2000 prepared a similar package of inputs comprising of 2kg of improved maize seed, 10 kg of NPK fertilizer (23:20:00+4S) and 5 kg of urea—and sold it to participating farmers at a small price. Different from the starter pack, the SG 2000 package was complemented with full support of agricultural extension development officers (previously called ‘field assistants’) for improved farm management and productivity. Farmers who participated in the starter pack programme practiced on the same 0.1 ha plot size (Ito, Matsumoto, & Quinones, 2007). In addition to the inputs received from SG 2000, farmers purchased the required herbicides by themselves. The main areas of focus in the Sasakawa programme were optimum plant densities, spacing, proper use of fertilizer, weed control and crop protection (Mkomwa, 2014). The programme also introduced reduced tillage to farmers to reduce erosion, reduce labour requirements and conserve moisture. During the implementation of the programme, record-breaking maize yields of 5.1 t/ha were registered (IFPRI 2012). Up to now, the Sasakawa programme continues to be a point of reference regarding when actual promotion of CA began in Malawi (HR Mloza-Banda & Nanthambwe, 2010) and the rest of Africa (Kwarteng, 2000).

1.2 4 Different components in CA package by different promoters

Projects implementing CA often differed in their working definitions. The variations in CA definitions were more pronounced between projects implemented by government agencies and NGOs (IFPRI 2012). These different stakeholders, in some cases, employ components that differ which frustrate efforts to come up with a working definition of CA in the Malawian context. It is reasonable to note that CA practices cannot be promoted as “one-size-fits-all” (Giller et al., 2009, as the technology requirements of farmers may vary according to the agro-ecological zones (Chikowo, 2011).

Key players in the CA campaign in Malawi promote different components, with the most common being three : minimum tillage, use of herbicides, and use of crop residue. For example, the CA principle of minimum disturbance to the soil has been defined by different projects as “reduced tillage”, “minimum tillage”, “no till of soil, or “zero tillage” (IFPRI,2012). Undoubtedly, the promoters of CA do not only include components as part of their CA package, but also the same components are given different names by different promoters. However, the differences in conceptualization of the same technology have the tendency to affect its adoption among farmers. In addition, some of the terminologies used in actual sense may be difficult for farmers to adopt. For instance, “no till of soil or “zero tillage” would mean no disturbance to the soil. However, this may not be applicable in Malawi because farmers still have to disturb the soil to place seed, as they do not use precision machinery.

In addition to the differences in terminologies used to describe CA components, it is also important to question the set of components that constitute an ideal CA package. While some programs promote only three CA techniques, others promote as many as five. A fundamental question that arises is: *Are these components designed according to the technological needs of farmers, their financial capacity or their technical skills?* It may also be useful to understand whether the number of components included in CA package determines the extent to which farmers adopt the package.

1.2.5 Farmers’ perception and attitudes on use of CA

It is necessary to understand how smallholder farmers perceive the principles and importance of CA as well as their attitudes in order to improve the adoption and adaptation of CA. While many stakeholders are promoting CA to smallholder farmers, many are still sceptical about what it can actually do in terms of improving crop productivity (HR Mloza-Banda & Nanthambwe, 2010). Even some agricultural scientists and extension workers as well as farmers are sceptical about the cost-effectiveness, the achievability and suitability for smallholder farmers to “throw away the hoe” for example, and rather grow crops without tilling the soil (Sosola 2011). Regarding the practice of minimum tillage, field evidence suggests that some farmers have raised concerns about the profitability of the practice especially hand weeding, which is labour intensive.

However, the use of herbicides to control weeds is the most preferred method as the labour needed for weeding is reduced or eliminated, although farmers often raised issues concerning the affordability of herbicides (HR Mloza-Banda & Nanthambwe, 2010). Similarly, previous research elsewhere reported that reduction in labour cost was the most compelling reason why farmer adopt minimum tillage component of CA package (Huang et al., 2008).

It is important to note that the adoption of CA in Malawi from the farmers' point of view will depend on three main factors: feasibility - the capacity of farmers to manage the technology, profitability - farmers perception that it is expensive to use herbicides are used for weeding) and acceptability - farmers attitude towards farming without using hand hoe (Swinkles and Franzel, 1997).

1.3 Rationale of the study

Scientists have been trying to develop and subsequently, have sought to encourage farmers to adopt sustainable intensification practices (SIPs) like conservation agriculture (CA), that reduce the consequences of land degradation following the dust bowl in North America in the 1930s. Even though, CA systems have successfully been adopted by commercial farmers in the Americas and Australia (Bolliger et al. 2006; Desprch 2002; Kirkegaard et al.2013), its adoption by smallholder farmers has remained well behind in the sub-Saharan Africa.

Nevertheless, the promotion of CA among the smallholder farmers in Malawi was the most suitable way to reduce soil erosion and increase crop yields (Benites et al. 1998). In 2004, CA was reintroduced by Sasakawa Global 2000 (Ito et al. 2007) although the initiative was criticized to be in a linear, top down approach, without the active participation of farmers, hence not sustainable (Giller et al. 2009). However, the challenge has been the ability to increase the food security of farmers by improving the productivity of soil through CA and intensification of improved varieties of maize and legume without creating new constraints (P. L. Mafongoya, Kuntashula, & Sileshi, 2006).

Since then, several programs like the international maize and wheat improvement center (CIMMYT), the donor community, government and non-governmental organisations of most southern Africa countries have had a growing interest in promoting SIPs. However, this has resulted in a very wide diversity in methodological approaches by various organisations promoting CA among the smallholders. As a result, this extensive promotion has sparked some debate, the opponents of CA claiming that smallholder farmers in the SSA are not able to apply all the three principles of CA due to competition of crop residues with livestock and small land holding sizes thus constraining farmers to practice crop rotation (Anderson & Giller 2012; Giller et al.2009; Baudron et al.2112b). On the other hand, proponents of CA contend that the question is not when or where is CA suitable but how it can be adapted for widespread intensification (Kassam et al.2009).

Regardless of the clear significance of this concern in the strategic design of research and extension approaches, most of the theoretical studies that have been conducted on agriculture technology adoption have delivered little information to assist farmers to decide between the package and the stepwise attitude to the development and delivery of the technology components (Feder, 1982; Rogers, 2004). Several studies have observed that while most agricultural technologies are presented as a package of interrelated components, farmers usually do not adopt the whole package but rather adopt pieces of the package in a step-wise manner (Leathers & Smale, 1991; C. K. Mann, 1978).

Consequently, most studies on adoption have measured the adoption of single innovations in segregation and have not taken into account the process of adoption among a set of components from a technological package (Feder, Just, & Zilberman, 1985; Feder & Umali, 1993). Most of these researchers have committed a 'pro-innovation' bias which assumes that the innovation is 'right' (Byerlee & de Polanco, 1986; Wozniak, 1984) but such studies have analysed adoption patterns based on farmers' different socio-economic characteristics (Rogers, 1976), disregarding conditions or perceptions.

Furthermore, these CA critics proposed a research agenda to identify socio-ecological niches for CA in SSA where it is best suited as well as identification of target group of farmers, which can allow flexibility and pragmatism in the use of CA principles. Such farmer classification or farmer typology would allow for strategic tillage in cases where CA would lead to soil crusting and sealing resulting in soil erosion (Kirkegaard et al.2013; Giller et al. 2011; Bolliger 2007). In addition, a meta – analysis of failures and successes of CA (Rusinamhodzi et al.2011) had no explanations of the critical success factors and potential solutions for addressing the constraints.

Even though, there has been a wide interest in these low-cost technologies among researchers and others (Kumwenda et al., 1996; S. S. Snapp et al., 2002a; S. S. Snapp

& Silim, 2002), little research has been done to formally study these SIPs in Malawi. Scientists and policy makers also have expressed frustration at the low adoption levels of sustainable intensification practices and expressed a desire to understand it. Hence, this thesis was designed to fill this knowledge gap.

Therefore, it was necessary to conduct this study in an attempt to provide scientific evidence on the performance of the sustainable intensification practices among the smallholder farmers in Malawi. This has been addressed by: firstly, classifying smallholder farmers into different categories for improved technology targeting. Secondly, by analysing stepwise adoption of the adapted CA methodological approaches promoted by various organisations in Malawi. Lastly, the opportunities and constraints of the intensification of improved varieties of maize and legumes in Malawi have been investigated.

This study provides useful feedback on the design, implementation and targeting of farmers for the adoption of sustainable intensification practices. The results and implications presented here are relevant to scientists and their funding sources, extension agents and funding bodies, policy makers, managers in government agencies, non-government conservation organisations and farmer organisations.

This research draws empirical data from Western Sydney University, collaborative work between the International Maize and Wheat Improvement Centre (CIMMYT), the Department of Agriculture and Extension Services (DAES), the Department of Agricultural Research Services (DARS), farmers, and farmer groups.

1.4 Objectives and Research Questions

The overall objective of this PhD research study was to investigate the diversity that exist and the adoption of the sustainable intensification practices among smallholder farmers in Malawi.

The specific objectives included the following:

1) To understand the diversity that exist among the smallholder farming systems for targeting of improved farm technologies (Chapter 2).

i) ***Research question***: What diversity exists among smallholder farming systems and its influence on improved farm technology adoption?

2) To explore household level factors that influence farmers' investment in the intensification of the improved maize and legume varieties for dietary fortification among smallholder farmers and ecological intensification in Malawi (Chapter 3).

*ii**)*** ***Research question***: What are the opportunities and constraints for maize and legume intensification among the smallholder farmers for dietary fortification and ecological intensification in Malawi?

3) To evaluate stepwise adoption of an adapted CA package and of the appropriateness of blanket recommendation of the CA package to all smallholder farmers in Malawi (Chapter 4).

*iii**)*** ***Research question***: What step by step pattern do smallholder farmers follow when adopting individual or various component combinations of the adapted CA package and factors that influence farmers' decision making?

Answers to the above four questions are important to the government, development partners, agriculture technology inventors and the farm households and should help to explain the opportunities and constraints to adoption of improved agriculture technologies by the smallholders. This is useful in developing strategies for scaling up farm technology adoption to achieve household food security across all farm households. Technology innovators have a further advantage of feedback on the performance of their technologies in the farmers' fields, for improvement. The smallholders are enabled to determine whether adaptation of the technologies to suit their requirements is the way to go or not.

1.5 Methodological approaches

1.5.1 Study Sites and Data

This study used two sets of data as explained below:

In order to study the extent to which smallholder farmers have adopted new methods of residue retention, crop rotation, minimum tillage and improved crop varieties of maize and legumes, we collected data from 891 households as part of baseline survey for the International Maize and Wheat Improvement Centre **(**CIMMYT**)** project of Sustainable Intensification of Maize and Legumes in Eastern and Southern Africa (SIMLESA) by the Ministry of Agriculture and Food Security in Malawi through the Department of Agricultural Research Services (DARS). Permission was granted for her to use the data in her doctoral dissertation (Chapters 2 &3) with the School of Science and Health at the Western Sydney University, Australia.

Our study focus was mainly on the SIMLESA districts where intervention in maize–legume intensification already exists, but the farmers interviewed in this survey were not participants or beneficiaries in the SIMLESA project. The SIMLESA project sites are located across two regions and six districts in Malawi. Multi-stage random sampling methods using probability-proportional-to-size (PPS) sampling was used to select a total of 891 households from 235 villages covering different Extension Planning Areas.

To eliminate measurement bias, research assistants were trained and assessed by CIMMYT scientists and the principal investigator of this research. The survey adopted a mixed approach (pre-tested semi-structured questionnaires and Focus Group Discussion [FGD] checklists) to collect information from the farmers at household and community levels. The FGD checklist information obtained from key informants (chiefs, teachers, health surveillance assistants, elders and experienced farmers who were not sampled) was used to check the validity of the semi-structured questionnaire.

Table 1.1: Main biophysical characteristics and livelihoods of the study sites

District (n)	Balaka (159)	Kasungu (137)	Lilongwe (325)	Mchinji (70)	Ntcheu (109)	Salima (91)
Site	**Rivirivi**	**Mtunthama**	**Mitundu**	**Kalulu**	**Nsipe**	**Tembwe**
Annual mean rainfall	684	763	900	952	900	700
Dominant soil type	Clay-loam	Ferallitic soils	Chromic luvisols	Clay-loam	Sandy loam	Sandy loam
Maize – staple and other food crops	Potato, legume	Cassava, legumes, sweet potato	Cassava, sweet potato, groundnuts	Cassava, sweet potato, legumes	Legumes	Legumes
Cash crops	Cotton	Tobacco, paprika	Tobacco, paprika, s/bean	Groundnut, tobacco	Potato, vegetable	Rice, tobacco

Chapter 4 used data from household survey conducted by Western Sydney University. Technical support (research assistants) from the Ministry of Agriculture and Food Security (MoAFS) in Malawi and Lilongwe University of Agriculture and Natural Resources (LUANAR)[1], eased the data collection process. The data collected during the household survey for this study was in relation to farmers' responsiveness to conservation agriculture and their

[1] formerly known as Bunda College of Agriculture under University of Malawi

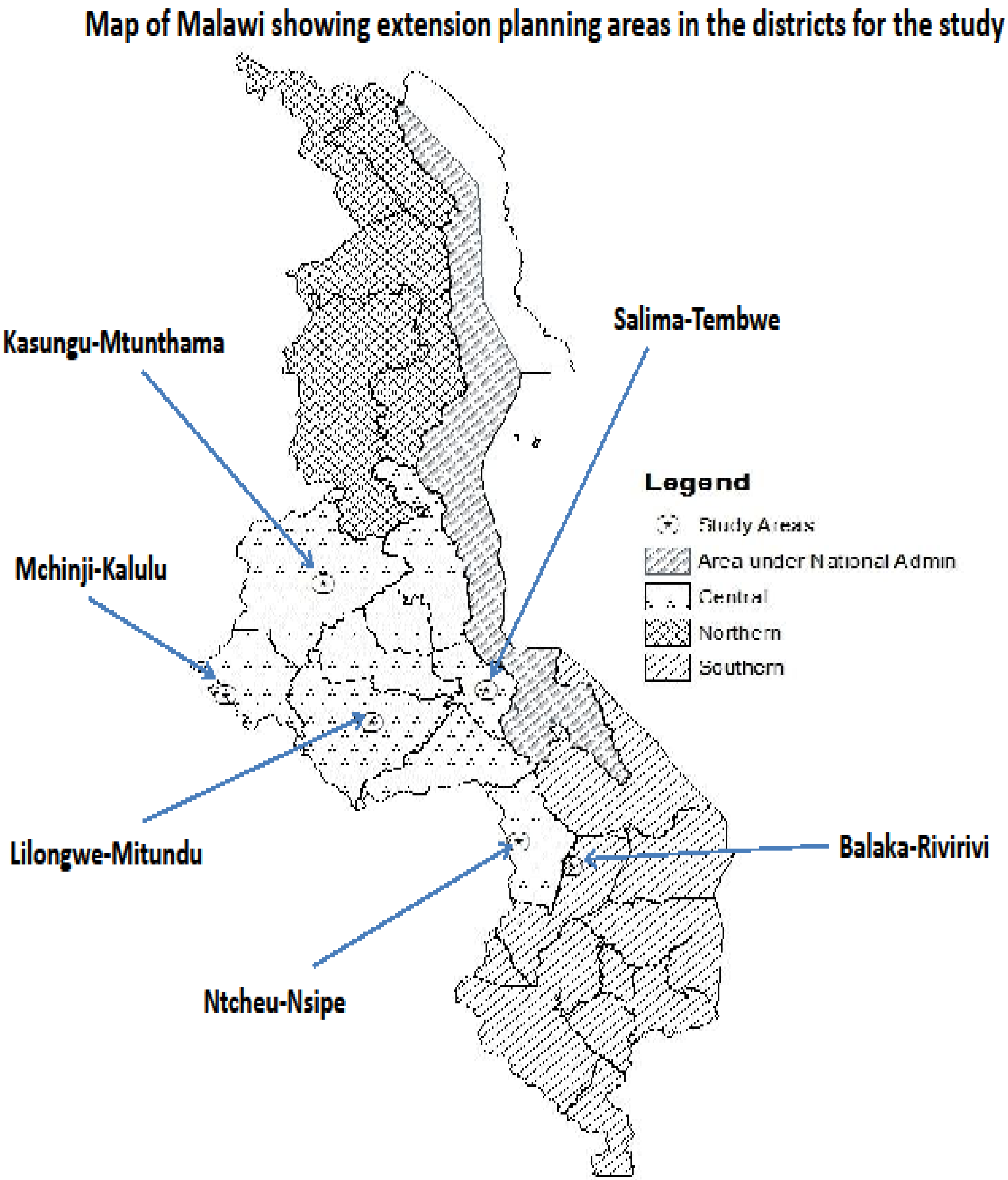

Figure 1.3: Showing districts and study sites also known as Extension Planning Areas (EPAs)

farm management practices. A questionnaire approved by the Human Research Ethics Committee for H9891 titled: *Malawi Farming Systems and Conservation Agriculture* was administered to the heads of households or members of the households who participated in decision making in farm operations. Research assistants asked farmers to recall their perceptions about CA, use of CA package and farm management practices for the previous three production years (2009/10, 2010/11, 2011/12 growing seasons). Participants in the survey were smallholder farmers from six districts, namely Mzimba, Kasungu, Balaka, Salima, Nkhotakota and Dowa across the three regions in Malawi. A total sample of 134 (panel of 402) smallholder farm households were selected and interviewed using a purposeful stratified three-stage sampling procedure of farmers, who have been exposed or are already doing CA from December 2012 to February 2013.

Quantitative analyses presented in the thesis came from two sets of data :

a) Firstly, the CIMMYT Baseline household survey data from 891 households in the six SIMLESA Malawi project sites (which includes Balaka, Ntcheu, Lilongwe, Mchinji, Salima and Kasungu in Malawi) analysed in Chapters Two and Three.
b) Farm household recall survey data collected from 134 (panelled to 402) households in six sites across three regions (Northern region = Mzimba; Central region = Kasungu, Nkhotakota, Salima and Dowa; Southern region = Balaka) analysed in Chapter Five.

1.5.2 Variable selection and Quantitative analyses

This study employed key approaches and variable selection commonly used for farm typology delineation and improved farm technology adoption are presented below (Mtambanengwe and Mapfumo 2005; Tittonell et al. 2005, 2010; Zingore et al. 2007). Farm types important for targeting improved farm technologies are typically constructed on the basis of information on resource endowments and production criteria derived from surveys, key informant interviews, focus group discussions and literature on biophysical and socio-economic characteristics of the farming systems (detailed variable selection in the methodology of each Chapter).

Ideally, farm types must readily reflect the potential access of different households to resources for managing their soils. Survey questionnaire was designed to capture biophysical, socio-economic and managerial aspects of farming households in an area, must capture information on key variables that include characteristics of the household head and family structure, labour availability, main source of house hold income, farm land use patterns, information on previous participation in marketing (volumes of crop produce sold or bought), use of agricultural inputs, food security, livestock ownership, links to nearby markets, and production orientation (Tittonell et al. 2005, 2010). The specific details include: household land ownership, family labour available, family members working off-farm, proportion of household income from off/non-farm activities, proportion of production for the market, total number of livestock and months of food self-sufficiency (Zingore et al. 2007) (See appendix 3).

Different statistical methods were employed to answer the research questions and this is detailed in Figure 1.2 below. These methods include multivariate statistical analysis (Chapter Three and first stage analysis of Chapter Four) using r-statistical software version R-3.2.2 in integration with the Statistica program to perform the analyses for these two chapters. Multivariate multilevel modelling (second stage analysis of Chapters Three and Four) using STATA version 12.0 was used to perform the analyses in these two last empirical chapters, as briefly shown in Figure 1.2 below. Detailed analysis is provided in each respective chapter.

1.6 Structure of the thesis

The thesis is composed of four parts as shown in Figure 1.1 below. **Part I** is an overview of the research. This comprises the Introduction (**Chapter One**) and background to this research, which reviews literature of the Malawi agriculture industry, comprising estate and smallholder farmers and the adoption of sustainable intensification practices (SIPs) among smallholder farmers. For this study, these SIPs are: improved farm technology, intensification of improved maize–legume varieties and the adapted conservation agriculture package. Therefore, the rest of the research is organised as follows; each research objective is answered in its own chapter independently, consisting of literature review, methodology, data analysis, results and discussion and these are presented in **Parts II** and **III** that follow.

Part II consists of two chapters (2&3) which focusses on the diverse technology uptake among the smallholder farmers. Therefore, **Chapter Two** examines the heterogeneity among smallholder farmers and develops a farm typology where their responses were analysed and their responses to agricultural technologies are discussed and reported. **Chapter Three** evaluates the opportunities and constraints for smallholder farmers' intensification behaviour in the intensification of improved legumes varieties and intercropping of improved maize and legume varieties for food security and ecological intensification.

Part III comprises of one chapter, **Chapter Four,** which examines the step wise adoption of the adapted Conservation Agriculture (CA) package adoption and the factors behind each adoption choice were analysed and uptake levels of each category are all discussed and reported.

Part IV contains the final chapter, **Chapter Five**, which concludes the thesis by synthesizing and integrating all the chapters, possible policy interventions, limitations and suggests areas for future research to improve the adoption of sustainable intensification practices among smallholder farmers in Malawi.

1.7 Chapter summary

This chapter has presented a summary of the sustainable intensification practices. These SIPs are improved farm technology, improved maize–legume varieties and an adapted conservation agriculture package. These technologies are vital to addressing the issue of low agricultural productivity due to land degradation, especially improving the fertility of the soil. Food insecurity and its associated poverty may have negative impacts among the smallholder farmers in Malawi. Even though scientists and agriculture extension staff have continually tried to improve adoption of these technologies, their uptake among the smallholder farmers is still questionable. Furthermore, even in places where adoption has taken place, big disparities exist across all smallholder farmers in the country.

The specific objectives of the thesis have been clearly stated in this chapter. Other areas in the chapter contain: main approaches to the study, rationale of the study and also the outline of the thesis.

The following chapter focusses on the diversity that exists among the smallholder farmers in Malawi. The chapter then analyses and discusses farmers' heterogeneity and their influence on soil fertility management among the smallholder farmers in Malawi. This is then followed by classification of the smallholder farms.

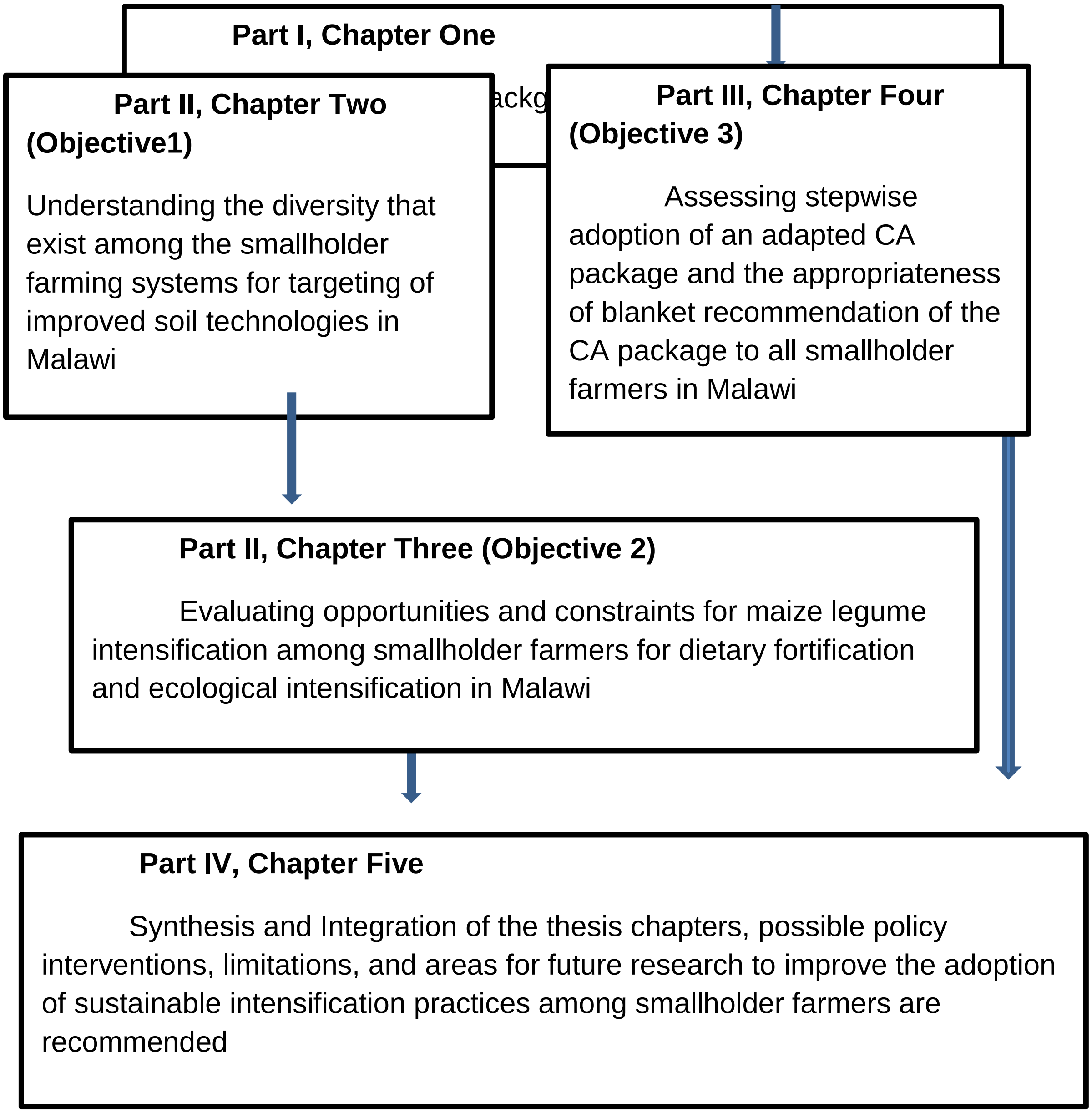

Figure 1.1: Flow chart linking the objectives to the structure of this thesis

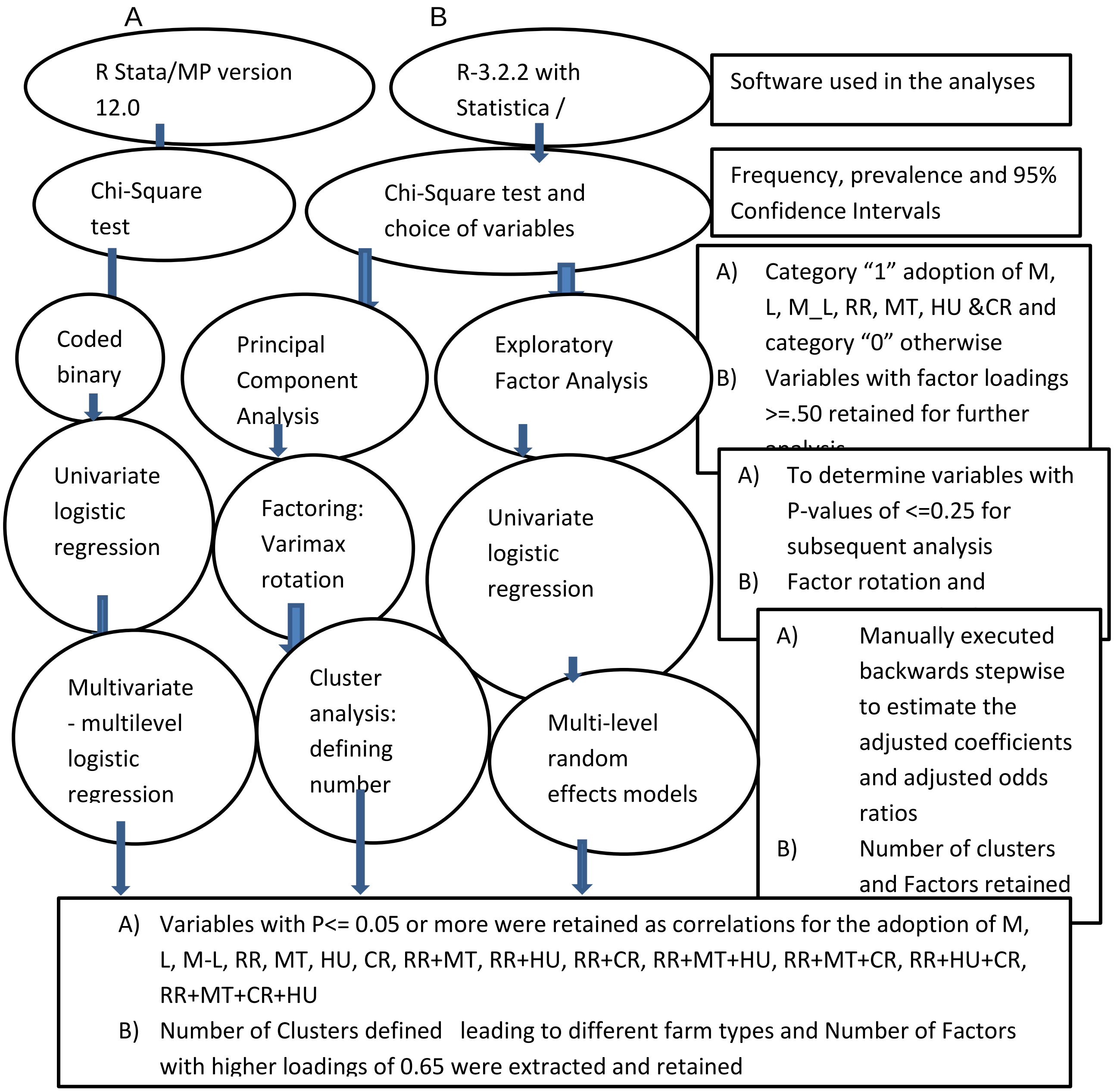

Figure 1.2: Showing a flow chart of the statistical analyses used in this thesis. M = mono-cropping of improved maize; L = mono-cropping of improved grain legume; intercropping of improved maize–legume; RR = residue retention; MT = minimum tillage; HU= herbicide use; CR = crop rotation.

PART II: DIVERSE TECHNOLOGY UPTAKE AMONG THE SMALLHOLDER FARMERS

CHAPTER TWO

Understanding the diversity that exist among the smallholder farming systems for targeting of improved farm technologies in Malawi

2.1. Introduction

Three salient features that characterize smallholder farmers in much of the Sub-Saharan Africa are poor soil fertility, low technology adoption and the wide diversity of farming households for both biophysical and socio-economic conditions at short ranges (e.g. Zingore et al. 2007; Tittonell et al. 2005). Poor soil fertility is a major barrier to smallholders' ability to improve their staple crop production (Kassam et al., 2009).Consequently, yields from smallholder agriculture are characteristically low due to poor agro-ecological potential, including low soil nitrogen and phosphorus, poor access to markets, and continuous cultivation. In addition, there is also little or no use of external inputs by most farm families (Chikowo et al., 2014).

