Determinants and livelihood impacts of natural resource management strategies among smallholder farmers in Malawi

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Summary

During the last five decades, policy approaches towards food security have promoted input-intensive agricultural technologies to increase global food production. However, there are concerns about the environmental, social and economic sustainability of this strategy. Environmental degradation causes the loss of 2 to 5 million hectares of arable land every year, mostly in developing countries. At the same time, undernutrition and micronutrient deficiencies affect up to 2 billion people worldwide and present a particularly huge burden among the poor. Further depletion of water, soil and land resources will impact the production capability of agricultural systems with negative implications for food production and quality. It is inevitable that the global food production system must strive for a more sustainable use of natural resources and reduce the environmental externalities of agricultural production. Simultaneously, agriculture must provide more nutrient-rich and diverse food items in order to tackle the complex challenges of food insecurity and malnutrition.

Natural resource management (NRM) strategies are a promising approach towards environmentally sustainable agricultural production. NRM practices, such as soil and water conservation and legume intercropping, may decrease soil erosion, improve soil fertility, and reduce production losses due to agricultural pests. NRM practices might also liberate smallholder farmers from the sole dependence on improved technologies and support asset-constrained households with affordable alternatives. Some policy agendas consider a simultaneous promotion of NRM and input-intensive technologies. The combination of these technologies can provide farmers with dual benefits: environmental externalities of agricultural production may be reduced, while achieving higher crop yields at the same time. Increasing the production potential of smallholders is very important to enhance farm households' food security. Under the condition of accessible, functioning food markets, increased production might also indirectly improve the quality of diets if crop sales can boost household income which in turn is used to purchase more diverse foods. An explicit resource management practice, that helps to reduce environmental externalities while improving dietary quality, is the diversification of own farm production, which is sometimes perceived as a key strategy to improve food and nutrition security among subsistence-oriented smallholder farms in remote rural areas.

In Malawi and other countries of sub-Saharan Africa (SSA), rural smallholder farmers dominate the agricultural sector. They are responsible for the bulk of national food supply, but also belong to the poorest and most food insecure population segments. Malawi has been the pioneer in re-introducing targeted farm input subsidies in SSA that support smallholders with improved seed varieties and chemical fertilizer. Recently, the government has added NRM strategies to the agricultural development agenda to overcome environmental challenges among smallholder farms and support agricultural diversification to improve nutrition and tackle malnutrition problems. Simultaneously, Malawi's agricultural sector wide approach (ASWAp) attempts to increase smallholder market integration in order to reduce poverty and food insecurity through increased income opportunities. The combination of these strategies is expected to foster environmental resilience of smallholder systems, increase productivity, and improve food and nutrition security via different pathways.

However, this complex situation might raise questions among policy makers in Malawi and other SSA countries who tread a similar path. This dissertation sheds light on specific issues of policy concern. Research objective (i) addresses the question if a simultaneous promotion of input-intensive and NRM technologies among smallholder farms is possible. In particular, it investigates the under-researched issue if and how input subsidies influence the use of specific NRM practices such as legume intercropping, soil ridges, terraces or vegetative strips. Another question, which might be of policy interest, is studied under research objective (ii): how can specific agricultural production approaches and agricultural markets help to improve dietary quality in smallholder farm households? While an emerging number of studies has investigated the relationship between crop diversification and household dietary diversity among smallholder farmers, the role of markets and agricultural technologies for dietary diversity has received little attention. This dissertation contributes to the emerging literature by studying the above mentioned relationships with alternative indicators while additionally analysing individual food consumption recall data. Simultaneous household and individual level analyses, although rare, are important to ensure comparability between household and individual level data with regard to statements for nutrition policies.

Research objectives (i) and (ii) are analysed with farm household survey data from rural Malawi. First, a multivariate probit framework combined with an instrumental variable approach is used to analyse research objective (i). The model results highlight that participation of smallholder farms in the input subsidy program is positively associated with the adoption of legume intercropping and vegetative strips, while promoting the use of modern inputs. In line with previous research, the results confirm a positive association between subsidy participation and manure use. The practice of soil ridging seems to be restricted by FISP. Independent of the subsidy program results show that farmers tend to use modern inputs and NRM practices complementarily, often combining different types of technologies.

Research objective (ii) is investigated by analysing a number of different regression models. The models examine how different factors affect household and individual dietary diversity, particularly for young children and mothers. The results show that farm production diversity is positively associated with household and individual dietary diversity, yet smallholder market integration seems to have a stronger influence. The estimates indicate that specific input-intensive and NRM technologies are also positively associated with dietary diversity. In particular, legume intercropping is linked with child dietary diversity, while chemical fertilizer use is positively associated with mothers and household dietary diversity. Dietary diversity of young children and mothers is largely influenced by the same factors as the household diet.

In conclusion, this dissertation shows that input-intensive and NRM technologies are compatible in smallholder farming systems. The findings imply that trade-offs between different policy approaches promoting one or the other strategy do not necessarily occur. Certain NRM practices are even more common among subsidy participants than non-participants. To understand how a simultaneous promotion of NRM and input-intensive technologies can be realized successfully, future research should investigate the role of extension services more explicitly. Among the desired outcomes of a successful promotion of these strategies is improved nutrition. Indeed, specific input-intensive and NRM technologies seem to contribute to diverse diets; and so do farm production diversification and smallholder market integration. While nutrition effects from diversified production might be largely direct and market effects indirect, specific farming technologies could affect nutrition through both pathways. Interestingly, these findings are largely similar for both, household and individual diets. Thus, household level food consumption data might be used to address broader nutritional issues at the individual level. Overall, policy approaches that harmonise the promotion of input-intensive and NRM technologies while strengthening market access and participation might be suitable strategies to improve dietary quality among and within smallholder farm households.

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Table of contents

Summary III

Acknowledgements VII

Table of contents IX

List of tables XI

List of figures XII

Abbreviations XIII

Chapter 1: Introduction 1

1.1 Towards more sustainable resource management in agriculture 1

1.2 Agriculture’s contribution to emerging food security challenges 3

1.3 The role of smallholder farmers for sustainable and diverse production 5

1.4 Problem statement and research objectives 6

1.5 Data collection and study location 10

1.6 Dissertation outline 12

Chapter 2: The influence of farm input subsidies on the adoption of natural resource management technologies 14

2.1 Introduction 14

2.2 Malawi and FISP 17

2.3 Materials and methods 19

2.3.1 Data 19

2.3.2 Multivariate probit model of technology adoption 19

2.3.3 Addressing unobserved heterogeneity and potential selection bias 21

2.4 Results 22

2.4.1 Descriptive statistics 22

2.4.2 FISP participation 26

2.4.3 MVP model results 28

2.5 Conclusion 33

Chapter 3: Agricultural biodiversity and dietary diversity in rural Malawi 35

3.1 Introduction 36

3.2 Materials and methods 39

3.2.1 Data 39

3.2.2 Analytical approach 39

3.2.3 Measurement of dietary diversity 40

3.2.4 Measurement of farm production diversity 41

3.2.5 Measurement of market access 42

3.2.6 Measurement of agricultural technologies 43

3.2.7 Regression estimators 44

3.3 Results 45

3.3.1 Descriptive statistics 45

3.3.2 Association between farm production diversity and dietary diversity 48

3.3.3 The role of markets 49

3.3.4 The role of agricultural technologies 52

3.4 Discussion 54

3.5 Conclusion 57

Chapter 4: Conclusion 58

4.1 Synopsis 58

4.2 Conclusions and policy implications 61

4.3 Scope for future research 63

References 65

Appendix A: Additional tables 77

Appendix B: Farm household questionnaire 2013 89

List of tables

Table 2.1 Descriptive statistics for explanatory variables used 23

Table 2.2 Adoption of different technologies by participation in input subsidy program 25

Table 2.3 Factors influencing FISP participation 27

Table 2.4 Correlation matrix for technology adoption equations 29

Table 2.5 Effects of FISP participation on technology adoption 31

Table 3.1 Description of variables (408 farm household observations) 46

Table 3.2 Association between crop species count and dietary diversity 48

Table 3.3 Association between production diversity score and dietary diversity..... 49

Table 3.4 Farm production diversity, market access and dietary diversity............... 50

Table 3.5 Farm production diversity, market access, agricultural technology and dietary diversity... 53

Table A1 Basic multivariate probit model 77

Table A2 Reduced multivariate probit model 80

Table A3 Multivariate probit model with Mundlak approach 83

Table A4 Percentage share of food groups consumed among farm households and individuals 86

Table A5 Importance of different marketing channels for crop sales†..................... 86

Table A6 Production diversity scores, market access and dietary diversity 87

Table A7 Market access, agricultural technology and dietary diversity................... 88

List of figures

Figure 1.1 Pathways from agriculture to nutrition, adapted from Herforth and Harris (2014) 4

Figure 1.2 Map of Malawi, adapted from Nations Online Project (2016) 11

Abbreviations

ASWAp	Agricultural Sector Wide Approach
CGIAR	Consultative Group for International Agricultural Research
CIA	Central Intelligence Agency
CIMMYT	Maize and Wheat Improvement Center
DARS	Department of Agricultural Research Services
DDS	Dietary diversity score
DPP	Democratic Progressive Party
FAO	Food and Agriculture Organization
FISP	Farm Input Subsidy Program
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IV	Instrumental variables
MaSSP	Malawi Strategy Support Program
MK	Malawi Kwacha
MoAFS	Ministry of Agriculture and Food Security
MVP	Multivariate probit
NRM	Natural resource management
OPV	Open-pollinated varieties
SI	Sustainable intensification
SIMLESA	Sustainable Intensification of Maize and Legume Systems for Food Security in Eastern and Southern Africa
SPIA	Standing Panel on Impact Assessment
SSA	Sub-Saharan Africa
TLU	Tropical livestock unit
WHO	World Health Organization

Chapter 1: Introduction

How can we achieve food security and protect the natural resource base for agriculture? And how can agricultural production help to decrease malnutrition? These questions comprise two of the major challenges agriculture is facing today. They also cause plenty of debate among researchers and policy makers (Godfray 2015; McKenzie and Williams 2015; Allen et al. 2014; Turner et al. 2013; Godfray et al. 2010).

1.1 Towards more sustainable resource management in agriculture

The depletion of natural resources is a major challenge for agricultural production. It has been shown that the degradation of soils, the exhaustion of fresh water resources and the loss of biodiversity directly contribute to reduced crop yields via increasing the risk of crop diseases and lowering the fertility of soils (Reynolds et al. 2015; Giovannucci et al. 2012; Tscharntke et al. 2012; Tilman et al. 2002). While input-intensive agricultural systems are needed to increase global food production, the use of external inputs such as chemical fertilizers is associated with negative environmental externalities (Pingali 2012; Graham et al. 2007). The degree of depletion of the natural resource base thereby depends on the management of agricultural systems and the choice of production technologies (Godfray 2015; Reynolds et al. 2015; Liniger et al. 2011). The negative environmental effects of input-intensive technologies are further aggravated by climate change and extreme weather events (Beddington et al. 2012; Garrity et al. 2010). There is a need for resource-preserving agricultural systems that secure future food production, while safeguarding the natural resource base they depend on.

Natural resource management (NRM) strategies contain a set of agricultural production practices that aim at reducing environmental externalities. For instance, intercropping and crop rotation can increase agrobiodiversity, reduce agricultural pest infestation and improve the soil nutrient cycle. In particular, legumes can help to preserve and build up soil nutrients and organic matter, and safe water resources through the fixation of atmospheric nitrogen and the exploitation of residual moisture (Snapp et al. 2010; Gilbert 2004; Tilman et al. 2002). Soil and water conservation practices can prevent soil and nutrient losses as they slow down water runoff and catch sediments, and increase soil water availability (Delgado et al. 2011). Recently, NRM practices have also been promoted as innovation packages or integrated system technologies. These strategies use synergistic effects between specific components to increase agricultural production while preserving the natural resource base. Examples include conservation agriculture (Andersson and D'Souza 2014; Kassam et al. 2009) or the system of rice intensification (Noltze et al. 2012).

Other approaches go beyond the combination of different NRM practices and advocate the integration of fundamentally different production concepts such as NRM and input-intensive technologies (Godfray 2015; Pretty and Bharucha 2014). The intention of this approach, sometimes referred to as sustainable intensification (SI), is to increase yields without damaging environmental resources and without exploring additional land for agriculture (Pretty and Bharucha 2014). SI places an equal focus on reaching environmental sustainability (through NRM technologies) and economic efficiency (through input-intensive technologies). Yet, it is controversially discussed how natural resources can be preserved, while using technologies that foster environmental externalities (Brooker et al. 2016; Godfray 2015; Pretty and Bharucha 2014). Nonetheless, the idea behind SI might suit current policy approaches in some developing countries and provide direct benefits for small farmers towards the emerging challenges of food security (Godfray 2015).

1.2 *Agriculture's contribution to emerging food security challenges*

Food security depends on access to sufficient calories, but even more on the quality and diversity of the food consumed. Approximately 780 million people in developing countries are undernourished (FAO 2015). However, some 2 billion people, mostly in developing countries, suffer from deficiencies in micronutrient consumption such as vitamin A, iron, iodine or zinc (IFPRI 2014). Micronutrients are vital to human health and the physical and mental development of the body, especially early in life (IFPRI 2014). Approximately 130 million preschool children in developing countries are vitamin A-deficient, leading to 650,000 annual deaths (West and Darnton-Hill 2008). 40 percent of preschool children and 50 percent of women of reproductive age (15 to 49 years) are anaemic due to iron deficiency (WHO 2007). Iodine deficiency is one of the major causes for impaired mental development among children (Black et al. 2008). A lack of zinc intake increases the incidence of diarrhoea and pneumonia and weakens the immune system which in turn raises the susceptibility to diseases and the likelihood of premature death (Black et al. 2013). Ultimately, malnutrition decreases people's potential to thrive in life and builds up to heavy losses for national and regional economies (IFPRI 2014).

The cause of micronutrient deficiencies is an inadequate intake of nutrient-rich foods caused by limited physical or economic access to diverse food items (Kennedy et al. 2003). Empirical evidence shows positive associations between dietary diversity, greater nutrient intake and positive growth and health outcomes (M'Kaibi et al. 2015; Bezner Kerr et al. 2011; Savy et al. 2006; Steyn et al. 2006). The agricultural sector plays an important role in improving the access to more diverse food in developing countries, especially in rural areas where agriculture employs a large share of the population and contributes to the livelihoods of the poor.

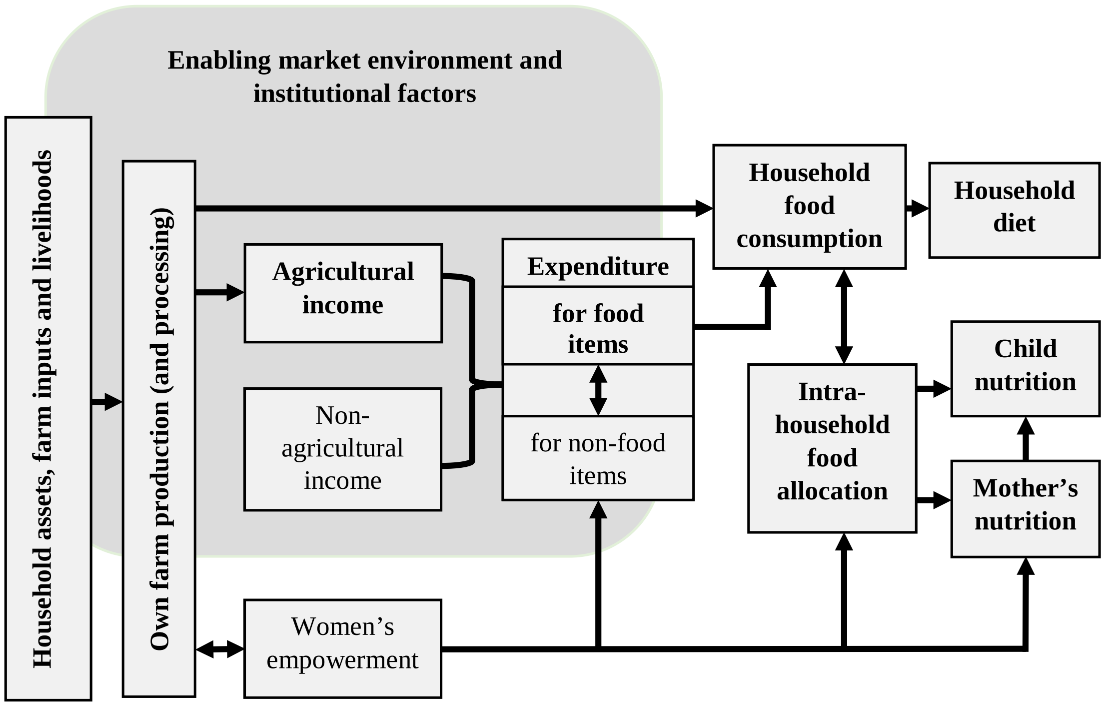

Figure 1.1 Pathways from agriculture to nutrition, adapted from Herforth and Harris (2014). This framework is simplified. For a broader and more detailed discussion on the pathways between agriculture and nutrition see Herforth and Harris (2014).

Figure 1.1 shows the principal pathways how agricultural production affects the nutritional status of rural farm households (Herforth and Harris 2014). The first and most direct pathway is the consumption of own farm produce, which improves household nutrition if a high diversity of farm products is produced and consumed in sufficient quantity. Second, sales of farm products or engagement in agricultural wage labour might provide income which can be used to purchase more diverse foods. The nutritional outcome of the second pathway depends on the availability of functioning markets, the degree of commercialisation among local farmers, the purchasing power of the buyer and the way income is used (Harris et al. 2015). A third pathway, women's empowerment, might be especially decisive for the individual diet of young children and women themselves (Herforth and Harris 2014). All pathways from agriculture to household nutrition should affect the nutritional status of individual household members (Harris et al. 2015; Herforth and Harris 2014). However, the individual outcome ultimately depends on intra-household allocation of food (Torheim and Arimond 2013; Quisumbing and Smith 2007).

1.3 The role of smallholder farmers for sustainable and diverse production

The challenge of achieving food and nutrition security, while protecting the natural resource base is unavoidably connected with the improvement of smallholder agriculture (IFAD 2013; FAO 2009). Smallholder farmers dominate the agricultural sector in developing countries. Some 500 million smallholder farms support the livelihoods of approximately 2.5 billion people (IFAD 2013). They produce about 80 percent of the global food consumption, feeding not only their own families but also supplying their production to local and national markets (FAO 2014; IFAD 2011). Yet, smallholders are among the poorest and most food insecure population segments, and are particularly vulnerable to economic and climatic shocks (FAO 2014; IFAD 2013). Many of them are living in remote, environmentally fragile locations and have limited access to input and output markets (FAO 2014). Improving food and nutrition security through and among smallholder farmers calls for innovative agricultural approaches that improve the efficiency and productivity of inputs, and conserve the natural resources which are vital for food production.

Past agricultural policies have often neglected smallholder farming or have not been able to address the specific needs of smallholder farmers in different locations (Sayer and Cassman 2013; Pingali 2012; Wiggins et al. 2010). The paradigm shift towards agricultural production systems that increase productivity while preserving natural resources has reinvented the role of smallholder farms in achieving food security and sustainable development (Pretty and Bharucha 2014). Indeed, smallholder agriculture has the potential to successfully fulfil this role. Smallholders have a higher potential for yield improvement compared to large-scale farms (FAO 2014), and have an important role in preserving the natural resource base on which their farm production and their livelihoods depend (FAO 2014; IFAD 2013; Altieri and Toledo 2011). The specific knowledge many smallholder farmers have gained through producing in resource-constrained environments might support research and development practitioners in developing location-specific production approaches (IFAD 2013). In general, small farms might be particularly suited to help tackling the emerging agricultural production and food security challenges. However, this will require broad governmental and institutional support (FAO 2014; Pretty and Bharucha 2014; Barrett 2008).

1.4 Problem statement and research objectives

In Malawi, the improvement of the smallholder sector has often been neglected in favour of developing a large-scale estate sector for high-value export commodities such as tobacco (Chirwa and Dorward 2013). During the last two decades governments increasingly recognised the vital role of smallholder farmers for national food security and economic development, and the challenges for smallholder farms, including declining maize yields, the need for fertilizers to raise yields and the limited access to inputs such as fertilizer and seed (Chirwa and Dorward 2013). The political orientation towards food security via improvement in smallholder farming has led to the implementation of a large scale farm input subsidy program (FISP) that particularly targets smallholder farmers with chemical fertilizer and improved maize varieties (Chirwa and Dorward 2013). Since the introduction of the FISP, maize production has increased at the national and farm household level, and has contributed to some improvement in food security and overall well-being (Lunduka et al. 2013). However, FISP has also been criticised for its low cost-effectiveness and limited effects on lowering domestic maize prices (Ricker-Gilbert et al. 2013b; Ricker-Gilbert and Jayne 2012).

Alongside controversial economic outcomes, concerns have been raised with regard to the subsidies' effects on the social and environmental sustainability within smallholder farming systems (Ricker-Gilbert et al. 2013a; Holden and Lunduka 2012). The general notion is that input-intensive technologies could simplify cropping systems, harm environmental resources and increase small farmer's dependencies on inputs as well as on specific crops (such as maize) (Greenpeace Africa 2015; The Montpellier Panel 2013; Marenya et al. 2012). This has brought the promotion of NRM technologies into consideration and has ultimately led to their integration into Malawi's latest agricultural policy program, the Agricultural Sector-Wide Approach (ASWAp) (MoAFS 2011). The ASWAp particularly tries to harmonise the subsidy program with other policy initiatives that promote the dissemination and adoption of NRM technologies.

However, a successful integration of subsidized input-intensive technologies and NRM practices is not assured. The few studies that analysed the compatibility between input subsidies and NRM strategies showed mixed results. Chibwana et al. (2012) found that the use of subsidized inputs contributes to a simplification of cropping patterns, while the results of Holden and Lunduka (2010) and Karamba (2013) point to an increased crop diversification. Chibwana et al. (2013) examined the effect of FISP on deforestation, and found that maize subsidies reduce expansion into forest areas, while tobacco subsidies contribute to deforestation. Holden and Lunduka (2012) showed that fertilizer use could possibly trigger the use of manure. Regarding the importance of this policy approach for Malawi and the general opinion about the incompatibility of agricultural intensification and NRM strategies, it is surprising that there is limited empirical evidence about the relationship between subsidised inputs and the adoption of NRM practices. Chapter 2 of this dissertation addresses this research gap by

i.1) analysing the effect of input subsidies on the use of specific NRM technologies such as maize-legume intercropping, soil ridges, terraces, or vegetative strips,

i.2) and determining the compatibility of input-intensive and NRM technologies.

While Malawi’s intensification strategy via input subsidies has largely contributed to maize self-sufficiency, it might lack the potential to tackle the nutrition challenges that come with micronutrient deficiencies. As mentioned above diversifying farm production offers such potential. A couple of studies have shown that farm production diversification is positively associated with farm household dietary diversity in Malawi (Sibhatu et al. 2015; Snapp and Fisher 2015; Jones et al. 2014). This seems plausible, as Malawi’s smallholder farms are often highly subsistence-oriented and consume large parts of their own production. Nevertheless, own farm production is usually not the only source of food consumption. Smallholder farm households are often net buyers of food items, spending a large share of their income on food (World Bank 2007). Yet, diverse, nutrient-rich food items can only be purchased if food markets are functioning in the respective locality. There is some evidence suggesting that market access is an important factor that determines a farm household’s dietary diversity; it might even have a larger effect on dietary diversity than own farm production diversity (Sibhatu et al. 2015; Hirvonen and Hoddinott 2014). Market access also increases a farm’s possibility to sell own farm products and earn income which can be used to buy diverse foods. Thus, promoting commercialisation among smallholder farmers could also be a promising strategy to improve the nutritional status of the rural population.

Chirwa and Matita (2012) found that commercialisation among Malawian smallholders is associated with a household’s food security status, smallholder market integration and more importantly with the access to input-intensive technologies. Snapp and Fisher (2015) suggest that yield gains from using improved maize varieties, accessed through input subsidies, increase crop income which contributes to more diverse household diets. Thus, the use of chemical fertilizer could have a similar effect on dietary diversity. Likewise the use of improved grain legume varieties and legume intercropping could improve dietary diversity. Grain legumes such as groundnuts do not only have commercial value but are also popular food crops that might directly contribute to dietary quality (Aberman and Roopnaraine 2015). However, the effect of such production technologies on dietary diversity has hardly been studied.

The pathways from agriculture to a diverse nutrition have commonly been studied at the household level. But without data on individuals´ food consumption the impact of household dietary diversity on individual dietary diversity remains uncertain, since intra-household food allocation decisions influence individual intake (Torheim and Arimond 2013; Quisumbing and Smith 2007). In order to support nutrition-related policy decisions more adequately, it is important to analyse the nutritional outcomes of dietary diversity both at household and individual levels. However, the few existing studies that also used individual level data are limited to context-specific impact evaluations of food diversification projects promoting traditional vegetables (Herforth 2010) and homegarden cultivation (Olney et al. 2009).