The availability of resources and its allocation to different activities are determined by the 'wealth' of the household depending on its priorities and production objectives. Therefore, nutrient use intensity varies between farms of different resource endowment and production orientation, leading to variation in soil fertility status and crop productivity at the farm level.

In order for technological interventions to efficiently address the problem of poor productivity, smallholder agricultural systems should be designed to target these socially diverse and spatially heterogeneous farms and farming systems (Tittonell et al. 2010). Implementing linear and largely top-down approaches, that do not sufficiently consider such complexity as essential, results in agricultural research and development efforts generating lower than expected impacts across much of SSA (e.g. Giller et al. 2011).

Maize is the main staple and continues to be the dominant crop among smallholder farmers in Malawi. Since almost 70% of smallholder farmland is devoted to maize cultivation, it is not surprising that maize availability describes the food security situation of the nation (Chirwa et al., 2008). However, production of maize has been low compared to population growth in the country (NSO, 2012). Malawi has a high human population density, of about 13.1 million people, with an annual growth rate of 3 %, and about 4 million ha of arable land (National Statistical Office 2008). This has created considerable pressure on land for agricultural production, given that most farmers mainly cultivate maize in summer due to unimodal rainfall. Farmers cultivate small fields, largely 1ha, and there is considerable expansion of agriculture to marginal lands (Chikowo et al, 2014).

While low crop productivity is attributable to many factors such as recurrent droughts and floods, the problem of low and declining soil fertility has been recognised as an immediate concern that is linked to the food (maize) shortages of the recent past in the country. The farmers' immediate option for reversing the decline in soil fertility is to increase the use of inorganic fertilizers; however, most are unable to manage soil fertility in this way. Smale and Phiri (1998) reported discontinuous use of inorganic fertilizer and hybrid maize seed by most smallholder farmers in Malawi, mainly due to cash constraints and lack of access to credit in most cases. In recognition of this challenge, in the past decade several alternative soil fertility technologies have been introduced e.g. conservation agriculture to improve the food production of smallholder farms in the most affordable way, as well as to preserve the environment for resource-poor farmers (SS Snapp, Blackie, & Donovan, 2003). Despite the introduction and dissemination of these technologies, however, maize yields (main staple) continue to be very low, as noted above. This could be explained by the fact that adoption of these technologies among smallholder farmers remains low.

Smallholder farmers do not generally base their decision on whether or not to adopt a novel technology on its economic performance (Randall Brummett & Haight, 1997); their main aim is food self-sufficiency which is constrained by the availability of resources. The availability and allocation of resources to various activities are determined by household 'wealth', and also depend on household priorities and production objectives (Chikowo et al., 2014). In order to increase the adoption of these technologies and increase maize productivity, there is need to deliberately involve farmers when developing the technologies (RE Brummett & Chikafumbwa, 1999).

There is a large diversity among smallholder farm families in terms of their levels of resource endowment, and how farmers' use the available resources to build their livelihood strategies (Crowley & Carter, 2000; P Tittonell, Vanlauwe, Leffelaar, Rowe, & Giller, 2005). Literature shows that the adoption of an alternative technology might vary among smallholder farmers due to different socio-economic characteristics (Asfaw & Admassie, 2004; de Graaf, 1996; Leeson, Sheard, & Thomas, 1999; Somda, Kamuanga, & Tollens, 2005). The development of household typologies is a useful tool to assist in unpacking, understanding and categorizing the wide diversity of livelihood strategies among smallholder farmers (Giller et al. 2011). Understanding how smallholder farmers use limited resources (natural, physical, human, financial and social) in terms of their livelihood security and influences on the environment can help identify likely interventions and pathways out of poverty (Ruben & Pender, 2004) (Daskalopoulou & Petrou, 2002; T. O. Williams, 1994). Significant progress has already been made on this subject, with several research groups defining farmer classes using criteria whose elements often overlap across regions and agroecological zones (e.g. Mtambanengwe and Mapfumo 2005; Zingore et al. 2007; Tittonell et al.,2010). Statistical methods such as multivariate data analysis like principal component analysis and cluster analysis enable us to create such typologies, especially with the availability of in-depth data bases. (Kostrowicki, 1977; Pablo Tittonell et al., 2010; P Tittonell et al., 2005).

The use of Principal Component Analysis is necessary to reduce the number of variables in the data, followed by Cluster Analysis to identify typical farm households.

This has been employed previously by (Daskalopoulou & Petrou, 2002; Jansen, Pender, Damon, Wielemaker, & Schipper, 2006; Köbrich, Rehman, & Khan, 2003; Usai et al., 2006). However, both methods have been demonstrated to be very useful but they have their own shortcomings. Principal Component Analysis results in loss of information (I. Jolliffe, 1973, 1986; I. T. Jolliffe, 1993) whereas Cluster Analysis suffers from problems of selecting the right number of clusters (Aldenderfer & Blashfield, 1984; Everitt, Landau, & Leese, 1993).

The classification of 'smallholder farmers' is not only related to targeting technologies, however, but also to understanding how production orientation and resource endowments of different households influence their response to alternative technologies (Carter, 1997). This varies from country to country and from continent to continent. For example, smallholdings in southern Brazil are classified as those smaller than 50 ha, whereas in sub-Saharan Africa (including Malawi), smallholder farmers usually have access to less than 2 ha of land (Bernard Vanlauwe et al., 2014). It is not sufficient to classify farmers solely on the basis of the size of their land or their wealth. There is a need to produce functional typologies (Pablo Tittonell et al., 2010) in order to improve the adoption of alternative agricultural technologies.

To address the issue of heterogeneity among smallholder farmers, a study by Kamanga (2002) introduced wealth ranking (poorest, poor, rich, and richest) to classify farmers in Chisepo in Kasungu District. The major limitation of that study was the issue of sample size and the restriction to a single district. Another study (Andrew Dorward, Fan, et al., 2004) modelled the Malawian rural economy on the basis of seven farm types across three agro-ecological zones (large farms, medium assets, borrower, poor male headed, poor female headed, employed and remittance), using integrated household survey data (IFPRI & NSO, 2002). The study again, was limited by the fact that the authors disregarded the diversity that exists among smallholder farms across as well as within districts and at village level. On the other hand, their main motivation was to use these models to develop a more general understanding of methods of pro-poor growth in a poor rural economy, and were not meant to be used to make detailed extrapolations of likely effects and reactions to particular changes – for example, in new technologies or cropping activities (AR Dorward, 2003). The present study builds upon the work of Kamanga (2002).

Based on literature review, this farm typology addresses, among other issues, the following key issues:

The study focused on disaggregating farms or farmers into typologies as a useful tool to assist in unpacking and understanding the wide diversity among farms, enabling identifying of interventions that should be targeted to specific ‘livelihood domains.’ The study also investigated the opportunities and constraints for improved maize legume intensification and the stepwise pattern and factors that influence the adoption for the adapted conservation agriculture package among smallholder farmers.

The purpose of the typology was to identify relevant farming systems and select representative farms from them to evaluate the response of peasant FSs to local development policies. It was hypothesised that these responses would depend essentially on the resources available, that is labour, land, resource endowment, income and capital among other things and that thus the typology had to be based on those factors.

This should contribute to improving target innovations to address the problem of poor soil fertility in Malawi. To this aim, we tested the typology in terms of its capacity to distinguish patterns of adoption of alternative soil technologies and status among farm types. We analysed socio-economic data rather than socio-cultural factors from the baseline survey data, as the latter exhibits less variation among farmers, clustered households into homogenous groups and studied variability in technology use within each group.

For this study, ‘alternative soil fertility technologies’ refers to maize–legume intensification (improved variety and proportions of land allocated to maize and legumes), and conservation agriculture (minimum tillage, residue retention and crop rotation), which are not generally used in the area of the study.

2.2 Methods

2.2.2 Statistical analysis

A range of several steps were taken to institute the farm typologies following an adapted procedure by (Escobar & Berdegué, 1990) in Köbrich et al. (2003) which involves:

(i) determining the specific theoretical framework for typification
(ii) obtaining SIMLESA project data from CIMMYT
(iii) selecting variables relevant to farm technology adoption
(iv) cleaning the SIMLESA project data set
(v) conducting a factor analysis
(vi) cluster analysis – extraction of factors through principal component analysis following the elimination of variables which produce clusters (I. Jolliffe, 1973).

The main reason for developing the theoretical framework was to outline the purpose of classification and establish the hypothesis to guide the process of typification (Köbrich et al., 2003). This was possible because the inputs which were required at the beginning were the researcher's previous experience and knowledge of the study area and the availability of the quantitative information (SIMLESA baseline data) (Escobar & Berdegué, 1990) in Köbrich et al. (2003). The aim was to obtain a valid summary of the data in order to interpret and predict adoption behaviour (Ferré, 1995).

All statistical analyses were carried out using R software. In the first statistical stage, outliers were removed from the data and missing data was interpolated using a simple mean-imputation method. There was strong correlation between the original and imputed data. In the second statistical stage, we assessed the relevant farm classification adoption variables and removed highly correlated variables based on livelihood strategies to classify heterogeneity (Daskalopoulou & Petrou, 2002) so that only variables that are most commonly used in literature for adoption studies were chosen (Aldenderfer & Blashfield, 1984).

2.2.3 Multivariate statistical analysis

The baseline survey data was analysed, which resulted in the construction of farm household typologies, by successively using two multivariate statistical techniques, namely Principal Component Analysis (PCA) and Cluster Analysis (CA). PCA condenses all the information from the original interdependent variables to a smaller set of independent variables. Reduction of variables is a necessary first step as CA cannot deal with numbers of variables as high as those in Table 2.2 (Jolliffe, 1986; Lewis-Beck, 1993).

In the second statistical stage, we assessed the relevant farm classification adoption variables and removed highly correlated variables based on livelihood strategies to classify heterogeneity (Daskalopoulou & Petrou, 2002) so that only variables that are most commonly used in literature for adoption studies were chosen (Aldenderfer & Blashfield, 1984). Therefore, we performed the Kaiser-Maier-Olkin test (KMO) and Bartlett's sphericity test to address this issue (Lattin et al., 2005; Field, 2005).

A review of publications that deals with farmer classifications indicates that the number of farm types generally ranges from 3 to 5. These farm types were principally defined by variables which included farm size, capital, labour, production pattern and managerial ability ownership of livestock and other assets and the degree of dependence on non-farm income (Table 1). Mtambanengwe and Mapfumo (2005);Tittonell et al. (2005,2010); Zingore et al. (2007); Kamanga et al. (2009); Kamanga (2011) among others basing on their internal and not external attributes (Köbrich et al., 2003). Using both attributes would presuppose rather than show their influence on the identification of farming systems (Kostrowicki, 1977).

Information collected on the various variables was screened prior to factor analysis and those variables that did not show variability were discarded following two steps. Initially, all variables that made little contribution, in terms of variability, to the measure of distance in forming clusters were discarded (Kobrich et al., 2003). Then, some variables that were not relevant to our research objective (which was the typification of farmers for the adoption of alternative technology) were discarded (Berdegue et al., 1990). Furthermore, for each given variable that was highly correlated with another variable, these results were eliminated as their contribution to the measure of distance was reflected by changes in other variables (Aldenderfer and Blashfield, 1984). In addition, all variables with missing data were discarded, instead of using the observations. This was done to meet the requirements of cluster analysis – that if data is missing then the complete observation be discarded (which results in a reduction in the number of farms) or average values used (leads to biasness of results). The final number of variables available for analysis that were consistent with our research aims was 34.

In the fourth statistical stage, in order to deal with the 'dimensionality 'of the problem due to the high correlation of the variables, factor analysis was conducted on the 34 variables in order to reduce the number of variables to 16 (Aldenderfer and Blashfield, 1984). This process is mainly concerned with the consistency of the internal relationships of a set of variables aimed at constructing a set of factors (Lawley & Maxwell, 1971). In other words, observed values (Y) were explained through a linear combination of factors (B) and a residual (E) or Y = XB + E. The factors were called '*common'* when they contributed to the variance for at least two observed variables or '*unique'* when their contribution was only towards one variable. Then the initial factors were extracted which were based on defined factors, principal component analysis (A. Comrey, Lee, Comrey, & Lee, 1992; Kim & Mueller, 1978).

Principal component analysis (PCA) was conducted and varimax method (orthogonal rotation) was chosen as a factoring method because of its ability to load a smaller number of highly-correlated variables onto each factor, resulting in easier interpretation (Field, 2005). This analysis resulted in10 high-loading PCs (Table 2.2) (Zwick & Velicer, 1986) and the eigenvalues of one or more variables were retained following Kaiser's rule (Kaiser, 1960).

However, we chose Euclidean distance (d), where $d = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2}$, to produce four clusters using Ward's hierarchical clustering method (Ward Jr, 1963). The results of this extraction was desirable because it is preferable to retain too many all-encompassing variables than too few (Reise, Waller, & Comrey, 2000) and risk missing some important insights, especially in developing countries.

This is the most commonly used and most straightforward approach and has the advantage that it deals with raw data rather than standardized data, which means that the distance between two clusters is not affected by the addition of new objects to the analysis (which may be outliers).

Ward's hierarchical procedure used retained factors from PCA in performing CA (Alfenderfer and Blashfield, 1984). Ward's method minimises the variance within clusters and tends to find clusters of relatively equal sizes (Kobrich et al., 2003). The numbers of clusters retained from Ward's method were used as starting values in the partitioning clustering method, i.e. the K-means method; consequently, the number of clusters that seemed most realistic and meaningful were chosen for the final solution. The optimal number of clusters was arrived at by using information from the dendogram, which is a product of the Ward's method in combination with the researcher's knowledge of farming in the area (GoR, 2002b). A dendogram is a graphical representation of the hierarchy of nested cluster solutions.

In addition to CA, we performed a one-way analysis of the variance test known as a Levene's test. The test allowed us to identify the differences in variance between clusters (Field, 2005). This way, variables that brought about larger differences between clusters were identified.

2.3 Results and Discussion

2.3.1 Appropriateness of factor analysis measured

The value of the KMO Measure of Sampling Adequacy for this set of variables was .751, and this would be labelled as 'middling' (Snedecor and Cochran, 1983). Since the KMO Measure of Sampling Adequacy meets the minimum criteria, we were not required to examine the Anti-Image Correlation Matrix. Bartlett's Test of Sphericity resulted in an approximate Chi-square of 17317.620, with 435 degrees of freedom at 1% level of significance.

Bartlett's test of sphericity was used to test the hypothesis that the correlation matrix was an identity matrix, suggesting that all of the variables were not correlated. Since the Sig. value for this test was .000, less than our alpha level, this Sig. value lead us to reject the null hypothesis and concluded that there were correlations in the data set and were suitable for factor analysis. This analysis met this requirement.

Table 2.2: *Descriptive statistics of selected variables on socio-economical, production orientation farm characteristics, and levels of adoption of various alternative agricultural technology in the study area

Variables	Balaka (n = 159)	Kasungu (n = 137)	Lilongwe (n = 325)	Mchinji (n = 70)	Ntcheu (n = 109)	Salima (n = 91)
Household size	5.0(1.9)	5.5(2.2)	5.2(2.1)	4.8(2.1)	4.9(2.0)	4.7(1.9)
Age of household head	45.9(16.2)	42.8(14.4)	41.7(14.0)	38.5(15.2)	43.0(14.0)	41.9(17.4)
Education household head	4.6(3.9)	6.7(3.4)	5.4(3.3)	4.9(3.9)	5.9(3.5)	5.0(3.9)
External village support from people	5.8(5.8)	6.2(5.5)	5.0(5.2)	5.5(5.9)	4.0(4.5)	6.5(7.9)
Experience in growing legumes	18.9(25.9)	19.1(23.3)	19.7(24.7)	19.8(26.2)	20.6(23.1)	14.7(20.0)
Average land owned	2.9(2.2)	5.9(7.0)	3.3(2.8)	3.8(2.9)	3.2(2.1)	3.0(2.3)
Maize plot size (ha)	1.5(1.1)	2.2(1.8)	1.7(1.2)	1.7(1.3)	1.6(1.2)	1.8(1.7)
Legume plot size (ha)	0.5(0.6)	0.9(0.9)	0.8(1.1)	1.0(1.0)	0.8(1.0)	0.5(0.5)
Residue retention 0 = No, 1 = Yes	0.8(0.4)	0.6(0.5)	0.8(0.4)	0.7(0.5)	0.9(0.3)	0.67(0.47)
Crop rotation 0 = No, 1 = Yes	0.7(0.5)	0.6(0.5)	0.9(0.4)	0.7(0.5)	0.9(0.4)	0.59(0.49)
Minimum tillage 0 = No, 1 = Yes	0.01(0.11)	0.0(0.0)	0.01(0.08)	0.0(0.0)	0.02(0.13)	0.0(0.0)
Owned sheep & goats (TLU)	2.2(7.7)	2.4(4.2)	3.3(2.2)	0.7(1.4)	2.1(3.1)	1.9(3.8)
Livestock value (US$)*	108.2(288.)	247.8(589)	361(1,187.)	270(1,003.8)	139(196.9)	91.3(167.1)
Access to input market in minutes	92.1(78.6)	115.7(8)	73.2(51.4)	88.7(65.2)	71.2(51.8)	89.6(76.6)
Number of traders outside the village	5.6(5.4)	6.4(6.5)	6.4(5.5)	7.0(7.5)	5.2(5.8)	6.8(6.0)
Number of traders within the village	2.3(3.9)	2.0(2.9)	3.5(4.7)	2.1(3.2)	2.6(3.4)	2.1(3.8)

*Exchange rate was at US$1 = 153.1661 MWK at the time of data collection in 2011. TLU= total live units

2.3.2 Alternative soil fertility technology uptake by farmers

In terms of alternative agriculture technology uptake (Table 2.2), 88% and 85% of the farmers in Ntcheu indicated that they left crop residues on the plot for fertility and were practicing crop rotation respectively. They had the shortest walking distance to the input market of only 71 minutes. Ntcheu was followed by Lilongwe which had 83% and 85% of farmers leaving residues on the plot and practicing crop rotation respectively, with only 73 minutes market access, while in the other sites the figure for leaving residues was less than 70% and very little variation.

2.3.3 Principal component analysis results

Table 2.3 below shows the absolute values of the loadings percentages of the first 10 PCs. The results of the principal component analysis have revealed the various relationships between variables used in clustering. In total, 16 variables were included in the principal component analysis (Table 2.3), of which 10 principal components with eigenvalues greater than 1 have been retained for further analysis (Table 2.3). These 10 variables explain 59.50% of the total variability.

Table 2.3: Absolute values of the loadings of the major classification variables with respect to the first 10 Principal components

Variable	Factor loadings (%)									
	PC1	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC7**	**PC8**	**PC9**	**PC10**
Farm production asset	**0.76**	0.01	0.29	0.16	0.10	0.07	0.01	-0.07	-0.01	0.05
Walking minutes to input market	0.00	**0.94**	0.09	0.04	0.02	-0.03	0.02	0.03	-0.03	0.02
Household size	-0.04	0.01	**0.91**	0.04	0.01	-0.14	0.03	0.10	-0.02	0.03
Consumption equivalent	-0.01	0.02	**0.95**	0.05	0.03	-0.09	-0.01	0.11	-0.05	.01
Total land owned	-0.04	0.02	0.06	**0.86**	0.01	-0.04	0.05	0.11	-0.07	-0.11
Cultivated land summer	0.13	0.08	0.09	**0.91**	0.02	0.02	0.03	-0.04	0.03	0.01
Sum of money equivalent	0.08	0.06	**0.83**	0.09	0.05	0.06	-0.03	0.03	-0.10	-0.07
External village support	0.07	-0.05	-0.09	0.09	-0.06	-0.05	0.09	-0.04	**0.87**	0.00
Media asset value	0.03	-0.04	-0.07	0.08	-0.02	0.04	**0.79**	0.01	0.04	-0.01
Age of household head	-0.04	-0.08	0.00	0.17	-0.03	0.07	0.10	0.06	-0.01	**-0.77**

Looking at each column of Table 2.3, we can clearly define each component according to the variables with which it is most strongly associated. To make it easier to identify relatively large loadings, correlations above 0.7 are in bold. The first component (PC1) had 76% positive loading which explained 12.29% of total variance, and is positively correlated with farm production asset value.

The second (PC2) is almost as important as the first component, and had 97% positive loading, which explained 11% of the total variance and is positively correlated with the distance to the input market. The third (PC3) component had 91%, 95% and 83% positive loadings on the size of the household, consumption equivalent and sum of money equivalent respectively, explaining a total of 7% of the total variance. This factor is positively associated with variables relating to human capital. This implies that farm households with large families were those that have more income, implying off-farm employment.

The fourth component (PC4) had 86% and 91% positive loading on total land owned and cultivated land in summer equivalently explaining 5.9% of total variance. This factor is strongly correlated with access to land by a farm family. The fifth (PC5) and sixth components (PC6) explained 5% and 4% of the variance respectively, with no high loading variable on both PCs.

The remaining four components each explained about 3% of the total variance. The seventh component (PC7) had a 79% positive loading on the media asset value. In other words, information through the media like leaflets, TV, radio or mobile phones is positively correlated with adoption. The eighth component (PC8) showed no higher loading on any of the variables, while the ninth (PC9) component was positively correlated with external village support, with a positive loading of 87%. The tenth (PC10) had a higher and negative loading of 77%, implying that the age of households negatively influences adoption. This result is similar to other findings elsewhere – older farmers are less likely to adopt new or alternate technology.

2.3.4 Cluster analysis results

The dendrogram, resulting from Walds' technique, shows the sequence in which farm households were amalgamated into the clusters that included four cutting lines (Figure 2.1). The most important issue in producing such diagrams was where to 'cut' the tree in order to get an appropriate number of clusters that was adequate for the data set. Shifting the cutting line to the right just below the height of 150 in Figure 2.1), a clear demarcation of four clusters is revealed. Cluster 1 (C1) has the highest number of farmers with 35.13% of the total households. Clusters 2 (C2) and 3 (C3) contributed to 31.43% and 25.36% of the total number of farmers respectively. However, cluster 4 (C4) had the least number of farmers with only 7.52% of the total households under this study. Detailed stratification of the farm types and their livelihoods is explained in detail in sections 2.4 and 2.5 below.

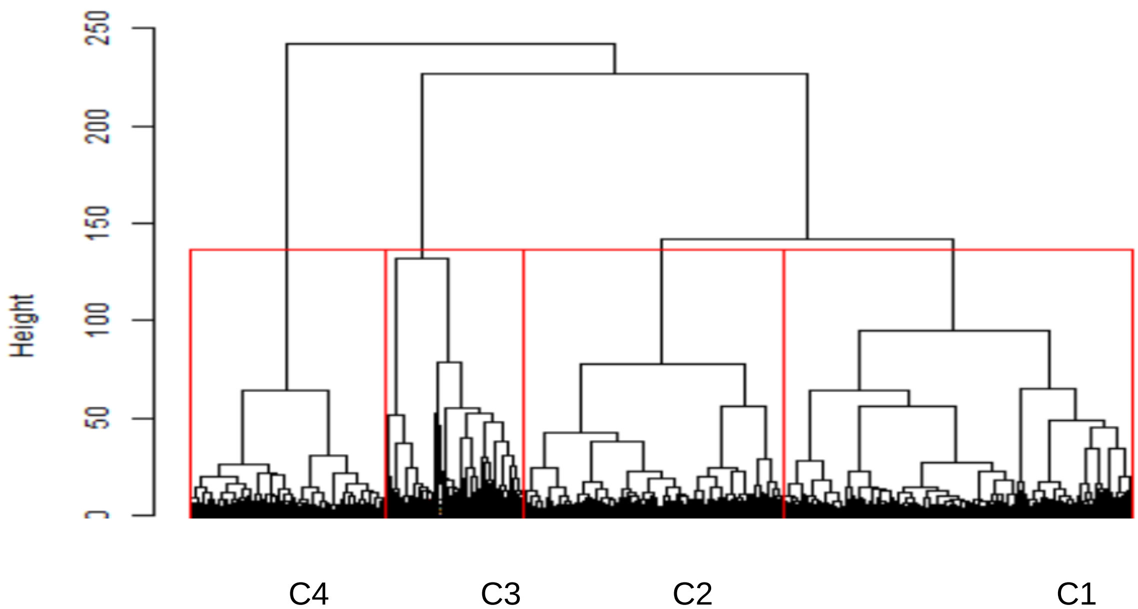

Figure 2.1: Ward's dendogram for four clusters

Dendogram of 4 clusters, N = 891, C1 = 313, C2 = 280, C3 =226, C4 = 67

2.3.5 Indicators of family food sufficiency, wealth and main livelihood strategies

Households were asked to define their family's food consumption in the previous year, taking into consideration all food sources, which included own food production, food purchased, help from different sources, food hunted from forest and lakes (Table 2.3 below). The variables selected for indicator were similar to the ones used in similar studies by Tittonell, 2010. About 19.5% of the farm families from Balaka experienced food shortage throughout the year and in addition 50% of the farmers in the same district had occasional food shortage. This could be explained by the fact that the district has different rainfall potential or they cultivated along the river banks.

Salima was second in line with about 15.4% and 36.3% of farmers facing food shortage and occasional food shortage experience respectively. Balaka had the lowest average farm asset production value (hoes, pangas, ploughs, ridgers) of US$9.99 and an average total income of US$579.56. Although Balaka had almost one-and-a-half times less value of farm production assets than Salima, amounting to $14.12, and an average total income of US$640.43 respectively, farmers from Salima had a higher number of people who experienced no food shortage, at 33%, and those who had food surplus were 15.4%, compared to Balaka which had 22.0% and 8.2% respectively. This could be explained by the fact that Salima farmers had a relatively higher total asset value of US$777.00 (richer than Balaka with the total asset value of US$264.91) and they were both cultivating 0.1hectare along the riverbanks – could be an asset due to low rainfall potential, which has a potential of improving the rain-fed yields of maize. This could also mean that they were able to buy more food (with 2.1 members working off the farm) from the market.

Table 2.4: Indicators of family food sufficiency, wealth and main livelihoods strategies

Indicators of family food sufficiency, wealth and main livelihoods strategies (*A*) Indicators of class of food consumption pattern, taking care of extreme ends where there is occasional food shortage throughout the year up to when the family has food surplus, number of family members who worked off the farm. (*B*)[1] Wealth indicators and farming strategies which is area cultivated and access to land along river banks for winter cropping to supplement the rain fed (summer) cropping.

District (*A*)% Within	Food shortage throughout the year	Occasional food shortage	No food shortage but no surplus	Food surplus	Number of off-farm workers (include ganyu-sale of labour, sale of firewood)
Balaka	19.5	50.3	22.0	8.2	2.1
Kasungu	4.4	38.0	38.7	19.0	1.4
Lilongwe	2.5	36.6	36.3	24.6	1.0
Mchinji	8.6	35.7	25.7	30.0	0.4
Ntcheu	7.3	32.1	33.0	27.5	1.6
Salima	15.4	36.3	33.0	15.4	1.0

(*B*[1]) Within	Average asset value owned (US$)	Average farm production asset value (US$)	Average total income (US$)	Cultivated Summer (ha)	Cultivated Winter (ha)
Balaka	777.00	9.99	579.56	2.58	0.07
Kasungu	467.48	26.15	3,595.47	4.53	0.17
Lilongwe	1,231.52	43.96	1,023.09	3.02	0.18
Mchinji	285.97	44.20	17,009.32	2.94	0.29
Ntcheu	591.24	10.84	926.89	2.66	0.13
Salima	264.91	14.12	640.43	2.84	0.1

B[1] Absolute values have been converted to United States dollar from Malawi Kwacha (MK), using the exchange rate of US$1: MK153.47 during the time data was collected (March, 2011)

2.4 Farm types and stratification

Four types of farms were demarcated from the 891 farm families by multivariate statistical methods, using resource endowment, current technology use and production orientation as criteria (Tables 2.5 and 2.6 and Figure 2.1). Household classification was based on several variables, mainly: total land owned; total land cultivated in summer; land cultivated in winter; maize plot size; livestock ownership and livestock products; farm production assets; value of productive asset value; time taken to walk to the plot; number of males in the household; amount of stored maize still available; holding size; possession of a farm plan; consumption equivalent; external village support; and the number of traders known by the farmer, both within and outside the village (Appendix A1). Variable selection was adapted from previous similar research on farm typology elsewhere by Tittonell et al, 2010.

These farm types were: Type 1 farms (35.13%) were classed as ‘small subsistence-oriented family farms’. Type 2 (31.43%) were classed as ‘small semi-subsistence family farms’. Type 3 (25.36%) were classed as ‘survivalist’ or ‘mixed’ (small, independent, semi-specialised family farms whose main objective was family sustenance). Type 4 (7.52%) were classed as ‘production-oriented, small, dependent, semi-specialised family farms’. The source of this classification for these four clusters was Daskalopoulou & Petrou, 2002 and are presented in Table 2.5 (appendix 1)disaggregated according to the six sites

The four farming systems were consistent at all sites, with very little difference in winter cultivation, which may have been due to geographical similarities. The age of the household head was not very different in all farming systems. Conservation agriculture component technology uptake across the sites was analysed. In both Ntcheu and Lilongwe, more than 80% of the farmers left crop residues on the plot to improve soil fertility, and 85% practised crop rotation and/or intercropping with legumes. Minimum tillage was the least practised component of the conservation agriculture package at all sites except Ntcheu, where about 20% of the farmers practiced minimum tillage.

2.5 Categories of household diversity

2.5.1 Type 1: Small subsistence-oriented farm families

The household rather than the farm component of the system was the focus when analysing these farms (Tables 2.5 and 2.6). While most farms were growing a wide range of crops (e.g., maize, millet, cassava, sweet potato, beans and groundnuts) and keeping a range of livestock (e.g., poultry, sheep, goats, cattle, pigs and/or rabbits), others were based on only one or two crops (e.g. maize and beans) and livestock such as poultry only. Totally self-sufficient farms were uncommon, but self-sufficiency remains their functional objective, just like in (Tittonell et al, 2010; Daskalopoulou & Petrou, 2002). Type 1 farms also tended to have a higher production asset value (hoes, axe and plough), which may explain the possible reason for the low adoption of minimum tillage and also as indicated by the results members of the household provided labour for tilling the farm, although 30% indicated that they worked off-farm. similar results have been reported elsewhere (Daskalopoulou & Petrou, 2002).

However, Types 1 and 2 farms shared many characteristics: some three-quarters of both farm types practiced crop rotation / intercropping and crop residue retention. They also had the second-largest land area allocated to legumes (Type 4 farms had the largest; see Table 2.6 in the appendix 2). They had the smallest household size, averaging 4.87 members, who contributed only 31.68% of the farm labour on their land, and consequently relied on hired labour for the remainder where they reported that payments was both in cash and food items.

2.5.2 Type 2: Smaller semi-subsistence farm families

Family sustenance was the basic goal of this farm type (Table 2.6), firstly by producing food crops for consumption and materials to be used on the farm. Secondly, the farm family aimed to generate some cash income for the purchase of essential items for the household – salt, milling of maize into flour, clothing, bicycles (the main mode of transport for farmers) and farming requirements such as pesticides, herbicides and fertilizer. This, among others, entailed the sale of produce like maize or beans that were excess to family needs, and the sale of some cash crops such as tobacco and cotton.

Most farms cultivated only during the summer season, except in the Mchinji and Ntcheu district where about 0.1 ha was cultivated during winter using treadle pumps, watering-can irrigation and through the use of residual moisture, which consisted essentially of maize and leguminous crops.

These families cultivated the land they owned to its maximum intensity, which was limited by rainfall or the amount of land available for river-fed (*dimba*) cropping. They were quite dissimilar to all other farms in terms of the number of crops and livestock and their products, and how they used them. The possible explanation could be that these farmers were young and still exploring, and they looked outside their community for new knowledge and gave themselves an advantage in the market partly because of their age (average 39.5 years) and also a higher average education of 5.28 years. This finding is similar to previous research elsewhere by Feder and Umali (1993), who found that farmers with title deeds were more likely to invest in conservation agriculture practices than those on rented land. On average, they indicated that they knew 5.9 traders outside the village who could buy their farm produce, which enabled them to earn a substantial amount of income from farming (48%). For example, a maize field might have been managed in such a way as to yield more than one primary product – for example, green pick for sale or roast, dry pick which was pounded or milled to produce flour for a thick porridge served with beans, meat and/or vegetables, as well as live stripped stalks to support bean crops, fodder for livestock, firewood, and the husks from the grain for brewing a local dry gin, known as '*kachasu*', for sale.

2.5.3 Type 3: Survivalist or 'mixed' small farm families

The main characteristic of Type 3 farms was that, in addition to being family sustenance-oriented (Tables 2.5 and 2.6), they were also small, independent family farms that specialised in a particular cash crop such as tobacco, cotton or legume, or in livestock such as poultry or fish farming. This differentiated them from the mixed Types 1 and 2 farms, and their individuality in farm management distinguished them from Type 4 farms. They sold part of their production, which made them partly commercial. They were also a subtype of Type 1 subsistence farms, but differed from the main body of near-subsistence farms in that only one main cash-crop production activity was pursued. Farmers in Salima and Ntcheu were keeping crop residues on the plot and this was the major technology they practiced, which was very seldom done at the other four sites. while the rest of the sites were not. The possible explanation for this could be that the studied locations influenced the adoption of conservation agriculture. This confirms previous studies (Ngwira, Johnsen, Aune, Mekuria, & Thierfelder, 2014) which found that some districts had a higher adoption rate than others..

Farmers in Balaka and Kasungu were not using the improved legume variety and consequently they were less interested in food crops than either cash crops or livestock. They operated at dual levels of technology – 'advanced' for some main crops (particularly tobacco), and 'traditional' for the rest: even when using improved maize or legumes they were not leaving residues from winter cropping. They were giving full employment to the family members and had a very small percentage of family members working away from the farm, therefore high demand of tobacco farmers.. They relied mainly on purchasing farm necessities rather than making them – for example, manure. This cluster comprised the oldest and least educated farmers, at an average age of 46.95 years and with 4.26 years of education. They participated least in the market, as revealed by indicating that they knew only 4.1 traders outside the village who could buy their farm produce. The possible explanation for this low adoption could be since there were older with little education had high commitment but limited market channels or information. This finding is in consistent to other research elsewhere it was found that older farmers rarely adopted improved farm technology (Kassie et al, 2014).

2.5.4 Type 4: Production-oriented small family farms

Type 4 farms were small and specialised, but relied on large estates where they sold tobacco to the landlord. They owned more land than the others (Tables 2.5 and 2.6). Other than their dependence in terms of decision-making, they were not very different from Type 3 in that they were money-making and almost at subsistence level. The only difference from all other farm types was that, as tenants, their high level of specialisation in tobacco growing was largely dictated by their landlord.

This lack of independence was a result of two factors:

a) Structural integration: Small, resource-poor farming families were incorporated more or less closely as production members of a larger tobacco-processing system that specified the time of planting, when to weed, the amount of fertilizer to be applied and when to start harvesting the ripe tobacco. They then sold it to the landlord at whatever price he decided to pay, regardless of its true value. The landlord sold it on, at a profit, to either the Tobacco Control Commission (TCC) or the Limbe Leaf Tobacco Company (LLTC). The tenant received advances for his farm inputs from the landlord, including foodstuff for the family, which was deducted at the end of the season. These payments were presented as attractive loans. Generally the farmer had no choice but to accept, then could only repay the amount – or gain their independence – by continuing to grow tobacco and sell it to the landlord on his terms.

b) Government directives: In Malawi, tobacco farmers lack independence in production decision-making due to lack of alternative market outlets. Although these farmers are specialists, there is no real independence in farm management because the only place to sell their produce is to the TCC and/or the LLTC (Mangisoni, Katengeza, Langyintuo, Rovere, & Mwangi, 2011). The prices are dictated by the government through auction floors buyers each season, and farmers either lose or make a profit. Tobacco growing is a gamble, and growers have no power to decide where to sell it. It is too bulky to transport to the main market or to better outlets, so that farmers resort to selling to middle-men who exploit them with low prices. There are also leakages from cross-border trade to neighbouring countries (Andrew Dorward, Morrison, Wobst, Lofgren, & Tchale, 2004). Type 3 and 4 farms were not usually self-sufficient in resource generation, as for example in farms continuously cropping tobacco, discussed above. Such farms exist with only minimal purchased inputs such as tobacco seed. The upland near-subsistence maize farms in Ntcheu and Salima had very low levels of adopting an improved maize variety and minimum tillage , and relied instead on retained 'local' seed. Some of these farms are located closer to the suppliers of inputs and product markets and that way could buy improved seed. The possible explanation for this partial package adoption of CA could be that farmers want to try part of the components and appreciate the results before adopting fully. Our findings revealed that farmers were not adopting the whole package, which is consistent with previous research on conservation agriculture (Ken E Giller et al., 2011).

2.6 Socio-economic diversity among smallholder farmers

The information derived from the semi-structured interviews was expressed in terms of both average values for different socio-economic indicators (e.g. family size, number of cattle) and frequencies (%) for categorical data, indicating the degree of adoption and/or use of management practices and inputs at the six sites (Tables 2.5 and 2.6). Variables selection was based on variables frequently used in farm categorization studies (Pablo Tittonell , 2005, 2011)**.**

The area, in hectares, of land under cultivation during winter has been compared to the total area cultivated in summer, in order to suggest the farmer's willingness to accept risk, given the small average size of their arable land during the summer rains, and the persistent problems of shortage of land along river banks, which they either rented, borrowed or inherited. Farmers cultivate small fields, largely less than1 ha, and given that rainfall is unimodal, there is considerable expansion of agriculture to marginal lands (Chikowo et al, 2014). Similar analysis was used in an earlier study on technology adoption elsewhere (Kassie, Jaleta, Shiferaw, Mmbando, & Mekuria, 2012b) which found that farmers tended not to use improved technologies on rented or borrowed land.

There was not much difference between some of the socio-economic indicators across the six sites. Mean household sizes in the six sites were almost equally distributed, ranging from 4.7 in Salima to 5.5 in Kasungu. The heads of households in Kasungu reported higher mean education levels than was the case for households in the other five sites. The average age of the head of the household ranged from 38–46 years in the six sites; the youngest farmers were in Mchinji, and the oldest in Balaka

However, there was variation between the sites regarding farm families who supplemented their food production by engaging in winter cropping. Owning land along riverbanks encouraged farmers to be more receptive to technologies, and increased the probability of adopting new practices in such places as Balaka where the average landholding is very much smaller than other sites. Similar results have also been reported in other studies elsewhere (Emtage Nicholas 2012). It was also noted that the income from off-farm activities in Balaka increased to 72.5% of the total farm income when compared to other sites; for example, in Salima only one adult was working off-farm, providing an average off-farm income of 49.7%, yet they were spending 58% of their income on food. This is consistent with previous research findings for Malawi (AR Dorward, 2003) which indicated that farmers with a high off-farm income spent more on food. On the other hand, more than 51% of farm families in Balaka experienced food shortages throughout the year, or occasional food shortages. In Ntcheu, an average of 60.1% off-farm income could be from selling vegetables (cabbages, tomatoes, onions and potatoes) at roadside locations.

The proportion of family members working off-farm in Balaka was about 21%, which was 17% more than in Mchinji. Although Balaka had more family members working on the farm, Kasungu had the highest proportion of income (72.5%) from off-farm activities, even though fewer farmers were engaged in off-farm activities. This finding gave the impression that Balaka farmers were either working more cheaply or were employed in manual labour for minimal pay. Own farm labour land was calculated without hired labour. Although Kasungu had an average of 1.4 adults per family working off-farm, they also adopted conservation technologies. Possible explanation could be that they have money which could possibly have enabled them to have income to purchase farm necessities for the largest area cultivated in summer. This supports previous research, which found that wealthier farmers have higher levels of technology adoption (Kassie, Jaleta, Shiferaw, Mmbando, & Mekuria, 2013). Kasungu farmers were cultivating substantial upland areas and along river flats, with the largest area of land under cultivation. Kasungu had the second-highest land ownership, cultivating the largest land area along the riverbanks to supplement the rain-fed crops.

Lilongwe farms had the higher number of livestock on average (Table 2.5 be), amounting to 1.4 cattle, goats, sheep and chicken with a value of US$269.89. Farms in Salima had the fewest livestock. However, there was very little variation in the value of livestock at the other four sites (US$108.18–$247.80). The total value of livestock (poultry, cattle, pigs and/or rabbits) was highest in districts with large farms. The explanation for this could be that farmers with a large land area and livestock had the highest probability of adopting agricultural technologies, because they already used manure to fertilize the soil. This is consistent with previous research elsewhere (Bidogeza, Berentsen, De Graaff, & Lansink, 2009; Chikowo et al., 2014).

Lilongwe farmers reported that they knew at least 1.4 more traders in the village who could buy their farm produce, which was more than the other sites, but they knew 0.6 fewer traders outside the village who could buy their farm produce (both dry and fresh) than all the other five sites. Ntcheu and Lilongwe were located at the shortest walking distances from the main market, which could be reached in approximately 70 minutes. It took Kasungu farmers a further 45.5 minutes to walk to market than Lilongwe and the other sites. It was also revealed that farmers in Ntcheu and Lilongwe have the highest levels of adoption, and are located at the shortest walking distance from the market for farming needs. This could possibly be explained by the fact that having access to information and markets increased the chances of technology adoption This confirms findings in Zambia (Ngombe, Kalinda, Tembo, & Kuntashula, 2014) which indicated that farmers' proximity and access to markets improved their agricultural knowledge.

2.7 Chapter summary

This section provides a summary of the study findings. It also draws out conclusions. The objective of the study was concerned with examining the diversity among smallholder farmers that influence the adoption of alternative farm technologies. It was motivated by low and regionally varying levels of adoption of alternative farm technologies, despite efforts to develop and disseminate them and promote uptake.

This study used a multivariate analysis approach that employs the use of PCA and CA consecutively to clearly define four typical farm households within the six SIMLESA sites with respect to alternative farm technology, using socio-economic factors. The data on 34 variables from 891 households were evaluated by multivariate statistical methods. PCA identified 10 PCs that accounted for 59.50% total variance in the original 34 variables. These 10 factors were then used in cluster analysis to typify farm households.

Results led to the identification of four farm types among smallholder farmers. Type 1 farms were characterized by small land size and occasional food shortage with a relatively high usage of residue retention and intercropping/ crop rotation. Type 2 represented households that were near subsistence with small land. Like Type 1 they adopted residue retention and intercropping / crop rotation but these were involved in market participation for both inputs and outputs. Type 3 farm types were independent in decision making in terms of production. They were market oriented but had less adoption levels of alternative farm technology. Type 4 farms represented tenants whose production decisions were dependent on their landlords. They participated in the market for their production.

The study has underlined the heterogeneity of farm families in relation to current technology use and the determinants of future use of alternative farm technologies. As some types seem to have better possibilities of adoption than others, extension messages need to be focussed on specific groups, such as these four farm types. Therefore, in building models for portraying farm family decision-making situations, classification of farming systems is the fundamental step.

CHAPTER THREE

Opportunities and constraints for maize and legume intensification among smallholder farmers in Malawi

3.1 Introduction

This chapter addresses the second objective of the thesis. Firstly, it seeks to explore household level factors that determine farmers' investments in the intensification of the improved maize and legume varieties in general. Secondly, methods which farmers use for intensification are assessed and factors that specifically influence farmers' decision on each intensification method are measured. The next section (section 3.2) of the chapter discusses the importance and declining levels of maize production, which is fundamental to the rural livelihoods, as maize is generally referred to as '*Chimanga ndi moyo'* – literally translated as 'Maize is life'. For the purpose of this study, 'maize–legume intensification partial analysis' is defined as: i) mono-cropping of improved maize seed, ii) monocropping of improved legume seed, and iii) intercropping of improved maize and legume seed.

Therefore, the rest of the chapter is organised as follows: Section 3.3 discusses literature on the potential of legumes in improving the production of maize and soil fertility in Malawi and the focus of the study. The methods used in the study are presented in section 3.4. Results of the analysis are presented in section 3.5. Section 3.6 then presents a discussion of the findings, and finally, section 3.7 concludes the chapter with a summary.

3.2 Importance and declining levels of maize production

Maize is Malawi's main staple food crop and is of strategic importance as the country's food security status is generally defined in terms of adequate availability of and access to maize. It contributes about 50–90% of the calorific intake -the large discrepancies could possibly other parts of the population supplement maize with rice, potato etc .This is poorly diversified diet dominated with starchy staples – making Malawi the highest per capita maize consumer in the world at 148 kg per person per annum (J. Mazunda & Droppelmann, 2012; HR Mloza-Banda & Nanthambwe, 2010; Smale & Jayne, 2003).

The crop is almost exclusively produced by smallholder farmers under rain-fed conditions, and is cultivated on over 70% of the arable land, which constitutes 89% of the land grown on cereals. Besides being cultivated on a large area, there is still a big difference in terms of the yields between what farmers actually get from their farms and those from experimental trials. For instance, the yields of local maize variety have rarely reached 1.5 tonnes per hectare; for hybrid maize these levels have been fluctuating between 1.5 and 2.5 tonnes per hectare in the past one and half decades, while the potential yields for hybrid ranges from 5–8 tons per hectare (J. Mazunda & Droppelmann, 2012; HR Mloza-Banda & Nanthambwe, 2010).

Following the Malawi food crisis of 2005 (FAO and WFP 2005), a large-scale farm input subsidy programme (FISP) was introduced during the 2005/06 crop season to tackle some of the key constraints faced by Malawian small farmers, including low yields and high costs of inputs. The main feature of the FISP is the provision of vouchers for seeds and fertilizer for maize production, targeting approximately 50% of small-scale farmers, which means the other half of the farmers are still struggling to afford inputs at high costs (Denning et al., 2009).

Even so, maize production has increased considerably, mainly due to the farm input subsidy program, with national maize production almost tripling within the first two years of the program from 1.06 million metric tons to 3.62 million metric tons between 2005/06 and 2011/12 (John Mazunda, 2013; Tchale, 2009). However, this was short lived as yields declined again in 2012/13 due to poor rains in most parts of the country (Andrew Dorward & Chirwa, 2011). In general, the agricultural productivity of the majority of Malawian farmers, particularly smallholders, continues to fall below average in spite of the available improved farm technologies (Tchale, 2009).

Therefore, maize production in Malawi is under risk, placing pressure on agriculture growth at levels adequate to provide foodstuffs for the growing population (NSO, 2008).

Due to diminishing landholding sizes, the most feasible motivating force to increase food production and alleviate poverty for the resource-poor smallholder farmers is enhancing the dissemination and adoption of diversified production of foods with high nutritive value (dietary fortification and nitrogen fixation) crops like the intensification of grain and legumes to farmers (Graham & Vance, 2003; B. C. Kamanga, 2002; Kankwamba, Mapila, & Pauw, 2012; Kumwenda, Waddington, Snapp, Jones, & Blackie, 1996; Mthakati Alexander R Phiri, Chilonda, & Manyamba, 2012; S. Snapp et al., 2003; SS Snapp, Phiri, & Moyo, 2013; S. S. Snapp & Silim, 2002; Tchale, 2009). The key grain leguminous crops include *Phaseolus vulgaris* (common bean), *Vigna unguiculata (*cowpea), *Glycine max* (soybean), *Cajanus cajun* (pigeon pea), and A*rachis hypogaea* (groundnut) which can be grown in association with maize crops. However, adoption levels of improved technologies still remain low (Smale, 2005; S. S. Snapp et al., 2002a; S. S. Snapp & Silim, 2002; Thierfelder, Cheesman, & Rusinamhodzi, 2013).

Usually, most smallholder farmers in Africa do not have access to adequate inorganic fertilizers, which limits soil fertility improvement opportunities for agriculture. Latest efforts to replenish and sustain soil nutrients in southern Africa incorporated legume cropping as one of the most cost effective and feasible means of food and soil fertility improvement among the smallholder farms (Kumwenda et al., 1996; P. Mafongoya, Bationo, Kihara, & Waswa, 2007). Previous research, in Malawi and elsewhere, has revealed that intercropping more legumes into maize systems makes available a low-cost source of soil nitrogen (N), which also helps in the fortification of cereal-based diets by providing cheap protein (Gilbert, 2004; B. C. Kamanga, Kanyama-Phiri, Waddington, Almekinders, & Giller, 2014; Kerr, Snapp, SHUMBA, & MSACHI, 2007; SS Snapp, Mafongoya, & Waddington, 1998). Even though legume technologies might not create enough N in the short run to produce potential maize yields, they still provide substantial quantities of soil N that can improve yields of maize. This could also stop soil fertility depletion at an affordable price and reduced risk for the resource-poor farmers (Ken E Giller, 2001; Mapfumo & Giller, 2001; Waddington, 2003).

3.3 Potential of legumes in improving maize production and soil fertility in Malawi

Including grain legumes either as an intercrop or in rotation with non-legumes conserves soils resources in subsistence agriculture (Cromwell & Winpenny, 1993; Leonard Rusinamhodzi, Corbeels, Nyamangara, & Giller, 2012; Thapa, 1996). Grain legume intercrops are mainly promoted because: they are able to reduce soil erosion by rapidly covering the soil surface (Ken E Giller & Cadisch, 1995); they suffocate weeds (Liebman & Dyck, 1993); increase atmospheric nitrogen (N_2) fixation (Ken E Giller, 2001); reduce diseases and pests (Trenbath, 1993); spread labour needs (Lithourgidis, Dordas, Damalas, & Vlachostergios, 2011); and improve land use efficiency (R. Morris & D. Garrity, 1993; R. Morris & D. P. Garrity, 1993).

Smallholder farmers usually strive to achieve food security and family nutrition, largely through diversification into non-maize food crops (Kankwamba et al., 2012; Ojiem, Franke, Vanlauwe, de Ridder, & Giller, 2014). But farmers in the tropics often prefer the grain–legumes to green manures because of their ability to contribute to food security (Ken E Giller, 2001) and dietary fortification (FAO, 2015). This is due to the fact that multi-purpose grain–legumes such as pigeon pea (*Cajanus cajan* (L.) Millsp.) when included in cereal–legume rotations in the tropic regions (Baudron, Tittonell, Corbeels, Letourmy, & Giller, 2012; Ken E. Giller, Witter, Corbeels, & Tittonell, 2009) are able to produce significant amounts of better quality organic matter inputs, resulting in increased productivity benefits than offered by continuous mono-cropping (DUùA & ROMAN, 2015; N. L. Hartwig & Ammon, 2002; Rochester, 2011; Schmidt, Clements, & Donaldson, 2003). Therefore, it is important for scientists to develop and promote varieties that are able to meet multiple farmer conditions such as improved food security, and an ability to tolerate and or improve low nutrient soils (B. C. G. Kamanga, 2011; L Rusinamhodzi & Delve, 2011; S. S. Snapp et al., 2002a)..

Although nitrogen (N) is the most abundant nutrient element in most soils, it is also the main nutrient element that limits plant growth in most agricultural systems because it is not readily available to plants (U. A. Hartwig, 1998; Vance, 2001). Decades of intensive cultivation by smallholders, in the absence of significant inorganic use of fertilizer, means soils nutrients have been depleted, predominantly nitrogen (Sanchez, 2002). N fertilizers have been used widely for several years as a methods to increase grain yields but high prices have made it almost impossible for resource-poor farmers to use (Vance, 2001). The relatively high population density in central and southern Malawi (at three times higher than in neighbouring countries for example, with 150 people per km^2 in Malawi compared with that of Zambia at only 14 per $km^{2)}$ (NSO, 2008), as well as the unforeseen upsurge in fertilizer costs has been the potential driving force for legume intensification and organic-matter based technologies (Adams & Mortimore, 1997; Wezi Grace Mhango, 2011 ; Mortimore, 1993; S. S. Snapp et al., 2002a).

Using legumes through rotations or intercropping is now regarded as an alternative and sustainable way of introducing N into lower input agro-systems (Fustec, Lesuffleur, Mahieu, & Cliquet, 2011). Previous farm research has shown that intimate interaction between plant roots and soil microflora is able to convert the most abundant but relatively inert form of nitrogen (N), atmospheric N_2, into biological substrates available for the growth of other plants, through two sequential processes; namely, N_2 fixation and N rhizodeposition. Therefore, if legumes are in companion with non-leguminous crops such as maize in intercropping, companion plants benefit from biological fixation by legumes and subsequent transfer of N from legumes to non-legumes (companion crops) through a process known as rhizodeposition (Fustec et al., 2011). It is against this background that scientists suggest that legumes possess characteristics that are regarded as a critical component of conservation agriculture (Meyer, 2010), which is confirmed by a recent meta-analysis study (Leonard Rusinamhodzi et al., 2011). Therefore, intercropping of maize and legumes seems to be a positive step in improving food production and attaining ecological intensification (Doré et al., 2011), helping to achieve positive social outcomes by producing more food per unit resource while conserving the environment (Cassman, 1999; Hochman et al., 2013).

Although there has been a wide interest in these low-cost technologies among the MoAFS and others (Kumwenda et al., 1996; S. S. Snapp et al., 2002a; S. S. Snapp & Silim, 2002), little research has been done to formally study the socio-economic factors that may positively or negatively influence smallholder farmers' intentions to invest in maize–legume intensification activities in these SIMLESA project sites in Malawi. The challenge is the ability to increase the food security of farmers through the improvement of soil productivity without creating new constraints (P. L. Mafongoya, Kuntashula, & Sileshi, 2006). The intercropping of grain legume crops into maize gives us a good start as intensification and diversification options because of their multi-purpose nature (food, fodder and soil fertility) and also because they need minor initial capital investment.

Accordingly, we hypothesised that if maize–legume intercropping is acceptable to the majority of farmers in an environment where soil disturbance through ridging and continuous mono-cropping is the order of the day , then it is a cheaper way to get rid of the binding constraints of poor soils, unreliable rainfall and drought that are characteristic of central and northern Malawi.

Therefore, the focus of this study was to assess the suitability of the maize and legume intensification activities among smallholder farmers in order to lessen the biophysical and socio-economic limitations that are mainly faced by smallholder farmers. To achieve this, household-level determining factors of farmers' investment in the maize–legume intensification activities were assessed among a sample of 891 farmers from six SIMLESA districts in Malawi. Indicators for both positive and negative influence on farmers' investments are defined, procedures for their determination are described and their general implications for future targeting and dissemination of these technologies in Malawi are discussed in the conclusions in Chapter Five. But the question still remains: *What factors influence an individual household's decision to participate or not to participate in the maize–legume intensification activities?*

3.4 Main approaches of the study

To assess the factors that influenced farmers' investment in the intensification of maize and legume activities among the smallholder farmers, a two-step multi-analysis criterion of the data was used to explore the factors. The first step Exploratory Factor Analysis (EFA) was used to reduce data to a similar set of summary variables and to identify the structure of the relationship between the variable and farmers' decision in the intensification of maize–legume activities. The second step was to calculate the number of farmers involved in each intensification activity namely, intercropping of maize–legumes, mono-cropping of improved maize and mono-cropping of improved legume varieties. Finally, possible factors that influenced farmers' choice of each intensification activity were analysed using a two-level random-effects logistic models.

3.4.1 Exploratory Factor Approach (EFA)

The main aim was to identify factors that help explain farmers' choice of improved maize and legume intensification activities. Therefore, factors were clearly identified from principal components through factor analysis: where they were well-established and located with respect to each other in factor space of marker variables. (Kline & Barrett, 1983). Since it is not easy in such studies to stipulate a 'target matrix' of expected factor loadings in enough detail to allow a unique solution, we jointly factored the marker variables with the new variables that farmers perceived to be attractive in the maize–legume intensification activities to a simple structure (Cattell & Horn, 1978; Nunnally & Bernstein, 1978). This step was necessary, although not sufficient, as it has been widely accepted that instituting a simple solution is essential (Lim et al., 2013; Thurston & Spengler, 1985), although not an adequate step when trying to demarcate replicable factors (Kline & Barrett, 1983). However, our sample was larger than 100, and was therefore quite sufficient and no replication of results was necessary (Guilford, 1956; Kline, 2014).

Therefore, in our study we adopted the five steps of Exploratory Factor Analysis (EFA) Protocol by Williams et al., (2012) which uses multivariate statistical computer packages involving several linear and sequential steps. The data analysis was conducted using R-software in integration with the Statistica program. EFA using principal component (PC) method with Varimax rotation package was chosen because it yields simple structure, as it has the advantage that the factor loadings are equivalent to the original analysis (Kaiser, 1958). Estimates based on EFA are more likely to generalize to confirmatory factory analysis (CFA) than those obtained from PCA in that, (Floyd & Widaman, 1995) unlike PCA, EFA and CFA are based on the common factor model. This is a noteworthy consideration in light of the fact that EFA is often used as a precursor to CFA in scale development and construct validation. Analysis was conducted on a correlation matrix and it was considered a very good sample of 891, well above the recommended 200 (A. L. Comrey & Lee, 2013; VanVoorhis & Morgan, 2007). Therefore it met the required *a priori* assumptions (Costello & Osborne, 2011). This is desirable because it produces more accurate results for research involving human behaviours by being similar to the oblique rotation method, which produces factors that are correlated (B. Williams, Brown, & Onsman, 2012).

In the first step, a total of 57 variables were selected (Appendix 1) from the survey data that have been frequently identified by other researchers as being influential in the adoption of an agricultural technology. These were explored through EFA (Feder & Umali, 1993; Kassie et al., 2013). Since the purpose was to examine the dimensionalities and psychometric properties of the variable, on that basis, 39 variables which had higher loadings > 0.65 on the first nine factors were identified and named.

The main goal in using EFA was to provide a better solution by extracting the highest factor loadings (Swisher, Beckstead, and Bebeau (2004), which resulted in large amounts of the proportional variance being explained. Therefore, Principal Components Analysis (PCA) was chosen as the method for factor extraction because the factors were real combinations of variables (Kline, 2014). Also PCA was recommended in establishing preliminary solutions in EFA (Pett, Lackey, & Sullivan, 2003), as well as being the most commonly used in the published literature (Thompson & Daniel, 1996). Variables were discarded using the B2 and B4 methods (I. Jolliffe, 1973) which associate a variable with each of the first PCs and reject those variables associated with the last few components due to their minimal contribution. The number of variables rejected (those that were not highlighted) in our case had a smaller eigenvalue of <0.65 associated with each of the PCs. Orthogonal Varimax was chosen as a suitable factor rotation method because it is simple to interpret the results (Thompson, 2004) and also it contributes to the structural validity of the measurement model (Tarkkonen & Vehkalahti, 2005).

In order to simplify factor solution, we simultaneously used two criteria procedures since no single criteria (Scree test or Kaiser rule) was giving a clear choice due to the confusing nature of factor analysis. This multiple decision rules to determine factor extraction is also reinforced by Thomson and Daniel (1996) and (Hair, Anderson, Tatham, & Black, 1995).

3.4.2 Multilevel variable analysis

In the second step of analysis, we categorised mono-cropping of improved maize varieties, mono-cropping of improved legume varieties and intercropping of improved varieties of maize and legume into binary outcomes as described in Venn diagram (Figure 3.1 below) and considered variables with high loading factors in our modelling.

The significance of maize–legume intensification activities among smallholder farmers through three cropping systems models was investigated:

a) mono-cropping of improved maize varieties
b) mono-cropping of improved legume varieties
c) intercropping of improved varieties of maize and legume.

Our aims were to find out:

a) how each model influences farmers' decision in growing improved varieties of maize and or legumes in each cropping systems
b) factors that were significantly influencing farmers' involvement in investing in each of the cropping systems models for the intensification of improved maize–legume varieties.

Therefore, in order to find the effects that each cropping system will have on farmers' intentions, three random-effects logistic models were estimated on all variables retained from EFA results (Table 3.2). The multilevel variable analysis models (univariate followed by multivariate) executed, used a stepwise backwards elimination procedure to identify variables that were significantly associated with the outcome variables of the study. To avoid any statistical bias, the backward elimination method was double-checked using the following procedures:

a) only variables that had a p-value of < 0.20 obtained in the univariate analysis were entered for backward elimination process
b) the backward elimination was tested by including all the potential determining factors (< 0.20)
c) any collinearity in the final models was tested and reported.

Ordinary ratios (ORs), standard errors (SEs) and 95% confidence intervals (CIs) were calculated to assess the factors that affected the study variables outcome, and those with $p < 0.05$ were retained in the final models. However, for the sake of space and clarity in data presentation we only reported the final random-effects models with ORs, SEs and their significance. The three separate models containing CIs are attached as Appendix 2 to this thesis, should there be a need to view them.

The Venn diagram below revealed that 72% of the farmers were involved in all the three cropping systems models having plots with improved maize only, improved legume only and mixed cropping of improved varieties of maize and legume. This means that the majority of the farmers in the study were practicing mixed cropping. This is not surprising because farmers are cultivating several kinds of crops for food security but due to land constraints with an average land holding size of 1.2ha (FAO, 2015), they can only achieve that through mixed cropping. The analysis also shows that, only 13% of the farmers were involved in mono-cropping of improved maize varieties only and 2% of the farmers were doing mono-cropping of improved legume varieties only. However, only 14% were not doing any of the three cropping systems models and the possible explanation for this could be that they were still growing maize and legumes but they were not using not using improved varieties.