Against this background, chapter 3 contributes to the existing research by analysing the association between farm production diversity and household dietary diversity as well as dietary diversity of children and mothers, with a focus on the role of markets and the use of specific agricultural technologies. It particularly addresses

- ii.1) how farm species diversity affects household and individual dietary diversity,
- ii.2) how smallholder market integration affects household and individual dietary diversity,

ii.3) how agricultural technology use shapes household and individual dietary diversity,

ii.4) and if there are different effects for drivers of household and individual dietary diversity.

1.5 Data collection and study location

This research is based on primary and secondary data from rural Malawi. The data base is derived from a panel of farm household surveys, conducted by the Maize and Wheat Improvement Center (CIMMYT) and the Malawian Department of Agricultural Research Services (DARS). The first round of data collection was carried out between March and May 2011 under the *Sustainable Intensification of Maize and Legume Systems for Food Security in Eastern and Southern Africa (SIMLESA) Program*. We collaborated with CIMMYT and participated in the second round of data collection between June and August 2013 under the *Adoption Pathways Project*, which builds upon the *SIMLESA Program*. The surveys covered six districts located in the central and southern region of Malawi (olive districts in Figure 1.2). In January and February 2014, CIMMYT conducted an additional survey and extended the number of districts to 16 to establish a nationally representative sample (olive and green districts in Figure 1.2). While the results presented in chapter 2 are based on the 2011 and 2013 data sets, chapter 3 uses the 2014 data. Household and individual level nutrition details were only captured in the 2014 survey round.

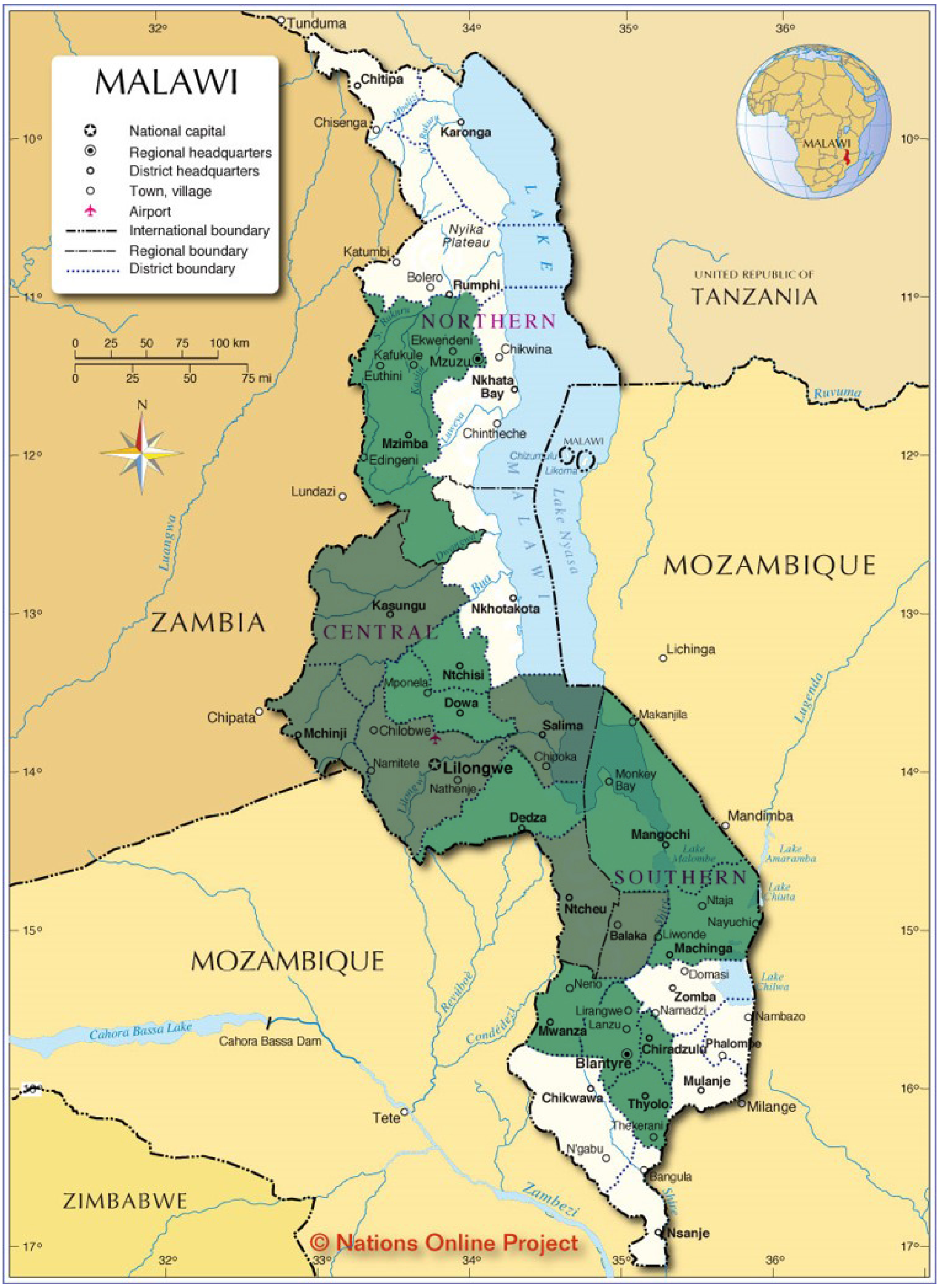

Figure 1.2 Map of Malawi, adapted from Nations Online Project (2016). Districts in olive depict 2011, 2013 and 2014 data collection; districts in green depict additional regions covered in 2014.

Prior to the survey, a multistage sampling procedure was employed. From each district, a set of villages and within each village, a set of households was selected randomly. Districts were selected based on their maize production potential. Villages and farm households were selected based on proportionate random sampling. The surveys covered 890 farm households in 2011, 757 in 2013 and 1482 in 2014. The data sets include comprehensive information on household demographic and socioeconomic status, agricultural production activities at the plot level, marketing of farm products, participation in off-farm activities, household expenditure for food and non-food products, asset ownership and access to capital and information, adaptation to climate change and participation in the subsidy program[1]. In addition, the 2014 survey captured food group consumption patterns of all household members and individuals (young children and mothers) via a 24-hour recall table.

1.6 Dissertation outline

The remainder of the dissertation is organized as follows. Chapter 2 addresses research objective (i). A multivariate probit (MVP) framework paired with an instrumental variable (IV) approach analyses panel data from smallholder farm households. The models explain the effect of input subsidies on the adoption of different NRM technologies, and the association between input-intensive and NRM technologies independent of participation in the FISP. Although controlling for potential selection bias via IVs in a multivariate probit framework is challenging, some policy conclusions are deduced from the results.

Chapter 3 deals with research objective (ii) by quantifying the implications of different factors on household and individual nutrition. In particular, we analyse how farm production diversification, smallholder market integration and the use of technological innovations influence household and individual dietary diversity of

[1] The English version of the questionnaire employed during data collection in 2013 is included in Appendix B.

young children and mothers. Different model specifications are run as robustness checks.

Chapter 4 summarizes the major findings of our study, draws conclusions, derives some policy implications and proposes directions for future research.

Chapter 2: The influence of farm input subsidies on the adoption of natural resource management technologies

Abstract. Farm input subsidies, which are common in many developing countries, are often criticized to be economically and ecologically unsustainable. The promotion of natural resource management (NRM) technologies, with greater emphasis on improved agronomy, are widely seen as more sustainable to increase agricultural productivity and food security. However, relatively little is known about how input subsidies affect farmers' decisions to adopt NRM technologies. There are concerns of incompatibility, because NRM technologies are one strategy to reduce the use of external inputs in intensive production systems. However, in smallholder systems of Africa, where the average use of external inputs is low, there may possibly be interesting complementarities. In this article, we analyse the situation of Malawi's Farm Input Subsidy Program (FISP). Using panel data from smallholder farm households collected in 2011 and 2013, we develop a multivariate probit model (n=1482) in order to examine how FISP participation affects farmers' decisions to adopt various NRM technologies, such as intercropping of maize with legumes, use of organic manure, water conservation practices, and vegetative strips. As expected, FISP increases the use of inorganic fertilizer and improved maize seeds. Yet, we also observe a positive association between FISP and the adoption of certain NRM technologies. For other NRM technologies no significant effects are found. The results suggest that input subsidies and the promotion of NRM technologies can be compatible strategies in an African context.

2.1 Introduction

Agricultural input subsidies have had a long and controversial history in sub-Saharan Africa, but have experienced a revival during the last decade (Denning et al.

2009). Malawi has been a pioneer in the reintroduction of large-scale input subsidies (Chirwa and Dorward 2013). Instead of market-wide subsidies, which were common in the past, a targeted, voucher based approach was launched. Since 2005/06, Malawi's Farm Input Subsidy Program (FISP) targets poor smallholder farmers with vouchers for inorganic fertilizer and improved crop seeds with the intention to raise national and household food security. Especially in its early years, FISP was praised as a success story. Malawi experienced bumper harvests, and the overall wellbeing of smallholders seemed to have increased with improved access to subsidized inputs and technologies (Lunduka et al. 2013). FISP became a role model for an African Green Revolution that many other African countries wanted to replicate (Denning et al. 2009; Lunduka et al. 2013).

However, more recently FISP has drawn substantial criticism in academic and policy arenas. Serious doubts have been raised concerning the Program's profitability, efficiency, and financial sustainability (MaSSP 2014). Recent studies showed low benefit-cost ratios and disappointing rates of return on subsidized fertilizer (Jayne et al. 2013; Lunduka et al. 2013). Moreover, the Program's ecological and social sustainability has been questioned by some (MaSSP 2014). Environmental NGOs in particular maintain that the use of agro-chemicals destroys the environment and contributes to small farmers' dependencies (Greenpeace Africa 2015). Also beyond NGO circles, there is broad agreement that sustainable productivity increases cannot build on input intensification alone, but that natural resource management (NRM) technologies, such as soil and water conservation practices, will have an important role to play (Marenya et al. 2012; The Montpellier Panel 2013; MaSSP 2014). Further development and wider adoption of NRM technologies could increase agricultural productivity, reduce environmental externalities, and make farming in Africa more resilient (Holden and Lunduka 2013).

With support from international donors, the Malawian government recently launched the Agricultural Sector-Wide Approach, a program to harmonize FISP with other policy initiatives that promote the dissemination and adoption of NRM technologies (MoAFS 2011). Yet, NRM technologies are often seen as a strategy to reduce the use of external inputs (Lee 2005), so it is unclear how compatible input subsidies and policies to promote NRM technologies actually are. Empirical evidence on how FISP might affect the adoption and use of NRM technologies is scarce. A few studies investigated the effect of FISP on cropland allocation with mixed results. Karamba (2013) and Holden and Lunduka (2010) suggested that FISP contributes to crop diversification and a decreasing share of land allocated to maize, while Chibwana et al. (2012) found evidence of less diversified cropping patterns. Holden and Lunduka (2012) analysed the relationship between fertilizer subsidies and the use of organic manure and observed a positive link. We are not aware of studies that have analysed the effects of input subsidies on the adoption of other soil and water conservation practices, such as maize intercropping with legumes, soil ridges, terraces, or vegetative strips, in Malawi or elsewhere. Here, we address this research gap.

In particular, we use panel data from smallholder maize producers collected in 2011 and 2013 to analyse how FISP affects farmers' adoption of different NRM technologies. Two specific research questions are investigated: Does FISP participation influence the use of NRM technologies, specifically soil and water conservation practices? And more generally, is the adoption of input-intensive technologies compatible with the adoption of NRM technologies? To answer these questions we develop and estimate a multivariate probit model that takes explicit account of the correlation between different adoption decisions. The possible unobserved heterogeneity and selection bias of FISP participation is tested and controlled for with a Mundlak regression approach.

The rest of this chapter is organized as follows. The next section provides some background on farming in Malawi and the FISP. Section 2.3 introduces the methods used. Section 2.4 presents and discusses the estimation results. Section 2.5 concludes.

2.2 Malawi and FISP

Agriculture accounts for 30% of Malawi's gross domestic product; about 90% of the population are engaged in agricultural activities (CIA 2015). Maize is the main staple food and is grown on 70% of the total cultivated land (Chirwa and Dorward 2013). Maize cultivation predominantly depends on rainfall with only one rainy season from December to April. The risk of crop failure due to drought and waterlogging is high. Input intensity among smallholders is relatively low, and the heavy reliance on maize cultivation further decreases soil fertility. Malawi's smallholder farmers regularly fall short of maize between January and March, when the stocks are decreasing. Rural households frequently suffer from severe food shortages (Denning et al. 2009). These circumstances have led to the implementation of input subsidy programs in the past and present (Chirwa and Dorward 2013).

FISP has been the latest addition to such policy initiatives aimed at increasing smallholder productivity, incomes, and food security (Lunduka et al. 2013). FISP targets about 50% of Malawi's farmers with vouchers for subsidized inputs. In 2012/13, eligible households were supposed to receive two vouchers for fertilizer and one for improved maize seeds. Each fertilizer voucher could be redeemed for one 50 kg bag of fertilizer at a small fee of 500 MK (Malawi Kwacha). Seed vouchers could be redeemed cost-free for 5 kg of hybrid maize seeds or 8 kg of open-pollinated variety (OPV) seeds. Additionally, vouchers for legume seeds were available. Over time, other subsidy components such as fertilizer for tobacco, tea, and coffee, as well as cotton seeds and chemical treatments were also added, but the core package of inorganic fertilizer and improved maize seeds remained in place (Chirwa and Dorward 2013).

Since 2009/10, the government has allocated the vouchers proportionally to the number of farm families within districts. Distribution across villages is executed by government extension services and local authorities. Within villages, potential beneficiaries are identified in open forum allocations. Eligible farm households must fulfil at least one of the following criteria (Chirwa and Dorward 2013). They are (i) resource poor, but own and cultivate a piece of land, (ii) long-time residents of the village, (iii) guardians looking after physically challenged or HIV/AIDS-affected persons, or (iv) especially vulnerable, such as farm families headed by women or elderly individuals (Chirwa and Dorward 2013). In short, FISP intends to benefit poor and vulnerable farm households that are able to make productive use of the inputs provided (Chibwana et al. 2014). However, the actual practice of targeting and voucher allocation has been criticized for inconsistencies (Chirwa and Dorward 2013; Lunduka et al. 2013).

Program costs are also an issue of concern. In 2011/12, FISP accounted for 140 million US$, equivalent to almost 50% of Malawi’s agricultural budget (Chirwa and Dorward 2013). These high costs have led to questions about the Program’s financial sustainability. Investigations also led to mixed evidence on the Program’s effectiveness and economic impact; while returns were shown to be positive at national level, farm level returns seem to be rather modest (Lunduka et al. 2013). This has also contributed to international donors now putting more emphasis on sustainable land management (Holden and Lunduka 2012). NRM practices were identified as a major strategy for sustainably increasing productivity on smallholder farms (Sauer and Tchale 2009). Against this background, better integrating input subsidies with approaches to promote NRM technologies seems to be a necessity to reach FISP's goals in the medium and long run (Holden and Lunduka 2012).

2.3 Materials and methods

2.3.1 Data

The data used for this study come from a farm household survey that was conducted in two rounds in collaboration with the International Maize and Wheat Improvement Center (CIMMYT) and the Malawian Department of Agricultural Research Services (DARS). The survey covers data for two cropping seasons, 2009/10 and 2012/13, and was implemented in six districts of Malawi, namely Lilongwe, Kasungu, Mchinji, Salima, and Ntcheu in the Central, and Balaka in the Southern region of the country. These six districts were selected purposively based on their maize production potential. A multistage proportionate random sampling procedure was then applied to select villages in each district and households in each village. In the first survey round 890 households were interviewed. Out of these, in the second round 757 were re-interviewed. Some sample attrition occurred, as is normal for panel survey rounds with several years in-between. The econometric analysis is based on an unbalanced panel and pooled observations from both rounds. Households with missing data were excluded. The final data set consists of 1482 observations. The empirical models draw on detailed information at the household and plot level.

2.3.2 Multivariate probit model of technology adoption

Smallholder farmers have to deal with multiple agricultural production constraints affecting their households' wellbeing. Farmers often use different strategies and technologies, whereby the adoption of one technology cannot be seen in isolation from other technologies and inputs used. The possibility that adoption decisions are interrelated has recently drawn a lot of attention (e.g., Kassie et al. 2013;

Kassie et al. 2015; Wainaina et al. 2016). The adoption of multiple technologies can result in complementarities and trade-offs, meaning that some combinations make more sense for farmers than others. A modelling approach that takes into account the complex decision-making in technology adoption is the multivariate probit model (MVP). The MVP simultaneously models the adoption of a set of technologies. In contrast to standard probit models with only one dependent variable, the MVP accounts for relationships between different technologies that can lead to correlation of unobserved factors and the error term in the adoption equations (Greene 2012).

We use an MVP to explain the adoption decisions for multiple innovations, including input-intensive and NRM technologies, and assess the role of FISP participation in these decisions. The general model can be written as follows:

$$TA_k^* = \beta_0 + \beta_{1k}FISP + \beta_{2k}H + \beta_{3k}R + \beta_{4k}T + \varepsilon_k \tag{2.1}$$

$$TA_k = \begin{cases} 1 \; if \; TA_k^* > 0 \\ 0 \; otherwise \end{cases} \tag{2.2}$$

where TA_k^* denotes a latent variable that can be understood as the expected net benefit from adopting technology k. The model considers 7 different technologies, as will be detailed below. TA_k^* is assumed to be a linear combination of explanatory variables and the unobserved error term ε. Given that TA_k^* is not observable, model estimation is based on the observed binary variable TA_k, which describes whether or not a farm household has adopted technology k.

The main explanatory variable of interest is $FISP_k$, which is a dummy for participation in the subsidy program, meaning that a household actually received vouchers for inorganic fertilizer and improved maize seeds. The effect of participation on technology adoption is measured by β_{1k}. A positive (negative) and significant coefficient β_{1k} would indicate that the input subsidy increases (decreases) the probability of adoption of technology k. In addition, a range of farm and household characteristics (*H*), regional characteristics (*R*), and a year dummy (*T*) for the survey round are included.

The error terms in the MVP model jointly follow a multivariate normal distribution with zero conditional mean and variance normalized to unity. The model generates a variance-covariance matrix that denotes the correlation of the error terms for any two equations (Kassie et al. 2013). This matrix allows us to describe the correlation between all technologies considered. Complementary technologies have a positive correlation, while negative correlations might indicate a substitutive relationship.

2.3.3 Addressing unobserved heterogeneity and potential selection bias

The particular design of FISP provides a challenge for empirical analysis, as the targeting process is non-random and can therefore lead to selection bias in the estimation of equation (2.1). Selection into FISP and the decision to adopt NRM technologies could be jointly determined by the same unobserved household characteristics, such as farm management ability or a farm household’s motivation. For instance, among the large number of potential beneficiaries of FISP, farms with higher management ability may have a greater chance to be selected because they are assumed to make better use of fertilizer and improved seeds. At the same time, these farmers may also be more innovative and thus more likely to adopt NRM technologies at an early stage. Unless controlled for, such unobserved characteristics can cause bias in the estimated effect of FISP participation.

Earlier studies that have analysed the effects of FISP have used instrumental variable (IV) approaches to control for unobserved heterogeneity and reduce selection bias (Ricker-Gilbert et al. 2011; Lunduka et al. 2013; Karamba 2013). However, the identification of reliable instruments is challenging, and the implementation of IV procedures in a multivariate probit framework is not straightforward. Another way to address this issue is to exploit the panel nature of the data and use a fixed effects estimator. Yet, there are two shortcomings of using fixed effects in our context: (1) the binary nature of the outcome variables might result in the incidental parameter problem (Greene 2012); (2) a fixed effects procedure would require the estimation of single adoption models and neglect the relationships between different technologies as explained above. As an alternative, the MVP model can be modified using an approach proposed by Mundlak (1978), which requires the inclusion of the means of all time-varying explanatory variables $\overline{X}$ (including FISP participation, household characteristics, and regional characteristics). Hence, the model can be written as follows:

$$TA_k^* = \beta_0 + \beta_{1k}FISP + \beta_{2k}H + \beta_{3k}R + \beta_{4k}T + \beta_{5k}\overline{X} + \varepsilon_k \qquad (2.3)$$

Including variable means as additional covariates controls for unobserved heterogeneity and addresses the selection bias in the MVP model (Kassie et al. 2015).

2.4 Results

2.4.1 Descriptive statistics

Descriptive statistics of explanatory variables in the regression models are shown in Table 2.1. Farms are relatively small with an average farm size of 3.3 acres. Fifty percent of the sample households had participated in FISP during the seasons covered by the two survey rounds, meaning that they received vouchers for subsidized fertilizer and maize seeds. Among the household characteristics used in the regression models are typical human capital variables – such as age, education, and gender of the household head – as well as assets – such as farm size and livestock ownership – that were shown to affect technology adoption in many situations. Moreover, a number of social capital and social network variables are considered, as well as shocks experienced in the past, because these can also influence technology adoption (Doss 2006; Kassie et al. 2015). Regional factors include infrastructure conditions, district-level population size, and a geographical dummy, among others.

Table 2.1 Descriptive statistics for explanatory variables used

Variable	Description	Mean	SD
Household characteristics			
FISP	Household has participated in FISP during the last season	0.50	(0.50)
Age	Household head age (years)	44.70	(14.75)
Female head	Household head female (dummy)	0.15	(0.36)
Education	Household head education (years)	5.24	(3.51)
Adults	Adult household members, ≥ 15 (number)	2.85	(1.31)
Children	Child household members, ≤ 12 (number)	2.01	(1.41)
Resources			
Asset value	Total value of major farm and household equipment (‘000 MK)	37.81	(144.37)
Livestock	Number of livestock (Tropical Livestock Units)	1.24	(2.75)
Farm size	Farm land owned (acres)	3.30	(2.79)
Business	Own business income (dummy)	0.46	(0.50)
Seasonal labor	Seasonal labor income (dummy)	0.59	(0.49)
Remittances	Income through remittances (dummy)	0.28	(0.45)
Credit access	Access to credit (dummy)	0.22	(0.41)
Previous subsidy recipient	Household has received subsidies in all previous seasons of FISP operation (dummy)	0.19	(0.39)
Shocks			
Socioeconomic shocks	Household experienced agricultural input shortage and food insecurity during the past ten years (dummy)	0.85	(0.36)
Water stresses	Household experienced drought or waterlogging during the past ten years (dummy)	0.75	(0.43)
Pests and diseases	Household experienced agricultural pests and diseases during the past ten years (dummy)	0.48	(0.50)
Social capital/network			
Social group member	Membership in church, women’s, or other social groups (dummy)	0.51	(0.50)
Relatives in village	Household can rely on relatives in the village (number)	4.09	(4.20)
Traders in village	Household trusts grain traders in the village (number)	1.94	(3.31)
Farmers’ group member	Membership in farmers’, input or marketing group (dummy)	0.10	(0.30)
Leadership connections	Relative of household holds leadership position (dummy)	0.53	(0.50)
Relatives outside village	Household can rely on relatives outside the village (number)	4.16	(4.51)
Traders outside village	Household trusts grain traders outside the village (number)	4.69	(5.56)
Government support	Household can rely on government when crop fails (dummy)	0.58	(0.49)
Years in village	Years the household has resided in the same village	28.71	(17.97)

Table 2.1 continued

Variable	Description	Mean	SD
Access to services			
Market distance	Distance to the main market (walking minutes)	88.11	(67.45)
Main road passable	Main road passable by cars for more than half the year (dummy)	0.91	(0.29)
Extension	Household benefitted from agricultural extension (average number of days per season)	1.73	(3.80)
Village characteristics			
Farm families in district	Total number of farm families residing in district ('000)	23.01	(7.48)
DPP	Ruling party, DPP, won district in 2009 election (dummy)	0.54	(0.50)
Southern	Household resides in the Southern region (dummy)	0.18	(0.38)
Year	Survey year 2013 (dummy)	0.46	(0.50)

The number of observations is 1482. All data are from the farm household survey, except for farm families in district, which were obtained from the Ministry of Agriculture and Food Security, and DPP, reflecting the 2009 election results as obtained from the Malawi Electoral Commission.

The technology adoption variables considered in this study comprise 7 different technologies, namely (i) inorganic fertilizer and (ii) improved maize seeds as two input-intensive technologies; and (iii) legume intercropping, (iv) manure, (v) soil ridges, (vi) terraces and stone bunds, and (vii) vegetative strips as five NRM technologies. Table 2.2 presents descriptive statistics for these 7 technologies.