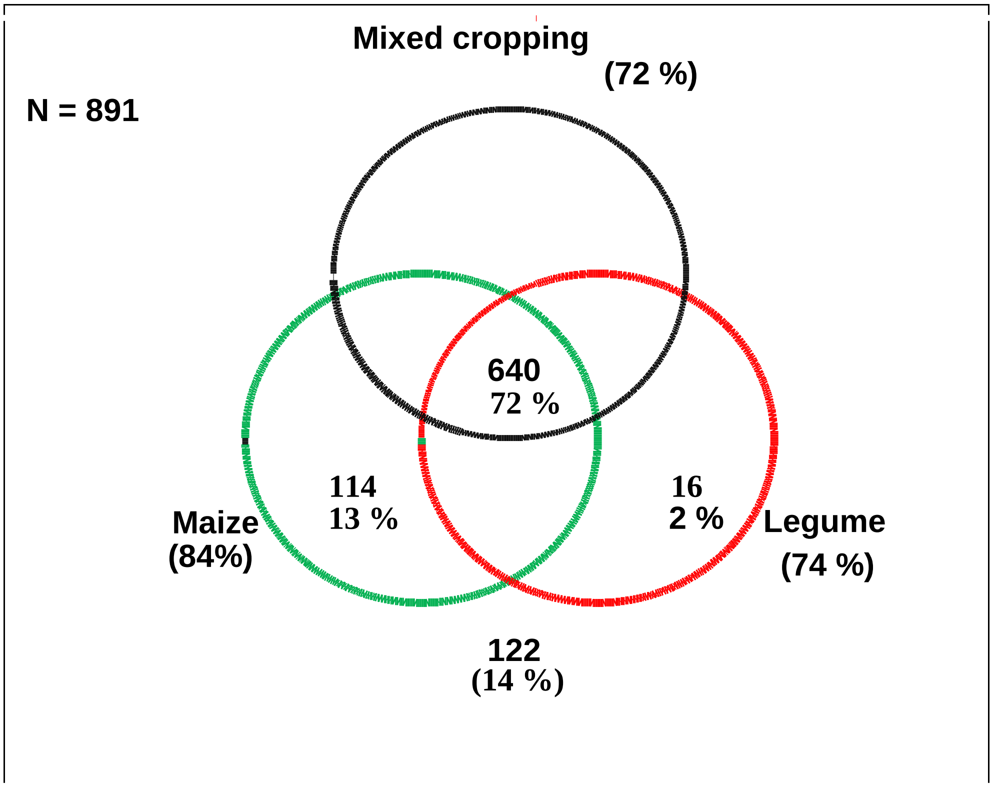

Figure 3.1: The Venn diagram of the outcome variables used in the study

3.5 Results and Discussion

In this section, descriptive statistics of the respondents' profile are presented, along with an EFA table showing factor loadings, number of farmers involved in each farming system and empirical results from the random-effects modelling. The maize and legume intensification activities were measured on the basis of the 891 baseline household survey data from CIMMYT. In the appendices, we also present original results from EFA (Appendix 1) and original random-effects models (Appendix 2).

3.5.1 Respondents' profile

Table 3.1 (appendix2), presents descriptive statistics that summarize the respondent profile according to the six sites of 891 households and the variables used in the analysis. Heads and family members of households who participated in the decision making of the farm activities, who were not part of the project beneficiaries, were considered to be the target population. The majority of the respondents were male-headed households 83.8%, with female-headed households only 16.2%. In all, only 17.8% of the respondents were from the southern region while 82.2% were from the central region, which means our study strongly represented farmers whose main legume crops grown were grain legumes like, cow peas, phaseolus beans and ground nuts. The majority of household heads had some form of education – about 43.2% had 5–8 years of education, while 14.4% had no education at all and only 21.2% had a post primary education level. Almost all heads of the households, about 92.1%, indicated crop farming and livestock as their main occupation while 4.9% had salaried employment as their secondary occupation. The variables shown in Table 3.1 were used in the EFA and subsequently in the multilevel modelling.

3.5.2 Variance explained in percentage and number of factors extracted

Upon the inspection of the Scree plot criteria (Cattell, 1966), in combination with the Kaiser's criteria of eigenvalue > 1 rule (Kaiser, 1960), a departure from linearity coinciding with a nine factor solution was evidenced which enabled us to settle for 71.9% of the cumulative percentage of variance explained. When determining the number of factors to be retained, we employed both multiple criteria and reasonable reflection to avoid overdependence on one factor and extracting few factors (Henson & Roberts, 2006; B. Williams et al., 2012; Zwick & Velicer, 1986).

A meaningful interpretation of at least two to three or more variables attributing to each factor (Thompson, 2004) were descriptively and subjectively labelled (Pett et al., 2003) for all the nine PCs, as shown in Table 3.2 (appendix4).

3.5.3 Factor analysis results

Table 3.2 shows extraction of the Varimax normalized factor loadings, with variance explained in percentages; cumulative variance explained in percentages; and Cronbach alpha (α) coefficient associated with each of the nine factors with an eigenvalue of greater than one explained 71.98% of the of the variance of the small holder farmers in the study area in Malawi.total variability. Looking at each factor row of Table 3.2, we defined each component according to the variables with which it is most strongly associated.

Seven of the nine factor loadings in the factor analysis showed the expected positive signs while the remaining two exhibited negative signs. The factor loading coefficients of distance to the market plus infrastructure, and variety and characteristic of pigeon pea legume were negatively associated with farmers' investment intentions in the technology. These two factor loadings had the highest Cronbach alpha coefficient of 0.90, indicating some lack of acceptability of the traits in pigeon pea legume. The possible explanation could be that farmers preferred phaseolus vulgaris (common beans) because it has fast cooking time and good taste. This finding is similar to previous research elsewhere the adoption of pigeon pea remains low (Snapp and Silim, 2002a). Distance to the market had negative loading, this could be explained that there was a constrained acquisition of inputs as the farmers had to walk a long distance or pay high transport costs to obtain inputs. This section therefore concludes that the above nine factors are correlated with farmers' investment decisions in the intensification of maize and legumes.

The Varimax-rotated factor arrangement (Table 3.2 in Appendix 3) suggests that the first factor concerns 'access to land' (5 items, α = 0.81), explaining 18.86% of variance. This factor is positively correlated with land size cultivated in summer, maize plot size and total landholding (owned, rented or borrowed) both in winter and summer and uncultivated land in winter. Large land size increased farmer participation.

The second factor relates to "access to information and extension training", (8 items, α = 0.83) explaining 13.77% of variance. This factor is positively correlated with farm planning, crop residue retention, improved variety of maize and legume, livestock production, pest in the field and storage Having information increased farmer participation.

The third factor concerns "distance to market and infrastructure", (5 items, α=.90). This factor is negatively correlated with distance to main market, inputs market and distance to the health centre. The long distance to the market decreased farmers participation in the maize-legume intensification.

The fourth factor concerns “winter crop production”, (5 items, α = .82). This factor is positively correlated with maize stover, nitrogen fertilizer, maize production, soil fertility, maize yield and available labour for maize winter” Having access to *dimba* for winter production increased farmers intention to invest in the maize legume intensification.

While the fifth factor concerns “characteristics of the bean legume”, (4 items, α= .80). This factor is positively correlated with bean stover, storability, bean plot size and bean yield. Farmers positive perception about the bean legume increased participation in the maize legume intensification.

The sixth factor concerns “household composition”, (3 items, α =.79). This factor is positively correlated average household size, adult equivalent and number of males in the household. The larger the household size and the higher the number of males or adults in the households increased farmers participation in maize legume intensification.

The seventh factor “livestock and livestock production”, (3 items, α=.79). This factor is positively correlated with total number of cattle, the value of livestock sales of animal products. The higher the number and the value of livestock and its products, the higher the farmer participation in the maize legume intensification.

The eighth factor concerns “characteristics of the head of the household”, (2 items, α = 0.79). This factor is positively correlated with experience in growing maize and the average age of the head of the household. It is also negatively correlated with average education of the head. Having older farmers with long years of experience in growing maize increased farmer participation while higher education levels negatively affected the adoption of maize legume participation.

The ninth factor concerns “the variety and characteristics pigeon pea legume”, (3 items, α=.90). This factor is negatively correlated with the size of the plot allocated to pigeon pea, stover and the production of pigeon pea. Having access to pigeon pea seed discouraged farmers to farmers to participate in the maize legume intensification.

Reliability for each of the factors was obtained using the calculation of a Cronbach's alpha coefficient. The Cronbach's alpha coefficients ranged from 0.79 to 0.90 for all the nine factors (Table 3.2 in Appendix). All the factors were above the cut-off criterion of 0.7 which is the acceptable rule of thumb (Nunnally 1978). However, Peterson (1994) suggested that an alpha value of 0.6 is the 'criterion-in-use'. Therefore, this suggests that all factors were well above the 'criterion-in-use' and thus acceptably reliable. The Cronbach's alpha was increasing as the correlations between the items increase and this is desirable because the goal in designing a reliable instrument is for scores on associated items not only to be internally consistent, but for each to contribute some unique information as well, (Peterson, 1994).

3.5.4. Empirical results

EFA results retained nine factors with 96% marker variables of >0.65 which influenced the intensification of improved maize and legume activities. However, the question that remained was whether this difference was a result of their direct influence per se or some other explanatory variables such as the cropping systems followed. The regression results below attempted to answer that question.

In all the regressions, three models were specified for the intensification of maize–legume intensification. The first model included the cropping system of both maize and legume improved varieties (intercropping); the second model included cropping of improved maize variety only; and the third model included cropping of legume variety only. All the regressions were based on the 891 observations for which data was available for all the explanatory variables.

As expected, variables were positive and statistically significant in all the models. These variables related to access to land (land owned in winter, land owned in summer, land uncultivated in winter, land allocated to the pigeon pea legume), access to information and extension training services (farm plan formulation, storage pest management, field pest management), distance to market (walking minutes to the inputs market, walking minutes to the village market) and total labour available from family members

3.5.5 Random-Effects Logit Regression results and discussion

In this study, the intensification of maize and legumes activity of smallholder farmers for food security was investigated using the SIMLESA baseline survey data for the 2009/10 growing season. The main reason was to shed light on the presence, types, levels and factors that influence farmers' investment behaviour in the maize–legume intensification activity. The main focus was on the number of farmers involved and factors that differentiated the activity between improved maize–legume intercropping, improved maize mono-cropping and or improved legume mono-cropping. In doing so, the intensification characteristics such as intercropping of maize and legume versus mono-cropping of either maize or legume improved varieties, number of farmers involved, and factors that influenced farmers investment in each activity were analysed.

Following Rosenbaum and Rubin (1983), Green (1997), Angrist (2001), and Amare et al., (2011) two different methods – first multivariate and second econometric techniques – were applied to correct for potential bias in estimating the factors and variables that influenced households' decisions on the adoption of maize–legume intensification. However, after the multilevel modelling, most of the 9 factors and 39 variables that were found to be significant in the exploratory factor analysis were found not to be significant through random effects models. Only four factors and nine variables were found to be significant. Farmers' investment in maize–legume intensification is significantly determined by two factors (EFA) and four variables for all the three model variables.

Table 3.3 Random-effects logit results for the maize–legume intensification in the SIMLESA baseline survey

Variable	Model(1) Maize–legume intercropping	Model(2) Maize cropping only	Model(3) Legume cropping only
Constant	0.239 (0.071)	0.655 (0.223)	0.288 (0.076)**
Walking minutes to farm inputs market	0.994 (0.002)**	Na	Na
Walking minutes to village market	1.014 (0.007)*	Na	Na
Total owned land in summer season	Na	1.192 (0.061)**	Na
Farm plan formulation /training	Na	2.139 (0.554)**	Na
Pigeon pea plot size	Na	Na	0.254 (0.166)*
Total owned land in winter season	1.232 (0.062)**	Na	1.168 (0.057)**
Total labour availability	0.998 (0.001)**	0.998 (0.001)*	0.999 (0.001)*
Uncultivated land in winter season	0.805 (0.059)**	0.822 (0.055)**	0.847 (0.061)*
Fieldpest treatment information	18.889 (5.821)**	5.875 (2.306)**	19.159 (6.022)**
Storage pest treatment information	3.254 (0.977)**	4.546 (1.845)**	3.910 (1.179)**
Observations	891	891	891
Groups (districts)	6	6	6
Wald $chi^2(6)$	269.35	146.41	266.07
Prob > chi^2	0.000	0.000	0.000

Log likelihood	-294.56872	-252.27895	-277.6019
Rho	0.078 (0.057)	0.078 (0.057)	0.034 (0.032)
Likelihood-ratio test of rho=0:			
chibar2(01)	8.57	12.35	4.38
Prob >= chibar2	0.002	0.000	0.018

Notes: $chibar^2$ = The likelihood ratio test statistics of rho; Wald chi^2 = The Wald hypothesis test statistic for the model.

Each cell lists the coefficients (b), the coefficient transformed to the odd ratios (OR) (i.e., e^b instead of b), and the absolute value of the standard errors are in parenthesis (** = significance at 1% and *=significance at 5%).

Rho is the proportion of the total variance contributed by the panel-level variance component. If Rho equals zero, then the panel estimation and the pooled estimator are not different.

The Likelihood-ratio test compares the panel estimator with the pooled estimator through the null hypothesis that they are not different.

Table 3.3 above, presents the random effects logit regression results for the SIMLESA survey-based maize–legume intensification indicator (maize–legume intercropping, maize only, and legume only).

We find access to information through extension systems and training meetings on field pests, storage pests' treatment, land left uncultivated in winter season (along the river banks) and total household labour availability to have a significant positive effect on intensification through all the three model cropping systems. Farmers who were closer to the inputs and village markets were another important determinant of maize–legume intensification through one model only of the maize–legume intercropping system.

Having land ownership (not title per se) in the summer season (upland), receiving training in farm plan formulation and abiding by it, also positively influenced the intensification of improved maize varieties through the mono-cropping system only. However, owning land in the winter season (river banks) explained the variation in farmers' investments to only be in two cropping systems – the maize–legume intercropping and mono-cropping of legumes for intensification. The most plausible explanation could be that farmers with access to riverbanks land generally have higher intensification behaviour than their counterparts who only have access to upland because they can take advantage of the winter season by practicing the new technology therefore risk of losing crop is spread. Similar results were also reported by previous researchers in Tanzania and elsewhere, who found land and extension to be significant in improving adoption – Amare et al., (2011), Shiferaw et al., (2008) and Gebreselassie and Sanders (2006).

Farmers' with access to larger land size held (not title per se) were most likely to participate in mono-cropping of maize in winter and intercropping of maize–legume. This could be explained by the fact that if farmers have a large piece of land they can practice the new technology on part of it and carry on the conventional technology so that they are sure of not losing their crop. This finding is consistent with previous research in Malawi and it was found that the adoption of improved technologies was positively associated with the large size of cultivatable land (E. W. Chirwa, 2004; Green & Ng'ong'ola, 1993; Obare, Mwakubo, & Ngigi, 2002; Zeller, Diagne, & Mataya, 1998).

Farmers who received information were more likely to participate in all three intensification models. Information on farm plan formulation and abiding by it during the cropping period increased farmer participation. The possible explanation for this could be due to the fact that extension is a primary instrument through which the government policies are spread to the smallholder farmers by agriculture extension officers in Malawi, therefore farmers were able to receive messages on good agricultural practices (Chowa, Garforth, & Cardey, 2013). These findings are consistent with the role of information and learning in a framework of role of risk, uncertainty and learning in adoption of agricultural technology (Marra et al. 2003).

The negative relationship between the market and adoption of technology showed that farmers who travel a long distance to reach the markets, via main roads, did not participate in the intensification activities. This could possibly be explained by the fact that farmers indicated that they planted legume seeds recycled from previous year's harvests; hence buying seed is not common amongst many farmers in Malawi. This finding supports previous research from Malawi and elsewhere that has also shown the same negative relationship between poor access to markets and low technology adoption (Ibrahim, Rahman, Envulus, & Oyewole, 2009; Jansen, Rodriguez, et al., 2006; B. C. Kamanga, 2002; B. C. G. Kamanga, 2011; Pender & Gebremedhin, 2008). On the contrary, other studies have found a positive influence between access to market and the adoption of new technology (Kankwamba et al., 2012; Kassie et al., 2012b; Kassie, Zikhali, Pender, & Köhlin, 2009).

The positive influence of winter season cultivation increases farmer participation. This could possibly be due to the fact farmers indicted that they practice *dimba* cropping in winter because it supplements food production at the time when the household is running out of food by utilising residual moisture, watering can or treadle pump irrigation. This finding confirms previous research where it was suggested that most households seek to secure sufficient maize as their primary objective by cultivating beyond the rainy season, which reinforced adoption (Arellanes & Lee, 2003; Ellis, 1998; Ellis, Kutengule, & Nyasulu, 2003; Kassie, Jaleta, Shiferaw, Mmbando, & Mekuria, 2012a).

The ability of the bean variety to resist both field and storage pests, and having the characteristic of high yielding varieties would positively influence the size of the plot allocated to the bean legume (*Phaseolus vulgaris*) in mono-cropping or intercropping. This could possibly be explained by the fact that farmers like varieties that are high yielding because they assist in keeping the house food secure. This finding is consistent with previous research in Malawi and elsewhere, where farmers indicated that a legume that has the possibility of meeting more than one household need such as food security and soil fertility improvement, has a high chance of being adopted (R. Chirwa & Phiri, 2006; R. M. Chirwa, Aggarwal, Phiri, & Mwenda, 2007; Gebremariam & Edriss, 2012; Graham & Vance, 2003; B. C. Kamanga, 2002; Wezi G Mhango, Snapp, & Phiri, 2013; S. S. Snapp & Silim, 2002).

Larger households, with a larger number of males and larger number of adult equivalents, had a positive effect. The most reasonable explanation could be that more labour available to invest in the labour demanding activities associated with maize–legume intensification. This finding is consistent with previous research here they found that larger households were likely to adopt labour intensive agricultural technology as they are able to provide family labour at the time this is available (Kankwamba et al., 2012; Kanyama-Phiri et al., 2000; Leach & Winson, 1995; Marenya & Barrett, 2007; Takane, 2008; Wall, 2007b; Whiteside, 2000).

The positive significant effect of having high livestock value and large numbers of livestock establishes an important component of the wealthier farms in the area, which closely integrates animals with crop activities. This could possibly be achieved by generating fodder for livestock, draught power and manure to sustain the fields by enhancing the efficiency of fertilizer to increase farm yields. This finding supports previous research elsewhere on the adoption of high yielding varieties and the increase in livestock products including manure, which assisted in soil fertility improvement. (Jansen, Pender, et al., 2006; Kassie et al., 2009; Marenya & Barrett, 2007; Cheryl A Palm, Gachengo, Delve, Cadisch, & Giller, 2001; Rashid, Haroon, & Nasir, 2014). However, other researchers have found a negative influence of high value of livestock and farmers investment in land management technologies (Adimassu, Kessler, & Hengsdijk, 2012).

The positive effect on intensification of the household head having long years of experience in growing maize activity might influence older farmers who are more experienced in the world of farming, with lessons learnt from previous training and mistakes from not participating. The age of the farmer also showed a positive effect on adoption, which is not surprising to us because more experienced farmers adopted and these experienced farmers had long years of experience. This could possibly be explained by the fact that as the number of years of practicing CA increases, and therefore more knowledge and experiences are gained on CA, the likelihood of allocating more land to CA increased, as farmers responded to, labour savings, and soil quality improvement among others . This finding is consistent with previous research where experience increased the probability of adoption (Ngwira, 2014 (Nyanga, 2012).

Surprisingly we found that, a higher level of education of the household head had a negative influence on farmers' intention to invest in maize–legume intensification activities. This could possibly be due to the fact that any additional years in education reduced the adoption of improved technologies because most farmers indicated that they were involved in preferred salaried employment elsewhere. This finding is in agreement with previous research both in Malawi and elsewhere where education discouraged adoption (Kankwamba et al., 2012; Pender & Gebremedhin, 2008). However, the finding also contradicts other research which found a positive relationship between adoption and education. (Ibrahim et al., 2009; Minot, 2006). This could possibly be explained by the fact that as people get more educated, they understand the benefits of adopting new technology than the less educated.

The negative effect of the small size of the plot allocated to pigeon pea legume (*Cajanus cajan*), influenced farmers' investment decisions in the maize–legume intensification activities. This could be explained by the fact that most farmers indicated that they did not perceive pigeon pea as the legume that they would produce on their farm and, because of its perennial nature after harvest free range goats like to feed on this crop which is a loss to farmers. This supports previous research in Malawi where farmers indicated that the crop was easily destroyed by farm animals, pests and diseases (B. Kamanga et al., 2010);(Waldman, et.al., 2016).

The negative effect of the amount of stover produced, negatively influenced farmers' decision in investing in maize–legume intensification activities. This could be explained by the fact that since this was an improved variety, it produced more yield than biomass hence farmers in this area felt that pigeon pea did not produce enough stover to be used both as animal feed and for soil fertility. This finding is supported by previous research elsewhere where farmers' perceptions about biomass and soil organic matter from legumes (and maize) and management of legumes were relevant to the adoption of soil fertility improving technologies (Ken E Giller, 2001; Marenya & Barrett, 2007).

The negative effect of low production (yield) associated with improved pigeon pea variety in this area due to frequent dry spells had a strong and negative influence on farmers' investment in the maize–legume intensification activities. Pigeon pea is mainly grown because it is regarded as a good plant for human protein and restoration of soil fertility, and is also grown as a hedge around the maize plot in this area instead of in rotation, due to land shortage. The possible could be explained by the fact that farmers land holding sizes are small and they usually practice intercropping with legumes and this pigeon pea is a tall legume, which means that it competes with maize for light. This confirms previous research showing that farmers have an intimate knowledge of their local environmental conditions, production problems, crop priorities and criteria for evaluation and experimentation as part of their evaluation of farming routine (Ong & Daniel, 1990; M. Phiri, 1999; Sieglinde S Snapp, Jones, Minja, Rusike, & Silim, 2003; Sumberg, Okali, & Reece, 2003)

3.6 Chapter summary

This section provides a summary of the study findings of Chapter Three. The objective of the chapter was to assess whether maize–legume intensification technology under the SIMLESA project was suitable for the smallholder farmers in central and southern Malawi (SIMLESA project sites) and attract imminent adopters. Therefore, we explored the determinants of adoption of three practices: use of improved maize varieties in mono-cropping system, use of improved legume varieties in mono-cropping, and use of maize–legume varieties in intercropping systems.

Exploratory factor analysis was used to reduce the data and preliminary explore variables that would determine the adoption of the maize–legume intensification practices. Factors that exhibited loadings of 0.50 or more were subjected to three different models for intensification that we developed, namely: mono-cropping of maize, mono-cropping of legumes and intercropping of maize–legume improved varieties.

Factors that were found significant with exploratory factor analysis – such as household size, age, education, experience of the farmer and the variety and characteristics of bean legume variety – were dropped in all the three intensification models. This revealed that two-stage analysis managed to sift out specific factors that were associated with farmers' investment decisions to grow more improved varieties of maize and legumes. In general, farmers seem largely to invest in the intercropping of maize–legume and mono-cropping of maize only, which largely translates to issues of land availability.

Even though, most farmers (72% of the total sample) preferred intercropping of maize–legume as the most affordable way to intensification , where land was a constraining factor, as has been commonly seen, farmers preferred to cultivate the whole piece of land with improved maize only. In summary, these empirical results strongly support the positive role of farmers' access to land in the intensification of maize–legume intensification, but the positive role is stronger for land left uncultivated in winter cropping for all the intensification activities.

PART III: Blanket recommendation of CA package to farmers

CHAPTER FOUR

Stepwise adoption of an adapted conservation agriculture package: Evidence from smallholder farmers

4.1 Introduction

This chapter focussed on investigating the pattern and factors that influence farmers' decision making in relation to the adoption of individual components of an adapted conservation agriculture package (CA). It addresses the third objective of the thesis. The chapter sets out with a brief discussion of the literature on technological package promotion for smallholder farmers in section 4.2. For this study, the adapted CA package components include residue (RR) retention, minimum tillage (MT), crop rotation (CR) and use of herbicides (HU). According to the study profile, the adoption pattern will be analysed for the years 2010, 2011 and 2012 growing seasons. This adapted CA package is different from the universal FAO definition of CA as it includes herbicide use as a fourth component instead of containing just three (RR, MT &CR).

The rest of the chapter is organised as follows: Section 4.3 discusses farmers' response in the uptake of packaged technologies. Section 4.4 explores some general theories that can help explain the application and adaptation of innovative agricultural technologies and whole package adoption. Section 4.5 examines the variables that explain adoption according to previous research and the methods to analyse the adoption process. The results of the adoption pattern and factors that influence adoption of the components are presented and discussed in section 4.6 and finally, a summary concludes the chapter in section 4.7.

4.4 Overview of Literature on whole package adoption

In efforts to improve food security in the midst of the growing concerns due to the implications of many conventional agricultural practices which have led to soil degradation, low agricultural productivity and poverty, scientists and the Food and Agriculture Organization of the United Nations (FAO), among others, have “naturally” endorsed a package of soil conserving practices under the banner of ‘conservation agriculture’ (CA) (Knowler & Bradshaw, 2007). This universal CA package entails three components including minimum soil disturbance, permanent soil cover with residue retention and/or the association of legumes as cover crops, and crop rotation (Thierfelder et al., 2014; Wall, 2007a). Proponents of CA have generally argued that a package is necessary for farmers to benefit from the positive connections that exist between the three components (Derpsch, 2005; P. Drechsel, Gyiele, & Cofie, 2001; FAO, 2011; Ken E. Giller et al., 2009; Stoorvogel & Smaling, 1998).

Several studies have also been carried out in the area of ‘technology packaging,’ where many agricultural technologies were made available at a given time as a package (Byerlee & De Polanco, 1986; Lele & Goldsmith, 1989; Charles K Mann, 1978). Researchers observed that farmers often chose only a part of a given technology package (Leathers & Smale, 1991), as opposed to the whole, and that they generally followed a stepwise process of adopting different pieces even though the components were strongly complementary. Leathers and Smale (1991) presented a theoretical model showing it could only be rational for imperfectly informed farmers to undertake stepwise adoption, even when farmers were risk neutral and the entire package would be more profitable if adopted. Furthermore, most previous empirical studies in developing countries have assumed that farmers do not view the timing of technology adoption as important. Several studies have also focused on the double selectivity of technologies which are related, but not from a single package (Khann and Madhu, 2001).

Other studies carried out have analysed the factors influencing agricultural technology adoption, focusing on a single improved technology (Caswell & Zilberman, 1985; Feder et al., 1985; Feder & Umali, 1993; Griliches, 1957; Leathers & Smale, 1991; R. K. Lindner, Pardey, & Jarrett, 1982; Marra, Pannell, & Ghadim, 2003). This work generally focused on the adoption of a single new technology or a set of new technologies viewed by farmers as a single unit. The objectives have been to find what determines whether farmers adopt or reject an innovation (Feder, Just, & Zilberman, 1982; Ghadim, Pannell, & Burton, 2005; R. Lindner, 1987; R. Lindner & Pardey, 1979). Farm characteristics influencing adoption that were commonly explored included farm size, land tenure, and other biophysical traits (Baidu-Forson, 1999; Nowak, 1987; Rahm & Huffman, 1984). Household characteristics, which included gender, age, education of household head, family size and other demographic traits, institutional factors such as credit constraints, availability of market information, and availability of extension services have also been examined.

Furthermore, most previous empirical studies in developing countries have concentrated on the partial adoption of CA rather than on the idea that farmers view each component in the package of adoption as important on its own. These were the issues that this current study focused on. As will be demonstrated, the sequential nature of adoption and enhancing the factors that influenced the inclusion of each component of the CA package were critical for the future packaging of the CA technology. Although this literature is extensive, little consideration has been focused on the simultaneous adoption within a single package of technologies. No work that we are aware of addresses the sequence of how CA technology adoption depends on which component is adopted first. The assumption is that farmers will adopt the minimum tillage first because hand weeding is a major concern for family labour (Wall, 2011). For the purpose of this study, and in relation to the study area, the adapted CA package components comprising of residue retention, minimum tillage, crop rotation and the use of herbicides will be analysed.

4.5 Materials and methods

4.5.1 Data and variable selection

This study used data from a household survey conducted by Western Sydney University. A questionnaire approved by the Human Research Ethics Committee for H9891 titled: *Malawi Farming Systems and Conservation Agriculture* was administered to the heads of households or members of the 134 households (panel of 402) who participated in decision making in farm operations (details in chapter 2).

The choice of variables which were assumed to influence the farmers' behaviour over adoption of CA were grouped into four categories. These variables included farmer and farm household characteristics, farmer experience, plot characteristics, wealth and household food availability, and access to markets, and have been summarized in Table 4.1 (Appendix 5). This study took into consideration previous study findings about factors that have affected the adoption of farm technologies like CA in variable selection (Kassie et al., 2012b; Ngombe et al., 2014; Nyanga, Johnsen, & Aune, 2011). In this study, an ‘adopter’ was considered to be someone who was practicing one or more CA components. This was considered to be stepwise decision manner adoption and the study involved looking at all possible combinations of adopting the four main components; three were the base of CA: minimum tillage, residue retention, crop rotation with legumes. (Kassam et al., 2009) and the fourth, use of herbicides according to our study area.

4.5.2 Econometric modelling sequential adoption of CA components

While sequential adoption and the impact of each CA component on adoption behaviour might be treated as distinct issues, we expect that sequencing is a better approach of modelling technology adoption behaviour for smallholder farmers with inadequate resources in the poor soil-fertility prone areas such as Malawi. If we ignore the fact that farmers view the CA components as pieces, adopted one after the other, this will possibly lead to inconsistent estimates of the effects of household characteristics on adoption. For instance, a non-sequential model of adoption would treat a package of four components to be adopted at different times as a single alternative, but a sequential model would rely on considering components of the package as four dissimilar choices, depending on which component was the first to be adopted (see Figure 4.1). The econometric specification we used incorporates the sequencing of technology adoption considering a rational farmer who has a discrete choice of combinations from 1 to 10. Farmers may view the adoption of one component before another as a choice that is distinct from adopting in a different sequence or adopting all of them at once. Each adoption was categorized as binary outcomes and multivariable analyses were used to assess the independent effect of each adoption, after controlling for other related covariates. All statistical analyses were conducted using STATA/MP

V.12.1 (StataCorp, College Station, Texas, USA) and multilevel binary regression models were fitted using STATA survey commands to adjust for the variability of clustering which were the districts.

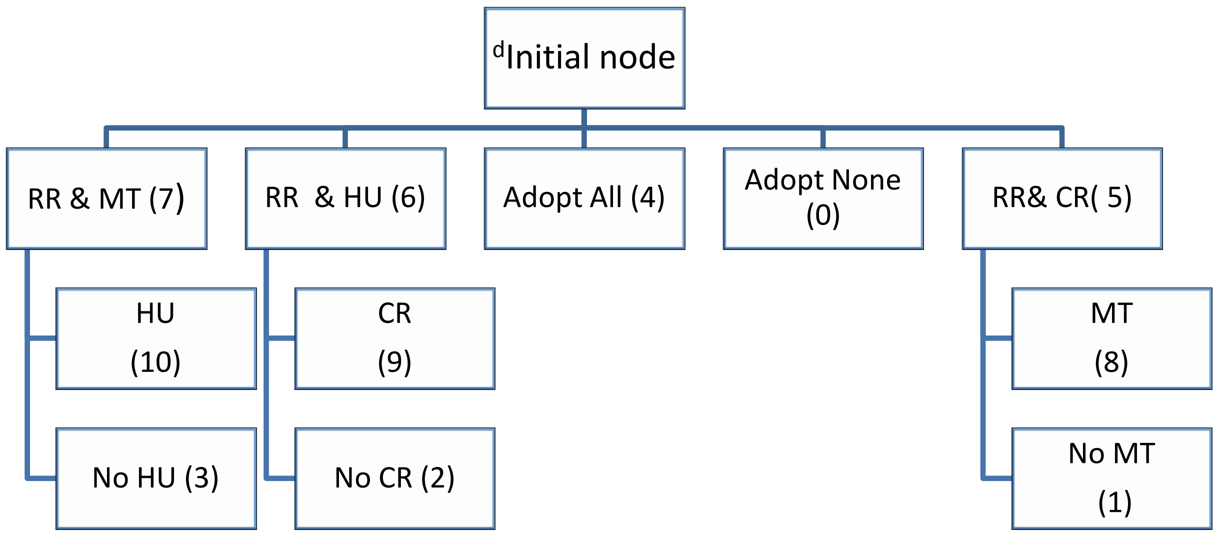

Figure 4.1: Stepwise decision-making tree of 1 to 10 potential farmer choice preferences for conservation agriculture components adoption

[d] RR = residue retention, MT= minimum tillage, CR = crop rotation, HU= use of herbicides

Due to cost-effectiveness, resource constraints, levels of risk, and lack of information about the 'new technology', sequential adoption is crucial to the decisions different households make. Figure 4.1 summarizes the choices of technology practices when space or timing of adoption is considered. Farmers were faced with an adapted package with four components, which offered:

a) retention of residues on the field instead of the traditional burning of residues done by farmers
b) minimum soil disturbance by placing seed using a jab planter
c) crop rotation (association of legumes because CR is non-existent)
d) use of herbicides to kill weeds and therefore reduce labour demand on the family.

Adoption of residue retention component is considered as first step in this situation because it is the one that is highly adopted among farmers. The first step would usually be that most farmers would consider adoption of residue retention and minimum tillage. For other farmers, residue retention and herbicide use may precede the residue retention and crop rotation. Others may choose to adopt all practices at the same time or nothing at all. But farmers might have an opinion about the components and view them as different practices to be adopted in some order; therefore, all combinations must be treated as potential choice preferences. Disregarding the possibility of sequencing would lead to mistakenly reducing the available choices.

4.5.3 Modelling approach

Consider the utility U of a rational farmer p who has a discrete choice of adopting component q. We used multilevel logistic regression to model and to examine covariates for a farmer adopting any of the component q. The probability of a component is defined as $P_{ijk} = Pr(y_{ijk=1})$, where $y_{ijk\,=\,1}$ indicates that the ith household of the jth farmer living in the kth district adopting any component q and the logit transformation of P_{ijk} is modelled as a linear function of the covariates in the model.

$$Log[P_{ijk}/(1 - P_{ijk})] = X'_{ijk}\beta_1 + X'_{jk}\beta_2 + X'_k\beta_3 + \mu_{jk} + \nu_k \qquad (1)$$

Where μ_{jk} is the farmer-level and ν_k is the district-level that are each normally distributed with zero mean and variance σ_u^2 andσ_v^2, respectively. Assuming that the observations are independent of condition on μ_{jk} and ν_k, which capture any observed effects common to household from the same farmer and the district. The strength of unobserved farmer and district effects with the intra-cluster correlation coefficient for the farmer (ρ_j) and district ρ_k can be summarised.

The first estimate reduced form model shown in equation (1) includes only the household (X_{ijk}), farmer (X_{ij}) and district (X_i) covariates. Adding intermediate household (W_{ijk}), farmer (W_{ij}) covariate to the model, we have:

$$\text{Log}\left[P_{ijk}/(1-P_{ijk})\right] = W'_{ijk}\gamma_1 + W'_{jk}\gamma_2 + X'_{ijk}\beta_1 + X'_{jk}\beta_2 + X'_k\beta_3 + \mu_{jk} + \nu_k \quad (2)$$

By comparing the estimates obtained from equations (1) and (2), we can examine how the various covariates examined affect adoption, both directly and indirectly. In particular, the results based on equation (1) shows the total effect of each covariate on adoption. Equation (2) shows how the covariates operate through the intermediate variables that are added to the model.

4.6 Results and discussion

4.6.1 Individual conservation agriculture component uptake

Residue retention (RR) was the highest component to be practiced at 86%. As expected, use of herbicides (HU) (70%) and minimum tillage (MT) (69%) seemed to be simultaneously adopted, meeting the need to suppress weeds at the beginning of the cropping season with retention of residues (Figure 4.2). Farmers' adoption of residue retention could be related to the fact that it is inexpensive. All they needed was the previous year's crop residues and old grass from the roofs of the house when they were doing maintenance.

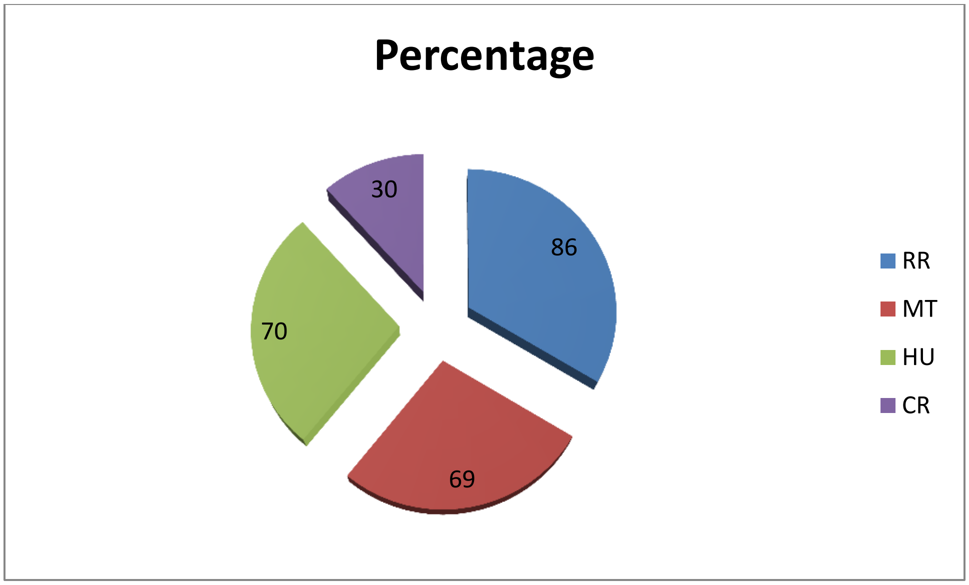

Figure 4.2: Conservation agriculture package uptake

RR = Residue retention, MT = Minimum tillage, HU = Use of herbicides, CR = Crop rotation

Crop rotation (CR) was the lowest component to be adopted; only 30% of the farmers adopted this component. Similar findings have been reported elsewhere – it is pointed out that a lot of farmers practicing CA in Malawi plant maize each year without rotation due to limited landholding sizes. In addition, most of the extension messages on CA do not emphasize crop rotation (HR Mloza-Banda & Nanthambwe, 2010).

Retaining part of the crop residues in Malawian fields was not only viewed as a prerequisite to CA adoption: it might also be the most viable option to maintain them in a productive state, whether they were ploughed in or retained as surface mulch. Researchers have admitted that increasing the use of mineral fertilizer, which is now estimated at an average 8 kg ha^{-1}(Groot, 2009), is required to increase crop production in Africa (Vitousek et al., 2009). Hence the need for residues, because soils that have low soil organic carbon content generally respond poorly or not at all to mineral fertilizers (B Vanlauwe et al., 2010). After preliminary data exploration there were some variations in terms of type of components adopted and other relevant activities. Therefore, we decided to run the sequential adoption models on the 402 recall panel data to come up with farmers' pattern of CA uptake using the modified adoption analysis adapted from Ersado et al., (2004).

4.6.2 Econometric results

Ignoring sequencing would mean the adoption model for CA components in Malawi includes only five alternative choices, q = 0, 1, 2, 3, 4 (Figure 4.1). This would suggest that the last six sequential alternatives can be lumped with (q = 4) which is a single choice.

Likelihood tests for sequential adoption revealed that sequential adoption described Malawi smallholder farmer behaviour by displaying strong evidence against the restricted model (p = 0.001). This confirmed that conventionally projected models, which pool technology component choices adopted at different times into a single alternative, have less explanatory power than models that accommodate sequential adoption. Wald tests lead us to reject the null hypothesis that the coefficients of sequential choices (q = 5, 6, 7, 8, 9, 10) were equivalent (p-value = 0.001). This entails that households in the study area undeniably believed the choice of (q = 5) was different from that of (q = 6) or (q = 7) or (q = 8), or (q = 9), or (q = 10) and each other. The issue of ordering came out to be clearly essential.

These were expected results, because most farmers were risk averse for new technologies, even when these have already been tested on other farmers, and also, they might not have had adequate resources to adopt all components in the CA package. While most applied studies on CA have a tendency to define 'adoption' as a binary outcome , researchers have agreed that CA adoption is not a binary process and is usually partial and incremental (Baudron & Network, 2007; Umar, Aune, Johnsen, & Lungu, 2011).

After controlling for potential confounders, in this section we present the results of our analysis of the estimates of the sequential choices of adoption using the Multinomial Logistic approach, as defined in Figure 4.1 (Stepwise decision-making tree of 1 to 10 potential farmer choice preferences for conservation agriculture components adoption) together with explanatory variables are shown in Table 4.2.

Table 4.2 Choices of stepwise adoption of the components of CA package by farmers							
Independent / dependent variables	**RR&MT**	**RR&HU**	**RR&CR**	**RR,MT&HU**	**RR,MT&CR**	**RR,HU&CR**	**ALL(R,MT,HU&CR)**
Constant	-4.005(1.121)***	-2.728(1.052)**	-1.135(1.281)	-4.838(1.173)***	-3.821(1.588)**	-1.288(1.552)	-(4.795(1.85)**
Total cultivated land	0.061 (0.074)	0.113 (0.077)	-0.016 (0.063)	0.131 (0.078)*	-0.033 (0.065)	0.005 (0.066)	-0.006 (0.07)
Labour in person days	-0.002 (0.004)	0.001 (0.004)	-0.005 (0.005)	0.001(0.004)	-0.003 (0.005)	-0.002 (0.005)	-0.004 (0.006)
Total owned land in acres	0.009 (0.073)	0.053 (0.073)	0.128 (0.077)*	0.088 (0.071)	0.162 (0.083)*	0.211 0.083)**	0.325 (0.1)***
Richer farmers	-0.355 (0.384)	0.32 (0.357)	0.533 (0.403)	-0.137 (0.381)	0.789 (0.451)*	0.311 (0.466)	0.637 (0.519)
Maize plot acres	0.202 (0.088)**	-0.094 (0.09)	0.146 (0.099)	0.066 (0.093)	0.157 (0.113)	0.175 (0.112)	0.165 (0.130)
Agroforestry technology	-0.337 (0.114)	-0.334 (0.114)	-0.228 (0.137)*	-0.282 (0.116)**	-0.425 (0.164)***	-0.219 (0.159)	-0.238 (0.177)
Soil type	0.112 (0.159)	0.09 (0.156)	-0.447 (0.19)**	0.18 (0.163)	-0.529 (0.213)**	-0.576 (0.228)**	-0.412 (0.242)*
Soil depth	0.181 (0.194)	0.876 (0.199)***	0.415 (0.246)*	0.564 (0.197)***	0.469 (0.267)*	0.845 (0.285)***	0.877 (0.309)***

Soil slope	0.007 (0.235)	0.432 (0.238)*	-0.536 (0.299)	0.278 (0.244)	-0.67 (0.356)*	-0.228 (0.346)	-0.125 (0.386)
Soil fertility on plot	-0.228 (0.264)	-0.252 (0.254)	0.189 (0.313)	-0.311 (0.267)	0.409 (0.343)	0.018 (0.354)	0.032 (0.394)
Plot manager	0.075 (0.164)	0.025 (0.164)	-0.591 (0.19)***	0.342 (0.169)**	-0.44 (0.21)**	-0.323 (0.221)	-0.225 (0.24)
Walking minutes to plot	0.01 (0.009)	-0.004 (0.008)	0.016 (0.011)	0.002 (0.009)	0.03 (0.012)**	0.007 (0.014)	0.015 (0.015)
Total asset value us$	-0.001 (0.001)	0.00 (0.001)	-0.001 (0.001)	0.001(0.00 1)	0 (0.001)	-0.002 (0.001)	-0.001 (0.002)
Household size	0.13 (0.068)*	-0.062 (0.065)	0.014 (0.076)	-0.054 (0.069)	0.071 (0.087)	-0.148 (0.095)	-0.088 (0.101)
Age of household head	0.047 (0.019)**	-0.02 (0.017)	0.026 (0.019)	0.033 (0.018)*	0.046 (0.021)**	0.02 (0.021)	0.042 (0.023)*
Minutes to agricul office	0.003 (0.002)*	0.001 (0.002)	-0.003 (0.002)	0.003 (0.002)	-0.007 (0.003)***	-0.009 (0.003)***	-0.008 (0.003)***
Minutes to inputs market	0.002 (0.003)	-0.000 (0.003)	-0.012 (0.004)***	-0.002 (0.003)	-0.013 (0.004)***	-0.015 (0.005)***	-0.019 (0.005)***
Minutes to main market	-0.002 (0.003)	0.003 (0.002)	0.011 (0.003)***	0.003 (0.003)	0.011 (0.004)***	0.017 (0.004)***	0.016 (0.004)***
Minutes to village market	-0.01 (0.005)	-0.004 (0.005)	-0.021 (0.009)**	-0.004 (0.005)	-0.013 (0.009)	-0.037 (0.011)***	-0.029 (0.012)**

Experience in CA (years)	0.066 (0.039)*	0.01 (0.033)	-0.062 (0.04)	0.029 (0.035)	-0.075 (0.043)*	-0.082 (0.048)*	-0.109 (0.05)**
Experience in maize	-0.031 (0.021)	0.012 (0.019)	-0.017 (0.022)	-0.047 (0.02)**	-0.036 (0.024)	-0.023 (0.025)	-0.038 (0.027)
Experience in pigeon pea	0.014 (0.014)	-0.000 (0.014)	-0.013 (0.016)	0.004 (0.014)	-0.003 (0.018)	-0.01 (0.02)	-0.012 (0.022)
Experience in cow peas	0.042 (0.019)**	0.041 (0.018)**	0.053 (0.019)**	0.063 (0.019)***	0.069 (0.022)***	0.088 (0.024)***	0.087 (0.026)***
Food surplus	0.897 (0.516)*	0.441 (0.512)	0.518 (0.703)	0.615 (0.558)	1.176 (0.902)	-0.363 (0.797)	-0.776 (1.165)
No food shortage no surplus	1.716 (0.538)***	1.349 (0.513)***	0.733 (0.648)	2.376 (0.569)***	1.903 (0.801)**	0.75 (0.718)	2.097 (0.871)**
Occasional food shortage	1.391 (0.481)**	0.858 (0.453)*	1.26 (0.596)**	1.282 (0.518)**	2.258 (0.78)***	1.174 (0.665)*	2.677 (0.85)***
_IZone_2	0.088 (0.373)	0.964 (0.372)***	-0.802 (0.419)*	0.217 (0.382)	-0.364 (0.476)	-0.675 (0.497)	-0.717 (0.539)

Experience is measured in years, Minutes is measured in walking distance, Land is measured in acres

RR = residue retention, MT = minimum tillage, HU = herbicide use, CR = crop rotation

4.6.3 Packages versus stepwise adoption pattern of CA components

The above patterns of adoption show that farmers have adopted the components in a sequential manner rather than a package. In detail, figures on adoption pattern as shown in Figure 4.3, revealed that full adoption of the CA package is uncommon, as we would have expected, and other researchers' experience shows similar results Ekboir (2002). Only 17.91% farmers adopted all components (RR + MT + HU + CR) in the first year (2010), remained the same in second year (2011) and dropped to 17.66% in the third year (2012). Similarly, according to the FAO definition of CA, only 21.64% (RR + MT + CR) of the farmers were practicing full CA package adoption in the first and second year; however, this adoption rate goes down in the third year (2012) to 20.9%.

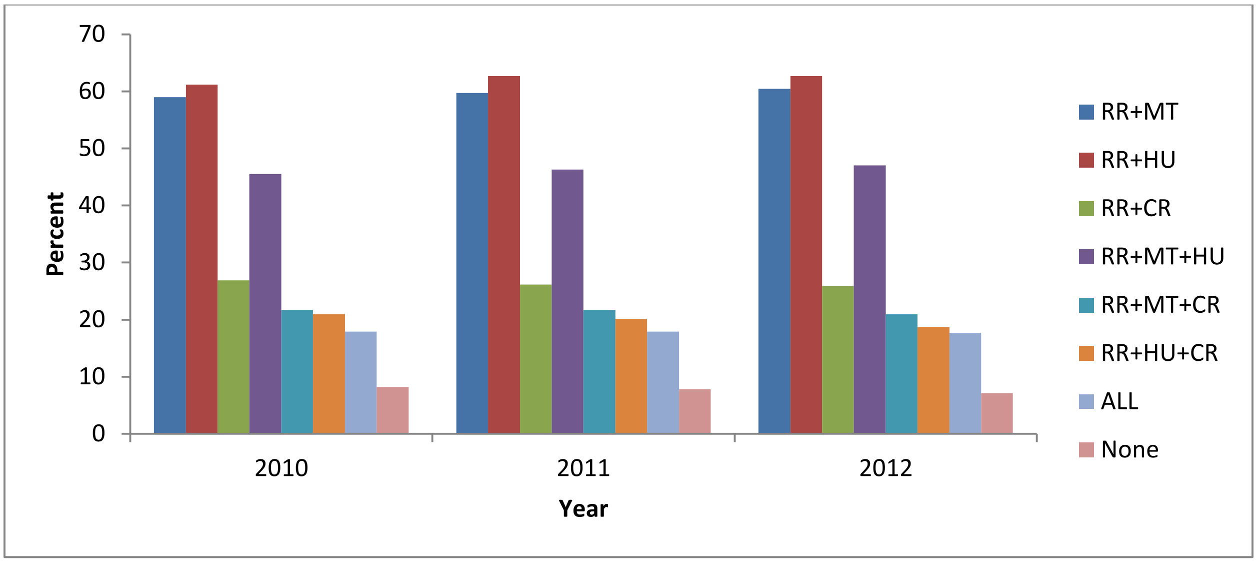

Figure 4.3: Component combination adoptions from CA package in percentage

N=134, RR = residue retention, MT = minimum tillage, HU = herbicide use, CR = crop rotation

Furthermore, for farmers who were adopting three components together, these were usually residue retention, minimum tillage and use of herbicides at 45.52% in 2010, 46.27% and 47.01% and this was the only combination that was incremental with each year, with no farmers dis-adopting, unlike the case with the universal CA package components.

Farmers who had two combination choices demonstrated the highest adoption of CA components, and this was either incremental or constant, with no dis-adoption. Farmers mostly adopted a combination of residue retention and use of herbicides at 61.19% in the first year (2010) and 62.69% in the third year (2012), which had no more adopters after the second year (2011). Although the combination of residue retention and minimum tillage was at 58.96% in 2010, which is about 2% lower than the residue retention and use of herbicides, this figure continued to increase in both 2011 and 2012. This finding supports previous research that usually farmers do not adopt the whole package but rather adopt pieces of the package in a step-wise manner (Leathers and Smale, 1991; Mann, 1978). Crop rotation was the rarest component to be simultaneously adopted with any other components, at only 26.87% in 2010, with farmers dis-adopting in the subsequent years of 2011 and 2012. Crop rotation continues to be a challenge among smallholder farming systems due to continuous cropping of maize (in part intercropped with legumes). This finding supports other research finding in the sub-Saharan Africa where crop rotation is limited due to land shortage (Thierfelder et al., 2010, 2013a).

4.6.4 Factors affecting choices of adoption of the different CA components

Factors that significantly influenced adoption combinations of components included plots managed by married couples, richer households, those who experienced occasional food shortage, those who neither experienced food shortage nor surplus, those who had experience in growing cowpeas, medium slope on the plot, soil type on the plot, no transport costs to the market and those who had the shortest distance to the main market. These were all statistically significant and displayed positive signs for the p-value, which indicated that the unobserved factors that influenced the adoption of residue retention also increased the likelihood of adopting the related components. The major factors that influenced adoption across all choices were farmers’ experience in growing cowpeas, soil depth and household food availability. However, household food availability played a major role in influencing adoption of all component combinations than wealth.

A larger size of the total land cultivated by a farmer caused positive differences in the probability of adoption of only one component of the combination of residue retention, minimum tillage and use of herbicides by 13%, but not in any of the remaining combinations among households. However, an increase of total land owned by the farmer (not title per se) by 1 acre, on average, raised the probability of significantly adopting a combination of residue retention and crop rotation by 12.8%; a combination of residue retention, minimum tillage and crop rotation by 16%; a combination of residue retention, use of herbicides and crop rotation by 21%; and very significant adoption of residue retention, minimum tillage, herbicide use and crop rotation combinations by 32.5%. The large size of the plot allocated to maize significantly increased the farmers' chances of adopting a combination of residue retention and minimum tillage by 2% more than their small plot sized counterparts. This could be explained by the fact that since most farmers are land constrained therefore risk averse to try out new technologies on small pieces of land, that is why farmer with larger pieces of land are able to invest on some parts of their land without risking the whole plot to some new technology. This finding supports previous research by Kerr et al., 2007.

Wealth and household food availability throughout the year positively influenced farmers' participation in the various combinations of the CA components. The total value of the farm household assets had no influence in the adoption of any particular component combinations of the CA package. Richer farmers were found to be associated with a higher probability of adopting a combination of residue retention, minimum tillage and crop rotation by 79% than their poor counterparts. They, however, did not have an influence on the probability of adoption of the rest of the possible combinations. Households with food surplus during the year had 90% advantage of adopting a combination of residue retention and minimum tillage over their counterparts who experienced food shortage during the year. Similar findings have been reported in past research where wealthier farmers had higher adoption behaviour than thei poor counterparts (Kassie et al., 2012a).

When compared with their counterparts who had food shortage throughout the year, occasional food shortage influenced farmers' adoption of all component combinations by:

- almost 1.39 times of residue retention and minimum tillage
- 0.85 times of residue retention and herbicide use
- 1.26 times of residue retention and crop rotation
- 1.28 times residue retention, minimum tillage and herbicide use,
- 2.25 times of residue retention, minimum tillage and crop rotation
- 1.17 times of residue retention, herbicide use and crop rotation times 2.67 times of the whole package.

However, households who had no food shortage but no surplus were more likely than their counterparts who had food shortage throughout the year to adopt combinations by:

- 1.7 times of residue retention and minimum tillage
- 1.3 times of residue retention and herbicide use
- 2.4 times of residue retention, minimum tillage and herbicide use
- almost twice of residue retention, minimum tillage and crop rotation
- twice of all the four component combinations.

Plot characteristics like depth of the soil, type of soil, slope of the soil and agroforestry technology on the plot had both positive and negative influence on the adoption of the CA components. Compared with farmers whose plots had shallow soils, deep soil on the plot positively influenced probability of CA adoption by:

- 87% on residue retention and herbicide use
- 41% on residue retention and crop rotation
- 56% on residue retention, minimum tillage and herbicide use
- 47% on universal CA definition package
- 84% on residue retention, herbicide use and crop rotation
- 88% on the whole package.

Plots which had fertilizer trees as type of agroforestry technology on the plots negatively influenced farmer adoption of residue retention and crop rotation by 23%, residue retention, minimum tillage and herbicide use by 28% and universal CA package by 42% compared with their counterparts who had live fence of non-fertilizer trees. This could be explained by those farmers feeling their plots were already fertile and hence they had no need to adopt more fertility enhancing technologies. Similar results have been reported by other researchers elsewhere (Akinnifesi et al., 2008).

Farmers whose plots had red soil were less likely to adopt; residue retention and crop rotation by 45%, universal CA package by 53%, residue retention and crop rotation by 58% and the whole package by 41% that their counterparts with plots which had black soil. Farmers whose plots had medium slopes were 43% more likely to adopt residue retention and herbicide use and 67% less likely to adopt residue retention, herbicide use and crop rotation than their counterparts whose plots were on flat slope.. This implies that farmers were only adopting the technologies on plots which they felt had good soil fertility. This finding is similar to previous research elsewhere farmers were adopting soil enhancing fertility technologies on plots they felt had good soil (Kassie et.al., 2013)

Larger households had a 13% higher chance of adopting only residue retention and minimum tillage and had no influence on the rest of the possible combinations than their smaller household counterparts.

Plots which were managed by single head of household were 59% and 44% less likely to adopt residue retention and crop rotation and universal CA package respectively than plots managed by married couples, who were more likely to adopt residue retention, minimum tillage and herbicide use by 34%. The possible explanation could be that married household heads are more likely to adopt the technologies as the spouses are able to share responsibilities in managing the farm activities. This finding is consistent to previous research where adoption of soil enhancing technologies was higher among married couples than single household heads (Chilongo, T.M.S., 2004).

Compared with their younger counterparts, older farmers had a higher probability of adopting residue retention and minimum tillage by 5%, residue retention, minimum tillage and herbicide use by 3%, universal CA package by 5% and residue retention, minimum tillage and herbicide use and CR by 4%. The most plausible explanation could be that older farmers had a long period of exposure to these new technologies so they might want to try it faster than their younger counterparts who have little knowledge. These results are in contrast with what Gebremariam, et al., 2012) found that age had no influence in the adoption of soil conservation practices.

Availability of family labour had no influence on the adoption of any component combinations among the farm households. This could be due to excess family labour being used not for technology adoption but instead for labour on other peoples' farms in exchange for money to meet immediate needs, in this case food. This finding confirms other research where they found that some household members were employed outside the farm (Chirwa, E., 2003; Amaza, Kwacha et al. 2007).

Proximity to the main market increased the probability of adopting; residue retention and minimum tillage by 1% (same as universal package). Adoption of residue retention and crop rotation increased by 2%, as it did for the whole package. Long distance to the inputs markets decreased farmers' chances of adopting; residue retention and crop rotation by 1%, just as it did for the universal CA package; and residue retention, herbicide use and crop rotation by 1% similar to the adapted CA package. Long distance to the agriculture office and the village market negatively affected the adoption of all possible component combinations of the CA package compared with their closer counter parts. This could mean that, functional markets for inputs and outputs, and proximity to extension advice that offer critical inputs such as proper seeds or herbicides and market opportunities for new crops (e.g. legumes) would be necessary for the promotion of CA. Similar experiences have been reported in Malawi and elsewhere by Madhu Khan, 2001; Ngwira et al., 2012a; Corbeels et al., 2013).

Farmers' experience in CA had both positive and negative influences on the adoption of the various component combinations of CA compared with their less experienced counterparts. Long years of experience in CA positively influenced the adoption of residue retention and minimum tillage by 6% more likely, but negatively influenced the adoption of the universal CA package by 7%. Higher number of years of CA experience also reduced the probability of adopting; residue retention, herbicide use and crop rotation by 8%; the adapted package by 10% compared with their counterparts who had less experience in doing CA. Farmers' experience in growing maize decreased the chance of adopting universal package by 5%. Experience in growing pigeon pea had no influence on all the possible component combinations of CA package adoption. However, farmers' experience in growing cowpeas had a positive and highly significance influence in the adoption of all the possible component combinations of CA package. Possible explanation could be that legumes (cowpeas) not only have the capacity to grow in low fertility environments, they also produce nutrient-enriched foods, e.g. high protein grain and leaves. This finding is consistent with previous research by Kerr, et al., (2007).

4.7 Chapter summary

This section provides a summary and conclusion on the adoption pattern of the adapted conservation agriculture (CA) package, factors that influenced adoption of each component and the feasibility of its 'one-size-fits-all' recommendation to all the smallholder farmers in Malawi. The adapted CA package entails residue retention (RR), minimum tillage (MT), herbicide use (HU) and crop rotation (CR).

The aim of the chapter was to find out the adoption rate and its pattern and factors that influenced the adoption of individual CA components of an adapted package among the smallholder farmers in Malawi. It examined the adoption of the individual components, component combinations and factors that influenced the adoption of each component combination. This was motivated by low and partial adoption of the CA package among farmers in Malawi.

Using a multilevel logistic modelling of farmer decision tree choices, the results reveal out that residue retention was the highest component to be adopted across the three years 2010, 2011 and 2012. In 2010, there was simultaneous adoption of minimum tillage and herbicide use while crop rotation was the least package to be adopted which had farmers dropping out in the following years, 2011 and 2012. Among the two-component combination, residue retention and herbicide use was the highest to be adopted followed by residue retention and minimum tillage.This implies that RR and HU need to practised jointly.

However, three component combinations were higher in residue retention, minimum tillage and herbicide use, at 47%, and the rate of adoption increased during the following two years and was the only component combination which did not have drop outs in adoption. Surprisingly, the adoption of the whole adapted package was at 17.91%, even lower than the universal CA package (according to FAO definition) of residue retention, minimum tillage and crop rotation at 21.64%.

Plots that were managed by couples, richer households, households with experience in food shortage, proximity to the market and the type of soil positively influenced farmers' adoption of the various component combinations of CA. Full adoption of the adapted CA package was rare, and farmers sequentially adopted the individual component combinations to meet their needs.

Therefore, this study has shown that the universal recommendation of the CA package will not improve adoption. CA adoption needs to be promoted according to agroecological and socioeconomic context and the inclusion of the herbicide use as a component of the package. Redefining crop rotation to intercropping, that is expanding the scope of legume association in the system will enable researchers to be able to record more of what farmers are actually doing to improve adoption rates and feedback to researchers.