The use of inorganic fertilizer and improved maize seeds is widespread in Malawi. In comparison, many of the NRM technologies are used less widely, although some have also been adopted by a considerable proportion of farmers. For instance, legume intercropping is practiced by almost one-third of the households. In Malawi, the use of pigeon pea, groundnut, soybean, and other bean species as intercrops is a common practice among farmers who want to diversify their cropping systems (Gilbert 2004). These legumes do not only fix atmospheric nitrogen, but they are also capable of exploiting residual moisture in the soil, so that intercropping with maize can be advantageous. In addition, intercropping can provide benefits in terms of soil organic matter and lower problems with pests (Tilman et al. 2002; Snapp et al. 2010). Use of organic manure is also quite common in Malawi, even though the quantities applied are typically low (Holden and Lunduka 2012).

Table 2.2 Adoption of different technologies by participation in input subsidy program

Technology	Description	Adoption rate		
		All (n=1482)	FISP (n=744)	Non-FISP (n=738)
Inorganic fertilizer	Farmer applied inorganic fertilizer (= 1, otherwise 0)	0.942	0.996	0.887***
Improved maize	Farmer used improved maize varieties (= 1, otherwise 0)	0.779	0.871	0.687***
Legume intercropping	Farmer practiced legume intercropping (= 1, otherwise 0)	0.306	0.353	0.257***
Manure	Farmer used manure (= 1, otherwise 0)	0.384	0.379	0.389
Ridges	Farmer constructed ridges (= 1, otherwise 0)	0.560	0.559	0.561
Terraces and stone bunds	Farmer constructed terraces and stone bunds (= 1, otherwise 0)	0.152	0.142	0.160
Vegetative strips	Farmer used vegetative strips (= 1, otherwise 0)	0.195	0.215	0.175**

Differences between FISP and Non-FISP farmers were tested for statistical significance. ***P≤0.01, **P≤0.05

Of particular interest among the NRM technologies are also soil and water conservation practices that can help to increase soil water availability, decrease soil erosion, and maintain nutrient levels (Delgado et al. 2011). In Malawi, soil ridges were already promoted during colonial times and in the post-independence era (Kassie et al. 2015), which is why over half of all farmers are using this practice. Ridges are soil embankments that run along the contour of a plot and thus slow down water runoff and sediment wash out. The size and the spacing of ridges can vary depending on slope and other factors. Ridges are usually renewed every season. In contrast, terraces and stone bunds, which serve a similar purpose as soil ridges, are longer-term structures involving higher investments for building (Critchley et al. 1994).

Stone bunds are semi-permeable barriers; excess runoff water can pass through and is filtered, so that sediments are caught. Filtration also promotes levelling off the field behind the stone bunds and the formation of terraces. Around 15% of the sample farmers have constructed terraces and stone bunds. They are commonly found on hillsides where stone is abundant. Vegetative strips are used to control runoff and soil erosion. For instance, vetiver grass is traditionally used for soil conservation; trees or shrubs might serve as living fences around cultivated fields to protect against erosion (Critchley et al. 1994).

Table 2.2 compares technology adoption rates between FISP participants and non-participants. The use of inorganic fertilizer and improved maize seeds is significantly higher among FISP participants, which is unsurprising. Strikingly, however, not all program participants use improved maize seeds. For most of the NRM technologies, no significant differences can be observed. Only for legume intercropping and vegetative strips we observe higher adoption rates among FISP participants. This is a first indication that FISP and the promotion of NRM technologies are not incompatible, which is analysed in more detail in the following.

2.4.2 FISP participation

Before analysing the effect of participation in the subsidy program on the adoption of NRM technologies, a probit model will explain participation in the FISP. Looking more closely at the factors that influence participation is interesting because it explains the functioning of the selection process into the subsidy program. Of particular interest are variables that capture the targeting criteria of FISP, such as age and gender of the household head, exposure to past shocks, and wealth status. Other studies have shown that social networks and political factors may also play a role for beneficiary selection and could influence voucher allocation (Mason and Ricker-Gilbert 2013). Such factors are also captured in the model.

Table 2.3 Factors influencing FISP participation

Explanatory variables	Marginal effects	P-value
Age	0.003	0.034
Female head	0.051	0.248
Education	0.008	0.085
Adults	0.000	0.979
Children	0.012	0.247
Asset value	-0.000	0.005
Livestock	-0.003	0.507
Farm size	0.033	0.012
Farm size, squared	-0.002	0.015
Socioeconomic shocks	0.129	0.001
Previous subsidy recipient	0.307	0.000
Business	0.032	0.260
Seasonal labour	0.008	0.792
Remittances	0.051	0.107
Years in village	0.002	0.075
Social group member	0.063	0.071
Relatives in village	0.005	0.149
Traders in village	0.010	0.032
Leadership connections	0.013	0.653
Main road passable	-0.005	0.915
Farm families in district	-0.002	0.448
DPP	0.130	0.000
Southern	0.195	0.000
Year	-0.021	0.567
Pearson’s goodness-of-fit statistic, prob>χ^2	0.51	
Percent correctly classified	65.52	

The number of observations is 1482. P-values are based on robust standard errors, adjusted for 827 household clusters.

Table 2.3 presents the estimates for the model explaining participation in FISP. The results suggest that older household heads are more likely to participate in FISP than younger farmers. This is in accord with the FISP guidelines that mention elderly-headed households as priority beneficiaries. The marginal effect for female household head is also positive, but not statistically significant. Education has a positive effect that is significant at the 10% level. In contrast to Chibwana et al. (2012), who suggested that better-off households may benefit more from FISP, we find asset values to be negatively associated with FISP participation, meaning that poorer households are more likely to benefit from input subsidies. Eligibility is confined to households with own land. Our results show that farm size has a positive effect on the likelihood of participation, but this effect is diminishing with increasing farm size, as indicated by the negative square term. The turning point is reached at a farm size of 9.8 acres, which is still within the range of hand-hoe based smallholder farms, which are defined in Malawi up to a size of 12.5 acres (Holden 2014).

In summary, the estimation results in Table 2.3 suggest that productive but asset-poor and vulnerable farm households are those who participate in the subsidy program with higher probability. In other word, FISP targeting seems to function reasonably well. Nevertheless, there seem to be some social and political factors that might be correlated with unobservable household characteristics, and could influence the selection into FISP, which would create potential issues of selection bias in the MVP model.

2.4.3 MVP model results

Interrelationships between technologies

Before presenting the MVP results themselves we look at the error term correlation matrix of the model, which provides an idea of possible interrelationships in the adoption of different technologies. The results in Table 2.4 suggest that the null hypothesis of zero correlation between the error terms of all equations needs to be rejected. Hence, the MVP model that accounts for error term correlation is appropriate.

Table 2.4 Correlation matrix for technology adoption equations

	Improved maize	Legume inter-cropping	Manure	Ridges	Terraces and stone bunds	Vegetative strips
Inorganic fertilizer	0.208***	0.009	-0.168**	0.114	-0.083	0.186*
	(0.080)	(0.080)	(0.078)	(0.076)	(0.083)	(0.099)
Legume intercropping		0.017	0.091*	-0.001	0.135**	0.039
		(0.052)	(0.050)	(0.048)	(0.062)	(0.054)
Manure			0.154***	0.253***	0.139**	0.052
			(0.045)	(0.046)	(0.055)	(0.052)
Ridges				0.084*	-0.025	0.136***
				(0.043)	(0.052)	(0.050)
Terraces and stone bunds					0.035	0.012
					(0.051)	(0.047)
Likelihood ratio test of all correlation coefficients jointly equal to zero: chi2(21) = 86.57***						

The number of observations is 1482. Robust standard errors – in parentheses - are adjusted for 827 household clusters. ***P≤0.01, **P≤0.05, *P≤0.1

Most of the correlation coefficients in Table 2.4 have positive signs, suggesting that farmers in Malawi do not consider certain technologies as substitutes for others. One exception is the negative correlation between inorganic fertilizer and manure. Both inputs are used to enhance soil nutrients; manure additionally helps to improve soil organic matter. While both inputs can be used together, farmers in Malawi who adopted one are less likely to adopt the other, probably due to resource constraints. This was also observed by Wainaina et al. (2016) in Kenya.

Positive and significant correlation coefficients point at complementarities between technologies. The positive relationship between inorganic fertilizer and improved maize is expected and in line with previous studies (e.g., Denning et al. 2009; Kassie et al. 2013). Improved varieties are often more responsive than traditional landraces to fertilizer application. We also observe positive relationships between different NRM technologies, indicating that farmers pursue different strategies of soil and water conservation in conjunction. Strikingly, however, the correlation matrix in

Table 2.4 shows significantly positive coefficients for a few combinations of input-intensive and NRM technologies, too. The results suggest that inorganic fertilizer is often adopted in combination with vegetative strips; improved maize seeds are used together with manure and with terraces and stone bunds. Similar complementarities between input-intensive and NRM technologies were also observed in other East African countries (Kassie et al. 2015; Wainaina et al. 2016). These findings challenge the widely-held public belief that input-intensive and NRM technologies are incompatible.

FISP participation and technology adoption

We now turn to the results of the MVP model itself, which we use to analyse the influencing factors of farmers' technology adoption. The full estimation results are shown in Tables A1-A3 in Appendix A. Several variables related to human capital, asset ownership, social networks, institutions, and agroecological factors have significant effects. Certain factors, such as asset ownership, have a positive influence on the adoption of input-intensive technologies but a negative effect on the adoption of NRM practices. Other variables, such as membership in farmer groups, are positively associated with both types of technologies. We refrain from a detailed discussion of all influencing factors (see Kassie et al. 2013; and Kassie et al. 2015; Wainaina et al. 2016 for recent analyses of technology adoption), because the focus here is primarily on the effect of FISP participation on the use of NRM technologies.

Table 2.5 summarizes the influence of FISP participation on technology adoption using three different specifications of the MVP model: (i) The basic model includes FISP participation as a dummy variable without controlling for potential selection bias. (ii) The reduced model does not control for possible selection bias either, but only includes equations for the five NRM technologies; this specification serves to test whether the effects of FISP participation are sensitive to inclusion of the input-intensive technologies in the MVP model. (iii) In the Mundlak model, we control for possible selection bias from unobserved heterogeneity by including the means of all time-varying covariates as described in the section 2.3.3.

Table 2.5 Effects of FISP participation on technology adoption

	Inorganic fertilizer	Improved maize	Legume inter-cropping	Manure	Ridges	Terraces and stone bunds	Vegetative strips
Basic model	1.713***	0.688***	0.153**	-0.017	-0.031	-0.076	0.172**
	(0.262)	(0.083)	(0.075)	(0.073)	(0.073)	(0.088)	(0.081)
Log pseudo likelihood = -4920.34; Wald chi2(231) = 1025.78***							
Reduced model			0.155**	-0.018	-0.034	-0.079	0.167**
			(0.075)	(0.073)	(0.073)	(0.088)	(0.081)
Log pseudo likelihood = -3997.44; Wald chi2(165) = 637.36***							
Mundlak model	1.474***	0.421***	0.010	-0.113	-0.053	-0.117	0.111
	(0.344)	(0.127)	(0.115)	(0.104)	(0.113)	(0.141)	(0.128)
Joint significance of mean of time-varying covariates (chi2)	81.91***	49.20***	22.17	35.98	28.59	21.99	37.09
Log pseudo likelihood = -4806.52; Wald chi2(427) = 2541.23***							

The number of observations is 1482; the number of draws is 50 for each MVP model. Robust standard errors – in parentheses - are adjusted for 827 household clusters. Full estimation results are shown in Tables A1-A3 in Appendix A. ***P≤0.01, **P≤0.05, *P≤0.1

Results from the basic model in Table 2.5 show significantly positive effects of FISP participation on the use of inorganic fertilizer and improved maize seeds. This is unsurprising, as the subsidy program intends to promote the adoption of these technologies. From this perspective, FISP seems to be effective, which was also shown in previous research (Chibwana et al. 2014; Snapp and Fisher 2015). In addition, the basic model suggests significantly positive effects of FISP participation on the adoption of some NRM technologies, as well. The positive effect on legume intercropping may be due to subsidized inputs contributing to higher productivity in maize (Chibwana et al. 2014). Some of the households that meet their subsistence needs of maize may decide to allocate more land to legumes (Karamba 2013), even though Chibwana et al. (2012) showed that this is not always the case. Another explanation is that FISP participants also received vouchers for improved legume seeds in some cases. The positive effect of FISP participation on the adoption of vegetative strips is not straightforward to explain, but underlines at least that input subsidies do not prevent farmers from using this agronomic technique. The reduced model confirms the results of the basic model without any considerable changes for the association between FISP participation and the adoption of NRM technologies. However, results from these two models should be interpreted with caution because of possible selection bias.

The lower part of Table 2.5 reports the results from the MVP model with the Mundlak approach. The null hypothesis that all coefficients of the mean of time-varying covariates are jointly significantly equal to zero is rejected only for the inorganic fertilizer and improved maize equations, thus supporting the presence of unobserved heterogeneity. Results from the Mundlak model confirm the positive effect of FISP on the adoption of inorganic fertilizer and improved maize seeds, but the coefficient estimates are slightly smaller. This points to an upward bias of results if unobserved heterogeneity is not corrected for. The estimated effects for the adoption of NRM technologies are slightly different. While the coefficients in the legume intercropping and vegetative strips equations remain positive, they are now insignificant. The signs of the coefficient estimates for the other NRM technologies remain the same throughout all equations. Although the coefficient estimates for the NRM equations are insignificant in the Mundlak model, the results support the finding that participation in the FISP has no significantly negative effect on the adoption of NRM technologies in smallholder farms.

2.5 Conclusion

The Farm Input Subsidy Program (FISP) which was launched in Malawi in 2005/06 has contributed to bumper harvests and improved wellbeing of poor farm households. FISP has even inspired other African countries to also introduce large-scale input subsidy programs. However, in recent years FISP has been increasingly criticized for not being economically and ecologically sustainable. In particular, there are doubts that FISP is compatible with natural resource management (NRM) technologies that build on improved agronomic practices to raise productivity and conserve soil and water.

We have used panel data collected from smallholder farm households in Malawi to analyse the effect of FISP participation on the adoption of various technologies, with a particular focus on NRM practices. The results show that FISP participation significantly increases the farmers' likelihood to use inorganic fertilizer and improved maize seeds. This was expected, because FISP participants receive vouchers for the purchase of these inputs at subsidized rates. For the adoption of certain NRM technologies, our results show positive effects of FISP in some of the model specifications. In particular, FISP participation is positively associated with the practice of legume intercropping and the use of vegetative strips. These effects are probably due to productivity increases in maize resulting from the use of subsidized inputs and a concomitant reallocation of land and other household resources. The effect of FISP on the adoption of other NRM technologies is not statistically significant. Independent of the subsidy program, the results indicate that farmers in Malawi tend to consider modern inputs and NRM practices as complementary, not as substitutes in most cases. Different types of technologies are often adopted in combination.

To control for unobserved heterogeneity and possible selection bias we used a Mundlak estimator. While some of the positive effects lose their statistical significance in the Mundlak model, the result that FISP participation does not affect the adoption of any of the NRM technologies in a negative way remains robust. The findings suggest that there are no inevitable policy trade-offs between targeted input subsidy programs and the promotion of NRM technologies in smallholder farming systems. In other words, the promotion of NRM technologies under FISP is feasible. Further research is needed that can help design improved extension strategies to harness synergistic relationships between different types of technologies in specific situations.

Chapter 3: Agricultural biodiversity and dietary diversity in rural Malawi

Abstract. *Objective*: The association between agricultural biodiversity and dietary diversity in smallholder farm households was recently analysed. Most existing studies build on household level dietary diversity indicators calculated from 7-day food consumption recalls. We revisit this association by using individual level 24-hour recall data, which are more precise for measuring nutritional quality. By comparing household and individual level estimates we test the robustness of previous findings. We also analyse the role of other factors, such as market access and agricultural technology. *Design*: A survey of smallholder farm households was carried out in Malawi in 2014. Dietary diversity scores are calculated from 24-hour recall data. Individual and household level regression models are developed and estimated. *Setting*: Data were collected in 16 districts, covering all rural areas of Malawi. *Subjects*: Smallholder farm households (n 408), young children (n 519) and mothers (n 408). *Results*: Farm species diversity is positively associated with dietary diversity. However, the estimated effects are small. Access to markets for buying food and selling farm produce and use of chemical fertilizers are shown to be more important for nutritional quality than diverse farm production. Similar results are obtained with household and individual level nutrition data. *Conclusions*: Further increasing production diversity may not be the most effective strategy to improve nutrition in smallholder farm households. Improving access to markets, productivity enhancing inputs and technologies seems to be more promising. Household dietary diversity scores are a suitable proxy for measuring nutritional quality of individual household members.

3.1 Introduction

Despite substantial improvements in food security over the last few decades, undernutrition remains a global burden. Approximately 800 million people are chronically hungry, most of them living in developing countries (FAO 2015). An estimated two billion people suffer from deficiencies in particular micronutrients, such as iron, zinc or vitamin A (IFPRI 2015). Nutritional deficiencies harm physical and mental human development, increase the susceptibility to infectious diseases and contribute to premature deaths. Women and children pay the heaviest toll. Forty-five percent of all child deaths under the age of five are linked to undernutrition (IFRPI 2015). Overall, undernutrition is the cause of 3.1 million child deaths annually (Black et al. 2013). Childhood undernutrition also decreases adult productivity and entails substantial economic losses in many developing countries (IFPRI 2015).

Nutrition is closely linked to agriculture, not only because agriculture is the sector that produces food, but also because many of the undernourished people worldwide are smallholder farmers (Frelat et al. 2016; Pinstrup-Andersen 2007). For a long time, the main agricultural policy response to undernutrition was to strengthen staple food production through price incentives and promoting improved farm technologies. The focus was primarily on a narrow range of cereal crops, especially wheat, rice and maize (Pingali 2015). While this strategy has clearly helped to reduce hunger, it has also contributed to lower levels of agricultural biodiversity (Khoury et al. 2014). More homogenous global food supplies may have decreased dietary diversity (Graham et al. 2007; Frison et al. 2006). And low levels of dietary diversity are associated with higher rates of micronutrient deficiencies, child stunting, child deaths and other negative health consequences (M’Kaibi et al. 2015; Bezner Kerr et al. 2011; Savy et al. 2006; Steyn et al. 2006).

More diversified agricultural and food systems may help to improve dietary quality and nutrition (Berry et al. 2015; Herforth 2015; Pingali 2015; Bowman and Zilberman 2013). However, appropriate levels of agricultural biodiversity are a question of scale. Food systems diversity does not necessarily imply that every single farm has to be extremely diverse. On the one hand, diverse farm production may promote diverse food consumption in the farm household. This is especially true in sub-Saharan Africa, where smallholder farms are often subsistence-oriented (FAO 2014). On the other hand, typical farms in Africa are already quite diverse. Further diversification might prevent gains from specialization and could thus result in income losses, with potential negative nutritional effects (Sibhatu et al. 2015). In spite of their subsistence orientation, smallholder farm households are engaged in market transactions. A substantial share of the food consumed in farm households is purchased from the market (Hirvonen et al. 2015; Luckett et al. 2015; Hirvonen and Hoddinott 2014; Barrett 2008).

Recent studies empirically analysed the link between farm species diversity and dietary diversity in a number of developing countries (Sibhatu and Qaim 2016; Sibhatu et al. 2015; Snapp and Fisher 2015; Jones et al. 2014). While the exact estimates differ, a significant but relatively small positive relationship was generally found. Yet, the same studies also pointed out that market access may be a more important factor influencing dietary diversity in smallholder farm households. These results have stirred an interesting debate (Berti 2015; Remans et al. 2015). In particular, questions about the indicators used to measure production and consumption diversity were raised.

We contribute to this emerging literature on the link between agricultural biodiversity and dietary diversity by using alternative indicators and comparing results. Previous studies used food consumption data to construct dietary diversity scores at the household level (Sibhatu and Qaim 2016; Sibhatu et al. 2015; Snapp and Fisher 2015; Jones et al. 2014). The use of household level consumption data is convenient, because such data are often available from nationally representative living standard measurement surveys. Living standard surveys often include a 7-day or 30-day consumption recall that can be used to construct dietary indicators. However, from a nutritional perspective, shorter recall periods are generally preferred (de Haen et al., 2011). Moreover, household level data do not account for issues of intra-household distribution and can therefore not be used for statements concerning particular population groups, such as children. We use data from a 24-hour dietary recall carried out at household and individual levels to analyse and compare the relationship between farm species diversity and dietary diversity. Furthermore, beyond measuring farm diversity in terms of a simple count of the species produced, we construct production diversity scores that better account for nutritional functions (Sibhatu and Qaim 2016; Berti 2015). Finally, in comparison to previous studies we use a larger set of variables to estimate the role of market access and agricultural technology.

For the empirical analysis, we use data from a recent survey of farm households in Malawi, covering household and individual level information. Malawi is an interesting study country for several reasons. First, Malawi is poor with high rates of undernutrition (Ecker and Qaim 2011). Second, farm households in Malawi are primarily subsistence-oriented. Third, several previous studies on the link between farm production and dietary diversity used household level data from Malawi’s Living Standards Measurement Survey (Sibhatu et al. 2015; Snapp and Fisher 2015; Jones et al. 2014). Focusing on the same setting with individual level data and alternative indicators has advantages in terms of comparability.

3.2 Materials and methods

3.2.1 Data

Data for this study come from a farm household survey that was conducted by the International Maize and Wheat Improvement Center (CIMMYT) and the Malawian Department of Agricultural Research Services (DARS) in early 2014. The survey covered 16 districts throughout all of the country's rural regions. Household selection was based on a multistage proportionate random sampling procedure. Interviews captured a wide array of information, including details on household demographics, household socioeconomic status, agricultural production and marketing and consumption of food and non-food products. A special section with a 24-hour food consumption recall captured dietary patterns of all household members combined, as well as individually for children below the age of five and their mothers. Overall, 1482 farm households were surveyed. Out of the sampled households, only 408 had children below the age of five. We want to compare dietary diversity at household level and individual level for children and mothers, which is most meaningful when focusing on the same households. Hence, this analysis builds on the 408 households with small children and their mothers.

3.2.2 Analytical approach

To analyse the relationship between farm production diversity and dietary diversity, we use the following regression model:

$$DD_{ij} = \alpha_0 + \alpha_1 PD_i + \varepsilon_{ij}, \qquad (3.1)$$

where DD_i is dietary diversity and PD_i is production diversity in farm household i. ε_i is a random error term, and α_0 and α_1 are coefficients to be estimated. We are particularly interested in the estimate for α_1. We estimate different versions of this model, changing the measures of *DD* and *PD*, as is further explained below. In one set of models, *DD* is measured at the household level. In alternative specifications, *DD* is measured for individual *j* living in household *i*. In particular, we consider children below five years of age and their mothers.

The model in equation (3.1) only includes production diversity as explanatory variable. Yet, there may also be other factors that could influence dietary diversity, such as market access and other socioeconomic and demographic characteristics. To better understand the role of such other factors, we extend the regression model as follows:

$$DD_{ij} = \alpha_0 + \alpha_1 PD_i + \alpha_2 M_i + \alpha_3 H_i + \varepsilon_{ij}. \qquad (3.2)$$

where M_i is a vector of variables capturing market access, and H_i is a vector of other socioeconomic and demographic variables, including farm size, household size, off-farm income, as well as age, education and gender of the household head. We use different indicators to capture market access and market use for agricultural sales and food purchases of household *i*.

To analyse the role of agricultural technology, we further extend this model as follows:

$$DD_{ij} = \alpha_0 + \alpha_1 PD_i + \alpha_2 M_i + \alpha_3 H_i + \alpha_4 AT_i + \varepsilon_{ij}, \qquad (3.3)$$

where AT_i represents a vector of dummy variables indicating the use of different types of agricultural technology. Further details of how variables are defined and measured are provided below.

3.2.3 Measurement of dietary diversity

We measure dietary diversity in terms of dietary diversity scores, a common indicator that counts the number of food groups consumed over a certain period of time (Headey and Ecker 2013; Kennedy et al. 2010; Ruel et al. 2003). Most previous studies that analysed the relationship between farm production diversity and dietary diversity calculated dietary diversity scores at the household level, using data from 7-

day food consumption recalls (Sibhatu and Qaim 2016; Sibhatu et al. 2015; Snapp and Fisher 2015; Jones et al. 2014). We use 24-hour recall data collected for the household as a whole and for children below five years of age and their mothers to calculate and compare dietary diversity scores at household and individual levels. We are aware of only two studies that examined the relationship between production and consumption diversity using individual level dietary diversity scores: both of these studies analysed the effects of concrete farm diversification projects, one in Cambodia (Olney et al. 2009) and the other in Kenya and Tanzania (Herforth 2010). We add to this literature by looking at farm households in a broader setting beyond particular diversification projects.