PART IV: SYNTHESIS, INTEGRATION AND POLICY IMPLICATIONS

CHAPTER FIVE

5.1 Summary

This chapter provides a synthesis and Integration of the thesis chapters, possible policy interventions, limitations, and areas for future research to improve the adoption of sustainable intensification practices among smallholder farmers. The thesis examined the diversity of the smallholder farmers and their adoption of the sustainable intensification practices (SIPs) in Malawi. The first objective of the thesis was to understand the diversity that exist among the smallholder farming systems for targeting of improved farm technologies. The second objective was to evaluate the opportunities and constraints for maize- legume intensification among the smallholder farmers for dietary fortification and ecological intensification. The third and last objective was to assess stepwise adoption of an adapted conservation agriculture package and the appropriateness of the blanket recommendation of the CA package to all smallholder farmers in Malawi. Overall, this thesis contributes both to literature and methodology.

Farmer household surveys were the focus of this study. The main purpose for the surveys was to facilitate feedback and the interpretation of farmers' experiences, to provide insights to researchers about the flow of information on the concepts, patterns, and determinants of low adoption of the technologies. The SIPs examined were the adoption of improved farm technologies, the intensification of maize–legume practices and the adapted conservation agriculture package of smallholder farmers in Malawi.

Two multivariate statistical technics were sequentially employed, that is, principal component analysis (PCA) and cluster analysis (CA) to estimate the diversity that existed among the smallholder farmers by using resource endowment, current technology use and production orientation as criteria, for coming with farm typologies among 891 smallholder farmers. PCA and CA results consistently indicated that four different farmer classes existed among the farmers which influenced their adoption of the improved soil fertility technologies. These farm types were: a) type 1 farms

(35.13%) were classed as ‘small subsistence-oriented family farms’, b) type 2 (31.43%) were ‘small semi-subsistence family farms’, type 3 (25.36%) were ‘survivalist’ (small, independent, semi-specialized family farms whose main objective was family sustenance) and, c) type 4 (7.52%) were ‘production-oriented, small, dependent, semi-specialized family farms’.

Farm typologies indicated that farm types 1 and 2 practiced crop residue retention and crop rotation by intercropping of maize–legumes improved varieties, potentially making them the possible adopters of improved farm technologies among the rest of the farm types. Minimum tillage adoptions remained sparse. Type 3 farms, in addition to being family sustenance-oriented, specialised in a cash crop such as tobacco, cotton, legume which made them party commercial, which had a negative impact on practicing of improved farm technology. Type 4 farms were like type 3 but different high level of specialization as tenants in tobacco growing largely dictated by their landlords, which limited their adoption of improved farm technology.

Evaluation of the opportunities and constraints for maize-legume intensification among the smallholder farmers for dietary fortification and ecological intensification was done by comparing results of three random effects regression models using multilevel logistic analysis. Two different methods - first multivariate and second econometric technics were applied to correct for potential bias in estimating the factors that influenced adoption of maize-legume intensification. The results of the models indicated that farmers who had a shorter distance to walk to the farm inputs market and village market, had a higher participation in the intensification of maize-legume by 72 % of the farmers.

The results also indicate that the size of total land owned (not title per se) by the farmer during the rainy season, farmers ability to formulate and adhere to a farm plan and was highly correlated with farmers adopting either only improved maize or legume monocropping intensification if the size of the land was small.

The thesis indicated that farmers decision to adopt or not to adopt each component combination from the adapted CA package (residue retention, minimum tillage, crop rotation and use of herbicides) was considered to be sequential and incremental. The results also revealed that the households' decision to adopt the individual component depended on farmers experience in growing cowpeas, soil depth and the households food availability throughout the year. Findings also show that most farmers (85%) adopted residue retention, 70% adopted minimum tillage, herbicide use was at 69% while crop rotation was the least at 30%. The highest component combinations adopted were two and not three, but were increasing with time especially the combination of residue retention and minimum tillage. The adoption combination of residue retention, minimum tillage, and crop rotation was much lower than the combination of residue retention, minimum tillage, and herbicide use.

5.2 Conclusions and policy implications

The findings of this thesis provide empirical evidence that the adoption of improved farm technologies mainly depends on the diversity that exist among the smallholder farmers. Since some farm types have demonstrated better possibilities for adopting alternative technologies than others, this implies that construction of farm typologies could be a useful tool in exploring the adoption of improved technologies. However, technological interventions to address the problem of poor productivity of smallholder agricultural systems must be designed to target these socially diverse and spatially heterogeneous farms and farming systems. Implementation of linear and largely top-down approaches, that do not sufficiently recognize such complexity as fundamental, results in agricultural research and development efforts generating lower than expected impacts across the country. The findings of this study propose for disaggregated extension messages and policy analysis that allows for variation between different household types in their responses to gains or losses from different policies. For example, policies should be promoted differently like moderately on farm types 1&2 and more intensified on farm type 3&4 to encourage change of mind set of farmers .

The study identifies the factors that indicated that the extent to which farmers could practice higher intensification of maize-legume could have a greater impact on smallholder farmers' food security. However, this largely depended on farmers' access to land (not title per se), access to information on farm plan formulation, extension services and trainings. This implies that there is need for government to normalise land ownership by instituting land reform which leads to people accessing land for farming.

The study revealed that the adoption of minimum tillage was highly associated with the use of herbicides. Therefore, findings in this research suggest that use of herbicides should be considered as a fourth rule of the adapted CA package. This could be achieved by subsidizing the cost of herbicides by government which would improve the adoption of an adapted CA package among the smallholder farmers.

Therefore, according to the findings of this study, the dissemination of CA package in Malawi, rather than following the three components package approach, which is a 'one size fits all' recommendation, should be designed by taking into account the fact that smallholder farmers depict different adoption behaviours and adopt the adapted CA package in a stepwise manner in different conditions and geographical areas.

Finally, Technologies developed at research stations have often failed to improve productivity at the farm-scale, due to gross mismatch of highly variable conditions when they are transferred for use by diverse farming households. Part of the problem has been the blanket promotion of single technologies, and failure to address production objectives and constraints across different types of farms. There is, therefore, need for systematic approaches and frameworks that will enable targeting of an adapted CA package for nutrient management according to farmers' socio-economic circumstances.

5.3 Strengths, limitations of this study and Future research

This study has contributed to understanding the diversity that exist, the factors that influence farmers' opportunities and constraints for the intensification of maize and legumes, and the factors that influence low adoption of the adapted CA package for food security among smallholder farmers in Malawi. More importantly, it has accounted for variations in:

a) the adoption of improved farm technology among the smallholder farmers
b) opportunities and constraints for the maize-legume intensifications among the smallholder farmers
c) stepwise adoption of the adapted CA package among the smallholder farmers.

Although the study attempted a possible explanation, it is important to note that the data used did not have sufficient information (missing data) on the use of manure, fertilizer, and conservation agriculture (CA) to consider soil fertility improvement to enhance yield. Future research, with the help of comprehensive data on the yields of legumes and maize, use of manure and fertilizer could provide conclusive insights into this paradox.

Future research should consider the effects of sequential adoption of the adapted CA (with four rules) on the productivity of maize and legumes among the smallholder farms. Currently, qualitative data was not available to triangulate the quantitative findings for causal directions.

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Appendix 1, Table 2.5: Farm family classification from independent analysis showing mean key socio-indicators: area of land, labour units and household distribution

Site (6)	Type of farm	land owned	cultivated summer	cultivated winter	Household	No of Family members labour contribution		Hired labour	Land available	[3]Farm production asset value	Maize self sufficiency	Proportion of farm income	[2]Livestock production
Name	No of farms	(ha)	(ha)	(ha)	No of people	Own farm	non-farm	m-d /year	Own labour	US$	(months)	(%)	(TLU)
Balaka	1(36)	1.74	1.42	0.09	4.9	1.9	0.3	1.1	0.79	10.69	8.4	26	0.55
n = 159	2(64)	1.14	1.02	0.02	4.9	1.94	0.2	0.7	0.54	6.45	6.2	23	0.89
	3(50)	0.98	0.89	0	5.2	1.61	0.2	0.6	0.55	8.91	5.5	33	0.16
	4(9)	2.4	2.2	1	7	6.5	1	1.8	0.49	38.36	12	36	1
Kasungu	1(34)	3.25	1.76	0.13	6.1	2.4	0	4.8	0.78	9.99	6.6	73	0.82
n = 137	2(35)	1.51	1.21	0.03	4.6	1.8	0.2	2.1	0.7	15.29	7.2	68	0.94
	3(54)	1.92	1.62	0.03	5.2	2.1	0.1	2.6	0.78	20.21	7.9	62	0.07
	4(14)	4.06	4.19	0.18	7.2	2.5	0.4	3.1	1.72	5.84	8.7	82	0.79
Lilongwe	1(111)	1.43	1.37	0.07	6.1	2.3	0.1	3.9	0.63	36.4	9.94	52	0.92
n = 325	2(105)	0.92	0.81	0.02	4.3	1.8	0.1	1.2	0.46	17.87	8.94	37	0.91
	3(70)	1.29	1.13	0.1	4.7	1.9	0	0.5	0.65	14.01	8.61	48	0.67
	4(39)	2.18	1.94	0.14	5.9	2.4	0.3	3	0.87	189.46	9.54	61	0.79
Mchinji	1(30)	1.67	1.11	0.12	5.1	1.8	0.1	3.1	0.69	29.44	6.1	58	0.33
n = 70	2(23)	1.22	0.92	0.11	4.3	1.7	0	1.6	0.59	7.54	5.1	87	0.74
	3(70)	2.29	2.76	0.04	5	1.9	0	0	1.46	315.37	7.6	82	0.8
	4(5)	1.45	1.17	0.13	4.8	2.3	0	3.8	0.57	38.36	6.9	74	0.83
Ntcheu	1(60)	0.96	0.82	0.02	4.6	1.9	0.1	1.3	0.45	8.49	9.27	34	0.95
n = 109	2(20)	1.03	0.84	0.08	4.2	1.4	0.2	2.7	0.67	3.92	8.6	25	0.45
	3(26)	2.04	1.72	0.11	6	2.1	0.1	1	0.86	21.41	9.65	33	0.92
	4(3)	1.93	1.8	0	5	2	0.7	0	0.9	12.38	10	15	0.67
Salima	1(42)	1.26	1.07	0.01	4.7	1.8	0	1.7	0.61	11.05	6.29	21	0.9
n = 91	2(33)	0.88	0.88	0.02	4.3	1.8	0.2	0.6	0.5	11.68	6.24	27	0.06
	3(14)	1.84	1.93	0.18	5.3	1.9	0.1	2.1	1.09	30.16	7.93	25	0.71
	4(2)	1.3	1.3	0	6	1.2	0.5	1.9	1.1	7.66	9	19	1
SED	**(S)**	**0.12**	**0.08**	**0.01**	**0.1**	**0.89**	**0.01**	**0.23**	**0.1**	**0.5**	**0.13**	**0.01**	**0.02**

Appendix 2: Table 2.6 Adoption ate of maize-legume intensification and CA

Appendix 2, 2.6: Adoption rate of maize–legume intensification and individual components of the conservation agriculture packages, stratified according to the suggested farm typology for

		Farmers that have				% of farmers practising				% of farmers
Site	**Farm type**	**Sheep & goats**	**Farmers with farm plan (%)**	**Legume plot size**	**Min. till. winter**	**Min. till. summer**	**RR winter**	**RR summer**	**Crop rotation**	**Improved variety**
Balaka	1	1	65	0.3	0	0	40	70	70	42
n = 159	2	0.95	99	0.2	0	1	10	84	94	92
Low-altitude	3	2.5	53	0.2	0	2	0	75	28	100
	4	13.4	100	0.5	0	0	100	100	100	89
Kasungu	1	2.4	97	0.5	0	0	32	79	91	91
n = 137	2	0.7	100	0.2	0	0	3	71	97	94
Mid-altitude	3	2.1	54	0.3	0	0	6	72	11	33
	4	7.9	100	0.9	0	0	21	50	93	93
Lilongwe	1	3.6	99	0.3	0	0	21	70	95	100
n = 325	2	1.7	96	0.2	0	0	15	64	99	100
	3	1.5	77	0.3	0	0	30	84	47	84
Mid-altitude	4	4.2	95	0.6	1	5	46	64	87	95
Mchinji	1	0.6	47	0.3	0	0	37	73	33	53
n = 70	2	0.3	96	0.2	0	0	35	83	91	100
Mid-altitude	3	2.6	80	1.2	0	0	0	20	60	100
	4	1.3	100	0.4	0	0	58	75	100	83
Ntcheu	1	1.7	98	0.2	2	2	1	87	100	98
n = 109	2	1.1	70	0.2	0	0	25	85	40	75
Mid-altitude	3	3.2	96	0.6	0	0	27	96	88	96
	4	6	100	1	0	33	0	100	67	67
Salima	1	1.3	100	0.2	0	0	5	79	98	83
n = 91	2	1.3	55	0.2	0	0	6	88	9	42
Low altitude	3	5.7	71	0.3	0	0	21	71	57	71
	4	0	100	0.4	0	0	0	50	100	50

[1] n: number of household distribution across each site and within farm type.

[2] Min. till.: minimum tillage practiced on the farm.[3] RR: residues retention on the farm in summer and winter.

Appendix 3 : Table 3.1 Respondents profile

Appendix 3 :Table 3. 1 Respondents' profile

Description of variable and units	[3]CV	Mean	[4]SD
Experience in growing maize (years)	0.73	17.8	13
Walking minutes to main market	0.87	81.7	71
Walking minutes to seed market	0.78	85.1	66
Walking minutes to fertilizer market	0.78	85.7	67
Walking minutes to herbicide market	0.79	86.6	68
Walking minutes to health center	0.82	79.5	65
Average household size (number)	0.39	5.1	2
Household adult equivalent	0.48	4.2	2
Average age of head of household (years)	0.35	42.5	15
Average education of household head (years)	0.74	5.4	4
Land size cultivated in summer (ha)	0.65	3.1	2
Maize plot size (ha)	0.59	1.7	1
Pigeon pea plot size (ha)		0	0
Length of months in storage of maize	0.51	7.9	4
Length of months in storage of beans	2.22	0.9	2
Length of months of storage of pigeon peas in storage	1.08	3.7	4
Total number of cattle	6.67	0.3	2
Value of livestock (MK)1	3.48	36332.9	126480
Farmers received training in crop rotation (1 = yes, 0 otherwise)	0.00	0.7	0
Farmers trained in storage pest management (1 = yes, 0 otherwise)		0.7	0
Farmers trained in farm plan formulation (1 = yes, 0 otherwise)		0.9	0
Farmers trained in field pest management (1 = yes, 0 otherwise)		0.7	0
Farmers trained in crop residue retention (1 = yes, 0 otherwise)		0.8	0

Farmers trained in livestock production management (1 = yes, 0 otherwise)		0.7	0
Farmers aware and using improved maize–legume varieties (1 = yes, 0 otherwise)		0.8	0
Farmers using improved legume varieties (1 = yes, 0 otherwise)		0.7	0
Total owned land in winter (ha)	1.11	3.6	4
Total owned land in Summer (ha)	1.08	3.7	4
Common (phaseolus) bean plot size (ha)	0.00	0.1	0
Uncultivated land in winter (ha)	1.11	3.6	4

[1] MK 153.47 = US$1 (MK- Malawi kwacha at the time of data collection in February, 2011)

[2] Respondent profiles: n = 891, male =747, female = 144

3 CV – coefficient of variation

4 SD – standard deviation

Appendix 4 : Table 3.2 Factor loadings Extraction

Appendix 4: Table 3.2, Factor Loadings (Varimax normalized) Extraction: Principal components (marked loadings are >.650000)

Factor / variable	**Factor Loading**	**Variance explained (%)**	**Cumulative variance explained (%)**	**Cronbach α**
Factor 1: Access to land		18.86	18.86	0.81
Cultivated land summer	0.681			
Maize plot size	0.576			
Total owned in winter	0.94			
Total owned in summer	0.943			
Uncultivated land winter	0.945			
Factor 2: Access to information and extension services		13.77	32.63	0.83
Crop rotation	0.824			
Storage pest	0.883			

Farm plan	0.652			
Field pest	0.881			
Crop residue retention	0.772			
Livestock production	0.804			
Maize variety (improved)	0.679			
Legume variety (improved)	0.757			
Factor 3: Distance to market and infrastructure		10.01	42.64	0.9
Walking minutes to main market	–0.801			
Walking minutes to seed market	–0.948			
Walking minutes to fertiliser market	–0.949			
Walking minutes to herbicides market	–0.94			
Walking minutes to health centre	–0.698			
Factor 4: Winter crop production		6.03	48.68	0.82
Stover (crop residue yield) in winter	0.781			
Maize nitrogen fertilizer in winter	0.679			
Maize production in winter	0.669			
Soil fertility for maize in winter	0.766			
Maize yield in winter	0.628			
Labour availability for maize in winter	0.713			

Appendix 4 contd: Table 3.2, Factor Loadings (Varimax normalized) Extraction: Principal components (marked loadings are >.650000)

Factor / variable	Factor Loading	Variance explained (%)	Cumulative variance explained (%)	Cronbach α
Factor 5: Bean legume characteristics				
Stover (residue yield) in summer	0.809			
Storability	0.821			
Bean plot size	0.809			
Bean yield	0.727			
Factor 6: Household composition		5.15	59.31	0.79
Average household size	0.941			
Adult equivalent in the household	0.952			

Number of males in the household	0.88			
Factor 7: Livestock and livestock products		4.64	63.94	0.79
Total number of cattle	0.891			
Livestock value	0.913			
Sales animal products	0.754			
Factor 8: Head of the household characteristics		4.27	68.22	0.79
Experience in growing maize	0.896			
Average age (years)	0.892			
Average education (years)	–0.621			
Factor 9: Variety and characteristics of pigeon pea legume		3.76	71.98	0.9
Pigeon pea plot size	–0.822			
Stover (residue yield)in summer	–0.796			
Pigeon pea production	–0.786			

Appendix 5: Table 4.1 Description of variables used in multivariate analysis

Table 4.1: Description of variables used in the multivariate logistic model

Variable name	Variable description	Expected effect on adoption of CA
Dependent variables		
Adoption 12[a] (RR&MT)	= 1 if residue retention= yes and minimum tillage= yes, 0 otherwise	+
Adoption 123 (RR,MT&HU)	= 1 if residue retention = yes and minimum tillage = yes and herbicide use = yes, 0 otherwise	+/-
Adoption 13 (RR&HU)	= 1 if residue retention = yes and herbicide use = yes, 0 otherwise	+
Adoption 124 (RR,MT&CR)	= 1 if residue retention = yes and minimum tillage = yes and crop rotation= yes, 0 otherwise	+/-
Adoption 1234 (RR,MT,HU&CR)	= 1 if residue retention =yes and minimum tillage=and herbicide = yes and crop rotation = yes, 0 otherwise	+/-
Adoption 134 (RR,HU&CR)	= 1 if residue retention=yes and herbicide = yes and crop rotation =yes, 0 otherwise	+/-
Adoption 14 (RR&CR)	= 1 if residue retention = yes and crop rotation = yes, 0 otherwise	+/-
Independent variables		
Farmer and household characteristics		
Household size	Household size	+
Wealth (*Malawi Kwacha*) (Farm production assets, land, media assets, transport assets, livestock and non-agricultural assets)	1 = Poorer, 2= Poor, 3 = Middle 4 = Richer, 5 = Richest	+/-
Level of education of house hold head (*years*)	Primary & secondary education = 1, 0 otherwise	+/-
Household food availability throughout the year	1 = Food shortage 2 = Food surplus 3 = No food shortage but no surplus 4 = Occasional food shortage	+/-
Average education of household	Number of years	-

Age of household head	Number of years	+/-
Labour availability	In man days (8 hours = one day)	+/-
Gender of household head	Gender (= 1 if male, 0 otherwise)	+/-
Total land owned (acres)	Land held (= 1 if yes, 0 otherwise)	+/-
Total land cultivated (acres)	Land cultivated (= 1 if yes, 0 otherwise)	+/-
Maize plot size (acres)	Small = <1, Medium = 1-2.5, Large = >2.5	+/-
Knowledge and experience of farmer		
Experience in growing common beans (years)	(2, 3, 4 = 1 'small'), (5, 6, 7 = 2 'average') (8–38 = 3 'high')	+/-
Experience in growing ground nuts (years)	(2, 3, 4 = 1 'small'), (5, 6, 7 = 2 'average') (8–38 = 3 'high')	+/-
Experience in growing cowpeas (years)	(2, 3, 4 = 1 'small'), (5, 6, 7 = 2 'average') (8–38 = 3 'high')	+/-
Experience in growing pigeon peas (years)	(2,3, 4 = 1 'small'), (5, 6,7 = 2 'average') (8 - 38 = 3 'high')	+/-
Experience in doing CA (years)	(2,3, 4 = 1 'small'), (5, 6,7 = 2 'average') (8–38 = 3 'high')	+/-
Plot characteristics		
Soil fertility on plot	1 = Good, 2 = Medium, 3 = Poor	+/-
Soil depth	1 = Shallow, 2 = Medium, 3= Deep	
Soil slope	1 = Gentle (flat), 2 = Medium slope, 3 = Steep slope	
Soil type	1 = Black, 2 = Brown, 3 = Red, 4 = Grey	
Agroforestry on plot	1 = Live fence, 2 = Fertilizer tree, 3 = Indigenous fruit trees, 4 = None	
Gender of plot manager	1 = male, 0 = female, 2= both	+/-

Access to information, market and plot		
Walking minutes to plot	Walking minutes to plot	+/-
Walking minutes to agriculture office	Walking minutes to agriculture office	+/-
Walking minutes to input office	Walking minutes to input office	+/-
Transport cost to main market	Transport cost to main market	+/-
Walking minutes to village market	30 minutes = short, 60 minutes = medium, 60+ minutes = far	
Zone_2 (Agro-ecological zone)	Zone 1= low attitude, Zone 2= mid attitude	

[a]1 = residue retention, 2 = minimum tillage, 3 = herbicide use, 4 = crop rotation and or association of legumes

RR = residue retention, MT= minimum tillage, CR = crop rotation, HU= use of herbicides

Appendix 6 : Table 4.2 , Choices of stepwise adoption of CA components

Table 4.2 Choices of stepwise adoption of the components of CA package by farmers							
Independent / dependent variables	**RR&MT**	**RR&HU**	**RR&CR**	**RR,MT&HU**	**RR,MT&CR**	**RR,HU&CR**	**ALL(R,MT,HU&CR)**
Constant	-4.005(1.121)***	-2.728(1.052)**	-1.135(1.281)	-4.838(1.173)***	-3.821(1.588)**	-1.288(1.552)	-(4.795(1.85)**
Total cultivated land	0.061 (0.074)	0.113 (0.077)	-0.016 (0.063)	0.131 (0.078)*	-0.033 (0.065)	0.005 (0.066)	-0.006 (0.07)
Labour in person days	-0.002 (0.004)	0.001 (0.004)	-0.005 (0.005)	0.001(0.004)	-0.003 (0.005)	-0.002 (0.005)	-0.004 (0.006)
Total owned land acres	0.009 (0.073)	0.053 (0.073)	0.128 (0.077)*	0.088 (0.071)	0.162 (0.083)*	0.211 0.083)**	0.325 (0.1)***
Richer farmers	-0.355 (0.384)	0.32 (0.357)	0.533 (0.403)	-0.137 (0.381)	0.789 (0.451)*	0.311 (0.466)	0.637 (0.519)
Maize plot acres	0.202 (0.088)**	-0.094 (0.09)	0.146 (0.099)	0.066 (0.093)	0.157 (0.113)	0.175 (0.112)	0.165 (0.130)
Agroforestry technology	-0.337 (0.114)	-0.334 (0.114)	-0.228 (0.137)*	-0.282 (0.116)**	-0.425 (0.164)***	-0.219 (0.159)	-0.238 (0.177)
Soil type	0.112 (0.159)	0.09 (0.156)	-0.447 (0.19)**	0.18 (0.163)	-0.529 (0.213)**	-0.576 (0.228)**	-0.412 (0.242)*
Soil depth	0.181 (0.194)	0.876 (0.199)***	0.415 (0.246)*	0.564 (0.197)***	0.469 (0.267)*	0.845 (0.285)***	0.877 (0.309)***
Soil slope	0.007 (0.235)	0.432 (0.238)*	-0.536 (0.299)	0.278 (0.244)	-0.67 (0.356)*	-0.228 (0.346)	-0.125 (0.386)
Soil fertility on plot	-0.228 (0.264)	-0.252 (0.254)	0.189 (0.313)	-0.311 (0.267)	0.409 (0.343)	0.018 (0.354)	0.032 (0.394)
Plot manager	0.075 (0.164)	0.025 (0.164)	-0.591 (0.19)***	0.342 (0.169)**	-0.44 (0.21)**	-0.323 (0.221)	-0.225 (0.24)
Walking minutes to plot	0.01 (0.009)	-0.004 (0.008)	0.016 (0.011)	0.002 (0.009)	0.03 (0.012)**	0.007 (0.014)	0.015 (0.015)
Total asset value us$	-0.001 (0.001)	0.00 (0.001)	-0.001 (0.001)	0.001(0.001)	0 (0.001)	-0.002 (0.001)	-0.001 (0.002)
Household size	0.13 (0.068)*	-0.062 (0.065)	0.014 (0.076)	-0.054 (0.069)	0.071 (0.087)	-0.148 (0.095)	-0.088 (0.101)
Age of household head	0.047 (0.019)**	-0.02 (0.017)	0.026 (0.019)	0.033 (0.018)*	0.046 (0.021)**	0.02 (0.021)	0.042 (0.023)*
Minutes to agricul office	0.003 (0.002)*	0.001 (0.002)	-0.003 (0.002)	0.003 (0.002)	-0.007	-0.009	-0.008 (0.003)***

					(0.003)***	(0.003)***	
Minutes to inputs market	0.002 (0.003)	-0.000 (0.003)	-0.012 (0.004)***	-0.002 (0.003)	-0.013 (0.004)***	-0.015 (0.005)***	-0.019 (0.005)***
Minutes to main market	-0.002 (0.003)	0.003 (0.002)	0.011 (0.003)***	0.003 (0.003)	0.011 (0.004)***	0.017 (0.004)***	0.016 (0.004)***
Minutes to village market	-0.01 (0.005)	-0.004 (0.005)	-0.021 (0.009)**	-0.004 (0.005)	-0.013 (0.009)	-0.037 (0.011)***	-0.029 (0.012)**
Experience in CA (years)	0.066 (0.039)*	0.01 (0.033)	-0.062 (0.04)	0.029 (0.035)	-0.075 (0.043)*	-0.082 (0.048)*	-0.109 (0.05)**
Experience in maize	-0.031 (0.021)	0.012 (0.019)	-0.017 (0.022)	-0.047 (0.02)**	-0.036 (0.024)	-0.023 (0.025)	-0.038 (0.027)
Experience in pigeon pea	0.014 (0.014)	-0.000 (0.014)	-0.013 (0.016)	0.004 (0.014)	-0.003 (0.018)	-0.01 (0.02)	-0.012 (0.022)
Experience in cow peas	0.042 (0.019)**	0.041 (0.018)**	0.053 (0.019)**	0.063 (0.019)***	0.069 (0.022)***	0.088 (0.024)***	0.087 (0.026)***
Food surplus	0.897 (0.516)*	0.441 (0.512)	0.518 (0.703)	0.615 (0.558)	1.176 (0.902)	-0.363 (0.797)	-0.776 (1.165)
No food shortage no surplus	1.716 (0.538)***	1.349 (0.513)***	0.733 (0.648)	2.376 (0.569)***	1.903 (0.801)**	0.75 (0.718)	2.097 (0.871)**
Occasional food shortage	1.391 (0.481)**	0.858 (0.453)*	1.26 (0.596)**	1.282 (0.518)**	2.258 (0.78)***	1.174 (0.665)*	2.677 (0.85)***
_IZone_2	0.088 (0.373)	0.964 (0.372)***	-0.802 (0.419)*	0.217 (0.382)	-0.364 (0.476)	-0.675 (0.497)	-0.717 (0.539)

Appendix 7: Exploratory factor analysis results (with all the loadings)

Table A1: Unedited exploratory factor analysis results

Factor Loadings (Varimax normalized) Extraction: Principal components (Marked loadings are >.650000)

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12	Factor 13	Factor 14	Factor 15
Experience growing maize	0.14	0.044	0.044	-0.011	-0.007	0.035	0.024	0.896	-0.015	-0.013	-0.027	-0.013	0.026	0.024	0.073
Walk minutes to main market	0.010	0.008	-0.801	-0.005	0.022	-0.062	-0.001	-0.027	-0.005	-0.036	0.030	0.002	0.055	0.033	-0.021
Walk minutes seed market	0.037	-0.048	-0.948	0.002	0.013	0.023	0.000	-0.007	0.010	0.063	0.012	-0.005	-0.024	-0.022	0.025
Walk minutes to fertiliser	0.035	-0.020	-0.949	0.004	0.018	0.022	0.004	-0.021	0.013	0.063	0.012	-0.014	-0.018	-0.034	0.020
Walking minutes to health centre	0.044	-0.035	-0.940	0.023	-0.001	0.034	0.000	-0.019	0.016	0.062	0.009	-0.014	-0.023	-0.031	0.026
Walking minutes to herbicide	0.022	0.006	-0.698	-0.022	0.063	0.008	-0.006	-0.036	-0.005	-0.055	-0.074	-0.057	0.047	-0.001	0.015
House hold size	0.146	0.036	-0.010	0.071	0.032	0.941	0.068	0.035	-0.009	-0.009	0.031	0.012	0.004	0.044	0.005
Adult equivalent in the house	0.161	0.028	0.004	0.054	0.041	0.952	0.094	0.078	0.009	-0.014	0.043	0.001	0.008	0.052	0.023
Age of household head	0.157	0.001	0.081	-0.035	-0.016	0.050	0.046	0.892	-0.047	-0.039	-0.028	0.004	0.017	-0.010	0.062

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12	Factor 13	Factor 14	Factor 15
Education of household head	0.165	0.060	0.005	-0.089	0.014	0.030	0.010	-0.621	0.007	-0.051	0.071	0.000	0.042	0.067	0.153
Transport asset value	0.023	0.020	-0.073	-0.010	-0.078	0.082	0.079	-0.031	0.041	0.007	0.032	0.004	0.169	-0.089	0.069
Cultivated area summer	0.681	-0.020	-0.070	-0.073	0.071	0.116	0.190	0.054	0.025	0.105	0.283	-0.006	0.094	0.043	0.279
Maize plot size	0.576	0.015	-0.002	0.088	-0.090	0.036	0.180	0.134	0.082	0.013	0.102	-0.019	-0.037	0.099	0.168
Pigeon pea plot size	0.026	-0.007	0.008	-0.044	-0.069	0.002	-0.025	0.065	-0.822	-0.008	-0.029	-0.006	0.031	0.001	-0.029
Crop residues retention winter	-0.022	0.042	0.016	0.781	0.131	0.027	0.076	0.021	0.051	-0.019	0.052	-0.025	0.013	-0.091	-0.025
Maize nitrogen used in winter	0.081	0.022	0.013	0.679	-0.061	0.040	-0.004	0.052	0.034	-0.008	-0.027	0.175	-0.073	0.243	0.214
Maize production in winter	0.044	-0.003	0.025	0.669	-0.054	0.053	0.007	0.023	-0.001	0.003	-0.007	0.248	-0.115	0.481	0.213
Crop sales	0.061	0.019	-0.036	-0.018	0.064	-0.025	0.010	0.004	0.006	0.990	0.012	-0.008	-0.010	0.003	0.018
Sales tax	0.057	0.020	0.025	0.035	0.005	0.047	-0.075	0.004	0.014	0.010	0.846	0.006	0.034	-0.004	-0.069
Transport cost	0.126	0.092	0.007	0.021	0.046	0.063	0.189	-0.036	0.059	0.027	0.624	0.053	-0.009	0.138	0.144
Maize soil fertility in winter	0.036	-0.015	-0.016	0.766	0.008	0.023	-0.038	0.019	-0.001	0.010	-0.006	0.015	0.121	-0.071	-0.099
Beans soil fertility in summer	-0.006	0.036	-0.034	0.062	0.809	0.030	-0.008	0.001	0.050	0.096	0.128	0.044	0.029	-0.021	-0.013
Pigeon pea soil fertility in	-	-	-	-	-	0.009	-	0.061	-	0.002	-	-	0.004	0.013	-

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12	Factor 13	Factor 14	Factor 15
summer	0.032	0.029	0.016	0.028	0.038		0.014		0.796		0.011	0.003			0.042
Pigeon pea soil fertility in Winter	-0.018	-0.129	0.013	0.149	-0.024	0.054	-0.007	-0.003	-0.195	0.045	0.000	-0.017	0.400	-0.155	-0.097

Appendix 8: Random effects models for the maize-legume intensification

Figure A2:Three Random Effects Models for Maize-Legume Intensification

Final model for legume mono-cropping

Figure A2:1 Legume model

Legvar	OR	Std. Err.	P-value	95% Conf. Interval	
Total labour	0.9984555	0.000762	0.043	0.996963	0.99995
Total owned land in summer	1.168444	0.057267	0.001	1.061425	1.286253
Pigeon pea plot size	0.2540716	0.165877	0.036	0.070669	0.913449
Uncultivated summer	0.8473673	0.061192	0.022	0.735535	0.976203
Fieldpest	19.15897	6.022135	0.000	10.34709	35.47527
Storepest	3.910025	1.178959	0.000	2.165327	7.060502
Observations	891				
Groups	6				
Wald $chi^2(6)$	266.07				
Prob > chi^2	0.000				
Log likelihood	-277.6019				
Rho	0.0342111	0.031676		0.005381	0.188256
Likelihood-ratio test of rho = 0:					
$chibar^2(01)$	4.38				
Prob >= $chibar^2$	0.018				

Note $chibar^2$ = The likelihood ratio test statistics of rho; Wald chi^2 = Wald hypothesis test for the model

Final model for maize mono-cropping

Figure A2:2 Maize model

Maizevar	OR	Std. Err.	P-value	95% Conf. Interval	
Fieldpest	5.874779	2.306293	0.000	2.721642	12.68096
Total labor	0.9981179	0.000803	0.019	0.996545	0.999693
Total owned land in summer	1.191964	0.060687	0.001	1.078762	1.317045
Famplan	2.138927	0.55386	0.003	1.287608	3.553108
Storepest	4.545544	1.84487	0.000	2.051702	10.07065
Uncultivated summer	0.8220472	0.055011	0.003	0.721	0.937257
Observations	891				
Groups	6				
Wald $chi^2(6)$	146.41				
Prob > chi^2	0.0000				
Log likelihood	-252.27895				
Rho	0.0780815	0.057216		0.017523	0.286823
Likelihood-ratio test of rho=0:					
$chibar^2(01)$	12.35				
Prob >= $chibar^2$	0.0000				

Note $chibar^2$ = The likelihood ratio test statistics of rho; Wald chi^2 = Wald hypothesis test for the model

Final model for mixed / intercropping cropping

Figure A2.3: Mixed cropping model

Mixed cropping	OR	Std. Err.	P-value	95% Conf. Interval	
Total labour	0.9979499	0.00069	0.003	0.996598	0.999304
Fieldpest	18.88945	5.821308	0.000	10.32519	34.55737
Total owned summer	1.231991	0.06176	0.000	1.116699	1.359185
Storepest	3.253959	0.976754	0.000	1.806773	5.86031
Walk minutes fertiliser	0.9936445	0.00244	0.009	0.988873	0.998439
Uncultivated summer	0.8046889	0.058826	0.003	0.697272	0.928654
Walk minutes village	1.013679	0.006897	0.046	1.000252	1.027287
Observations	891				
Groups	6				
Wald $chi^2(7)$	269.35				
Prob > chi^2	0.000				
Log likelihood	-294.56872				
rho	0.0780815	0.057216		0.017523	0.286823
Likelihood-ratio test of rho=0:					
$chibar^2(01)$	8.57				
Prob >= $chibar^2$	0.002				

Note $chibar^2$ = The likelihood ratio test statistics of rho; Wald chi^2 = Wald hypothesis test for the model

MALAWI FARMING SYSTEMS AND CONSERVATION AGRICULTURE

Appendix 9: Household Interview Questionnaire – Dec 2012--Jan 2013

UNIVERSITY OF WESTERN SYDNEY

PART 0. INTERVIEW BACKGROUND

1. Respondent's name: ....2.. Mobile /Home phone o…..............................

3. EPA....................................4. District:…..………………......... 5. Section ……………..……………….........

6. Village....................................7. Interviewed by (enumerator's name)..

8. Date of interview: Day:…..……………Month:............................Year:…..…………

9.Checked by (principal investigators name………….………………………………..)

10. Date checked:
Day:……..…..…………………..Month:...................................Year:…………………..

11. Date entered:
Day:……………………..Month:...............................Year:……..……................

PART 1. FARMERS IDENTIFICATION AND VILLAGE CHARACTERISTICS

Does main residential house have the following inbuilt? **Codes A** 1. Kitchen............... 2. Grain store..................

3. Livestock pen...........

Main walling material of main residential house……..............………………………..................(**Codes B**)

Main roofing material of main residential house………………............……………………………….(**Codes C**)

Experience in conservation agriculture practices. (years)..

Experience in growing maize (years)…………………………….......................………………………........

Experience in growing legumes (years) Common bean................... Soybean......…….........Pigeonpea….............… Groundnut......…..…Cowpea……........... Other, specify name ....Years of experience……....

Taking into consideration ALL food sources (own food production + food purchase + help from different sources + food hunted from forest and lakes, etc), how would you define your family's food consumption in the last year? (**Codes D**) ....

Distance to the village market from residence (km) ....minutes of walking time ....

What means of transport do you use mainly to get to the village market? (**Codes E**).

Average single trip transport cost (per person) to the village market using this means of transport (MK/person)....................

Distance to the nearest main market from residence (km)………........……minutes of walking time......……...…

Number of months the road to main market is passable for cars in a year..

Quality of road to the main market (**Codes F**)……………………...

Average single transport cost (per person) to the main market using a car (MK/person).......................................

Distance to the nearest source of farm inputs dealer from residence (km) ....minutes of walking time

Distance to the nearest agricultural extension office from residence (km)….....….minutes of walking time…..…

Codes A: 0. No; 1. Yes

Codes B: **1. Burned bricks; 2. Unburned bricks; 3. Mud bricks; 4. Stone; 5. Earth; 6. Wooden (timber); 7. Other, specify………………………**

Codes C: **1. Grass thatch; 2. Iron sheet; 3. Tiles; 4. Other, specify…………………………………………………………………………………**

Codes D: 1. Food shortage through the year, 2. Occasional food shortage, 3. No food shortage but no surplus, 4. Food surplus.

Codes E: 1. Walking; 2. Bicycle; 3. Tractor; 4. Car ;   5. Cart, 6. Other, specify……………………**Codes F:** 1= Very poor; 2= Poor;

3= Average; 4=Good; 5= Very good

PART 2: HOUSEHOLD COMPOSITION AND CHARACTERISTICS (Currently)

Family code	Name of household member (start with respondent)	Codes A	Age (years) [A]	Codes B	Education (years) **Codes C**	Relation to HHhead Codes D	Occupation **Codes E** Main	Secondary	Own farm labour contribution Codes F
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
01									
02									
03									
04									
05									
06									
07									
08									
09									
10									

Codes A	**Codes B**	**Codes C**	**Codes D**	**Codes E**	**Codes F**	**Codes G**
0. Female 1. Male	1. Married living with spouse 2. Married but spouse away 3. Divorced/separated 4. Widow/widower 5. Never married 6. Other, specify……	0. None/Illiterate 1. Adult education or 1 year of education * Give other education in years	1. Household head 2. Spouse 3. Son/daughter 4. Parent 5. Son/daughter in-law 6. Grand child 7. Other relative 8. Hired worker 9. Other, specify……	1. Farming (crop + livestock) 11. Other, specify..... 2. Salaried employment 3. Self-employed off-farm 4. Casual labourer on-farm 5. Casual labourer off-farm 6. School/college child 7. Non-school child 8. Herding 9. Household chores. 10. No secondary occupation	1. 100% 2. 75% 3. 50% 4. 25% 5. 10% 6. Not a worker	0. No 1. Yes

PART 3: SOCIAL CAPITAL AND NETWORKING

Have you and/or your spouse been member/s of formal and informal institutions in the last 3 years?.............1= Yes; 0=No. If yes please ask the following table and if no go to next section.

Section A. Membership in formal and informal institutions in the last 3 years (husband and wife/wives only. One group membership per row.)

Family code	Type of group the husband/wife is/was a member of: (**codes A**)	Three most important group functions: **(codes B)**			Year joined (YYYY)	Role in the group **(codes C)**	Still a member now? **(codes D)**	If No in column 8, reason/s for leaving the group (**codes E**), Rank 3		
		1st	2nd	3rd				1st	2nd	3rd
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**

Codes A 1. Input supply/farmer coops/union 2. Crop/seed producer and marketing group/coops 3. Local/religion administration 4. Farmers'/womens/youth Association/group 5. Saving and credit group Residue retention	6Conservation Agriculture 7. 8. legume maximum cover 9.crop rotation 10. Pit planting11 Other, specify…………….	**Codes B** 1. Produce/seed production and marketing 2. Pit planting 3.Crop/ Seed production 4. Farmer research group 5. Savings and credit 6. Residue retention 7. Tree planting and nurseries 8. Crop rotation **9.Rain water harvesting** **10. Contour ridges** **11. Box ridges** **12. vertiva grass**	13. Church group /congregation 14. Input credit 15.Minimum tillage 16 Pit planting group 17. Legume intensification 18.Manure making 92. Other, specify………	**Codes C** 1. Official 2. Ex-official 3. Ordinary member **Codes D** 1. Yes 0. No	**Codes E** 1. Left because organization was not useful/profitable 2. Left because of poor management 3. Unable to pay annual subscription fee 4. Group ceased to exist 5.Labour intensive 6.lack of extension advice 7. lack of inputs / credit 8. Other, specify……………

Section B. Social networks

Number of years the respondent has been living in this village ....

Are any of your friends or relatives in leadership positions in formal or informal institutions within and outside this village ?................. Codes: 1. Yes, 0. No

3Generally speaking, do you see any difference between crops grown using CA system and traditional farmer practice? Codes: 1. Yes, 0. No

If answer in Question 3 above is 1, then which types of CA do you practice?

Codes: 1.Residue retention; 2. Minimum tillage; 3.herbicide use; 4. Crop rotation; 5. Pit planting 6. Others , specify ....

And what was the reason for your answer in 4 above?...

....

Do you think you can rely on government support (subsidies, food aid etc) if your crop fails?.........................

Codes: 1.Yes; 0. No

Do you get enough skills of government officials including NGO's extension workers to do their job in your trainings of CA?...(**Codes** A)

Codes A: 1. Strongly disagree; 2. Disagree; 3. Slightly disagree; 4. Slightly agree; 5. Agree; 6. Strongly agree

Codes B: 1, Drought tolerance, 2.Grain yield is much higher , 3.Water logging tolerance, 4. Crop residue yield is high 5. Output grain price is high 6. Labour input saving 7.Other specify..

Household Identification Number..........................

PART 4. HOUSEHOLD ASSETS

Section A: Production equipment and other accessories to farming

Asset	Number (if no equipment put zero)	Original purchase price (MK) (if more than two items reported in column 2 take average price)	If you would sell [….] how much would you receive from the sale? (MK) (if more than two items reported in column 2 take average price)	Total current Value
1	**2**	**3**	**4**	**5= 2*4**
1.Wheelbarrow /push cart				
2. Donkey/ox cart				
3.Jab Planter				
4.Radio/Tv				
5. Ox-plough/ridger				
6. Sickle / panga knife				
7. Pick Axe/Axe				
8. Handhoe/Jembe				
9. Knapsack sprayer				
10. Mechanical water pump (hand, foot, "*treadle pump")*				
11. Motorized water pump (diesel)				
12. Spade or shovel				
13. Cell phone				
14. Bicycle				
15. Motorbike				
16. Cars /pickups /trucks(lorry)				
17. Other specify				

Section B: Land holding (acres) during the cropping year and Adoption or Adaptation of CA (4 last cropping years, separate answer by comas by year

Land category/Plots	**Upland/Rainfed season (Nov/Dec 2008,09,10,11)**		**Residual moisture/Dambo (river banks) season (Apr/May 2009,10,11,12)**	
	Cultivated (vegetables + annual + permanent crops (e.g., maize, coffee, mangoes) acres	What soil fertility enhancement practices and technologies are practiced? Codes A	Cultivated (vegetables, maize, coffee, mangoes etc i.e. annual + permanent crops) acres	What soil enhancement practices and technologies are practiced? Codes A
1	**2**	**3**	**4**	**5**
1.Own land used (A)				
2. Rented in land (B)				
3. Rented out land (C)				
4. Borrowed in land (D)				
5. Borrowed out land (E)				

6. Total owned land (A+C+E)				
7. Total operated land (A+B+D)				
8. Bought land during the seasons				
9. Sold land during theseasons				

Codes A: 1. Minimum tillage, 2. Residue retention, 3.Legume cover crops, 4. Crop rotaion, 5. Herbicides use, 6. Box ridges, 7. Vertiva grass, 8. Contour ridges, 9.Other, specify........

PART 5. CONSERVATION AGRICULTURE PACKADGE KNOWLEDGE AND ADOPTION

Section A. CA package knowledge, sources of information and CA part, adopted and or adapted

							If Yes in column 5					If **NO** in column 12		
							First CA individual practice							
Only individual CA practices aware/heard of **Codes D**	In your own words ,are you aware of CA as a packadge, what does it involve, <u>If no, put 0</u>	Year CA practice known/ heard **YYYY**	Sources of CA information **Codes A,** Rank 3	Ever practiced ? **Codes B**	If **NO in** **Column 5,** Why? **Codes C** Rank 3	If **YES in column 5,** year first adopted **YYYY**	What was the first CA part you adopted? **Codes D**	Plot size in acres	Why, was this the first part you adopted? **Codes E,**	No. of seasons this CA part has been <u>practiced</u>	Land practiced this CA package in 2011/2012 **Codes F**	Have/Will you adopt another part of CA after	If yes in column 13 Which packad ge Codes	If No in Column 13, why not, **Codes C**

Household Identification Number.........................

									Rank 3			this / in future **Codes B**	D	**Rank 3**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**

*

Codes A		**Codes B**	**Codes C**		**Codes D**		**Codes E**	
1. Government extension 2. Farmer Coop/Union 3. Farmer group	7. On-farm trials 8. Relative 9. Neighbour 10. Radio/newspaper/TV	0. No 1. Yes	1. labour intensive 2. Lack of cash/credit to buy herbicides 3.Susceptible to	5. did not receive seed and fertilizer coupon subsidy 6. used to making ridges 8. don't believe one can	**1Minimum Tillage** **2. Crop rotation** **3.Maximum crop cover(legumes)**	**7.Box ridges (rain water harvesting** **8.vertiva grass** **9.Contour ridges**	1. source of protein 2.easy to use 3. saves labour 4.on farm trials	6. Subsidy 7. Advance pay from coop 8. Other, specify……

4. NGO/CBO 5. Research centre (trials/demos/field days) **6. Farmer to farmer extension**	11. Total Land Care **12. Extension demo plots** **13. Farmer groups/Coops** ………		diseases/pests 4. difficult to carry manure to the farm 5. Require high skills	plant without tillage 9. Lack of enough land 11. Other, specify……….	**4.Residue retention** **5.Herbicides use** **6.Pit Planting**	10. Other**, specify**……… Codes F **Upland** **Dambo(river banks)**	impressive results 5.saw it worked on farm demonstration	

PART 6. CROP PRODUCTION FOR <u>ALL CROPS</u> (cereals / legumes annual + perennial + vegetables) GROWN BY THE HOUSEHOLD DURING 2011/12, crop calendar

Section A. Plot characteristics, investment and input use and yield

Definitions: A plot is a piece of land physically separated from others; a subplot is a subunit of a plot. If more than one crop is grown on a plot (that is, on different subplots), repeat the plot code in next row and use subplot code. If the (sub) plot is intercropped, use same row and separate the different intercrops by comma e,g.,(1,2) for maize and beans. Consider <u>only 2 main intercrops</u> if more than 3 on a (sub) plot.

Serial number	Season **Codes A**	Plot code (start with one next to residence)	Plot location name (as called by farmer)	(Sub)plot code	(Sub)plot size (acres)	Crop(s) grown (Annex 1 codes)	Crops variety (Annex 2 codes)	Type of fertilizer used in kgs **Codes B**	Intercrop	intercrop (e.g. 50,50)	residence (walking minutes)	**Codes C**	**Codes D**	**Codes E**	**Codes F**	**Codes G**	**Codes H**	Conservation Agriculture method – **Codes I**	Agro-forestry technology on the (sub)plot –**codes J**	Yield of intercrop **1** in **Kgs**	Yield of intercrop **2** in **kgs**	Household food secure (1= Yes, 0= No): Amount consumed kgs	Household food secure (1= Yes, 0= No): Amount sold or shared **kgs**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**

Household Identification Number……………..

Codes A	**Codes B**	**Codes C**	**Codes D**	**Codes E**	**Codes F**	**Codes G**	**Codes H**	**Codes I**	**Codes J**
1. Rainfed season /Upland (Nov/Dec) 2. Residual moisture /Dambo (Apr/May)	1. NPK 2. Urea 3. Other ……	1. Owned 2. Rented in 3. Rented out 4. Borrowed in 5.Borrowed out 6. Other, specify….	0. Women 1. Men 2. Both equally	1. Good 2. Medium 3. Poor	1. Gently slope (flat) 2. Medium slope 3. Steep slope	1. Shallow 2. Medium 3. Deep	1. Black 2. Brown 3. Red 4.Grey 5. Other, specify…	0. None 1. Crop rotation 2. Pit planting 3. Grass strips 4. maximum crop cover(legume) 5. Residue retention 6.Minimum till 7.Contour ridges 8.Herbicide use 9. Box ridges 10.Other, specify…	0. Live fence 1 Fertilizer tree 2.Fodder banks 3.Indegenous fruit tree 4.Other

Section B: Input use for <u>all crops</u> grown by the household during 2009/10

(Serial number, plot code, sub-plot code, and crop(s) grown in this Section should be in <u>exactly the same order as in Section A</u> above)

Serial number	Season	Plot code	Subplot code	Crop(s) grown	Crops variety	crop grown (Annex	Fertilizer (If not used, put Zero)	Seed use (if intercropped, <u>separate by comma</u>)	Manure (dry equivalent)	Herbicides

Household Identification Number……………..

							Amount of NPK/D-Compound etc (Kg)	Total cost (MK)	Amount of Urea/CAN etc (Kg)	Total cost (MK)	Main method of payment for fertilizer (**Codes A**)	Non-bought seed (own saved, subsidy program, farmers to farmers exchange, etc (**kg or Nos**)	No. of seasons own saved seed recycled	Bought including using credit & coupons		Main method of payment for seed (**Codes A**)	own	Bought		Litres /kg	Total cost (MK)
														Amount(kg)	Total cost (MK)		kg	kg	Total cost (MK)		
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**

Household Identification Number................

Codes A		
1.Own cash	5. Money got as gift from relative & non-relatives	**10. Credit micro-finance**
2. Subsidy government coupon	**6. Credit SACCO**	**11. Credit from NGO**
3. Coupons bought from other beneficiaries	**7. Credit bank**	**12. Own saved seed**
4. Coupons from public work programme	8. Credit money lender	**13. MRFC**
	9. Credit from relative/neighbour/friend	**14. Other, specify …**

Section B: Input use for all crops grown by the household during 2010/11

(Serial number, plot code, sub-plot code, and crop(s) grown in this Section should be in exactly the same order as in Section A above)

Serial number	Season	Plot code	Subplot code	Crop(s) grown	Crops variety (Annex 2 codes)	grown **(Annex 1 codes)**	Fertilizer (If not used, put Zero)					Seed use (if intercropped, separate by comma)					Manure (dry equivalent)			Herbicides	
							Amount of NPK/D-Compound etc (Kg)	Total cost (MK)	Amount of Urea/CAN etc (Kg)	Total cost (MK)	Main method of payment for fertilizer (**Codes A**)	Non-bought seed (own saved, subsidy program, farmers to farmers exchange, etc (**kg or Nos**)	No. of seasons own saved seed recycled	Bought including using credit & coupons		Main method of payment for seed (**Codes A**)	own	Bought		Litres /kg	Total cost (MK)
														Amount(kg)	Total cost (MK)		kg	kg	Total cost (MK)		
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**

Household Identification Number……………..

Codes A		
1.Own cash	5. Money got as gift from relative & non-relatives	**10. Credit micro-finance**
2. Subsidy government coupon	**6. Credit SACCO**	**11. Credit from NGO**
3. Coupons bought from other beneficiaries	**7. Credit bank**	**12. Own saved seed**
4. Coupons from public work programme	8. Credit money lender	**13. MRFC**
	9. Credit from relative/neighbour/friend	**14. Other, specify …**

Section B: Input use for <u>all crops</u> grown by the household during 2011/12

(Serial number, plot code, sub-plot code, and crop(s) grown in this Section should be in <u>exactly the same order as in Section A</u> above)

Serial number	Season	Plot code	Subplot code	Crop(s) grown	Crops variety (Annex 2 codes)	grown **(Annex 1 codes)**	Fertilizer (If not used, put Zero)					Seed use (if intercropped, <u>separate by comma</u>)					Manure (dry equivalent)			Herbicides	
							Amount of NPK/D-Compound etc (Kg)	Total cost (MK)	Amount of Urea/CAN etc (Kg)	Total cost (MK)	<u>Main</u> method of payment for fertilizer (**Codes A**)	Non-bought seed (own saved, subsidy program, farmers to farmers exchange, etc (**kg or No**s)	No. of seasons own saved seed <u>recycled</u>	Bought including using credit & coupons		<u>Main</u> method of payment for seed (**Codes A**)	own	Bought		Litres /kg	Total cost (MK)
														Amount(kg)	Total cost (MK)		kg	kg	Total cost (MK)		
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**

Household Identification Number……………..

Codes A

1.Own cash

2. Subsidy government coupon

3. Coupons bought from other beneficiaries

4. Coupons from public work programme

5. Money got as gift from relative & non-relatives

6. Credit SACCO

7. Credit bank

8. Credit money lender

9. Credit from relative/neighbour/friend

10. Credit micro-finance

11. Credit from NGO

12. Own saved seed

13. MRFC

14. Other, specify …

Section C: Input use and crop harvested 2009/10

(Serial number, plot code, sub-plot code, and crop(s) grown in this Section should be in exactly the same order as in Section A above)

					Herbicides		Plowing days (using oxen and/or hand hoe)		Total labour (family and hired) use in person days Intercrops: record harvesting and threshing/shelling separately (by comma)												Total harvested per (sub)plot Intercrops: separate by comma	
									Land preparation & planting		Weed control			Harvesting/ shelling		Manure making and application						
Serial number	Season	Plot code	Subplot code	Crop(s) grown	Litres/kg	Total cost (MK)	Plowing Freq	Total Plowing oxen days	Male	Female	Weeding freq	Male	Female	Male	Female	Male	Female	Cost of oxen hired (MK)	Cost of hired labour /shelling, threshing (MK)	**Codes A**	Fresh or green (kg)	Dry (kg)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**

Codes A: **0. No stress; 1. Insect pests; 2. Diseases; 3. Water logging; 4. Drought; 5. Frost; 6. Hailstorm; 7. Animal trampling; 8. Other, specify……………………**

Section C: Input use and crop harvested 2010/11

(Serial number, plot code, sub-plot code, and crop(s) grown in this Section should be in <u>exactly the same order as in Section A</u> above)

number	Season	Plot code	code	Crop(s) grown	Herbicides	Plowing days (using oxen and/or hand hoe)	Total labour (family and hired) use in person days Intercrops: record harvesting and threshing/shelling separately (by comma)	Cost of oxen hired	Cost of hired labour	on plot	Total harvested per (sub)plot Intercrops: separate by

Household Identification Number……………..

																		(MK)	/shelling, threshing (MK)		comma	
									Land preparation & planting		Weed control			Harvesting/ shelling		Manure making and application					Fresh or green (kg)	Dry (kg)
					Litres/kg	Total cost (MK)	Plowing Freq	Total Plowing oxen days	Male	Female	Weeding freq	Male	Female	Male	Female	Male	Female					
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**

Codes A: **0. No stress; 1. Insect pests; 2. Diseases; 3. Water logging; 4. Drought; 5. Frost; 6. Hailstorm; 7. Animal trampling; 8. Other, specify……………………**

Section C: Input use and crop harvested 2011/12

(Serial number, plot code, sub-plot code, and crop(s) grown in this Section should be in exactly the same order as in Section A above)

Serial number	Season	Plot code	Subplot code	Crop(s) grown	Herbicides		Plowing days (using oxen and/or hand hoe)		Total labour (family and hired) use in person days Intercrops: record harvesting and threshing/shelling separately (by comma)									Cost of oxen hired (MK)	Cost of hired labour /shelling, threshing (MK)	Codes A	Total harvested per (sub)plot Intercrops: separate by comma	
									Land preparation & planting		Weed control			Harvesting/ shelling		Manure making and application						
					Litres/kg	Total cost (MK)	Plowing Freq	Total Plowing oxen days	Male	Female	Weeding freq	Male	Female	Male	Female	Male	Female				Fresh or green (kg)	Dry (kg)

Household Identification Number……………..

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

Codes A: **0. No stress; 1. Insect pests; 2. Diseases; 3. Water logging; 4. Drought; 5. Frost; 6. Hailstorm; 7. Animal trampling; 8. Other, specify……………………**

Section D: Utilization of crop produced and household food security 2009/10

Different from Sections A-C: one row per crop and season (e.g. add production from all maize plots together for season 1)

Crop (From section C)	Season (From section C)	**Form Codes A**	Carry over stock from 2009/10 harvest (kg)	Production of 2009/10 (last columns of Section C) (kg)	Total available stock for 2010/11 use (kg)	From the total available stock (**column 6**)…					Amount left in store before 2010/11 harvest (kg)	If total available stock (column 6) was not sufficient for consumption until 2010/11 harvest:	
						Quantity sold (kg)	In-kind payments (labour, land & others) paid during 2010/11 cropping year (kg)	Seed used during 2010/11cropping year (kg)	Gift, tithe, donations given out during 2010/11 cropping year (kg)	Consumption during 2010/11 cropping year (kg)		Amount bought (kg)	Food aid/gifts received (kg)
1	**2**	**3**	**4**	**5**	**6=4+5**	**7**	**8**	**9**	**10**	**11**	**12=6-7-8-9-10-11**	**13**	**14**

Household Identification Number……………..

Codes A: 1. Fresh/green; 2. Dry

Section D: Utilization of crop produced and household food security 2010/11

Different from Sections A-C: one row per crop and season (e.g. add production from all maize plots together for season 1)

Crop (From section C)	Season (From section C)	**Form Codes A**	Carry over stock from 2010/11, harvest (kg)	Production of 2011/12 (last columns of Section C) (kg)	Total available stock for 2011/12 use (kg)	From the total available stock (**column 6**)…					Amount left in store before 2011/12 harvest (kg)	If total available stock (column 6) was not sufficient for consumption until 2011/12 harvest:	
						Quantity sold (kg)	In-kind payments (labour, land & others) paid during 2011/12 cropping year (kg)	Seed used during 2011/12 cropping year (kg)	Gift, tithe, donations given out during 2011/12 cropping year (kg)	Consumption during 2011/12 cropping year (kg)		Amount bought (kg)	Food aid/gifts received (kg)
1	**2**	**3**	**4**	**5**	**6=4+5**	**7**	**8**	**9**	**10**	**11**	**12=6-7-8-9-10-11**	**13**	**14**

Household Identification Number……………..

Codes A: 1. Fresh/green; 2. Dry

Household Identification Number……………..

Section E: Marketing of crops 2009/10

Different from Sections A-D: one row per sale (different months, different buyers), per crop and per season

Crop (From Column 1 of Section D)	Season (From Column 2 of Section D)	Form (From Column 3 of Section D)	Market type **Codes A**	Month sold Codes C	Quantity sold (kg) (sum should be equal to Column 7 of Section D)	Who sold Codes B	Price (MK /kg)	Buyer Codes D	Period to payment after selling, weeks (if immediate write zero)	Relation to buyer Codes E	Quality Codes F	Sales tax or charges (MK)	Time taken to sell crop (minutes)	Time taken to get to the market (minutes)	Mode of transport Codes G	Actual transport cost (MK)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**

Household Identification Number……………..

Codes A	**Codes B**	**Codes C**	**Codes D**	**Codes E**	**Codes F**	**Codes G**
1. Farmgate 2. Village market 3. Main/district market	0. Female 1. Male 2. Both	1. January 2. February 3. March 4. April 5. May 6. June 7. July 8. August 9. September 10. October 11. November 12. December	1. Farmer group 2. Farmer Union or Coop 3. Consumer or other farmer 4. Rural assembler 5. Broker/middlemen 6. Rural grain trader 7. Rural wholesaler 8. Urban wholesaler 9. Urban grain trader 10. Exporter, 11. Other, specify…….	1. No relation but not a long time buyer 2. No relation but a long term buyer 3. Relative 4. Friend 5. Money lender 6. Other, specify……	1. Below average 2. Fair and Average 3. Above average	1. Bicycle 2. Hired truck 3. Public transport 4. Donkey 5. Oxen/horse cart 6. Back/head load 7. Other, specify….

Household Identification Number……………..