Dietary diversity scores can be calculated based on different numbers of food groups. Many studies consider 12 different food groups, but there is no international consensus (Ruel et al. 2012). Sometimes, food groups with low micronutrient densities are excluded to reflect more healthy diets (Kennedy et al. 2011). Other studies consider a larger number of food groups to analyse dietary patterns in particular situations (Keding et al. 2012). Here, we use the following 12 food groups to calculate dietary diversity scores at household and individual levels: cereals; tubers and roots; vegetables; fruits; meat and poultry; eggs; fish; pulses, legumes and nuts; milk and milk products; oils and fats; sugar and honey; and miscellaneous, including spices, condiments and beverages (Kennedy et al. 2011; Swindale and Bilinsky 2006).

3.2.4 Measurement of farm production diversity

We measure farm production diversity in terms of a crop species count. Counting the number of species produced is a common indicator of agricultural biodiversity at the farm level that was used in several recent studies (Sibhatu et al. 2015; Jones et al. 2014; Herforth 2010). Sometimes the animal species produced are counted as well. We do not include animal species, because related details were not captured in the survey. However, the survey includes more general information about the type and numbers of animals kept, which was used to construct a livestock variable that we include as covariate in the extended regression models.

As an alternative to the crop species count, we also calculate production diversity scores that better account for the nutritional functions of farm species by counting the number of food groups produced (Sibhatu and Qaim 2006; Malapit et al. 2015; Hirvonen and Hoddinott 2014). We use the same 12 food groups that were already explained above. Hence, if a farm produces several species that belong to the same food groups, the production diversity score will be smaller than the crop species count. In the calculation of production diversity scores, we include crop and livestock products. Even though we do not have details about the different animal species produced, we have sufficient data to know whether households produced meat, fish, eggs and milk. The two production diversity indicators (crop species count and production diversity scores) are used in separate regressions to test the robustness of the results.

3.2.5 Measurement of market access

Markets can play an important role for farm households who act as both sellers and buyers of food and other agricultural commodities. We capture access to two different types of markets, namely small local village markets and larger district markets. Local markets are relevant for sales and purchases of smaller quantities, in order to satisfy immediate needs. Local markets also play an important role for fresh fruits, vegetables and dairy products that cannot be stored for longer periods of time. As local markets are not available in every village in Malawi, we construct a dummy variable that takes a value of one if such a market exists in the village where a household resides, and zero otherwise. Larger markets are available in every district, usually in the district capital. Farm households use these district markets to sell farm produce and to buy food and non-food items. Reaching district markets usually involves walking a longer distance, hence most households do this only occasionally. We capture access to district markets through distance expressed in walking hours, which is a continuous variable.

These two market access variables describe the market infrastructure conditions a household faces, but there may also be other factors that influence actual market participation. To gain further insights into the role of markets, we define three market participation variables that we use in alternative model specifications. First, the share of maize sold. Maize is the most important staple food in Malawi that almost all farm households produce, often primarily for subsistence purposes. Yet, even subsistence-oriented households often sell some of their maize to buy other goods needed. Second, the share of other food crops sold, such as legumes, fruits, vegetables etc. Third, the farm area share grown with non-food cash crops, such as tobacco or cotton. Non-food cash crops are entirely sold. In principle, agricultural sales can influence household nutrition in positive and negative ways. Positive effects on dietary diversity could occur when the cash revenues are used to buy food groups that are not produced by the households themselves. Negative effects could occur when less food is produced at home and the cash revenues are not spent on improving nutrition and health.

3.2.6 Measurement of agricultural technologies

There is a relatively large body of literature that has analysed effects of agricultural technology adoption on farm incomes, but only a few studies have looked more specifically at the link between technology adoption and household nutrition

(Snapp and Fisher 2015; Shiferaw et al. 2014; Qaim and Kouser 2013). In Malawi, the government has recently promoted different technologies to sustainably increase agricultural productivity and reduce poverty. On the one hand, this includes modern inputs such as improved crop varieties and chemical fertilizers, which have been promoted through a targeted input subsidy scheme for several years (Chirwa and Dorward 2013). On the other hand, there are also efforts to preserve soil fertility through crop diversification and intercropping with legumes (Mhango et al. 2013; Bezner Kerr et al. 2007). To analyse the role of these technologies for dietary diversity, we construct four technology variables: (1) improved maize varieties, (2) improved legume varieties, (3) chemical fertilizers and (4) maize-legume intercropping (i.e., growing maize and legumes simultaneously on the same plot of land). These variables are defined as dummies taking a value of one when the particular technology was adopted, and zero otherwise.

3.2.7 Regression estimators

The regression models described in equations (3.1) to (3.3) above have dietary diversity as the dependent variable. Dietary diversity is a count variable that is not normally distributed. We use a Poisson estimator and a maximum likelihood procedure, which is a common approach to obtain consistent estimates for count data models (Greene 2012). In Poisson models, the estimated coefficients can be interpreted as semi-elasticities. That is, a coefficient estimate states by what percentage the dietary diversity score changes when the explanatory variable changes by one unit. All models are estimated with robust standard errors to account for heteroscedasticity (Cameron and Trivedi 2009).

It should be mentioned that some of the explanatory variables are potentially endogenous, meaning that they may be correlated with unobserved factors that could also influence dietary diversity. Such endogeneity can cause omitted variable bias. Our approach of using different indicators and adding covariates in a stepwise fashion can help detect such bias up to a certain extent: when the estimates of the main variables of interest change drastically when more variables are added, omitted variable bias is more likely than when the estimates remain relatively robust. Furthermore, because of potential issues of endogeneity we are very cautious not to overinterpret the estimates as proof of causality. We rather interpret in terms of associations, which is permissible also when the explanatory variables are endogenous.

3.3 Results

3.3.1 Descriptive statistics

Descriptive statistics for the variables used in this study are shown in Table 3.1. The upper part of Table 3.1 shows dietary diversity scores (DDS) at the household level, and individually for children and mothers. At the household level, mean DDS is 4.17, that is, the average household has consumed 4.17 food groups during the reference day. Forty percent of the households have consumed fewer than four food groups, only 10 percent have consumed more than six food groups. The most frequently consumed food groups were cereals and vegetables (see Table A4 in Appendix A). Fish was consumed by 20 percent, meat by 6 percent, and eggs and milk or milk products by less than 5 percent of the sample households. These patterns point at relatively low levels of dietary diversity and nutritional quality among rural households in Malawi.

Table 3.1 Description of variables (408 farm household observations)

Variables	Description	Mean (SD)
Dietary diversity scores (DDS)		
DDS household	Household dietary diversity score	4.17 (1.62)
DDS children†	Dietary diversity score of young children (6 months to 5 years)	3.87 (1.92)
DDS mothers	Dietary diversity score of mothers of young children	4.11 (1.67)
Farm production diversity		
Crop species count	Number of different crop species cultivated on farm	5.79 (2.89)
Production diversity score	Number of different food groups produced on farm	4.88 (1.69)
Market access		
Village market	Village market exists in community (dummy)	0.56
Time to district market	Distance to the district market in walking hours	1.34 (1.13)
Market participation		
Share of maize sold	Percentage of total maize production sold	7.38 (13.71)
Share of other food crops sold	Percentage of other food crop production sold	34.71 (32.23)
Area share of non-food cash crops	Percentage of farm area cultivated with non-food cash crops	10.97 (17.92)
Agricultural technologies		
Improved legume varieties	Farm household cultivates improved legume varieties (dummy)	0.62
Improved maize varieties	Farm household cultivates improved maize varieties (dummy)	0.81
Chemical fertilizer	Farm household uses chemical fertilizer (dummy)	0.92
Maize-legume intercropping	Farm household practices maize-legume intercropping (dummy)	0.51
Other socioeconomic and demographic factors		
Livestock	Number of animals kept in tropical livestock units (TLU)	0.88 (1.50)
Off-farm income	Cash income from off-farm activities (thousand Malawi Kwacha)	91.34 (157.16)
Farm size	Total area owned in acres	2.89 (1.99)
Household size	Total number of household members	6.23 (2.02)
Age of head	Age of the household head in years	40.81 (11.91)
Male head	Household head is male (dummy)	0.86
Education of head	Education of the household head in years	5.39 (3.42)

† The total number of children (<5 years) in the 408 households is 519.

Individual level DDS are somewhat lower than those measured at the household level. This is expected because at household level consumption of all household members is covered, including children above the age of five, adolescents, male adults etc. However, the differences between household and individual level DDS are relatively small, and the different measures are strongly correlated. The correlation coefficients between child and household DDS and between mother and household DDS are 0.78 and 0.90, respectively. Within the group of children, we examined whether age and gender have a systematic influence on dietary diversity scores, but found no significant effects.

The lower part of Table 3.1 shows the variables that we use as covariates in the different specifications of the regression models. The average farm produces 5.79 different crop species and 4.88 different food groups. In terms of market access, 56 percent of the sample households live in villages that have a local market. The average walking distance to the larger district market is 1.34 hours. Less than 8 percent of the maize produced is sold in the market, underlining that the sample farms are indeed fairly subsistence-oriented. On the other hand, around one-third of the harvest from other food crops is sold on average, and around 11 percent of the area is cultivated with non-food cash crops. These numbers reveal that – in spite of their subsistence orientation – farm households in Malawi participate in market transactions and depend on agricultural cash incomes to buy goods and services that they do not produce themselves. Farm gate sales, village markets and district markets all play important roles for smallholder crop marketing (see Table A5 in Appendix A).

In terms of agricultural technologies, improved maize and legume varieties are used by 81 percent and 62 percent of the farm households, respectively. Over 90 percent of the households use chemical fertilizers for crop production. Maize-legume intercropping is practiced by about half of the farm households. Hence, it seems that modern inputs and improved agricultural practices have been adopted relatively widely by smallholder farmers in Malawi, which may be the result of special support and dissemination programs run by governmental and non-governmental organizations during the last 10 years.

3.3.2 Association between farm production diversity and dietary diversity

We now look at results from the regression model explained in equation (3.1) with dietary diversity as dependent and farm production diversity as independent variables. In Table 3.2, the crop species count was used as indicator of production diversity. Crop species count is positively associated with dietary diversity. Yet the coefficient estimates are relatively small. The second column suggests that cultivating one additional crop species is associated with only a 1.1 percent increase in household dietary diversity. The estimates in the other columns in Table 3.2 – with individual level DDS as dependent variables – are larger, but only marginally. Cultivating one additional crop species is associated with a 1.9 percent and a 1.4 percent increase in child and mothers' dietary diversity, respectively. Overall, results from the household and individual level models are similar.

Table 3.2 Association between crop species count and dietary diversity

	Household DDS	Child DDS	Mother DDS
Crop species count	0.0111*	0.0189***	0.0139**
	(0.0063)	(0.0068)	(0.0063)
Constant	1.3641***	1.2413***	1.3324***
	(0.0429)	(0.0487)	(0.0449)
Observations	408	519	408
Log likelihood	-788.75	-1088.32	-798.30
Chi2	3.12*	7.71***	4.79**

DDS, dietary diversity score. Coefficient estimates are shown with robust standard errors in parentheses. ***P<0.01, **P<0.05, *P<0.1

In Table 3.3, results from the same type of regression models are shown, but now using the production diversity score instead of the crop species count as independent variable. Again, the estimates reveal a significantly positive association between production and consumption diversity. The estimated effects are larger than those in Table 3.2, meaning that the number of food groups produced has a stronger influence on dietary diversity than the number of crop species grown. This should not surprise in subsistence-oriented households, where a large part of what is produced on the farm is consumed in the farm household. Nevertheless, in all models the effect for each additional food group produced remains below 5 percent. Hence, a more substantial improvement in dietary diversity would require very high levels of food group diversification if this were the only strategy to be pursued. Once more, results from the household and individual level models are similar in general.

Table 3.3 Association between production diversity score and dietary diversity

	Household DDS	Child DDS	Mother DDS
Production diversity score	0.0319***	0.0435***	0.0292**
	(0.0118)	(0.0133)	(0.0120)
Constant	1.2718***	1.1369***	1.2700***
	(0.0627)	(0.0715)	(0.0638)
Observations	408	519	408
Log likelihood	-787.20	-1085.98	-797.66
Chi2	7.36***	10.71***	5.93**

DDS, dietary diversity score. Coefficient estimates are shown with robust standard errors in parentheses. ***P<0.01, **P<0.05, *P<0.1

3.3.3 The role of markets

We now analyse the role of markets for dietary diversity by estimating the regression models explained in equation (3.2). In one set of models, we use the market access variables as covariates. In another set of models, we use the market participation variables instead. Due to the correlation between market access and market participation, including both types of variables in the same models would lead to problems of collinearity. In addition to the market variables, we include a vector of other socioeconomic and demographic covariates. Results are shown in Table 3.4.

Table 3.4 Farm production diversity, market access and dietary diversity

	Market access models			Market participation models		
Variables	Household DDS	Child DDS	Mother DDS	Household DDS	Child DDS	Mother DDS
Crop species count	0.0141**	0.0251***	0.0158**	0.0096	0.0202***	0.0124*
	(0.0067)	(0.0075)	(0.0068)	(0.0063)	(0.0074)	(0.0065)
Village market	0.0701*	0.0953**	0.0366			
	(0.0374)	(0.0432)	(0.0382)			
Time to district market	-0.0511***	-0.0489***	-0.0575***			
	(0.0192)	(0.0180)	(0.0165)			
Share of maize sold				0.0035**	0.0042***	0.0034**
				(0.0015)	(0.0014)	(0.0014)
Share of other food crops sold				0.0012**	0.0008	0.0013**
				(0.0006)	(0.0007)	(0.0006)
Area share of non-food cash crops				-0.0004	-0.0018	-0.0002
				(0.0011)	(0.0013)	(0.0011)
Livestock	0.0149	0.0322***	0.0218*	0.0070	0.0260**	0.0139
	(0.0118)	(0.0105)	(0.0116)	(0.0135)	(0.0117)	(0.0135)
Off-farm income	0.0003***	0.0004***	0.0004***	0.0003***	0.0003***	0.0004***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Farm size	0.0069	-0.0029	0.0056	-0.0025	-0.0081	-0.0034
	(0.0143)	(0.0134)	(0.0142)	(0.0145)	(0.0132)	(0.0144)
Household size	-0.0313***	-0.0513***	-0.0420***	-0.0254**	-0.0453***	-0.0362***
	(0.0113)	(0.0134)	(0.0127)	(0.0117)	(0.0134)	(0.0129)
Age of head	0.0027	-0.0007	0.0014	0.0044**	0.0009	0.0031
	(0.0019)	(0.0023)	(0.0021)	(0.0020)	(0.0024)	(0.0021)
Male head	0.0082	0.0252	0.0099	0.0192	0.0381	0.0238
	(0.0583)	(0.0722)	(0.0648)	(0.0615)	(0.0744)	(0.0670)
Education of head	0.0113*	0.0030	0.0089	0.0114*	0.0033	0.0090
	(0.0067)	(0.0072)	(0.0063)	(0.0067)	(0.0073)	(0.0063)
Constant	1.3248***	1.4759***	1.4501***	1.1748***	1.3635***	1.2627***
	(0.1206)	(0.1292)	(0.1162)	(0.1136)	(0.1277)	(0.1101)
Observations	408	519	408	408	519	408
Log likelihood	-777.72	-1068.46	-785.47	-777.39	-1067.61	-785.35
Chi2	48.01***	56.35***	52.23***	46.55***	59.95***	50.17***

DDS, dietary diversity score. Coefficient estimates are shown with robust standard errors in parentheses.
***P<0.01, **P<0.05, *P<0.1

The village market dummy is positively associated with dietary diversity. In the household and child models, the estimated coefficients are statistically significant. Distance to the district market is negatively associated with dietary diversity, with significant coefficients in all three models. These results confirm that access to markets plays an important role for nutritional quality. At the same time, the estimates for the crop species count remain quite robust. Comparing the magnitude of the estimates suggests that market access may be more important for improving dietary diversity than diversified farm production. The existence of a village market is associated with a 7 percent higher household dietary diversity score and a 9.5 percent higher child dietary diversity score. That is, a village market has the same effect as increasing the number of crops produced on a farm by 4-5 species.

The role of actual market participation is analysed in the models shown on the right-hand-side of Table 3.4. The share of maize and other food crops sold is positively associated with household and individual dietary diversity. The coefficient estimates imply that a 10 percentage point increase in the share of maize sold is associated with a 3.5 percent higher household dietary diversity score. This effect is equivalent to increasing farm production diversity by 2-3 crop species. It seems that the cash incomes generated from maize sales are used to buy more food diversity in the market. The coefficients for the sale of other food crops are somewhat smaller.

Table 3.4 also shows estimates for the role of other socioeconomic and demographic factors. Livestock ownership is associated with higher dietary diversity scores, especially for children. This is likely due to the more regular availability of eggs and milk from own production. Education of the household head plays a positive role for household dietary diversity. Interesting to observe are also the effects of off-farm income, which are positive and highly significant in all models. This is another signal for the important role of markets for purchasing food diversity.

To test the robustness of the results, we re-estimated these models but using production diversity scores instead of the crop species count (see Table A6 in Appendix A). These alternative estimates confirm that the number of food groups produced has a larger effect on household and individual level dietary diversity than the number of crop species produced. The important role of market access and actual market participation for dietary diversity is also confirmed.

3.3.4 The role of agricultural technologies

A final set of regression models examines the role of agricultural technology for dietary diversity, as described in equation (3.3). As explained, we look at four concrete technologies that are included into the models as dummy variables. Results are shown in Table 3.5. The estimated coefficients for the four technologies are predominantly positive, but many of these coefficients are not statistically significant. One exception is the use of chemical fertilizer, with positive and highly significant coefficients in the household models and the individual models for mothers. Using chemical fertilizer in crop production is associated with a 15 percent higher household dietary score. This effect is bigger than that of any other single factor included and points at the important role of crop productivity for farm household nutrition. At the same time, the fertilizer effect further stresses the important role of markets. Access to input and output markets facilitates farmers' adoption of fertilizers and other productivity enhancing inputs.

Table 3.5 Farm production diversity, market access, agricultural technology and dietary diversity

	Market access models			Market participation models		
Variables	Household DDS	Child DDS	Mother DDS	Household DDS	Child DDS	Mother DDS
Crop species count	0.0114*	0.0222***	0.0128*	0.0082	0.0191**	0.0110*
	(0.0067)	(0.0076)	(0.0069)	(0.0063)	(0.0075)	(0.0066)
Village market	0.0589	0.0765*	0.0235			
	(0.0371)	(0.0436)	(0.0385)			
Time to district market	-0.0543***	-0.0529***	-0.0612***			
	(0.0191)	(0.0178)	(0.0163)			
Share of maize sold				0.0032**	0.0039***	0.0030**
				(0.0015)	(0.0014)	(0.0014)
Share of other food crops sold				0.0013**	0.0008	0.0013**
				(0.0006)	(0.0007)	(0.0006)
Area share of non-food cash crops				-0.0004	-0.0014	-0.0003
				(0.0011)	(0.0014)	(0.0011)
Improved maize varieties	0.0580	0.0622	0.0636	0.0389	0.0349	0.0459
	(0.0475)	(0.0581)	(0.0515)	(0.0491)	(0.0581)	(0.0530)
Improved legume varieties	0.0274	0.0175	0.0228	0.0037	-0.0070	-0.0028
	(0.0405)	(0.0472)	(0.0435)	(0.0417)	(0.0479)	(0.0450)
Chemical fertilizer	0.1539**	0.0895	0.1856**	0.1528**	0.1002	0.1770**
	(0.0768)	(0.0821)	(0.0873)	(0.0773)	(0.0827)	(0.0892)
Maize-legume intercropping	0.0147	0.0811*	0.0214	0.0193	0.0826*	0.0219
	(0.0390)	(0.0456)	(0.0416)	(0.0388)	(0.0459)	(0.0417)
Livestock	0.0160	0.0345***	0.0229**	0.0074	0.0274**	0.0144
	(0.0119)	(0.0108)	(0.0117)	(0.0137)	(0.0116)	(0.0136)
Off-farm income	0.0003***	0.0003***	0.0003***	0.0003***	0.0003***	0.0003***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Farm size	0.0036	-0.0037	0.0020	-0.0043	-0.0082	-0.0052
	(0.0144)	(0.0136)	(0.0142)	(0.0146)	(0.0136)	(0.0145)
Household size	-0.0304***	-0.0520***	-0.0409***	-0.0245**	-0.0461***	-0.0352***
	(0.0113)	(0.0133)	(0.0125)	(0.0116)	(0.0133)	(0.0127)
Age of head	0.0022	-0.0009	0.0009	0.0039*	0.0006	0.0026
	(0.0019)	(0.0024)	(0.0021)	(0.0020)	(0.0025)	(0.0022)
Male head	0.0125	0.0281	0.0140	0.0212	0.0384	0.0255
	(0.0585)	(0.0727)	(0.0641)	(0.0611)	(0.0741)	(0.0658)
Education of head	0.0098	0.0018	0.0071	0.0100	0.0020	0.0074
	(0.0067)	(0.0072)	(0.0064)	(0.0067)	(0.0073)	(0.0064)
Constant	1.1639***	1.3405***	1.2613***	1.0240***	1.2272***	1.0894***
	(0.1311)	(0.1383)	(0.1390)	(0.1242)	(0.1375)	(0.1349)
Observations	408	519	408	408	519	408
Log likelihood	-775.65	-1065.25	-782.77	-775.81	-1065.04	-783.31
Chi2	57.29	64.13	60.06	56.02	68.85	57.01

DDS, dietary diversity score. Coefficient estimates are shown with robust SEs in parentheses. ***P<0.01, **P<0.05, *P<0.1

Fertilizer adoption is positively correlated with the adoption of improved seeds. This correlation and the resulting inflation of standard errors may explain why the coefficients for improved maize and legume varieties are not statistically significant, in spite of the relatively large point estimates. Maize-legume intercropping as an improved agronomic technique is significant in the child models. Adoption of this intercropping practice is associated with an 8 percent higher child dietary diversity score. As the adoption of agricultural technologies may influence farm production diversity and vice versa, we re-estimated the same models but excluding the crop species count (see Table A7 in Appendix A). The estimates for the remaining variables do not change much.

Overall, the estimates for the main variables of interest remain quite robust across the different models and specifications, which we interpret as a signal that omitted variable bias is probably not a major issue.

3.4 Discussion

We have analysed the role of agricultural biodiversity, market access and technology adoption for dietary diversity in smallholder farm households in Malawi. Even though we used different data and indicators of dietary diversity, our results are in line with those from previous studies (Sibhatu and Qaim 2016; Sibhatu et al. 2015; Snapp and Fisher 2015; Jones et al. 2014). Yet, the analysis also offers a few new insights.

Our results confirm that production diversity is positively associated with dietary diversity. But the effect is relatively small. Previous studies measured production diversity in terms of a simple species count, which we also did in some of the model specifications. In other specifications, we used production diversity scores, defined as the number of food groups produced. When using production diversity scores instead of a species count, the effect on dietary diversity gets larger. This is plausible in a subsistence-oriented setting like rural Malawi, where a significant share of what is produced on the farm is consumed in the farm household. Interestingly, the opposite was found in a previous study that had used data from more commercially-oriented farms in Indonesia, Kenya and Uganda (Sibhatu and Qaim 2016). In more commercialized settings with better market access, increasing the number of food groups produced on a farm may entail lower cash revenues and foregone benefits from specialization.

But even in a more subsistence-oriented setting like rural Malawi we found an important role of markets for dietary diversity. Access to local village markets as well as larger district markets is significantly associated with dietary diversity. Farm households use markets to sell agricultural produce and buy foods that they do not or cannot produce themselves. Even foods that are produced on the farm may not always be stored for the entire year; issues of seasonality are particularly important for fresh fruits and vegetables (Hirvonen et al. 2015). Previous studies have shown that foods purchased from the market contribute considerably to farm household diets also in subsistence-oriented settings (Luckett et al. 2015; Sibhatu et al. 2015).

Our results suggest that promoting market access may be a more effective strategy to improve farm household nutrition than further diversification. For instance, the existence of a local market in the village has the same effect on household dietary diversity as increasing the number of crops produced on a farm by 4-5 species. We also went beyond market access and analysed the role of actual agricultural sales. Controlling for other factors, sales of maize and other crops are positively associated with dietary diversity. Finally, our analysis has shown that the adoption of agricultural technologies – such as modern inputs and improved agronomic practices – is positively associated with dietary diversity. These results clearly suggest that productivity enhancing innovation and commercial orientation are conducive for better nutrition in smallholder farm households.

Most previous studies that had analysed the role of farm production diversity and other factors for dietary diversity used 7-day recall data collected at the household level. In this study, we have used 24-hour recall data to calculate dietary diversity scores at household level and individual levels for young children and mothers. Some of the results differ in terms of the details. For instance, access to village markets was found to have a stronger positive effect in the child dietary diversity models than in the models for mothers and household dietary diversity. This may be due to the fact that typical weaning foods, including milk, egg and fruits, are often bought in small quantities at local village markets (Chikhungu et al. 2014). Overall, however, the estimation results for the household and individual level models are surprisingly similar.

Dietary diversity scores calculated from 24-hour recall data are systematically lower than those calculated from 7-day recall data. Hence, mean dietary diversity scores collected from different recall periods cannot be compared directly. But regression models try to explain data variation, not mean values. Interestingly, most of our regression results are consistent with those from previous studies. Hence, results do not seem to be driven by the method of measurement of dietary diversity. This is good news for researchers wishing to use secondary data sources. Many nationally representative living standard measurement survey nowadays contain 7-day food consumption recalls at the household level, whereas individual level 24-hour recall data are available only from more specialized surveys with a particular nutrition focus.

3.5 Conclusion

Farm species diversity is positively associated with dietary diversity in Malawi. Hence, on-farm crop diversification may help to improve household nutrition to some extent. However, the magnitude of the estimated coefficients suggests that the positive dietary effects of further adding crop species to the farm portfolio will be small. Access to markets for buying food and selling farm produce and the adoption of modern agricultural technologies were shown to be more important for nutritional quality. Hence, improving access to markets through better infrastructure and institutions and promoting the spread of productivity enhancing technologies seem to be more promising approaches to improve farm household nutrition. If diversification is pursued, it should not obstruct smallholder market integration and commercialization.

Different models were used, comparing effects on dietary diversity scores at household and individual levels. Overall, the results were similar across the different models. This similarity suggests that household level food consumption data, which are more often available from secondary statistics than individual level data, can be used for broader nutritional questions without introducing a significant bias. Of course, for planning interventions that focus on particular target groups, more detailed individual level data will be required.

Chapter 4: Conclusion

4.1 Synopsis

Natural resources form the base of our food and agricultural production system, but we have not been particularly successful in managing them in a sustainable manner. Past agricultural policy approaches towards food security have mainly focused on intensifying production and have thereby contributed to negative environmental externalities. In the recent past, the depletion of ecosystems is aggravated by climate change and extreme weather events. The effects on the food and agricultural production system are already drastic, especially for the poor population segments whose livelihoods heavily depend on agriculture.

These complex problems are further intensified by emerging nutrition challenges beyond merely feeding a rapidly growing world population. Micronutrient deficiencies such as vitamin-A, iron, iodine or zinc deficiency affect almost one in three people and are causing severe problems from single livelihoods to whole economies. Scholars and policy makers have recognized that agriculture’s contribution to food security requires not only the provision of calories, but also the provision of diverse, nutrient-rich foods. Yet, this can only be achieved if the natural resource base for agricultural production is preserved. This calls for policy approaches that promote more sustainable and diversified farming strategies, especially in the smallholder farming systems of developing countries.

Natural resource management technologies are meant to preserve natural resources and minimize negative environmental effects from agricultural intensification. As single technologies or innovative system approaches NRM practices support the aggregation of soil nutrients, safe water resources, help creating a diversified farming environment and foster the diversification of farm production.

Thus, NRM technologies are being integrated in agricultural development agendas. In some countries, such as Malawi, NRM technologies are part of a wider agricultural development agenda that already promotes agricultural intensification strategies e.g., through subsidies for input-intensive technologies. Independent of the type of promotion among farmers, intensification and NRM technologies are often seen as incompatible. Yet, there is an increasing perception that both technology strains are essential to tackle emerging nutrition problems. Supporters of the so-called sustainable intensification approach encourage the combination of agricultural intensification and NRM technologies. These supporters argue that the solution to produce more nutrient-rich food while preserving the environment demands the use of the best available production technologies irrespective of specific farming philosophies.

But the pathways from agriculture to a diverse, nutrient-rich diet are shaped by more than just own farm production. Agricultural policy approaches will need to broaden their strategies e.g., by including smallholder market integration or paying special attention to the nutrition pathways of vulnerable individuals, such as young children and women. All in all, productive and environment-preserving approaches towards food security will require more knowledge about the compatibility of NRM and input-intensive technologies, as well as the pathways from agriculture to more diversified diets. This dissertation has contributed to the existing literature by analysing these aspects among smallholder farmers in rural Malawi.

Empirical results from chapter 2 have shown that using subsidized inputs such as chemical fertilizer and improved crop varieties does not necessarily preclude the use of NRM technologies on smallholder farms. Subsidy participants are actually more likely to use certain NRM technologies. Participation in the farm input subsidy program is positively associated with legume intercropping, the use of vegetative strips and organic manure. The positive relationships are probably facilitated by productivity increases from maize production which lead to the reallocation of land and other farm resources. A negative association was discovered between subsidy participation and the practice of soil ridging. Irrespective of the use of subsidized inputs the results revealed complementary relationships between modern inputs and NRM technologies. This implies that smallholder farmers in Malawi combine different kinds of technologies for agricultural production.

The findings from chapter 3 revealed that different aspects of smallholder farming are associated with dietary diversity through different pathways. For instance household dietary diversity is positively associated with farm production diversity. The results also show a positive association between dietary diversity and physical access to markets and market participation via crop sales. Thus, markets seem to facilitate income earnings from crop sales and spending of income on more diverse foods. A comparison of correlation coefficients showed that the role of markets is bigger than that of own farm production diversity. The analysis also revealed a highly positive association between household dietary diversity and the use of chemical fertilizer. This effect is probably due to enhanced productivity in maize or cash crops which facilitates income generation and the purchase of more diverse foods. Results for the individual dietary diversity models of young children and mothers revealed very similar results. But in contrast to the household diet, child dietary diversity shares a stronger positive association with access to village markets and is positively associated with maize-legume intercropping. While the former effect probably derives from the income pathway, the latter could result from both, direct consumption from own production and cash income from crop sales spend on food. Overall, household and individual dietary diversity models seem comparable.

4.2 *Conclusions and policy implications*

Tackling the complex challenges of food insecurity and malnutrition needs innovative policy approaches that foster a simultaneous improvement of productivity and sustainability in agricultural systems. Some policy agendas are already pursuing such a strategy, but improving economic outcomes while reducing environmental externalities is challenging in smallholder farming systems. The findings from this dissertation might offer some guidance for future policy challenges regarding environmentally sustainable and nutrition-sensitive smallholder agriculture.

The compatibility of input-intensive and NRM technologies in agricultural systems is controversially discussed. In Malawi, trade-offs from simultaneous promotion of these technology strains do not necessarily occur. The higher likelihood of NRM adoption among FISP participants compared to non-participants assumes that a simultaneous promotion among smallholder farmers is indeed feasible. The mostly complementary use between some input-intensive and NRM technologies independent of input subsidies supports this conclusion. These positive interrelations between input-intensive and NRM technologies are likely to foster synergistic effects that enhance positive environmental externalities. For instance, the concomitant use of improved maize varieties and manure as well as terraces and stone bunds can enhance soil nutrients, improve the accumulation of soil organic matter and avoid soil loss through erosion. Simultaneous productivity enhancement can be achieved by the addition of chemical fertilizer which is often combined with improved seeds. Extension services should emphasize such existing complementarities and should promote them emphatically. Agricultural development agendas could promote complementary technologies in packages and offer additional incentives for fertilizer and improved seed use when smallholder farmers are willing to adopt NRM technologies. Farmer participatory approaches could help to further explore positive effects of simultaneous adoption of input-intensive and NRM technologies within smallholder farming systems and attract the dissemination of complementary technologies through exchange between farmers. Executing these suggestions successfully and improving both, productivity and environmental sustainability, might require improved extension services.

The adoption of input-intensive technologies and NRM strategies is also likely to improve food and nutrition security among smallholder farmers. Some farming strategies have the particular potential to diversify food consumption. Diversification of household and individual diets among and within smallholder farm families seems to be influenced through at least two pathways: (1) more diversified farm production and, (2) the purchase of more diverse foods from the market through income; whereas income from crop sales seems to play a particular role. The functioning of the first pathway depends on a successful adoption of farm diversification strategies and the resources to produce sufficient quantities of diverse foods. The second pathway to a more diverse diet via food purchases requires adequate market access and a certain degree of commercialisation to participate in market transactions i.e. selling own farm produce and buying diverse food products via agricultural income. The second pathway seems to be a more promising strategy. Thus, policy approaches should aim at improving market access and market participation among smallholder farmers in rural areas. Particular policy actions could include upgrades of existing village market infrastructure or the establishment of new markets in remote rural areas. Better village market infrastructure can improve the access to perishable food products such as eggs, milk products and fruits which are important weaning foods for young children. Furthermore, road and transportation infrastructure should be improved to grant better access to larger district markets. District markets are not only offering greater potential as sales outlets for own farm produce, but might also ease access to external inputs for farm production. Policy makers should also facilitate commercialisation among smallholders so that improved physical market access results in market participation. Smallholder commercialisation can be supported through strengthening the access to productivity enhancing technologies so that farms can produce beyond subsistence and sell surplus at the market.

4.3 Scope for future research

The aforementioned conclusions provide some guidance for policy makers, but areas for future research remain. The analysis in chapter 2 dealt with potential selection bias of subsidy participation through an instrumental variable approach. However, identifying suitable instruments is a challenge, and the implementation of IV procedures in a multivariate probit framework with panel data is not straightforward. Further research should look into more advanced methodologies in this direction. Selection bias e.g., with regard to technology adoption, could also induce problems in the analysis in chapter 3. Therefore different model specifications have been used as robustness checks. However, conclusions from these results have to be drawn carefully and should not be interpreted as causal relationships. Future studies, which want to establish causal relationships about the pathways between agriculture and nutrition among smallholder farmers, and give more explicit policy implications on development agendas such as Malawi’s ASWAp, could use IV or matching techniques, or even panel data analysis, especially with large data sets like those from living standard surveys.

The promotion of complementary NRM technologies under FISP was found to be feasible. While it is understood that extension services play a role for the promotion of these technologies in general, this study can only offer speculations about their role. Future research should investigate how extension services function under agricultural development agendas such as ASWAp, and learn about areas that need improvement to achieve full synergistic effects of the technologies. Therefore it is also necessary to gain deeper understanding of the impact mechanisms behind technology combinations on smallholder farmers' income, food security and overall well-being. Since not all farmers receive input subsidies it might also be interesting to examine how knowledge about the positive effects of combining intensification and resource-preserving technologies disseminates outside the FISP, how these mechanisms lead to desirable adoption or why adoption does not occur.

Market access and market participation through crop sales and the use of modern agricultural technologies seem to have a bigger effect on dietary diversity than own-farm diversification. This calls for the improvement of smallholder market integration and commercialisation. Thus, future research should examine the constraints that hinder smallholder farmers from participation as consumers and sellers in the food market and as consumers in agricultural input markets. Further, studies should analyse how local and regional food markets function and which farm products have potential for smallholder commercialisation. With regard to current supply shortfalls in subsidized inputs (FEWS Net 2016), it should particularly be examined how the input market chain functions and how access to external inputs or alternative input sources can be improved.

References

Aberman, N.-L, Roopnaraine, T. (2015) Understanding the pathways to improved diets from the production of nutritious and marketable commodities. N.-L. Aberman, J. Meerman, T. Benson (Eds.) *Mapping the linkages between agriculture, food security and nutrition in Malawi*. Lilongwe: International Food Policy Research Institute (IFPRI).

Allen, T., Prosperi, P., Cogill, B., *et al.* (2014) Agricultural biodiversity, social–ecological systems and sustainable diets. *Proceedings of the Nutritional Society* **73**, 498–508.

Altieri, M.A., Toledo, V.M. (2011) The agroecological revolution in Latin America: rescuing nature, ensuring food sovereignty and empowering peasants. *The Journal of Peasant Studies* **38**, 587–612.

Andersson, J.A., D'Souza, S. (2014) From adoption claims to understanding farmers and contexts: a literature review of Conservation Agriculture (CA) adoption among smallholder farmers in southern Africa. *Agriculture, Ecosystems & Environment* **187**, 116–132.

Angrist, J.D. (2001) Estimation of limited dependent variable models with dummy endogenous regressors. *Journal of Business and Economic Statistics* **19**, 2-28.

Barrett, C.B. (2008) Smallholder market participation. Concepts and evidence from eastern and southern Africa. *Food Policy* **33**, 299–317.

Beddington, J., Asaduzzaman, M., Clark, M., *et al.* (2012) *Achieving food security in the face of climate change: final report from the Commission on Sustainable Agriculture and Climate Change.* CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. Available online at: www.ccafs.cgiar.org/commission

Berry, E.M., Dernini, S., Burlingame, B., *et al.* (2015) Food security and sustainability: can one exist without the other? *Public Health Nutrition* **18**, 2293–2302.

Berti, P.R. (2015) Relationship between production diversity and dietary diversity depends on how number of foods is counted. *Proceedings of the National Academy of Sciences USA* **112**, E5656.

Bezner Kerr, R., Berti, P.R., Shumba, L. (2011) Effects of a participatory agriculture and nutrition education project on child growth in northern Malawi. *Public Health Nutrition* **14**, 1466–1472.

Bezner Kerr, R., Snapp, S., Chirwa, M., *et al.* (2007) Participatory research on legume diversification with Malawian smallholder farmers for improved human nutrition and soil fertility. *Experimental Agriculture* **43**, 437–453.

Black, R.E., Allen, L.H., Bhutta, Z.A. *et al.* (2008) Maternal and child undernutrition: global and regional exposures and health consequences. *The Lancet* **371**, 243–260.

Black, R.E., Victora, C.G., Walker, S.P., *et al.* (2013) Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet* **382**, 427-451.

Bowman, M.S., Zilberman, D. (2013) Economic factors affecting diversified farming systems. *Ecology and Society* **18**, 33.

Brooker, R.W., Karley, A.J., Newton, A.C., *et al.* (2016) Facilitation and sustainable agriculture: a mechanistic approach to reconciling crop production and conservation. *Functional Ecology* **30**, 98–107.

Cameron, A.C., Trivedi, P.K. (2009) *Microeconometrics using Stata*. College Station, TX: Stata Press.

Chibwana, C., Fisher, M., Shively, G. (2012) Cropland allocation effects of agricultural input subsidies in Malawi. *World Development* **40**, 124–133.

Chibwana, C., Jumbe, C., Shively, G. (2013) Agricultural subsidies and forest clearing in Malawi. *Environmental Conservation* **40**, 60–70.

Chibwana, C., Shively, G., Fisher, M., *et al.* (2014) Measuring the impacts of Malawi's Farm Input Subsidy Programme. *African Journal of Agriculture and Resource Economics* **9**, 132–147.

Chikhungu, L.C., Madise, N.J., Padmadas, S.S. (2014) How important are community characteristics in influencing children's nutritional status? Evidence from Malawi population-based household and community surveys. *Health & Place* **30**, 187–195.

Chirwa, E.W., Dorward, A. (2013) *Agricultural input subsidies. The recent Malawi experience.* Oxford: Oxford University Press.

Chirwa, E.W., Matita, M.M. (2012) Smallholder commercial farming in Malawi: A case of NASFAM commercialisation initiatives. *Future Agricultures Consortium Working Paper* **037**. University of Sussex, Brighton.

Chirwa, E.W., Matita, M.M., Mvula, P.M., *et al.* (2013) Repeated access and impacts of the Farm Input Subsidy Programme in Malawi: any prospects of graduation? *Future Agricultures Consortium Working Paper* **065**. University of Sussex, Brighton.

CIA (2015) *The World Factbook: Malawi.* Available online at: https://www.cia.gov/library/publications/the-world-factbook/geos/mi.html

Critchley, W., Reij, C., Willcocks, T. J. (1994) Indigenous soil and water conservation: a review of the state of knowledge and prospects for building on traditions. *Land Degradation & Development* **5**, 293–314.

de Haen, H., Klasen, S., Qaim, M. (2011) What do we really know? Metrics for food insecurity and undernutrition. *Food Policy* **36**, 760-769.

Delgado, J.A., Groffman, P.M., Nearing, M.A., *et al.* (2011) Conservation practices to mitigate and adapt to climate change. *Journal of Soil and Water Conservation* **66**, 118A-129A.

Denning, G., Kabambe, P., Sanchez, P., *et al.* (2009) Input subsidies to improve smallholder maize productivity in Malawi: toward an African Green Revolution. *Plos Biology* **7**, e23.

Di Falco, S., Veronesi, M., Yesuf, M. (2011) Does adaptation to climate change provide food security? A micro-perspective from Ethiopia. *American Journal of Agricultural Economics* **93**, 829-846.

Doss, C.R. (2006) Analyzing technology adoption using microstudies: limitations, challenges, and opportunities for improvement. *Agricultural Economics* **34**, 207–219.

Ecker, O., Qaim, M. (2011) Analyzing nutritional impacts of policies: an empirical study for Malawi. *World Development* **39**, 412-428.

FAO (2009) *The special challenge for sub-Saharan Africa.* Rome: Food and Agriculture Organization.

FAO (2014) *The state of food and agriculture. Innovation in family farming.* Rome: Food and Agriculture Organization.

FAO (2015) *The state of food insecurity in the world (SOFI).* Rome: Food and Agriculture Organization.

FEWS Net (2016) *Maize supplies continue to be tight during the final months of the 2015/16 marketing years. Malawi Food Security Outlook, February to September 2016*. Famine Early Warning Systems Network. Available online at: http://www.fews.net/southern-africa/malawi/food-security-outlook/february-2016

Frelat, R., Lopez-Ridaura, S., Giller, K.E., *et al.* (2016) Drivers of household food availability in sub-Saharan Africa based on big data from small farms. *Proceedings of the National Academy of Sciences USA* **113**, 458-463.

Frison, E.A., Smith, I.F., Johns, T., *et al.* (2006) Agricultural biodiversity, nutrition, and health: making a difference to hunger and nutrition in the developing world. *Food & Nutrition Bulletin* **27**, 167–179.

Garrity, D.P., Akinnifesi, F.K., Ajayi, O.C., *et al.* (2010) Evergreen Agriculture: a robust approach to sustainable food security in Africa. *Food Security* **2**, 197–214.

Gilbert, R.A. (2004) Best-bet legumes for smallholder maize-based cropping systems of Malawi. M. Eilittä, J. Mureithi, R. Derpsch (Eds.) *Green manure/cover crop systems of smallholder farmers*. Netherlands: Springer.

Giovannucci, D., Scherr, S., Nierenberg, D., *et al.* (2012) *Food and Agriculture: the future of sustainability. A strategic input to the Sustainable Development in the 21st Century (SD21) project.* Division for Sustainable Development. New York: United Nations Department of Economic and Social Affairs.

Godfray, H.C.J. (2015) The debate over sustainable intensification. *Food Security* **7**, 199–208.

Godfray, H.C.J., Beddington, J.R., Crute, I.R., *et al.* (2010) Food Security: the challenge of feeding 9 billion people. *Science* **327**, 812–818.

Graham, R.D., Welch, R.M., Saunders, D.A., *et al.* (2007) Nutritious subsistence food systems. D.L. Sparks (Ed.) *Advances in Agronomy, Vol. 92*. New York: Academic Press.

Greene, W.H. (2012) *Econometric Analysis, 7th Edition.* Boston: Prentice Hall.

Greenpeace Africa (2015) *Fostering economic resilience: the financial benefits of ecological farming in Kenya and Malawi.* Johannesburg: Greenpeace Africa.

Harris, J., Meerman, J., Aberman, N.-L. (2015) Introduction to conceptual issues related to agriculture, food security, and nutrition. N.-L. Aberman, J. Meerman, T. Benson (Eds.) *Mapping the linkages between agriculture, food security and nutrition in Malawi.* Lilongwe: International Food Policy Research Institute (IFPRI).

Headey, D.; Ecker, O. (2013) Rethinking the measurement of food security: from first principles to best practice. *Food Security* **5**, 327-343.

Herforth, A. (2010) Promotion of traditional African vegetables in Kenya and Tanzania: a case study of an intervention representing emerging imperatives in global nutrition. Dissertation, Ithaca: Cornell University.

Herforth, A. (2015) Access to adequate nutritious food: new indicators to track progress and inform action. D. Sahn (Ed.) *The fight against hunger and malnutrition: the role of food, agriculture, and targeted policies*. Oxford: Oxford University Press.

Herforth, A., J. Harris (2014) Understanding and applying primary pathways and principles. *Technical Brief Series. Strengthening Partnerships, Results, and Innovations in Nutrition Globally (SPRING) Project.* Arlington, VA.

Hirvonen, K., Hoddinott, J. (2014) Agricultural production and children's diets: evidence from rural Ethiopia. *Ethiopia Strategy Support Program Working Paper* **69**, Washington, DC: International Food Policy Research Institute.

Hirvonen, K., Taffesse, A.S., Hassen, I.W. (2015) Seasonality and household diets in Ethiopia. *Public Health Nutrition*, doi:10.1017/S1368980015003237

Holden, S. (2014) Agricultural household models for Malawi: household heterogeneity, market characteristics, agricultural productivity, input subsidies, and price shocks. A baseline report. *Working paper* **05/14**. Centre for Land Tenure Studies, Norwegian University of Life Sciences.

Holden, S., Lunduka, R. (2010) Too poor to be efficient? Impacts of the targeted fertilizer subsidy program in Malawi on farm plot level input use, crop choice and land productivity. *Noragric Report* **55**. Department of Economics and Resource Management, Norwegian University of Life Sciences.

Holden, S., Lunduka, R. (2012) Do fertilizer subsidies crowd out organic manures? The case of Malawi. *Agricultural Economics* **43**, 303–314.

Holden, S., Lunduka, R. (2013) Who benefit from Malawi's targeted farm input subsidy program? *Forum for Development Studies* **40**, 1–25.

IFAD (2011) *Viewpoint: Smallholders can feed the world.* Rome: International Fund for Agriculture and Development (IFAD).

IFAD (2013) *Smallholders, food security and the environment.* Rome: International Fund for Agriculture and Development (IFAD).

IFPRI (2014) *Global Nutrition Report 2014: actions and accountability to accelerate the world's progress on nutrition.* Washington, DC: International Food Policy Research Institute (IFPRI).

IFPRI (2015) *Global Nutrition Report 2015: Actions and accountability to advance nutrition & sustainable development.* Washington, DC: International Food Policy Research Institute (IFPRI).

Jayne, T.S., Mather, D., Mason, N., *et al.* (2013) How do fertilizer subsidy programs affect total fertilizer use in sub-Saharan Africa? Crowding out, diversion, and benefit/cost assessments. *Agricultural Economics* **44**, 687-703.

Jones, A.D., Shrinivas, A., Bezner Kerr, R. (2014) Farm production diversity is associated with greater household dietary diversity in Malawi: findings from nationally representative data. *Food Policy* **46**, 1–12.

Karamba, R.W. (2013) Input subsidies and their effect on cropland allocation, agricultural productivity and child nutrition: evidence from Malawi. Doctoral Thesis, American University, Faculty of the College of Arts and Sciences, Washington, DC.

Kassam, A., Friedrich, T., Shaxson, F., *et al.* (2009) The spread of Conservation Agriculture: justification, sustainability and uptake. *International Journal of Agricultural Sustainability* **7**, 292–320.

Kassie, M., Jaleta, M., Shiferaw, B., *et al.* (2013) Adoption of interrelated sustainable agricultural practices in smallholder systems: evidence from rural Tanzania. *Technological Forecasting and Social Change* **80**, 525–540.

Kassie, M., Teklewold, H., Jaleta, M., *et al.* (2015) Understanding the adoption of a portfolio of sustainable intensification practices in eastern and southern Africa. *Land Use Policy* **42**, 400–411.

Keding, G.B., Msuya, J.M., Maass, B.L., *et al.* (2012) Relating dietary diversity and food variety scores to vegetable production and socio-economic status of women in rural Tanzania. *Food Security* **4**, 129-140.

Kennedy, G., Ballard, T., Dop, M.C. (2011) *Guidelines for Measuring Household and Individual Dietary Diversity.* Rome: Food and Agriculture Organization.

Kennedy, G., Berardo, A., Papavero, C., et al. (2010) Proxy measures of household food consumption for food security assessment and surveillance: comparison of the household dietary diversity and food consumption scores. *Public Health Nutrition* **13**, 2010–2018.

Kennedy, G., Nantel, G., Shetty, P. (2003) The scourge of "hidden hunger": global dimensions of micronutrient deficiencies. *Food, Nutrition and Agriculture* **32**, 8–16.

Khoury, C.K., Bjorkman, A.D., Dempewolf, H., *et al.* (2014) Increasing homogeneity in global food supplies and the implications for food security. *Proceedings of the National Academy of Sciences USA* **111**, 4001–4006.

Lee, D.R. (2005) Agricultural sustainability and technology adoption: issues and policies for developing countries. *American Journal of Agricultural Economics* **87**, 1325–1334.

Liniger, H.P., Studer, R.M., Hauert, C., *et al.* (2011) *Sustainable land management in practice – guidelines and best practices for sub-Saharan Africa.* TerrAfrica, World Overview of Conservation Approaches and Technologies (WOCAT) and Food and Agriculture Organization (FAO).