Section E: Marketing of crops 2010/11

Different from Sections A-D: <u>one row per sale (different months, different buyers), per crop and per season</u>

Crop (From Column 1 of Section D)	Season (From Column 2 of Section D)	Form (From Column 3 of Section D)	Market type **Codes A**	Month sold Codes C	Quantity sold (kg) (sum should be equal to Column 7 of Section D)	Who sold Codes B	Price (MK /kg)	Buyer Codes D	Period to payment after selling, weeks (if immediate write zero)	Relation to buyer Codes E	Quality Codes F	Sales tax or charges (MK)	Time taken to sell crop (minutes)	Time taken to get to the market (minutes)	Mode of transport Codes G	Actual transport cost (MK)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**

Household Identification Number……………..

Codes A	**Codes B**	**Codes C**		**Codes D**		**Codes E**	**Codes F**	**Codes G**
1. Farmgate 2. Village market 3. Main/district market	0. Female 1. Male 2. Both	1. January 2. February 3. March 4. April 5. May 6. June	7. July 8. August 9. September 10. October 11. November 12. December	1. Farmer group 2. Farmer Union or Coop 3. Consumer or other farmer 4. Rural assembler 5. Broker/middlemen 6. Rural grain trader	7. Rural wholesaler 8. Urban wholesaler 9. Urban grain trader 10. Exporter, 11. Other, specify…….	1. No relation but not a long time buyer 2. No relation but a long term buyer 3. Relative 4. Friend 5. Money lender 6. Other, specify……	1. Below average 2. Fair and Average 3. Above average	1. Bicycle 2. Hired truck 3. Public transport 4. Donkey 5. Oxen/horse cart 6. Back/head load 7. Other, specify….

Household Identification Number………………

Section E: Marketing of crops 2011/12

Different from Sections A-D: <u>one row per sale (different months, different buyers), per crop and per season</u>

Crop (From Column 1 of Section D)	Season (From Column 2 of Section D)	Form (From Column 3 of Section D)	Market type **Codes A**	Month sold Codes C	Quantity sold (kg) (sum should be equal to Column 7 of Section D)	Who sold Codes B	Price (MK /kg)	Buyer Codes D	Period to payment after selling, weeks (if immediate write zero)	Relation to buyer Codes E	Quality Codes F	Sales tax or charges (MK)	Time taken to sell crop (minutes)	Time taken to get to the market (minutes)	Mode of transport Codes G	Actual transport cost (MK)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**

Codes A	**Codes B**	**Codes C**	**Codes D**	**Codes E**	**Codes F**	**Codes G**
1. Farmgate 2. Village market 3. Main/district market	0. Female 1. Male 2. Both	1. January 2. February 3. March 4. April 5. May 6. June 7. July 8. August 9. September 10. October 11. November 12. December	1. Farmer group 2. Farmer Union or Coop 3. Consumer or other farmer 4. Rural assembler 5. Broker/middlemen 6. Rural grain trader 7. Rural wholesaler 8. Urban wholesaler 9. Urban grain trader 10. Exporter, 11. Other, specify…….	1. No relation but not a long time buyer 2. No relation but a long term buyer 3. Relative 4. Friend 5. Money lender 6. Other, specify……	1. Below average 2. Fair and Average 3. Above average	1. Bicycle 2. Hired truck 3. Public transport 4. Donkey 5. Oxen/horse cart 6. Back/head load 7. Other, specify….

Section F: Percent (%) utilization of crop residues produced during 2009/10 season

Same order of crops and seasons as section D. Note that percentages need to add up to 100% for every row.

Crop (same order as in section D above)	Season (From Column 2 of Section D)	Total production of crop residues (kg)	Burnt in the field (%)	Used as firewood (%)	Left on land for soil fertility (%)	Feed for livestock (%)	Used for construction (%)	Sold (%)	Other uses (%)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

Section F: Percent (%) utilization of crop residues produced during 2010/11 season

Same order of crops and seasons as section D. Note that percentages need to add up to 100% for every row.

Crop (same order as in section D above)	Season (From Column 2 of Section D)	Total production of crop residues (kg)	Burnt in the field (%)	Used as firewood (%)	Left on land for soil fertility (%)	Feed for livestock (%)	Used for construction (%)	Sold (%)	Other uses (%)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

Section F: Percent (%) utilization of crop residues produced during 2011/12 season

Same order of crops and seasons as section D. Note that percentages need to add up to 100% for every row.

Crop (same order as in section D above)	Season (From Column 2 of Section D)	Total production of crop residues (kg)	Burnt in the field (%)	Used as firewood (%)	Left on land for soil fertility (%)	Feed for livestock (%)	Used for construction (%)	Sold (%)	Other uses (%)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

PART 7: LIVESTOCK PRODUCTION AND MARKETING

Section A: Livestock production activities during 2009/10 cropping year

Livestock type	Number of livestock at end of 2009/10 cropping season (including bought ones)	Total amount Manure Produced in the Kraal for each type (eg, goats house, cattle house etc) kg	Average total days milked per animal	Average daily milk yield per animal (litres)	Total milk production (litres) & honey production (kg)	Amount of manure applied on the farm plots	Total Cost of Production (MK)			
							Fodder	Labour	Veterinary care	Artificial insemination
1	**2**	**3**	**4**	**5**	**6=2*4*5**		**7**	**8**	**9**	**10**
Cattle										
1. Indigenous milking cows										
2. Cross-bred milking cows										
3.Exotic milking cows										
4. Non milking cows (mature)										
5. Trained oxen for ploughing										
6. Bulls										
7. Heifers										
8. Calves										
Goats										
9. Mature female goats										
10. Mature male goats										
11. Young male goats										

12.Young female goats										
Sheep										
13. Mature female sheep										
14. Mature male sheep										
15. Young female sheep										
16. Young male sheep										
Other livestock										
17. Mature trained donkeys										
18. Young donkeys										
19. Pigs mature										
20. Pigs young										
21. Mature chicken										
22. Bee hives										
Others ...										

PART 7: LIVESTOCK PRODUCTION AND MARKETING

Section A: Livestock production activities during 2010/11 cropping year

Livestock type	Number of livestock at end of 2009/10 cropping season (including bought ones)	Total amount Manure Produced in the Kraal for each type (eg, goats house, cattle house etc) kg	Average total days milked per animal	Average daily milk yield per animal (litres)	Total milk production (litres) & honey production (kg)	Amount of manure applied on the farm plots (kg)	Total Cost of Pro	
							Fodder	Labo
1	**2**	**3**	**4**	**5**	**6=2*4*5**		**7**	**8**
Cattle								
1. Indigenous milking cows								
2. Cross-bred milking cows								
3.Exotic milking cows								
4. Non milking cows (mature)								
5. Trained oxen for ploughing								
6. Bulls								
7. Heifers								
8. Calves								
Goats								
9. Mature female goats								
10. Mature male goats								
11. Young male goats								
12.Young female goats								
Sheep								
13. Mature female sheep								
14. Mature male sheep								
15. Young female sheep								
16. Young male sheep								
Other livestock								
17. Mature trained donkeys								
18. Young donkeys								
19. Pigs mature								

20. Pigs young								
21. Mature chicken								
22. Bee hives								
Others ...								

PART 7: LIVESTOCK PRODUCTION AND MARKETING

Section A: Livestock production activities during 2011/12 cropping year

Livestock type	Number of livestock at end of 2009/10 cropping season (including bought ones)	Total amount Manure Produced in the Kraal for each type (eg, goats house, cattle house etc) kg	Average total days milked per animal	Average daily milk yield per animal (litres)	Total milk production (litres) & honey production (kg)		Total Cost of Pro	
						Amount of manure applied on the farm plots kg	Fodder	Labo
1	**2**	**3**	**4**	**5**	**6=2*4*5**		**7**	**8**
Cattle								
1. Indigenous milking cows								
2. Cross-bred milking cows								
3.Exotic milking cows								
4. Non milking cows (mature)								
5. Trained oxen for ploughing								
6. Bulls								
7. Heifers								
8. Calves								
Goats								
9. Mature female goats								
10. Mature male goats								
11. Young male goats								
12.Young female goats								
Sheep								
13. Mature female sheep								
14. Mature male sheep								

15. Young female sheep								
16. Young male sheep								
Other livestock								
17. Mature trained donkeys								
18. Young donkeys								
19. Pigs mature								
20. Pigs young								
21. Mature chicken								
22. Bee hives								
Others ...								

Section B: Livestock and livestock products selling and buying activities last year

Livestock/products	Selling				Buying			
	Quantity sold	Unit	Who sold 1 = Men 0 = Women 2=Both	Average per unit price (MK/unit)	Quantity bought	Unit	Who Bought 1 = Men 0 = Women 2=Both	Average per unit price (MK/unit)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1. Indigenous milking cows								
2. Crossbred milking cows								
3.Exotic milking cows								
4. Non milking cows (mature)								
5. Trained oxen for ploughing								

6. Bulls								
7. Heifers								
8. Calves								
9. Mature milking goats								
10. Other mature female goats								
11. Mature male goats								
12. Young female goats								
13.Young male goats								
14. Mature female sheep								
15. Mature male sheep								
16. Young female sheep								
17.Young male sheep								
18. Mature trained donkeys								
19. Young donkeys								
20. Manure								
21. Mule								
22. Mature chicken								
23. Local Bee hives								
24.Modern Bee hives								
25.Pigs, mature								
26.Pigs, young								
27.Turkeys, mature								
28.Guinea fowls, mature								

29.Ducks, mature								
30.Rabbit, mature								
31. Other								
32.								
33.								
Animal products								
34.Milk (check sale if production recoded)								
35.Eggs								
36.Butter								
37.Beef								
38.Mutton								
39.Yoghurt								
40.Honey								
41Fish								
42.Hide								
43.Skin								
44.Manure								
45. Sour milk (*chambiko*)								
46.Other..........................								

PART 8: TRANSFER AND OTHER SOURCES OF INCOME 2009/10

Sources	Who earned/ received? 0= None; 1=Women 2=Men; 3=Both	No. of units worked/ received	Unit (e.g. month, week, day, year, kg, no.)	Amount per unit (Cash & in-kind)		Total income (cash & in-kind)		Total income **(MK)**
				Cash **(MK)**	Payment in kind **Cash equivalent**	Cash **(MK)**	Payment in kind **Cash equivalent**	
1	**2**	**3**	**4**	**5**	**6**	**7= 3x5**	**8=3x6**	**9= 7+8**
1. Rented/sharecropped out land								
2. Rented out oxen for ploughing								
3. Salaried employment								
4. Farm labour wages								
5. Non-farm labour wages								
6. Non-farm agribusiness NET income (e.g. grain milling/trading)								
7. Other business NET income (shops, trade, tailor, sales of beverages etc)								
8. Pension income								
9. Drought/flood relief								
10.Safety net or food for work								
11. Remittances (sent from non-resident family and relatives living elsewhere)								
12. Marriage Gifts								
13. Sales of firewood, brick making, charcoal making, poles from own and communal sources etc								
14. Sale of maize crop residues								
15. Sale of legumes crop residues								
16. Sale of wheat crop residues								
17. Sale of finger millet crop residues								
18. Sale of other crop residues								
19. Sale of hay								
20. Quarrying stones								
21. Sale of dung cake								
22.Rental property (other than land and oxen)								

23. Interest from deposits								
25. Social cash transfer								
26. Other, specify								
27.								

PART 8: TRANSFER AND OTHER SOURCES OF INCOME 2010/11

Sources	Who earned/ received? 0= None; 1=Women 2=Men; 3=Both	No. of units worked/ received	Unit (e.g. month, week, day, year, kg, no.)	Amount per unit (Cash & in-kind)		Total income (cash & in-kind)		Total income **(MK)**
				Cash **(MK)**	Payment in kind **Cash equivalent**	Cash **(MK)**	Payment in kind **Cash equivalent**	
1	**2**	**3**	**4**	**5**	**6**	**7= 3x5**	**8=3x6**	**9= 7+8**
1. Rented/sharecropped out land								
2. Rented out oxen for ploughing								
3. Salaried employment								
4. Farm labour wages								
5. Non-farm labour wages								
6. Non-farm agribusiness NET income (e.g. grain milling/trading)								
7. Other business NET income (shops, trade, tailor, sales of beverages etc)								
8. Pension income								
9. Drought/flood relief								
10.Safety net or food for work								
11. Remittances (sent from non-resident family and relatives living elsewhere)								
12. Marriage Gifts								
13. Sales of firewood, brick making, charcoal making, poles from own and communal sources etc								
14. Sale of maize crop residues								
15. Sale of legumes crop residues								
16. Sale of wheat crop residues								
17. Sale of finger millet crop residues								
18. Sale of other crop residues								
19. Sale of hay								
20. Quarrying stones								

21. Sale of dung cake								
22.Rental property (other than land and oxen)								
23. Interest from deposits								
25. Social cash transfer								
26. Other, specify								
27.								

PART 8: TRANSFER AND OTHER SOURCES OF INCOME 2011/12

Sources	Who earned/ received? 0= None; 1=Women 2=Men; 3=Both	No. of units worked/ received	Unit (e.g. month, week, day, year, kg, no.)	Amount per unit (Cash & in-kind)		Total income (cash & in-kind)		Total income **(MK)**
				Cash **(MK)**	Payment in kind **Cash equivalent**	Cash **(MK)**	Payment in kind **Cash equivalent**	
1	**2**	**3**	**4**	**5**	**6**	**7= 3x5**	**8=3x6**	**9= 7+8**
1. Rented/sharecropped out land								
2. Rented out oxen for ploughing								
3. Salaried employment								
4. Farm labour wages								
5. Non-farm labour wages								
6. Non-farm agribusiness NET income (e.g. grain milling/trading)								
7. Other business NET income (shops, trade, tailor, sales of beverages etc)								
8. Pension income								
9. Drought/flood relief								
10.Safety net or food for work								
11. Remittances (sent from non-resident family and relatives living elsewhere)								
12. Marriage Gifts								

13. Sales of firewood, brick making, charcoal making, poles from own and communal sources etc									
14. Sale of maize crop residues									
15. Sale of legumes crop residues									
16. Sale of wheat crop residues									
17. Sale of finger millet crop residues									
18. Sale of other crop residues									
19. Sale of hay									
20. Quarrying stones									
21. Sale of dung cake									
22.Rental property (other than land and oxen)									
23. Interest from deposits									
25. Social cash transfer									
26. Other, specify									
27.									

PART 9: ACCESS TO FINANCIAL CAPITAL, INFORMATION AND INSTITUTIONS

Section A: Household credit need and sources during 2009/10cropping year

Reason for loan	Needed credit? **Codes A**	If **No** in column 2, then Why? **Codes B**	If **Yes** in column 2, then did you get it? **Codes A**	If **NO in column 4**, then why not? **Rank 3 (codes C)**			If **Yes in column 4**				
				1st	2nd	3rd	Source of Credit, **Codes D**	How much did you get **(MK)**	Did you get the amount you requested **Codes A**	Annual interest rate charged **(%)**	Debt outstanding including interest rate at end of season **(MK)**

1	2	3	4	5	6	7	8	9	10	11	12
1. Buying seeds											
2. Buying fertilizer											
3. Buy herbicide and pesticides											
4. Buy farm equipment/implements											
5. Invest in transport (bicycle etc)											
6. Buy oxen for traction											
7. Buy other livestock											
8. Invest in irrigation system											
9. Invest in seed drill or minimum tillage system											
10. Non-farm business or trade											
11. To pay land rent											
12. Buy food											
13. Consumption needs (health/education/travel/tax,)											

Codes A	**Codes B**	**Codes C**			**Codes D**		
0. No 1. Yes	1. Not cash constrained 2. Activity is not profitable 3. Never thought of this investment 4. Other, specify.......	1. Borrowing is risky 2. Interest rate is high 3. Too much paper work/ procedures	4. Expected to be rejected, so did not try it 5. I have no asset for collateral 6. No money lenders in this area for this purpose	7. Lenders don't provide the amount needed 8. No credit association available 9. Not available on time 10. Other, specify………	1. Money lender 2. Farmer group/coop 3. Merry go round	4. Microfinance 5. Bank 6. SACCO	7. Relative 8. MRFC 9. Other, specify..

PART 9: ACCESS TO FINANCIAL CAPITAL, INFORMATION AND INSTITUTIONS

Section A: Household credit need and sources during 2010/11cropping year

Reason for loan	Needed credit? **Codes A**	If **No** in column 2, then Why? **Codes B**	If **Yes** in column 2, then did you get it?	If **NO in column 4**, then why not? **Rank 3 (codes C)**	If **Yes in column 4**

Household Identification Number…………….

			Codes A	1st	2nd	3rd	Source of Credit, **Codes D**	How much did you get **(MK)**	Did you get the amount you requested **Codes A**	Annual interest rate charged **(%)**	Debt outstanding including interest rate at end of season **(MK)**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1. Buying seeds											
2. Buying fertilizer											
3. Buy herbicide and pesticides											
4. Buy farm equipment/implements											
5. Invest in transport (bicycle etc)											
6. Buy oxen for traction											
7. Buy other livestock											
8. Invest in irrigation system											
9. Invest in seed drill or minimum tillage system											
10. Non-farm business or trade											
11. To pay land rent											
12. Buy food											
13. Consumption needs (health/education/travel/tax,)											

Codes A	**Codes B**	**Codes C**			**Codes D**		
0. No 1. Yes	1. Not cash constrained 2. Activity is not profitable 3. Never thought of this investment 4. Other, specify.......	1. Borrowing is risky 2. Interest rate is high 3. Too much paper work/ procedures	4. Expected to be rejected, so did not try it 5. I have no asset for collateral 6. No money lenders in this area for this purpose	7. Lenders don't provide the amount needed 8. No credit association available 9. Not available on time 10. Other, specify………	1. Money lender 2. Farmer group/coop 3. Merry go round	4. Microfinance 5. Bank 6. SACCO	7. Relative 8. MRFC 9. Other, specify..

PART 9: ACCESS TO FINANCIAL CAPITAL, INFORMATION AND INSTITUTIONS

Section A: Household credit need and sources during 2011/12 cropping year

Reason for loan	Needed credit? **Codes A**	If **No** in column 2, then Why? **Codes B**	If **Yes** in column 2, then did you get it? **Codes A**	If **NO in column 4**, then why not? **Rank 3 (codes C)**			If **Yes in column 4**				
				1st	2nd	3rd	Source of Credit, **Codes D**	How much did you get **(MK)**	Did you get the amount you requested **Codes A**	Annual interest rate charged **(%)**	Debt outstanding including interest rate at end of season **(MK)**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1. Buying seeds											
2. Buying fertilizer											
3. Buy herbicide and pesticides											
4. Buy farm equipment/implements											
5. Invest in transport (bicycle etc)											
6. Buy oxen for traction											
7. Buy other livestock											
8. Invest in irrigation system											
9. Invest in seed drill or minimum tillage system											
10. Non-farm business or trade											
11. To pay land rent											
12. Buy food											
13. Consumption needs (health/education/travel/tax,)											

Codes A	**Codes B**	**Codes C**			**Codes D**		
0. No 1. Yes	1. Not cash constrained 2. Activity is not profitable 3. Never thought of this investment 4. Other, specify.......	1. Borrowing is risky 2. Interest rate is high 3. Too much paper work/ procedures	4. Expected to be rejected, so did not try it 5. I have no asset for collateral 6. No money lenders in this area for this purpose	7. Lenders don't provide the amount needed 8. No credit association available 9. Not available on time 10. Other, specify………	1. Money lender 2. Farmer group/coop 3. Merry go round	4. Microfinance 5. Bank 6. SACCO	7. Relative 8. MRFC 9. Other, specify..

Section B: Household savings 2009/10

Saving family member (1=Husband; 2=Wife; 3= both)	Has bank account (0=No; 1=Yes)	Saving with (codes A)	Total amount saved in the year (MK)
1	**2**	**3**	**5**

Codes A

1. Saving at home (personal)	3. Rural micro-finance	5. Merry go-round	7. Saving by lending to money lender
2. Commercial or other banks	4. SACCO (credit society)	6. Mobile phone banking (e.g. ZAP)	8. Other, specify…………..…

Section B: Household savings 2010/11

Saving family member (1=Husband; 2=Wife; 3= both)	Has bank account (0=No; 1=Yes)	Saving with (codes A)	Total amount saved in the year (MK)
1	**2**	**3**	**5**

Codes A

1. Saving at home (personal)	3. Rural micro-finance	5. Merry go-round	7. Saving by lending to money lender
2. Commercial or other banks	4. SACCO (credit society)	6. Mobile phone banking (e.g. ZAP)	8. Other, specify…………..…

Section B: Household savings 2011/12

Saving family member (1=Husband; 2=Wife; 3= both)	Has bank account (0=No; 1=Yes)	Saving with (codes A)	Total amount saved in the year (MK)
1	**2**	**3**	**5**

Codes A

1. Saving at home (personal)	3. Rural micro-finance	5. Merry go-round	7. Saving by lending to money lender
2. Commercial or other banks	4. SACCO (credit society)	6. Mobile phone banking (e.g. ZAP)	8. Other, specify…………..…

Section C: Access to extension services 2009/10, 2010/11, 2011/2012

Issue	Did you receive training or information on […...] separate years responses by coma (**Codes A**)	Received training or information on […..]separate years responses by coma (**Codes A**)	Main information source separate years responses by coma **Rank 3** (codes B)			Number of contacts during separate years responses by coma (days/year)		
			Rank 1	Rank 2	Rank 3	Govt extension	Non-profit NGOs	Private Companies
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1. New varieties of maize								
2. New varieties of legumes								
3. Field pest and disease control								
4. Soil and water management								
5. Crop rotation								
6. Minimum tillage								
7. Leaving crop residue in the field								
8. Adaptation to climate change								
9. Irrigation								
10. Crop storage pests								
11. Output markets and prices								
12. Input markets and prices								
13. Collective action/farmer organization								
14. Livestock production								
15. Maximum crop cover								
16. Crop rotation								
17. Residue retention								
18. Pit planting								

Codes A	**Codes B**					
0. No	1. Government extension service	4. Seed traders/Agro-dealers	7. Total land care	10. Farmer business school	13.Mobile phone	16. Other, specify..........
1. Yes	**2. Farmer Coop or groups**	5. Relative farmers	**8. Private Company**	11. Radio/TV	14.NASFAM	
	3. Neighbour farmers	6. NGOs	**9. Research center**	**12. Newspaper**	15. Farmer Field School	

Section D. Market access 2011/12

Crop	Did you get market information before you decided to sell the crop? **(code A)**	If yes in column 2, where did you get the information? (**Code B**) Rank 3	<u>Ever failed</u> to sell due to lack of buyers or poor price? **Codes A**		<u>No. of buyers</u> who came to buy at farm gate last season (2011/12)				If you did not sell to some of these buyers, then why? **Codes C** (Rank 3)			
			Lack of buyers	Poor price	Assemblers or brokers	Wholesalers	Farmer group or coops	Consumers	Assemblers or brokers	wholesalers	Farmer group or coops	Consumer
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1. Maize												
2. C.beans												
3. Pigeonpea												
4. Groundnut												
5. Soybean												
6. Cowpea												

Codes C:

1. No buyer came
2. Price offered was low
3. Unreliable scale or weight
4. Unable to meet the desired quality
5. Other, specify………………

Section E: Constraints in accessing key inputs and crop production

Input and production constraints	Maize		Common beans		Pigeonpea		Groundnut		Other, specify…………	
	Constraint ? **Codes A**	Rank its importance (only those with **Yes** in column 2)	Constraint ? **Codes A**	Rank its importance (only those with **Yes** in column 4)	Constraint ? **Codes A**	Rank its importance (only those with **Yes** in column 6)	Constraint? **Codes A**	Rank its importance (only those with **Yes** in column 8)	Constraint ? **Codes A**	Rank its importance (only those with **Yes** in column 10)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Socioeconomic										
1. Timely availability of improved seed										
2. Prices of improved seed										
3. Quality of seed										
4. Availability of credit to buy seed										
5. Timely availability of fertilizer										
6. Price of fertilizer										
7. Availability of credit to buy fertilizer										
8. Access to markets and information										
9. Reasonable grain prices										
Biophysical										
10. Drought										
11. Floods										
12. Pests										
13. Diseases										

14. Soil fertility										

Codes A: 0. No; 1. Yes

Rainfall assessment in the last 3 years

1. Did the rainfall season come on time? (Codes A) …………………………………………..

2. Was there enough rain at the beginning of the growing season? (Codes A).......................................

3. Was there enough rain during the growing season? (Codes A)...

4. Did the rains stop on time? (Codes A)..

5. Did it rain near the harvest time? (Codes A)...

Household Identification Number……………..

PART 10: RISK, LIVELIHOOD SHOCKS AND COPPING STRATEGIES

Risk factor	How many times did […] occur in the past ten years?	Rank importance of […] in affecting household livelihood (1=most important)	Important copping strategies before […], **Codes A**; Rank 3			Important copping strategy after […] occurrence **Code B**; Rank 3			How did […] affect production of <u>main food crop</u> of the household **(% reduction)**	As a result of […] did you lose (part of) your income **(% reduction)**	Do you think […] will become more important in future due to climate change **Codes C**	If **Yes**, how often do you think […] will occur in the next ten years?	Which crops were most susceptible **<u>– rank 3</u>** **Codes in Annex 1 -** attached sheet
			1st	2nd	3rd	1st	2nd	3rd					
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1. Drought													
2. Too much rain or floods													
3. Crop pests/diseases													
4. Hail storm													
5. Livestock diseases or death of livestock													
6. Large decrease in agricultural output prices													
7. Large increase in agricultural input prices													
8. Large increase in food prices													
9. Family sickness													
10. Death of household member													
11. Reduced/failure household business income													
12. Reduced/loss of employment income													
13. Theft of assets or crops													
14. Discrimination for social or ethnic reasons													
15. Conflict/violence													

Codes A				Codes B			Codes C
1. Planting drought tolerant crops	4. Plant disease/pest tolerant varieties	6. Increase seed rate	9. Soil and water conservation	1. Replanting	4. Selling other assets	7. Borrowing	0. No
2. Plant drought tolerant varieties	5. Crop diversification	7. More non-farm work	10. None	2. Selling livestock	5. Eat less (reduce meals)	8. Seek treatment	1. Yes
3. Early planting		8. Saving	11. Food preservation	3. Selling land	6. Out-migration	9. Stop sending children to school	
			12. Seek veterinary services			10. None	
			13. Other, specify…………			11. Other, specify……………	

PART 12: PARTICIPATION IN SEED AND FERTILIZER SUBSIDY PROGRAMME

Section A: Fertilizer coupons

Did you receive fertilizer coupons in 2009/10 cropping season?...

1=Yes; 0=No

If the answer for question 1 is **yes**, how many coupons did you receive? ....

If the answer for question 1 is **yes**, for which fertilizer types did you receive the coupons....................................1= NPK (23:21:0+4S); 2=UREA; 3. Other, specify............

If the answer for question 1 is **yes** , did you use all the coupons to purchase fertilizer to apply on your farm?..1=Yes; 0=No

If the answer for question 4 is **yes**, how much did you pay for the 50kg bag of fertilizer you bought with the coupon?..

Did you buy fertilizers during 2009/10 without use of coupons i.e. using your own or borrowed money?..1=yes; 0=No

How many seasons have you received fertilizer coupons since 2004/05..................................

Section B: Seed coupons

Did you receive seed coupons in 2009/10 cropping seasons?...

1=Yes; 0=No

If the answer for question 1 is **yes**, how many coupons did you receive? ....

If the answer for question 1 is **yes**, for which seed types did you receive the coupons....................................1= Maize; 2=Common beans; 3= Groundnut; 4= Soya beans; 5. Piegoenpea; 6. Tobacco; 7..Other, specify.........

If the answer for question 1 is **yes** , did you use all the coupons to purchase seed to apply on your farm?..1=Yes; 0=No

If the answer for question 4 is **yes**, how much did you pay for the 2kg bag of seed you bought with the
coupon?..

Did you buy seed during 2009/10 without use of coupons i.e. using your own or borrowed money?..1=yes; 0=No

How many seasons have you received seed coupons since 2004/05...................................

ANNEX 1: CROP CODES

SIMLESA Crops	Other cereals	Other Pulses (legumes)	Oil Crops	Root crops/tubers/vegetable
1. Maize	10. White Teff	23. Faba bean	32. Nigerseed	42. Cassava
2. Haricot bean	11. Red Teff	24. Lentil	33. Sunflower	43. Irish potato
3. Soybean	12. Mixed Teff	25. Grass pea	34.Sesame	44. Sweet potato
4. Pigeonpea	13. Bread Wheat	26. Kabuli Chickpea	35.Linseed	45. Onion
5. Groundnut	14. Durum Wheat	27. Desi chickpea	36.Rapeseed	46. Gralic
6. Cowpea	15. Barley	28. Field pea	37.Lupin	47. Pepper
7. Other1.............	16. Sorghum	29. Other1 …………	38. Other1 …………	48. Tomato
8. Other 2………	17. Finger Millet	30 Other2 …………	39. Other2 …………	49. Ginger
9.Other3 …….....	18. Pearl millet	31 Other3…………..	40. Other3 …………	50. Cabbage
	19. Rice		41. Other4…………..	51. Kale
	20. Other1 ……			52. Carrot
	21. Other2……….			53. Pumpkin
	22.Other3 ……….			54.Other2 ………………..
				55.Other3………………..

ANNEX 2: CROP VARIETY CODES

Maize	11. SC 627	**Common bean**	43 Other1......	**Pigeonpea**	**Groundn**
1. MH 26	12. SC 719	25. Maluwa	44 Other2........	50.Sauma	57. Chalin
2. MH27	13. SC 5	26. Kholophethe		51. Kachangu	58. Malim
3. MH 18	14. PHB 30G19	27. Kabalabala	**Soybean**	52. ICEAP 0057	59. Mani I
4. DKC 8035	15. ZM 621	28. Kambidzi	45. Makwacha	53. ICPL 87105	60. RG 1
5. DKC 8053	16. ZM 523	29. Nagaga	46. Nasoko	54. ICPL 93026	61. Mawa
6. DKC 8073	17. ZM 623	30. Sapatsika	47. Ocepara-4	55.Other1.......................	62. Chiten
7. PAN 53	18. ZM 309	31. Napilira	48 Other1.................	56. Other2	63. CG 7
8. PAN 4M-19	19 ZM 721	32. Mkhalira	49.Other2		64. Nsinji
9. SC 403	20. ZM 521	33.Kalima			65. Kakor
10.SC 513	21. Chitedze 2 QPM	34.Bwenzilalana			66. Baka
	22. PHB 30G33	35 Nasaka			67 Chalim

	23. Other1……… 24. Other2……….	36 Bunda 93 37 Kamzama 38 Kamtsilo 39 Chimbamba 40 Sapelekedwa 4 NUA 45 42 NUA 59			68 Other1 69 Other2 70 Other3