Luckett, B., DeClerck, F., Fanzo, J., *et al.* (2015) Application of the nutrition functional diversity indicator to assess food system contributions to dietary diversity and sustainable diets of Malawian households. *Public Health Nutrition* **18**, 2479-2487.

Lunduka, R., Ricker-Gilbert, J., Fisher, M. (2013) What are the farm-level impacts of Malawi's Farm Input Subsidy Program? A critical review. *Agricultural Economics* **44**, 563–579.

M'Kaibi, F.K., Steyn, N.P., Ochola, S., *et al.* (2015) Effects of agricultural biodiversity and seasonal rain on dietary adequacy and household food security in rural areas of Kenya. *BMC Public Health* **15**, 422.

Malapit, H.J.L., Kadiyala, S., Quisumbing, A.R., *et al.* (2015) Women's empowerment mitigates the negative effects of low production diversity on maternal and child nutrition in Nepal. *Journal of Development Studies* **51**, 1097–1123.

Marenya, P., Nkonya, E., Xiong, W., *et al.* (2012) Which policy would work better for improved soil fertility management in sub-Saharan Africa, fertilizer subsidies or carbon credits? *Agricultural Systems* **110**, 162-172.

Mason, N.M., Ricker-Gilbert, J. (2013) Disrupting demand for commercial seed: input subsidies in Malawi and Zambia. *World Development* **45**, 75–91.

MaSSP (2014) *Eight years of FISP – impact and what next?* Malawi Strategy Support Program (MaSSP). Lilongwe: International Food Policy Research Institute (IFPRI).

McKenzie, F.C., Williams, J. (2015) Sustainable food production: constraints, challenges and choices by 2050. *Food Security* **7**, 221–233.

Mhango, W.G., Snapp, S.S., Phiri, G.Y.K. (2013) Opportunities and constraints to legume diversification for sustainable maize production on smallholder farms in Malawi. *Renewable Agriculture and Food Systems* **28**, 234–244.

MoAFS (2011) *Malawi Agricultural Sector Wide Approach. A prioritised and harmonised agricultural development agenda: 2011-2015*. Lilongwe: Ministry of Agriculture and Food Security (MoAFS).

Noltze, M., Schwarze, S., Qaim, M. (2012) Understanding the adoption of system technologies in smallholder agriculture: the system of rice intensification (SRI) in Timor Leste. *Agricultural Systems* **108**, 64–73.

Olney, K.D., Talukder, A., Iannotti, L.L., *et al.* (2009) Assessing impact and impact pathways of a homestead food production program on household and child nutrition in Cambodia. *Food & Nutrition Bulletin* **30**, 355–369.

Pingali, P. (2015) Agricultural policy and nutrition outcomes – getting beyond the preoccupation with staple grains. *Food Security* **7**, 583-591.

Pingali, P.L. (2012) Green Revolution: impacts, limits, and the path ahead. *Proceedings of the National Academy of Sciences USA* **109**, 12302–12308.

Pinstrup-Andersen, P. (2007) Agricultural research and policy for better health and nutrition in developing countries: a food systems approach. *Agricultural Economics* **37**, 187–198.

Pretty, J., Bharucha, Z.P. (2014) Sustainable intensification in agricultural systems. *Annals of Botany* **114**, 1571-1596.

Qaim, M., Kouser, S. (2013) Genetically modified crops and food security. *PLoS ONE* **8**, E64879.

Quisumbing, A.R., Smith, L.C. (2007) Case study #4-5, intrahousehold allocation, gender relations, and food security in developing countries. P. Pinstrup-Andersen, F. Cheng (Eds.) *Food policy for developing countries: case studies.* Online available at: http://cip.cornell.edu/dns.gfs/1200428166

Remans, R., DeClerck, F., Kennedy, G., *et al.* (2015) Expanding the view on the production and consumption diversity link: scale, function and change over time. *Proceedings of the National Academy of Sciences USA* **112**, E6082.

Reynolds, T.W., Waddington, S.R., Anderson, C.L., *et al.* (2015). Environmental impacts and constraints associated with the production of major food crops in Sub-Saharan Africa and South Asia. *Food Security* **7**, 795–822.

Ricker-Gilbert, J, Jayne, T, Shively, G. (2013a) Addressing the “Wicked Problem” of Input Subsidy Programs in Africa. *Applied Economic Perspectives & Policy* **35**, 322–340.

Ricker-Gilbert, J., Jayne, T.S. (2012) Do fertilizer subsidies boost staple crop production and reduce poverty across the distribution of smallholders in Africa? Quantile regression results from Malawi. *Selected Paper, IAAE Triennial conference.* Foz do Iguaçu, Brazil. Available online at: http://ageconsearch.umn.edu/handle/126742

Ricker-Gilbert, J., Jayne, T.S., Chirwa, E. (2011) Subsidies and crowding out: a double-hurdle model of fertilizer demand in Malawi. *American Journal of Agricultural Economics* **93**, 26–42.

Ricker-Gilbert, J., Mason, N.M., Darko, F.A., et al. (2013b) What are the effects of input subsidy programs on maize prices? Evidence from Malawi and Zambia. *Agricultural Economics* **44**, 671–686.

Ruel, M.T. (2003) Operationalizing dietary diversity: a review of measurement issues and research priorities. *Journal of Nutrition* **133**, 3911S - 3926S.

Ruel, M.T., Harris, J., Cunningham, K. (2012) Measuring dietary quality in developing countries: a review of the usefulness of individual dietary diversity indicators. V.R. Preedy (Ed.) *Diet Quality: An Evidence-Based Approach*. New York: Springer.

Sauer, J., Tchale, H. (2009) The economics of soil fertility management in Malawi. *Review of Agricultural Economics* **31**, 535–560.

Savy, M., Martin-Prével, Y., Traissac, P., *et al.* (2006) Dietary diversity scores and nutritional status of women change during the seasonal food shortage in rural Burkina Faso. *Journal of Nutrition* **136**, 2625–2632.

Sayer, J., Cassman, K.G. (2013) Agricultural innovation to protect the environment. *Proceedings of the National Academy of Sciences USA* **110**, 8345–8348.

Shiferaw, B., Kassie, M., Jaleta, M., *et al.* (2014) Adoption of improved wheat varieties and impacts on household food security in Ethiopia. *Food Policy* **44**, 272-284.

Sibhatu, K.T., Krishna, V.V., Qaim, M. (2015) Production diversity and dietary diversity in smallholder farm households. *Proceedings of the National Academy of Sciences USA* **112**, 10657-10662.

Sibhatu, K.T., Qaim, M. (2016) Farm production diversity and dietary quality: linkages and measurement issues. *GlobalFood Discussion Paper* **80**. Goettingen: University of Goettingen.

Snapp, S.S., Blackie, M.J., Gilbert, R.A., *et al.* (2010) Biodiversity can support a Greener Revolution in Africa. *Proceedings of the National Academy of Sciences USA* **107**, 20840–20845.

Snapp, S.S., Fisher, M. (2015) “Filling the maize basket” supports crop diversity and quality of household diet in Malawi. *Food Security* **7**, 83–96.

Steyn, N.P., Nel, J.H., Nantel, G., *et al.* (2006) Food variety and dietary diversity scores in children: are they good indicators of dietary adequacy? *Public Health Nutrition* **9**, 644–650.

Swindale, A., Bilinsky, P. (2006) *Household Dietary Diversity Score (HDDS) for Measurement of Household Food Access: Indicator Guide (V.2)*. FHI 360/FANTA. Washington, DC: USAID.

The Montpellier Panel (2013) *Sustainable intensification: a new paradigm for African Agriculture*. London: Imperial College London.

Tilman, D., Cassman, K.G., Matson, P.A., *et al.* (2002) Agricultural sustainability and intensive production practices. *Nature* **418**, 671–677.

Torheim, L.E., Arimond, M. (2013) Diet quality, micronutrient intakes and economic vulnerability of women. V.R. Preedy, L.-A. Hunter, V.B. Patel (Eds.) *Diet quality: an evidence-based approach, volume 1*. New York: Humana Press.

Tscharntke, T., Clough, Y., Wanger, T.C., *et al.* (2012) Global food security, biodiversity conservation and the future of agricultural intensification. *Advancing Environmental Conservation* **151**, 53–59.

Turner, R., Hawkes, C., Waage, J., *et al.* (2013) Agriculture for improved nutrition: the current research landscape. *Food & Nutrition Bulletin* **34**, 369–377.

Wainaina, P., Tongruksawattana, S., Qaim, M. (2016) Tradeoffs and complementarities of the adoption of improved seeds, fertilizer, and natural resource management technologies in Kenya. *Agricultural Economics,* DOI: 10.1111/agec.12235

West, K.P., Darnton-Hill, I. (2008) Vitamin A Deficiency. R.D. Semba, M.W. Bloem, P. Piot (Eds.) *Nutrition and health in developing countries, 2nd edition.* Totowa, NJ: Humana Press.

WHO (2007) *Assessing the iron status of populations: including literature reviews, 2nd edition*. Joint World Health Organization/Centers for Disease Control and Prevention Technical Consultation on the Assessment of Iron Status at the Population Level. Geneva, Switzerland.

Wiggins, S., Kirsten, J., Llambí, L. (2010) The future of small farms. *World Development* **38**, 1341–1348.

World Bank (2007) *World Development Report 2008. Agriculture for development*. Washington, DC: World Bank.

Appendix A: Additional tables

Table A1 Basic multivariate probit model

Explanatory variables	(1) Inorganic fertilizer	(2) Improved maize	(3) Legume intercropping	(4) Manure	(5) Ridges	(6) Terraces and stone bunds	(7) Vegetative strips
FISP	1.713***	0.688***	0.153**	-0.017	-0.031	-0.076	0.172**
	(0.262)	(0.083)	(0.075)	(0.073)	(0.073)	(0.088)	(0.081)
Age	0.004	-0.005	-0.002	-0.003	0.006**	-0.009***	-0.003
	(0.005)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Female head	-0.261	0.079	0.273**	-0.009	-0.165	-0.005	-0.023
	(0.177)	(0.116)	(0.107)	(0.108)	(0.101)	(0.129)	(0.117)
Education	0.044**	0.015	0.000	0.010	0.012	-0.020	0.003
	(0.020)	(0.013)	(0.012)	(0.012)	(0.011)	(0.013)	(0.013)
Adults	-0.034	-0.042	0.067**	0.060**	0.013	0.025	-0.030
	(0.053)	(0.034)	(0.033)	(0.030)	(0.029)	(0.034)	(0.034)
Children	-0.002	0.058*	0.050*	0.033	-0.026	-0.041	0.040
	(0.050)	(0.031)	(0.027)	(0.027)	(0.026)	(0.031)	(0.029)
Asset value	0.005**	0.000	-0.002***	-0.001***	-0.000	-0.000	0.000
	(0.003)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Livestock	-0.011	0.012	0.018	0.073***	-0.003	0.006	0.017*
	(0.030)	(0.016)	(0.015)	(0.023)	(0.012)	(0.010)	(0.010)
Farm size	0.091	0.045	0.019	0.045	0.057**	0.050	0.123***
	(0.059)	(0.031)	(0.034)	(0.035)	(0.029)	(0.034)	(0.034)
Farm size, squared	-0.003*	-0.001	-0.003	-0.004*	-0.002	-0.002	-0.006***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Socioeconomic shocks	-0.036	0.036	0.010	-0.171*	0.065	0.099	0.260**
	(0.191)	(0.109)	(0.101)	(0.097)	(0.097)	(0.114)	(0.120)
Business	-0.113	0.060	0.147**	0.061	0.119	-0.052	0.012
	(0.126)	(0.081)	(0.074)	(0.071)	(0.073)	(0.083)	(0.083)
Seasonal labor	-0.306**	-0.038	0.083	0.054	0.115	0.033	-0.157*
	(0.138)	(0.082)	(0.080)	(0.072)	(0.075)	(0.088)	(0.082)

Table A1 continued

Explanatory variables	(1) Inorganic fertilizer	(2) Improved maize	(3) Legume intercropping	(4) Manure	(5) Ridges	(6) Terraces and stone bunds	(7) Vegetative strips
Remittances	-0.010	-0.093	0.157*	0.109	-0.043	0.313***	0.085
	(0.156)	(0.089)	(0.082)	(0.076)	(0.073)	(0.087)	(0.087)
Credit access	0.187	-0.129	0.114	0.186**	0.091	0.211*	-0.054
	(0.173)	(0.107)	(0.093)	(0.091)	(0.091)	(0.108)	(0.101)
Social group member	0.133	-0.044	-0.006	0.050	-0.190**	0.070	-0.140
	(0.173)	(0.099)	(0.089)	(0.085)	(0.089)	(0.092)	(0.101)
Relatives in village	-0.000	0.013	-0.011	-0.001	-0.016*	0.001	0.008
	(0.017)	(0.011)	(0.010)	(0.009)	(0.009)	(0.011)	(0.010)
Traders in village	-0.002	-0.023*	0.008	0.007	-0.003	0.023*	0.023*
	(0.022)	(0.012)	(0.011)	(0.011)	(0.011)	(0.012)	(0.012)
Farmer’s group member	0.377	0.299**	0.023	-0.042	0.356***	0.415***	0.100
	(0.280)	(0.146)	(0.119)	(0.120)	(0.112)	(0.119)	(0.130)
Leadership connections	-0.128	0.025	0.041	0.177**	-0.134*	-0.046	0.098
	(0.136)	(0.081)	(0.076)	(0.071)	(0.073)	(0.086)	(0.079)
Relatives outside village	0.014	0.014	0.017*	-0.012	-0.018**	0.005	0.001
	(0.016)	(0.010)	(0.009)	(0.009)	(0.009)	(0.010)	(0.010)
Traders outside village	-0.009	0.022**	0.005	0.001	0.000	0.003	-0.004
	(0.013)	(0.009)	(0.007)	(0.007)	(0.007)	(0.008)	(0.008)
Government support	0.144	-0.054	0.052	-0.010	-0.359***	0.184**	-0.101
	(0.120)	(0.078)	(0.074)	(0.071)	(0.071)	(0.086)	(0.080)
Extension	0.028	0.010	0.006	0.016*	0.011	-0.007	0.024**
	(0.018)	(0.009)	(0.009)	(0.009)	(0.009)	(0.013)	(0.010)
Water stresses	0.086	-0.217**	0.126	0.098	0.306***	0.071	-0.177**
	(0.145)	(0.095)	(0.084)	(0.082)	(0.082)	(0.097)	(0.089)
Pests and diseases	0.009	-0.061	0.282***	0.113	-0.100	-0.024	0.162**
	(0.129)	(0.077)	(0.073)	(0.069)	(0.070)	(0.083)	(0.080)
Market distance	0.009***	-0.002	-0.000	0.001	0.001	0.001	0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Market distance, squared	-0.000**	0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Table A1 continued

Explanatory variables	(1) Inorganic fertilizer	(2) Improved maize	(3) Legume intercropping	(4) Manure	(5) Ridges	(6) Terraces and stone bunds	(7) Vegetative strips
Main road passable	-0.007	-0.081	0.156	0.106	-0.052	-0.074	0.152
	(0.233)	(0.133)	(0.136)	(0.127)	(0.131)	(0.138)	(0.129)
Farm families in district	0.008	0.019***	0.003	0.004	0.006	-0.009	0.000
	(0.011)	(0.006)	(0.006)	(0.006)	(0.005)	(0.006)	(0.006)
DPP	0.459**	-0.170*	0.255***	-0.155	0.210**	-0.092	-0.197**
	(0.185)	(0.099)	(0.097)	(0.096)	(0.090)	(0.105)	(0.100)
Southern region	-0.922***	0.153	0.243**	0.001	-0.305***	0.208	0.082
	(0.220)	(0.121)	(0.114)	(0.119)	(0.108)	(0.129)	(0.119)
Year	-0.748***	0.031	0.187*	0.103	0.496***	-0.078	0.211*
	(0.194)	(0.108)	(0.108)	(0.097)	(0.099)	(0.108)	(0.116)
Constant	0.418	0.309	-1.825***	-1.010***	-0.587**	-0.822***	-1.545***
	(0.497)	(0.320)	(0.300)	(0.282)	(0.274)	(0.316)	(0.320)

The number of observations is 1482. Pseudo log-likelihood: -4920.34; Wald chi2(427): 1025.78***; Number of draws: 50. Robust SEs, adjusted for 827 household clusters, in parentheses. ***P≤0.01, **P≤0.05, *P≤0.1

Table A2 Reduced multivariate probit model

Explanatory variables	(3) Legume intercropping	(4) Manure	(5) Ridges	(6) Terraces and stone bunds	(7) Vegetative strips
FISP	0.155**	-0.018	-0.034	-0.079	0.167**
	(0.075)	(0.073)	(0.073)	(0.088)	(0.081)
Age	-0.002	-0.003	0.006**	-0.009**	-0.003
	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
Female head	0.273**	-0.007	-0.161	-0.002	-0.022
	(0.107)	(0.109)	(0.101)	(0.129)	(0.117)
Education	0.000	0.010	0.012	-0.020	0.004
	(0.012)	(0.012)	(0.011)	(0.013)	(0.013)
Adults	0.067**	0.061**	0.014	0.024	-0.028
	(0.033)	(0.030)	(0.029)	(0.034)	(0.034)
Children	0.050*	0.032	-0.025	-0.040	0.040
	(0.027)	(0.027)	(0.026)	(0.031)	(0.029)
Asset value	-0.002***	-0.001***	-0.000	-0.000	0.000
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Livestock	0.018	0.072***	-0.002	0.006	0.018*
	(0.015)	(0.023)	(0.012)	(0.010)	(0.010)
Farm size	0.019	0.044	0.056*	0.050	0.124***
	(0.034)	(0.035)	(0.029)	(0.034)	(0.035)
Farm size, squared	-0.003	-0.004*	-0.002	-0.002	-0.006***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Socioeconomic shocks	0.010	-0.172*	0.066	0.091	0.259**
	(0.101)	(0.097)	(0.097)	(0.114)	(0.119)
Business	0.146*	0.059	0.120*	-0.055	0.015
	(0.075)	(0.071)	(0.073)	(0.082)	(0.083)
Seasonal labor	0.082	0.052	0.112	0.032	-0.153*
	(0.080)	(0.072)	(0.075)	(0.088)	(0.082)
Remittances	0.156*	0.108	-0.044	0.310***	0.085
	(0.082)	(0.076)	(0.073)	(0.087)	(0.087)
Credit access	0.113	0.183**	0.088	0.210*	-0.056
	(0.093)	(0.091)	(0.091)	(0.108)	(0.101)

Table A2 continued

Explanatory variables	(3) Legume intercropping	(4) Manure	(5) Ridges	(6) Terraces and stone bunds	(7) Vegetative strips
Social group member	-0.008	0.052	-0.189**	0.065	-0.142
	(0.089)	(0.086)	(0.089)	(0.092)	(0.101)
Relatives in village	-0.011	-0.000	-0.015*	0.001	0.008
	(0.010)	(0.009)	(0.009)	(0.011)	(0.010)
Traders in village	0.007	0.007	-0.003	0.024*	0.023*
	(0.011)	(0.011)	(0.011)	(0.012)	(0.012)
Farmer's group member	0.024	-0.044	0.355***	0.416***	0.098
	(0.119)	(0.120)	(0.112)	(0.119)	(0.130)
Leadership connections	0.038	0.177**	-0.135*	-0.048	0.098
	(0.076)	(0.071)	(0.073)	(0.086)	(0.079)
Relatives outside village	0.018*	-0.012	-0.018**	0.005	0.001
	(0.009)	(0.009)	(0.009)	(0.010)	(0.010)
Traders outside village	0.005	0.001	0.000	0.003	-0.005
	(0.007)	(0.007)	(0.007)	(0.008)	(0.008)
Government support	0.054	-0.011	-0.356***	0.182**	-0.099
	(0.074)	(0.071)	(0.071)	(0.085)	(0.080)
Extension	0.006	0.016*	0.011	-0.007	0.025**
	(0.009)	(0.009)	(0.009)	(0.013)	(0.010)
Water stresses	0.127	0.098	0.307***	0.073	-0.173*
	(0.084)	(0.082)	(0.082)	(0.097)	(0.089)
Pests and diseases	0.283***	0.115*	-0.102	-0.023	0.161**
	(0.073)	(0.069)	(0.070)	(0.083)	(0.080)
Market distance	-0.000	0.001	0.001	0.001	0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Market distance, squared	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Main road passable	0.154	0.105	-0.058	-0.069	0.148
	(0.136)	(0.127)	(0.131)	(0.139)	(0.130)
Farm families in district	0.003	0.004	0.006	-0.009	0.000
	(0.006)	(0.006)	(0.005)	(0.006)	(0.006)
DPP	0.254***	-0.153	0.211**	-0.092	-0.199**
	(0.097)	(0.096)	(0.090)	(0.106)	(0.101)

Table A2 continued

Explanatory variables	(3) Legume intercropping	(4) Manure	(5) Ridges	(6) Terraces and stone bunds	(7) Vegetative strips
Southern region	0.241**	0.003	-0.310***	0.213*	0.082
	(0.114)	(0.119)	(0.107)	(0.129)	(0.120)
Year	0.189*	0.105	0.495***	-0.077	0.218*
	(0.108)	(0.097)	(0.100)	(0.108)	(0.116)
Constant	-1.829***	-1.016***	-0.581**	-0.815***	-1.555***
	(0.300)	(0.282)	(0.275)	(0.314)	(0.322)

The number of observations is 1482. Pseudo log-likelihood: -3997.44; Wald chi2(165): 637.36***; Number of draws: 50. Robust SEs, adjusted for 827 household clusters, in parentheses.

***P≤0.01, **P≤0.05, *P≤0.1

Table A3 Multivariate probit model with Mundlak approach

Explanatory variables	(1) Inorganic fertilizer	(2) Improved maize	(3) Legume intercropping	(4) Manure	(5) Ridges	(6) Terraces and stone bunds	(7) Vegetative strips
FISP	1.474***	0.421***	0.010	-0.113	-0.053	-0.117	0.111
	(0.344)	(0.127)	(0.115)	(0.104)	(0.113)	(0.141)	(0.128)
Age	-0.045*	-0.027	-0.023	-0.022	0.012	-0.013	-0.030
	(0.024)	(0.021)	(0.015)	(0.020)	(0.021)	(0.014)	(0.019)
Female head	-0.940**	0.207	0.267	-0.018	-0.072	0.048	0.125
	(0.472)	(0.326)	(0.300)	(0.259)	(0.300)	(0.342)	(0.362)
Education	0.145	-0.023	-0.087	-0.044	0.031	-0.052	0.099
	(0.100)	(0.058)	(0.080)	(0.065)	(0.076)	(0.070)	(0.098)
Adults	-0.069	-0.137**	0.029	0.120**	0.022	-0.020	0.025
	(0.111)	(0.062)	(0.055)	(0.054)	(0.058)	(0.075)	(0.071)
Children	-0.022	0.059	0.021	0.077*	0.007	-0.083	-0.079
	(0.105)	(0.060)	(0.055)	(0.045)	(0.057)	(0.075)	(0.065)
Asset value	0.001	-0.001	-0.002**	-0.001*	-0.000	-0.000	-0.000
	(0.004)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Livestock	-0.054*	-0.014	0.023	0.064**	0.005	-0.030	0.006
	(0.030)	(0.037)	(0.033)	(0.027)	(0.034)	(0.038)	(0.037)
Farm size	0.131*	0.053	0.039	0.153***	0.104**	0.050	0.141**
	(0.075)	(0.052)	(0.052)	(0.053)	(0.051)	(0.057)	(0.058)
Farm size, squared	-0.003	-0.002	-0.003	-0.008**	-0.003	-0.004	-0.008***
	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Socioeconomic shocks	-0.130	0.008	-0.015	-0.228*	-0.063	0.136	0.400**
	(0.320)	(0.173)	(0.143)	(0.135)	(0.157)	(0.180)	(0.170)
Business	0.088	0.174	0.237**	0.150	0.021	-0.016	0.037
	(0.229)	(0.122)	(0.111)	(0.101)	(0.112)	(0.125)	(0.121)
Seasonal labor	-0.499**	-0.060	0.109	0.187*	0.250**	0.121	-0.071
	(0.216)	(0.118)	(0.123)	(0.099)	(0.120)	(0.139)	(0.128)
Remittances	-0.026	-0.075	0.104	0.116	-0.132	0.262*	0.115
	(0.274)	(0.133)	(0.127)	(0.104)	(0.109)	(0.147)	(0.132)
Credit access	0.627*	-0.079	0.159	0.134	0.135	0.462**	-0.158
	(0.364)	(0.169)	(0.160)	(0.139)	(0.156)	(0.195)	(0.175)

Table A3 continued

Explanatory variables	(1) Inorganic fertilizer	(2) Improved maize	(3) Legume intercropping	(4) Manure	(5) Ridges	(6) Terraces and stone bunds	(7) Vegetative strips
Social group member	0.019	-0.244	0.001	-0.175	-0.404***	0.122	-0.167
	(0.256)	(0.149)	(0.133)	(0.122)	(0.132)	(0.152)	(0.153)
Relatives in village	-0.011	0.019	-0.009	0.008	-0.030**	-0.014	-0.021
	(0.025)	(0.015)	(0.014)	(0.013)	(0.014)	(0.016)	(0.015)
Traders in village	0.014	-0.023	-0.006	-0.008	0.001	0.013	0.049***
	(0.025)	(0.017)	(0.018)	(0.014)	(0.017)	(0.020)	(0.019)
Farmer’s group member	0.227	0.156	0.032	-0.033	0.306	0.213	0.226
	(0.366)	(0.232)	(0.218)	(0.180)	(0.223)	(0.229)	(0.232)
Leadership connections	-0.295	-0.206*	0.181*	0.191**	-0.101	0.075	0.310***
	(0.186)	(0.113)	(0.110)	(0.096)	(0.109)	(0.127)	(0.119)
Relatives outside village	0.091***	0.027*	0.027**	-0.017	-0.013	0.017	0.005
	(0.027)	(0.014)	(0.014)	(0.013)	(0.014)	(0.016)	(0.016)
Traders outside village	-0.003	-0.001	0.010	0.011	0.005	0.006	-0.003
	(0.020)	(0.012)	(0.012)	(0.009)	(0.010)	(0.011)	(0.014)
Government support	-0.014	-0.016	0.016	0.092	-0.333***	0.214	-0.171
	(0.206)	(0.113)	(0.111)	(0.102)	(0.107)	(0.136)	(0.124)
Extension	0.025	-0.018	0.007	0.021	0.005	0.009	0.013
	(0.034)	(0.014)	(0.012)	(0.016)	(0.012)	(0.020)	(0.013)
Water stresses	0.204	-0.340**	-0.037	-0.028	0.147	0.116	-0.256*
	(0.273)	(0.140)	(0.125)	(0.114)	(0.122)	(0.150)	(0.138)
Pests and diseases	0.056	0.033	0.301***	0.058	-0.200*	0.039	0.090
	(0.205)	(0.109)	(0.107)	(0.097)	(0.108)	(0.137)	(0.121)
Market distance	0.009***	-0.001	-0.000	0.002	0.001	0.001	0.002
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Market distance, squared	-0.000***	0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Main road passable	-0.165	-0.101	0.172	0.130	-0.045	-0.069	0.167
	(0.232)	(0.138)	(0.139)	(0.128)	(0.132)	(0.139)	(0.130)
Farm families in district	0.126***	-0.025	0.003	-0.002	0.008	-0.009	0.005
	(0.035)	(0.015)	(0.013)	(0.012)	(0.013)	(0.017)	(0.016)

Table A3 continued

Explanatory variables	(1) Inorganic fertilizer	(2) Improved maize	(3) Legume intercropping	(4) Manure	(5) Ridges	(6) Terraces and stone bunds	(7) Vegetative strips
DPP	0.801***	-0.279***	0.240**	-0.162	0.224**	-0.093	-0.207**
	(0.226)	(0.104)	(0.101)	(0.101)	(0.095)	(0.107)	(0.105)
Southern region	-1.487***	0.176	0.203*	-0.044	-0.339***	0.204	0.053
	(0.258)	(0.129)	(0.117)	(0.124)	(0.110)	(0.132)	(0.122)
Year	-1.500***	0.337**	0.207	0.273*	0.612***	-0.150	0.420**
	(0.283)	(0.163)	(0.157)	(0.140)	(0.149)	(0.162)	(0.182)
Constant	0.452	-0.096	-1.911***	-0.995***	-0.752**	-0.753**	-1.492***
	(0.588)	(0.371)	(0.342)	(0.332)	(0.312)	(0.372)	(0.369)
Joint significance of mean of time-varying covariates (chi2)	81.91***	49.20***	22.17	35.98	28.59	21.99	37.09

The number of observations is 1482. Pseudo log-likelihood: -4806.52; Wald chi2(427): 2541.23***; Number of draws: 50. Robust SEs, adjusted for 827 household clusters, in parentheses.

Mundlak approach (inclusion of means of all time-varying covariates) was used for estimation. ***P≤0.01, **P≤0.05, *P≤0.1

Table A4 Percentage share of food groups consumed among farm households and individuals

Food group	Households	Children	Mothers
Cereals	99	90	98
Vegetables	82	73	80
Miscellaneous†	62	58	61
Fruits	51	51	51
Oils and fats	31	29	31
Sugar and honey	30	28	30
Legumes and nuts	22	21	21
Fish	20	19	20
Tubers and roots	7	6	7
Meat and poultry	6	7	6
Eggs	4	3	4
Milk and milk products	3	3	3

† Miscellaneous includes spices, condiments and beverages.

Table A5 Importance of different marketing channels for crop sales†

Marketing channel	Total number of sales during last season	Share of sales in percent
Farm gate sales	233	31
Village market sales	200	26
District market sales	323	43

† 84 percent (341 of 408) of the sample farms sold crops during the last season prior to the survey.

Table A6 Production diversity scores, market access and dietary diversity

Variables	Market access models			Market participation models		
	Household DDS	Child DDS	Mother DDS	Household DDS	Child DDS	Mother DDS
Production diversity score	0.0369***	0.0496***	0.0330***	0.0255**	0.0383***	0.0219*
	(0.0109)	(0.0129)	(0.0113)	(0.0116)	(0.0137)	(0.0118)
Village market	0.0572	0.0712*	0.0199			
	(0.0363)	(0.0423)	(0.0371)			
Time to district market	-0.0530***	-0.0490***	-0.0581***			
	(0.0193)	(0.0177)	(0.0163)			
Share of maize sold				0.0033**	0.0040***	0.0033**
				(0.0015)	(0.0014)	(0.0014)
Share of other food crops sold				0.0011*	0.0006	0.0012*
				(0.0006)	(0.0007)	(0.0007)
Area share of non-food cash crops				-0.0002	-0.0015	0.0000
				(0.0011)	(0.0013)	(0.0011)
Off-farm income	0.0003***	0.0003***	0.0004***	0.0003***	0.0003***	0.0004***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Farm size	0.0066	0.0032	0.0080	-0.0029	-0.0018	-0.0006
	(0.0142)	(0.0136)	(0.0145)	(0.0145)	(0.0138)	(0.0148)
Household size	-0.0272**	-0.0446***	-0.0367***	-0.0233**	-0.0407***	-0.0329**
	(0.0116)	(0.0138)	(0.0129)	(0.0118)	(0.0137)	(0.0130)
Age of head	0.0027	-0.0004	0.0014	0.0043**	0.0009	0.0030
	(0.0020)	(0.0023)	(0.0021)	(0.0020)	(0.0024)	(0.0022)
Male head	0.0033	0.0216	0.0077	0.0162	0.0383	0.0244
	(0.0578)	(0.0709)	(0.0644)	(0.0613)	(0.0734)	(0.0669)
Education of head	0.0129*	0.0058	0.0108*	0.0123*	0.0055	0.0102
	(0.0066)	(0.0072)	(0.0063)	(0.0066)	(0.0073)	(0.0063)
Constant	1.2175***	1.3365***	1.3626***	1.1003***	1.2592***	1.2090***
	(0.1251)	(0.1391)	(0.1242)	(0.1192)	(0.1341)	(0.1194)
Observations	408	519	408	408	519	408
Log likelihood	-776.48	-1069.79	-785.70	-776.73	-1069.11	-785.78
Chi2	52.00***	49.92***	50.13***	49.48***	54.28***	48.56***

DDS, dietary diversity score. Coefficient estimates are shown with robust standard errors in parentheses. ***P<0.01, **P<0.05, *P<0.1

Table A7 Market access, agricultural technology and dietary diversity

	Market access models			Market participation models		
Variables	Household DDS	Child DDS	Mother DDS	Household DDS	Child DDS	Mother DDS
Village market	0.0428	0.0458	0.0054			
	(0.0360)	(0.0427)	(0.0371)			
Time to district market	-0.0540***	-0.0530***	-0.0609***			
	(0.0192)	(0.0178)	(0.0163)			
Share of maize sold				0.0031**	0.0038***	0.0029**
				(0.0015)	(0.0014)	(0.0014)
Share of other food crops sold				0.0013**	0.0010	0.0014**
				(0.0006)	(0.0007)	(0.0007)
Area share of non-food cash crops				-0.0003	-0.0010	-0.0001
				(0.0011)	(0.0014)	(0.0011)
Improved maize varieties	0.0610	0.0697	0.0672	0.0423	0.0443	0.0506
	(0.0476)	(0.0584)	(0.0519)	(0.0492)	(0.0582)	(0.0533)
Improved legume varieties	0.0392	0.0426	0.0362	0.0111	0.0132	0.0073
	(0.0405)	(0.0468)	(0.0429)	(0.0417)	(0.0475)	(0.0444)
Chemical fertilizer	0.1601**	0.0978	0.1926**	0.1544**	0.0990	0.1791**
	(0.0767)	(0.0823)	(0.0872)	(0.0776)	(0.0840)	(0.0901)
Maize-legume intercropping	0.0188	0.0829*	0.0261	0.0219	0.0830*	0.0255
	(0.0389)	(0.0459)	(0.0416)	(0.0387)	(0.0462)	(0.0417)
Livestock	0.0190	0.0393***	0.0262**	0.0099	0.0324***	0.0177
	(0.0118)	(0.0108)	(0.0116)	(0.0133)	(0.0113)	(0.0132)
Off-farm income	0.0003***	0.0003**	0.0003***	0.0003***	0.0003**	0.0003***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Farm size	0.0063	0.0011	0.0051	-0.0021	-0.0040	-0.0022
	(0.0147)	(0.0140)	(0.0146)	(0.0148)	(0.0139)	(0.0148)
Household size	-0.0298**	-0.0505***	-0.0402***	-0.0242**	-0.0450***	-0.0348***
	(0.0116)	(0.0136)	(0.0129)	(0.0117)	(0.0135)	(0.0129)
Age of the head	0.0021	-0.0011	0.0007	0.0038*	0.0005	0.0024
	(0.0020)	(0.0024)	(0.0021)	(0.0020)	(0.0024)	(0.0022)
Male head	0.0176	0.0349	0.0198	0.0253	0.0459	0.0310
	(0.0591)	(0.0734)	(0.0645)	(0.0613)	(0.0744)	(0.0659)
Education of head	0.0104	0.0034	0.0077	0.0104	0.0034	0.0079
	(0.0067)	(0.0072)	(0.0064)	(0.0067)	(0.0073)	(0.0064)
Constant	1.2075***	1.4249***	1.3102***	1.0485***	1.2831***	1.1223***
	(0.1291)	(0.1357)	(0.1372)	(0.1223)	(0.1357)	(0.1335)
Observations	408	519	408	408	519	408
Log likelihood	-776.39	-1068.43	-783.69	-776.21	-1067.48	-784.02
Chi2	50.49***	52.39***	52.56***	52.46***	56.71***	51.91***

DDS, dietary diversity score. Coefficient estimates are shown with robust standard errors in parentheses. ***P<0.01, **P<0.05, *P<0.1

Appendix B: Farm household questionnaire 2013

HOUSEHOLD QUESTIONNAIRE MODULES FOR ADOPTION PATHWAYS (PRIMARY RESPONDENT)

Introductory statement: "Dear Sir/Madam, I work for Bunda college of Agriculture in Lilongwe. We are conducting out this survey to study production and technology adoption constraints in your village. Your response to these questions would remain anonymous. Taking part in this study is voluntary. If you choose not to take part, you have the right not to participate and there will be no consequences. Thank you for your kind co-operation"

MODULE 1. HOUSEHOLD AND VILLAGE IDENTIFICATION

Household ID……………………

Household Identification	Detail/ Code
1. Region (Code)	
2. District (Code)	
3. EPA (Code)	
4. Section (Code)	
5. Village	
6. New Village name	
7. Name of household head	
8. Sex of household head	1= Male 0= Female
9. Name of respondent (including grandfather name)	
10. Sex of respondent	1= Male 0= Female
11. Name of respondent's spouse	
12. Cell phone number	
GPS reading of homestead	
13. Way point number	
14. Latitude (South)	
15. Longitude (East)	
16. Altitude (above sea level)	

Interview details	Details/ Code
17. Date of interview (dd/mm/yyyy)	**2 0 1 3**
18a. Time started (24 HR)	
18b. Time finished (24 HR)	
19. Name of enumerator	
20. Name of supervisor	
21. Name of data entry clerk	

MODULE 2: HOUSEHOLD COMPOSITION AND CHARACTERISTICS AND HOUSING CONDITIONS

PART A: HOUSEHOLD COMPOSITION AND CHARACTERISTICS (Household members=Persons who live together and eat together from the same pot (share food), including workers, students and spouse living and working in another location but excluding visitors) ***Household ID……….***

ID CODE	Name of household member [Start with respondent]	Sex 1 = M 0 = F	Relationship to the household head **CODE 1**	Age (complete years)	Marital status? **CODE 2**	Education (years) **CODE 3**	Primary occupation **CODE 4**	How many months in the past year was [NAME] present in the household?	Labour contribution to farms cultivated by household in 2012/2013 **CODE 5**
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									

CODE 1		**CODE 2**	**CODE 3**	**CODE 4**	**CODE5**
1.Household head 2.Spouse 3.Son/daughter 4.Son/daughter-in-law 5.Grandson/granddaughter 6.Mother/Father 7.Brother/sister Nephew/niece	8.Cousin 9.Brother/sister-in-law 10.Mother/father-in-law 11.Domestic worker 12. Other relationship (specify)……………..	1. Married living with spouse 2. Married living without spouse 3. Single/never married 4. Divorced/separated 5. Widowed	0. None/Illiterate 100. Religious education 1. Adult education or 1 year of education * Give other education in years	1. Agriculture self employed 2. Agriculture wage labour 3. Non-agricultural self-employment 4. Non-agricultural wage labour 5. Salaried worker 6. Domestic work 7. Student 8. Unemployed 9. Retired 10. Too young 11. (under 5 years) 12. Other, (specify)………	1. Full time 2. Part time 3. Not a worker

MODULE 2: HOUSEHOLD COMPOSITION AND CHARACTERISTICS AND HOUSING CONDITIONS *Household ID……*

PART B: HOUSING CONDITIONS

Variable code	Questions	Code		Response
B1	Does the household own the main house they stay in?	0=No 1=Yes		
B2	Major material of the exterior walls of the main house the respondent stays in: **ENUMERATOR TO OBSERVE**	1=Wood and Mud 2=Wood and Grass 3=Reed and Bamboo 4=Mud and Stones 5=Mud/soil	6=Cement and Stones 7=Hollow Bricks 8=Bricks 9=mud bricks 10=Other (specify)……….	
B3	Major material of the floor of the main house the respondent stays in: **ENUMERATOR TO OBSERVE**	1=Earth/Mud 2=Wood 3=Cement	4=Ceramics/Tiles 5=Other (specify)…………….	
B4	Major roofing material of the main house the respondent stays in: **ENUMERATOR TO OBSERVE**	1=Corrugated Iron Sheet 2=Thatch and Grass 3=Wood and mud 4=Reed and Bamboo 5=Clay 6=Other (specify)……………………….		
B5	Total number of rooms in the main house the respondent stays in			
B6	Does this main house have access to electricity?	0=No 1=Yes		
B7	Does this household have access to piped water?	0=No 1=Yes		
B8	Total number of buildings including kitchens, but not including toilets			
B9	Type of toilet facility this household uses	1=Pit latrine (Private) 2=Pit latrine (Shared) 3=Flush toilet (Private) 4=Flush toilet (Shared)	5=Field/Forest 6=Other (specify)……………	

MODULE 3: CROP PRODUCTION FOR ALL CROPS GROWN BY THE HOUSEHOLD DURING THE 2012/13 MAIN SEASON PRODUCTION

Household ID……………………

PART A: Plot Information: Agricultural practices, crops and varieties cultivated and cropping area

(Definitions: A plot is a piece of land physically separated from others; a sub-plot is a sub-unit of a plot; Include rented/borrowed in/out plots, plots occupied by homestead, grazing and fallow land)

A0: What is the total household land holding? (Acres) ……………………………….

Serial No	Plot ID (start with one next to residence)	Sub-plot ID	Plot location name	Sub-plot area **acres**	Sub-plot distance to residence (walking minutes)	Sub-plot tenure **CODE 1**	Who in the hhld owns this sub-plot? **CODE 2**	Who in the hhld makes decisions on crops to be planted, input use, and timing of cropping activities on this [Sub-PLOT]?**CODE 2**	Inter-cropping on this plot? 0=No 1=Yes	Main crops grown on [Sub-PLOT] (if intercrop list up to 3 with primary crop first) **If not applicable put NA** **ANNEX 1 CODE**			Varieties grown on [Sub-PLOT] (in same order as for A11a-A11c) **ANNEX 2 CODE**			Percent of area under each intercrop? (e.g. first column 50 then next column 50)		
A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11a	A11b	A11c	A12a	A12b	A12c	A13a	A13b	A13c

Codes Module 3, Part A7-A9

A/ for rented out/shared out and borrowed out plots, please fill up to COLUMN A8

CODE 1		CODE 2	
1. Owned 2. Rented/shared in 3. Rented/shared out	4. Borrowed in 5. Borrowed out 6. Other, specify…..	1. Self 2. Mainly spouse	3. Self and spouse jointly 4. Other household member 5. Other (specify)………………..

MODULE 3: CROP PRODUCTION FOR ALL CROPS GROWN BY THE HOUSEHOLD DURING THE 2012/13 MAIN SEASON PRODUCTION (Continued) ***Household ID……………………***

PART A: Plot information: Soil fertility indicators, conservation agriculture practices, and crop residue utilization

Serial No	Plot ID **(Same order as in above)**	Sub-plot ID **(Same order as in above)**	Soil Questions: How fertile is the soil of this [sub-plot]? **CODE 1**	Soil Questions: What is the soil slope of this [sub-plot]? **CODE 2**	Soil Questions: What is the soil depth of this [sub-plot]? **CODE 3**	Soil Questions: What is the soil type of this [sub-plot]? **CODE 4**	Crop Rotation: Previous crop(s) grown **[ANNEX 1 CODE]**			Crop Rotation: Crop(s) grown before one in A18 **[ANNEX 1 CODE]**			Soil & water conservation methods on this plot (List 3 main techniques) **CODE 5**			Were crop residues left on this sub-plot from previous season (2011/12)? (1=Yes>>A22; 0=No>>A23)	Proportion (%) of crop residue from previous harvest still on plot at planting time for (2012/13)
A1	**A2**	**A3**	**A14**	**A15**	**A16**	**A17**	**A18a**	**A18b**	**A18c**	**A19a**	**A19b**	**A19c**	**A20a**	**A20b**	**A20c**	**A21**	**A22**

CODE 1	**CODE 2**	**CODE 3**	**CODE 4**	**CODE 5**	
1. Good	1. Gently slope (flat)	1. Shallow	1. Black	1. None	6. Minimum till
2. Medium	2. Medium slope	2. Medium	2. Brown	2. Terraces	7. Soil bunds
3. Poor	3. Steep slope	3. Deep	3. Red	3. Mulching	8. Stone bunds
			4. Grey	4. Grass strips	9. Box ridges
			5. Other (specify)…………..	5. Trees on boundaries	10. Other (specify)……………

MODULE 3: CROP PRODUCTION FOR ALL CROPS GROWN BY THE HOUSEHOLD DURING THE 2012/13 MAIN SEASON PRODUCTION (Continued)

Household ID……………………

PART A: Plot information: Conservation agricultural practices and input use

Serial No	Plot ID (Same order as in above)	Sub-plot ID (Same order as in above)	Minimum tillage: Has minimum tillage ever been practiced on this [sub-PLOT]? 1=Yes; 0=No	Minimum tillage: Was minimum tillage practiced on this [sub-PLOT] in 2012/13? 1=Yes; 0= No	Herbicide use: Herbicide(s) used on [sub- PLOT] **if not used, put NA** 1.Round up/glyphosate 2.Bullet 3.Harness 4. Other……….		Herbicide use: Total quantity used (kg or liter) **0 if NA in A24a**	Herbicide use: Total cost (MK) **If 0 in A24a, put NA**	Pesticide use: Quantity of pesticide used on this [sub-PLOT] (kg or liter) **If none put 0**	Pesticide use: Total cost (MK) **If 0 in A25a, put NA**	Fertilizer use:If no fertilizer was used on: NPK use on this [sub-PLOT]? Quantity (kg) **If none put 0**	NPK use: Total cost (MK) **If 0 in A26a, put NA**	UREA use on this [sub-PLOT]? Quantity (kg) **If none put 0**	UREA use: Total cost (MK) **If 0 in A27a, put NA**	Main method of payment for Fertilizer? **CODE 1**	Manure use: Mode of manure application to plot **CODE 2**	Manure use: Quantity of own manure (kg)	Bought manure: Quantity (kg)	Bought manure: Total cost(MK)	Was compost applied to plot? **CODE 3**
A1	**A2**	**A3**	**A23a**	**A23b**	**A24a**	**A24b**	**A24c**	**A24d**	**A25a**	**A25b**	**A26a**	**A26b**	**A27a**	**A27b**	**A28**	**A29**	**A30**	**A31a**	**A31b**	**A32**

CODE 1			**Code 2**	**Code3**
1.Own cash 2. Money got as gift from relative & non-relatives 3. Credit from bank	5. Credit from relative/neighbour/friend 6. Credit from micro-finance 7. Credit from NGO 8. Credit from input dealers	9. Credit from coops 10. Provided free by government 11. Own cash + subsidy	1. None 2. Transferred 3. Kralling 4. Transferred and kraaling	1.Yes 0.No

MODULE 3: CROP PRODUCTION FOR ALL CROPS GROWN BY THE HOUSEHOLD DURING THE 2012/13 MAIN SEASON PRODUCTION (Continued)

Household ID……………………

PART A: Plot information: Input use, seed sources and recycle information

Serial No	Plot ID **[same order as in above]**	Sub-plot ID **[same order as in above]**	Seed use **(In same order as in A11a-A11c)**																	
			Quantity of non-bought seed (kg or No) (Own saved, farmers to farmers exchange, etc.)			Bought seed including using credit						Number of seasons improved seed was recycled (write zero only for improved seeds purchased during current season)			Main method of payment for seed **CODE 1**			Main source of seed **CODE 2**		
						Quantity (kg or No)			Total cost of bought seed (MK)											
A1	**A2**	**A3**	**A33a**	**A33b**	**A33c**	**A34a**	**A34b**	**A34c**	**A35a**	**A35b**	**A35c**	**A36a**	**A36b**	**A36c**	**A37a**	**A37b**	**A37c**	**A38a**	**A38b**	**A38c**

CODE 1			**CODE 2**		
1. Own cash 2. Money got as gift from relative & non- relatives 3. Credit from bank	4. Credit from money lender 5. credit from seed dealers 6. Credit from relative/neighbour/friend 7. Credit from micro-finance 8. Credit from NGO	9. Credit from coops 10. Own cash + subsidy 11. Other (specify)…………………	1. Own saved seed 2. Government extension 3. Trader 4. Private seed suppliers	5. Gift from family/neighbour 6. Farmer to farmer seed exchange 7. Local market 8. On-farm trials 9. Extension demo plots	10. Farmer groups/Coops 11. Local seed producers 12. Provided free by NGOs/govt 13. Research centres 14. Other (specify)...................

MODULE 3: CROP PRODUCTION FOR ALL CROPS GROWN BY THE HOUSEHOLD DURING THE 2012/13 MAIN SEASON PRODUCTION (Continued) ***Household ID……………………***

PART A: Plot information: labour required for each agricultural operation (Children= below 14 years; men & women= 14 years and above; 1 person day= 8 hours)

Serial No	Plot ID **[same order as in above]**	Sub-plot ID **[same order as in above]**	**Land preparation & planting**								**Weeding**					
			What did you use for ploughing? 1.Animal traction 2.tractor 3.hand	How many times was this [sub-PLOT] ploughed?	Total family labour in person days			Total hired labour in person days		Who decides how this plot will be prepared in[sub-plot]?**CODE 1**	How many times was this [sub-PLOT] weeded?	Total family labour in person days			Total hired labour in person days	
					children	men	women	men	women			children	men	women	men	women
A1	**A2**	**A3**	**A39**	**A40**	**A41a**	**A41b**	**A41c**	**A42a**	**A42b**	**A43**	**A44**	**A45a**	**A45b**	**A45c**	**A46a**	**A46b**

Code 1

1. Self 2. Spouse 3. Self and spouse jointly 4. Other household member 5. Self and other household member 6. Spouse and other household member

MODULE 3: CROP PRODUCTION FOR ALL CROPS GROWN BY THE HOUSEHOLD DURING THE 2012/13 MAIN SEASON PRODUCTION (Continued) ***Household ID……………………***

PART A: Plot information: labour required for each agricultural operation (Children= below 14 years; men & women= 14 years and above; 1 person day= 8 hours) (CONTINUED)

Serial No	Plot ID **[same order as in above]**	Sub-plot ID **[same order as in above]**	**Harvesting** Intercrops: record separately by comma					**Threshing** Intercrops: record separately by comma						Were combine harvester and/or tractor used in [sub-PLOT] for harvesting and threshing? 1=Yes; 0=No
			Total family labour in person days			Total hired labour in person days		Was crop harvest threshed? **0.No 1.Yes**	Total family labour in person days			Total hired labour in person days		
			children	men	women	men	women		children	Men	women	men	women	
A1	**A2**	**A3**	**A47a**	**A47b**	**A47c**	**A48a**	**A48b**	**A49a**	**A49b**	**A49c**	**A49d**	**A50a**	**A50b**	**A51**

MODULE 3: CROP PRODUCTION FOR ALL CROPS GROWN BY THE HOUSEHOLD DURING THE 2012/13 MAIN SEASON PRODUCTION (Continued) ***Household ID……………………***

PARTA: Plot information: Decisions on production, production costs, production stress, and crops harvested

Serial No	Plot ID [**same order as in above**]	Subplot ID [**same order as in above**]	Who decides when to harvest the crop in[sub-plot]?**CODE1**	total cost of hired oxen (MK)	total cost of hired tractor (MK	total cost of hired labour (MK)	**Stresses**				Total harvested per sub-plot **[same crop order as inA11a-A11c)**					
							Stress incidence on [sub-PLOT]? 1.Yes 0.NO	Two major stresses **CODE 2**		Level of stress; **CODE 3**	Fresh or green (kg) (dry equivalent, except for vegetables)			Dry (kg)		
A1	**A2**	**A3**	**A52**	**A53**	**A54**	**A55**	**A56a**	**A56b**	**A56c**	**A57d**	**A58a**	**A58b**	**A58c**	**A59a**	**A59b**	**A59c**

CODE 1	**CODE 2**		**CODE 3**
1.Self 2.Spouse 3.Self and spouse jointly 4.Other household member 5.Self and other household member(s) 6.Spouse and other household member(s)	1.insects/pests 2.Disease 3.WaterLogging 4.Drought 5.Frost	6.Hailstorm 7.Animal trampling 8. Other, specify…………….	1.Moderate 2.Severe 3.catastrophic

MODULE 4: CONSTRAINTS IN ACCESSING KEY INPUTS AND CROP PRODUCTION (GENERAL)

Household ID……………………

PART A:

Input and production constraints	Maize		Main legume………. 1. Common beans 2. Groundnuts 3. Pigeon pea 4.	
	Is [CONSTRAINT] an issue in your maize production? (1=Yes>>B2; 0=No>>next [constraint)]	Rank its importance (only those with **Yes** in column A1) (1= most important)	Is [CONSTRAINT] an issue in your main legume production? (1=Yes>>B4; 0=No>> next [constraint)	Rank its importance (only those with **Yes** in column A3) (1= most important)
	A1	**A2**	**A3**	**A4**
Socioeconomic				
1. Timely availability of improved seed				
2. Prices of improved seed				
3. Quality of improved 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 output markets and information				
9. Access to input markets and information				
10. Access to labour				
11.Grain prices				

MODULE 5: IMPROVED CROP VARIETY KNOWLEDGE AND ADOPTION/ DIS-ADOPTION DURING 2012/13 *Household ID……………………*

PART A: Maize variety knowledge, sources of information and seed adoption and dis-adoption

Names of improved maize varieties grown in last 3 seasons **[For 2012/13 season, see Part A, column A12a-A12c, page 4]**	Type of maize variety **CODES** 1.hybrid 2.OPV 3.Dont know	Which year did you first hear about [VARIETY] **YYYY**	How did you first learn about the variety? **Code A**	When did you start cultivating this variety? **YYYY**	Where did you get the first seed? **Code B**	Will you continue growing [VARIETY] in future? 1=Yes, 0=No	If no to A7 **Rank** the three main reasons for not wanting to grow it **Code C**		
A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8a**	**A8b**	**A8c**

Codes A		**Codes B**		**Codes C**	
1. Govt extension 2. Farmer Coop/Union 3. Farmer group 4. NGO/CBO 5. Research centre (trials/demos/field days)	6. Seed/grain stockist 7. Another farmer relative 8. Another farmer neighbour 9. Radio/newspaper/TV 10. Other (Specify)….........	1. On-farm trials 2. Extension demo plots 3. Farmer groups/Coops 4. Local seed producers 5. Agro-dealers/Agrovets	6. Farmer to farmer seed exchange 7. Provided free by NGOs/govt 8. Govt subsidy program 9. Inherited from family 10. Research centre 11. 11 Other (specify)……………	1. Seed not available 2. Lack of cash to buy seed (credit) 3. Susceptible to diseases/pests 4. Poor taste 5. Low yielding variety	6. Low grain prices 7. No market 8. Theft during green stage 9. Lack of enough land 10. Requires high skills 11. Wild animals 12. Other (specify)…………………

MODULE 5: IMPROVED CROP VARIETY KNOWLEDGE AND ADOPTION/ DIS-ADOPTION DURING 2012/13 (Continued)

Household ID……………………

PART B: Legume variety knowledge, sources of information and seed adoption and dis-adoption

Names of improved legume varieties grown in last 3 seasons **[For 2012/13 season, see Part A, column A12a-A12c, page 4]**	Which year did you first hear about [VARIETY] **YYYY**	How did you first learn about the variety? **Code A**	When did you start cultivating this variety? **YYYY**	Where did you get the first seed? **Code B**	Will you continue growing [VARIETY] in future? (1=Yes, 0=No)	If no to B6 Rank the three main reasons for not wanting to grow it **Code C**		
B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7a**	**B7b**	**B7c**

Codes A		**Codes B**		**Codes C**	
1. Govt extension 2. Farmer Coop/Union 3. Farmer group 4. NGO/CBO 5. Research centre (trials/demos/field days)	6. Seed/grain stockist 7. Another farmer relative 8. Another farmer neighbour 9. Radio/newspaper/TV 10. Other, Specify….........	1. On-farm trials 2. Extension demo plots 3. Farmer groups/Coops 4. Local seed producers 5. Agro-dealers/Agrovets	6. Farmer to farmer seed exchange 7. Provided free by NGOs/govt 8. Govt subsidy program 9. Inherited from family 10 Other (specify)……………	1. Seed not available 2. Lack of cash to buy seed (credit) 3. Susceptible to diseases/pests 4. Poor taste 5. Low yielding variety ……	6. Low grain prices 7. No market 8. Theft during green stage 9. Lack of enough land 10. Requires high skills 11. Require high amount of rainfall 12. low poundability 13. Other, specify…………………….

MODULE 6: CLIMATE CHANGE AND ADAPTATION OPTIONS

Household ID……………………

PART A: RISK, LIVELIHOOD SHOCKS, AND COPPING STRATEGIES

Risk factor	How many times did [RISK] occur in the past ten years? (if zero put 0>> go to next [RISK] type)	Rank importance of [RISK] in affecting household livelihood (1=most important)	Important risk management strategies before [RISK]occurrence **CODE 1**; **Rank 3**			Important copping strategies after [RISK] occurrence **CODE 2**; **Rank 3**			How did [RISK] affect production of <u>main food crop</u> of the household **(% reduction)**	Which crops were most susceptible? Rank up to 3 crops, with most susceptible first **ANNEX 1 CODE**			As a result of [RISK] how much of your income did you lose? **(% reduction)**	Do you think [RISK] will become more important in future?**(**0=No 1=Yes>A9)	If **Yes**, how often do you think [RISK] will occur in the next ten years?
			1st	2nd	3rd	1st	2nd	3rd		1st	2nd	3rd			
	A1	**A2**	**A3a**	**A3b**	**A3c**	**A4a**	**A4b**	**A4c**	**A5**	**A6a**	**A6b**	**A6c**	**A7**	**A8**	**A9**
1. Drought															
2. Too much rain or floods															
3. Crop pests/diseases															
4. Hail storm															

CODE 1				CODE 2		
1. Change crop varieties 2. Early planting 3. Crop diversification (intercropping + rotation) 4. Tree planting	5. Change from crop to livestock 6. Minimum tillage 7. Soil and stone bunds 8. Increase seed rate	9. More on-farm casual work 10. More off-farm casual work 11. Saving in cash 12. Saving in kind (e.g. Jewellery)	13. Food preservation 14. None 15. Other (specify)………	1. Change crop varieties 2. Replanting 3. Selling livestock 4. Selling land 5. Rent out land 6. Selling other assets (specify)…………	7. Change from crop to livestock 8. Eat less 9. Reduce meals 10. Out-migration 11. Borrowing	12. Stop sending children to school 13. More on-farm casual work 14. More off-farm casual work 15. None 16. Other (specify)……….

MODULE 6: CLIMATE CHANGE AND ADAPTATION OPTIONS

Household ID……………………

PART A: RISK, LIVELIHOOD SHOCKS, AND COPING STRATEGIES (CONTINUED)-,

Risk factor	How many times did [RISK] occur in the past five years? (if zero put 0 >> go to next [RISK] type)	Rank importance of [RISK] in affecting household livelihood (1=most important)	Important risk management strategies before [RISK], **CODE 1**; Rank 3			Important copping strategy after [RISK] occurrence **CODE 2**; Rank 3			How did [RISK] affect production of main food crop of the household (% reduction)	Which crops were most susceptible? Rank up to 3 crops, with most susceptible first **ANNEX 1 CODE**			As a result of [RISK] how much of your income did you lose? **(% reduction)**	Do you think [RISK] will become more important in future? **(0=No; 1=Yes>>A18)**	If **Yes to A8**, how often do you think [RISK] will occur in the next ten years?
			1st	2nd	3rd	1st	2nd	3rd		1st	2nd	3rd			
	A10	**A11**	**A12a**	**A12b**	**A12c**	**A13a**	**A13b**	**A13c**	**A14**	**A15a**	**A15b**	**A15c**	**A16**	**A17**	**A18**
1. Crop damage by livestock & wild life															
2. Livestock diseases or death															
3. Large decrease in agricultural output prices															
4. Large increase in agricultural input prices															
5. Large increase in food															
6. Family sickness															
7. Death of household member															
8. Reduced/failure household business income															
9. Reduced/loss of employment income															
10. Theft of assets or crops															

CODE 1				**CODE 2**		
1. Change crops 2. Early planting	3. Crop diversification (intercropping + rotations) 4. More on-farm casual work 5. More off-farm casual work	6. Saving in cash 7. Saving in kind 8. Food preservation 9. Look for market	10. Seek veterinary services 11. Change from crop to livestock 12. None 13. Other (specify)………	1. Selling livestock 2. Renting out land 3. Selling land 4. Selling other assets (specify). ….	5. Eat less 6. Reduce meals 7. Out-migration 8. Borrowing 9. Seek treatment 10. Stop sending children to school	11. More on-farm casual work 12. More off-farm casual work 13. None 14. Other (specify)……….

MODULE 7: PARTICIPATION IN SEED AND FERTILIZER SUBSIDY PROGRAMME ***Household ID……………………***

PART A: FERTILIZER COUPONS

1. Did you receive fertilizer coupons in 2012/13 main cropping season?.. 1=Yes; 0=No
2. If answer in question 1 is yes, what was the source of the coupon? ……………. 1. Government extension 2. Other farmers benefiting from program 3. Other (specify)……………….
3. If the answer in question 1 is **yes**, how many coupons did you receive? ....
4. If the answer in question 1 is **yes**, for which fertilizer types did you receive the coupons..........1= NPK (23:21:0+4S); 2=UREA; 3. Both NPK (23:21:0+4S) and UREA 4. Other, specify……….
5. If the answer in question 1 is **yes** , did you use all the coupons to purchase fertilizer to apply on <u>your farm</u>?..........................1=Yes; 0=No
6. If answer to 5 is **no**, why? ………….. 1. Fertilizer not available; 2. Fertilizer cost more than coupon price; 3. Sold coupon to satisfy other needs; 4. Shared with other farmers 5. Other (specify)………………..
7. If used coupon to purchase fertilizer, how much did you pay for the 50kg bag of fertilizer you bought with the coupon? ....
8. Did you buy fertilizer during 2012/13 main cropping season without use of coupons i.e. using your own or borrowed money?............1=yes; 0=No

SECTION B: SEED COUPONS

1. Did you receive seed coupons in 2012/13 main cropping season?..1=Yes; 0=No
2. If the answer to question 1 is yes, what was the source of the coupon? ……… 1. Government extension 2. Other farmers benefiting from program 3. Other (specify)……………….
3. If the answer for question 1 is **yes**, how many coupons did you receive? ....
4. 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. Pigeonpea; 6. Tobacco; 7.Other, specify.........
5. If the answer in question 1 is **yes** , did you use all the coupons to purchase seed to plant on <u>your farm</u>?..1=Yes; 0=No
6. If answer to 5 is **no**, why? ………….. 1. Seed not available; 2. Seed cost more than coupon price; 3. Sold coupon to satisfy other needs; 4. Shared with other farmers 5. Other (specify)………………..
7. If used coupon to purchase seed, how much did you pay for the 2kg bag of seed you bought with the coupon?...
8. Did you buy seed during 2012/13 main cropping season without use of coupons i.e. using your own or borrowed money?...1=yes; 0=No

Time finished (24 HR)……………….

Thank you very much for your time and patience!

ANNEX 1: CROP CODES

SIMLESA Crops	Other cereals	Other Pulses (legumes)	Oil Crops	Root crops/tubers/ vegetables	Perennial crops	Fodder legumes
1. Maize 2. Common bean 3. Soybean 4. Pigeonpea 5. Groundnut 6. Cowpea	9. Wheat 11. Barley 12. Sorghum 13. Finger Millet 14. Pearl millet 20. Rice	24. Chickpea 26. Field pea	28. Sunflower 29.Sesame 30.Linseed 31.Rapeseed 32.Lupin	34. Cassava 35. Irish potato 36. Sweet potato 37. Onion 38. Garlic 39. Pepper 40. Tomato 41. Ginger 42. Cabbage 43. Carrot	44. Coffee 46. Banana 47. Orange 48. Mango 51. Sugar cane 52. Eucalyptus	53. Lablab 54. Clover 55. Vetch 56. Alfalfa 57. Sesbania 58. Grazing land 59. Fallow 76. Tobacco 100. Other crops (specify).........

ANNEX 2: Crop Variety Codes

Maize

1. Bantum
2. Chisowa
3. DK8021
4. DK8031
5. DK8033 (Mkangala)
6. DK8035
7. DK8053 (Mapasa)
8. DK8051
9. DK8071
10. DK8073
11. DK90-89 (Fumba)
12. Kagoro
13. Kanjerenjere
14. Masika
15. MH17
16. MH18 (Chokonoka)
17. MH26
18. MH27
19. MH41 (Kachamsana)
20. PAN41
21. PAN53
22. PAN67 (Kaswiri)
23. PAN83
24. PHB30G19 (Pioneer)
25. Popcorn
26. SC403 (Kanyani)
27. SC407 (Mbizi)
28. SC513
29. SC627 (Mkango)
30. SC709
31. SC715
32. SC717
33. SC719 (Njovu)
34. Sundwe
35. ZM309
36. ZM421
37. ZM521
38. ZM523
39. ZM621 (Mbewu ya phindu)
40. ZM623
41. ZM721
42. Local
43. Other Improved (specify……….)
44. Other Improved (specify……….)
45. Other Improved (specify……….)

Common bean

46. Maluwa
47. Kholophethe
48. Kabalabala
49. Kambidzi
50. Nagaga
51. Sapatsika
52. Napilira
53. Mkhalira
54. Kalima
55. Bwenzilalana
56. Nasaka
57. Bunda
58. Kamzama
59. Kamtsilo
60. Chimbamba
61. Sapelekedwa
62. NUA 45
63. NUA 59
64. Local
65. Other improved (specify………….)
66. Other improved (specify………….)
67. Other improved (specify…………)

Soybean

68. Makwacha
69. Nasoko
70. Ocepara-4
71. Local
72. Other improved (specify……………….)
73. Other improved (specify……………….)
74. Other improved (specify……………….)

Groundnut

75. Chalimbana
76. Malimba
77. Mani Pintar
78. RG 1
79. Mawanga
80. Chitembana
81. CG 7
82. Nsinjiro
83. Kakoma
84. Baka
85. Chalimbana 2005
86. Other improved (specify……………….)
87. Other improved (specify……………….)
88. Other improved (specify……………….)

Cowpea

89. Sudan- 1
90. IT82E-16
91. Other improved (specify……………….)
92. Other improved (specify……………….)
93. Other improved (specify……………….)

Pigeon Pea

94. Sauma
95. Kachangu
96. ICEAP 0057
97. ICPL 87105
98. ICPL
99. Other improved (specify……………….)
100. Other improved (specify……………….)
101. Other improved (specify……………….)

Other crops

102. Improved
103. Local

INDIVIDUAL QUESTIONNAIRE MODULES FOR ADOPTION PATHWAYS

(PRIMARY RESPONDENT AND SPOUSE INTERVIEWED CONCURRENTLY BUT SEPARATELY)

Introductory statement: "Dear Sir/Madam, I work for Bunda college of Agriculture in Lilongwe. We are conducting out this survey to study production and technology adoption constraints in your village. Your response to these questions would remain anonymous. Taking part in this study is voluntary. If you choose not to take part, you have the right not to participate and there will be no consequences. Thank you for your kind co-operation"

MODULE 1. INDIVIDUAL AND VILLAGE IDENTIFICATION

Household ID……… Respondent ID……..

Household Identification	Detail/ Code
1. Region (Code)	
2. District (Code)	
3. EPA (Code)	
4. Section (Code)	
5. Village	
6. New Village name	
7. Name of household head	
8. Sex of household head	1= Male 0= Female
9. Name of respondent (including grandfather name)	
10. Sex of respondent	1= Male 0= Female
11. Name of respondent's spouse	
12. Cell phone number	
GPS reading of homestead	
13. Way point number	
14. Latitude (South)	
15. Longitude (East)	
16. Altitude (above sea level)	

Interview details	Details/ Code
17. Date of interview (dd/mm/yyyy)	**2 0 1 3**
18a. Time started (24 HR)	
18b. Time finished (24 HR)	
19. Name of enumerator	
20. Name of supervisor	
21. Name of data entry clerk	

MODULE 2. PARTICIPATION IN RURAL INSTITUTIONS AND ACCESS TO KEY SERVICES

PART A: Participation in rural institutions *Household ID……… Respondent ID……..*

Variable Code	Institution Type	Are you currently a member of any of the following group? 0=no; 1=yes	Year joined group **YYYY**	How much input do you have in making decisions in this [GROUP]? **CODE 1**
	A1	**A2**	**A3**	**A4**
1.1	Savings and credit association			
1.2	Merry-go-round (chipereganyo)			
1.3	Input supply group, farmer			
1.4	Crop or seed production group			
1.5 1.6	Water User's Association Crop marketing group			
1.7	Women's Association/group			
1.8	Youth Association			
1.9	Church/mosque			

CODE 1		
1. No input 2. Input into very few decisions	3. Input into some decisions 4. Input into most decisions	5. Input into all decisions

MODULE 3: SOCIAL CAPITAL, NETWORKING *Household ID……… Respondent ID……..*

PART A: Social networks

QUESTION			CODE	RESPONSE
A1	How many years have you been living in this village?			
A2	How many people that live WITHIN this village can you rely on in times of need?	Relatives	Number of RELATIVES	
		Non-relatives	Number of NON-RELATIVES	
A3	How many people that live OUTSIDE this village can you rely on in times of need?	Relatives	Number of RELATIVES	
		Non-relatives	Number of NON-RELATIVES	
A4	Are any of your friends or relatives in leadership positions in governmental institutions within and outside this village?		0=No 1=Yes	
A5	How many grain traders do you know WITHIN this village who could buy your grain?		Number of grain traders	
A6	How many grain traders do you know OUTSIDE of this village who could buy your grain?		Number of grain traders	
A7	Generally speaking do you believe that grain traders can be trusted?		1=Strongly disagree 2=Disagree 3=Slightly disagree 4=neither agree or disagree 5=Slightly agree 6=Agree 7=Strongly agree	
A8	Which types of traders do you trust more **(rank 3)?**		1=Wholesalers 2=Retailers 3=Assemblers 4=Brokers 5=others	
A9	**Main reason** for trusting traders in A8 **(follow order above)**		1=Relatives 2=Regular customer 3=Give always better price 4= Has reliable scale 5=Provide credit 6= Other (specify)…………	
A10	Do you think you can rely on government support (subsidies, food aid, etc.) if your crop fails?		0=No 1=Yes	
A11	Are you confident of the skills of government officials including extension workers to do their job?		1=Strongly disagree 2=Disagree 3=Slightly disagree 4=neither agree or disagree 5=Slightly agree 6=Agree 7=Strongly agree	

MODULE 4: HOUSEHOLD ASSETS, ACCESS TO CAPITAL AND INFORMATION *Household ID……… Respondent ID……..*

PART A: Household credit need and sources during 2012/13 cropping year

Reason for Loan		Did you need credit? 0=No>>A2 1=Yes>>A3	Why did you not need credit? **CODE 1**	Did you receive credit? 0=No>> A4 1=Yes >>A5-A11	Why did you not receive credit (Rank 3 reasons) **CODE 2**			Who applied for the credit? **CODE 4**	If Yes in A3, What was the source of the credit? **CODE 3**	What was the amount of credit received? **(MK)**	Did you receive the amount you requested? 0=No 1=Yes	What was the monthly interest rate charged? **(%)**	What is the debt outstanding including interest at end of season **(MK)**	Who made the decision about what to do with the money/ item borrowed? **CODE 4**
		A1	**A2**	**A3**	**A4a**	**A4b**	**A4c**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**	**A11**
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	Buying livestock for fattening													
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	Non-food consumption needs (health/education/travel/tax,)													

CODE 1	**CODE 2**		**CODE 3**	**CODE 4**
1=Not cash constrained 2=Activity is not profitable 3=Never thought of this investment 4=Already had investment 5= Other (specify)…………	1=Borrowing is risky 2=Interest rate is high 3=Too much paper work/ procedures 4=Expected to be rejected, did not try 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 9=Not available on time 10=Other (specify)…………………..	1=Money lender 2=Farmer group/coop 3=Merry go round (chipereganyo) 4=Microfinance 5=Bank 6=Relative 7= Other (specify)…………………….	1=Self 2=Spouse 3=Self and spouse jointly 4=Other household member 5=Self and other household ember(s) 6=Spouse and other household member(s)

MODULE 4: CAPITAL, CONTINUED ***Household ID……… Respondent ID……..***

PART B: Household Savings, *Enumerator, put 1 source of savings per row.*

B1. Did household save money in the last two years? ....0. No, 1. Yes if yes, answer questions below; if no go to module 4 part C

Savings ID	Where did you save money? **CODE 2**	Who made the decision to save money? **CODE 1**	Who made the saving? **CODE 1**	What was the total amount you saved during 2012/13? (MK)	Who makes decisions about what to do with savings? **CODE 1**
	B1	**B2**	**B3**	**B4**	**B5**
1					
2					
3					
4					
5					

CODE 1		**CODE 2**
1=Self 2=Spouse 3=Self and spouse jointly 4=Other household member 5=Self and other household member(s) 6=Spouse and other household member(s) 7=Someone outside the household	8=Self and other outside people 9=Spouse and other outside people 10=Self, spouse and other outside people 11= Other (specify)…………	1=Saving at home (personal) 2=Commercial or other banks 3=Rural micro-finance 4=Saving by lending to money lender 5=SACCOs 6= Other (specify)…………

MODULE 4: HOUSEHOLD ASSETS, ACCESS TO CAPITAL AND INFORMATION

Household ID……… Respondent ID……..

PART C: Access to extension services

Issue		Did the household need extension training/advice/ information about [ISSUE] **in** 2012/13? **0=No>> C2and C3;** **1=Yes>>C3**	Why did you not need training/ advice on [issue]? **CODE 1**	Did household receive extension training/advice on about [ISSUE] *during* 2011/12? **0=No;1=Yes**	Did household receive extension training/advice about [ISSUE] *during* 2012/13? **0=No>>next issue** **1=Yes**	Who in household received extension in 2012/2013? **CODE 2**	Do you feel that you got adequate training/informati on/advice about [ISSUE] in 2012/2013? **0=No;1=Yes**	What was your main source of information about [ISSUE] during 2012/13? Rank up to 3 information sources, with primary source first. **CODE 3**			If yes to C4, how many contacts did you have with each of the sources in column 6 (follow order) during 2012/13? (days/year) If zero write 0.		
								Source 1	Source 2	Source 3			
		C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7a**	**C7b**	**C7c**	**C8a**	**C8b**	**C8c**
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.	Intercropping												
7.	Minimum tillage												
8.	Leaving crop residue in the field												
9.	Irrigation												
10.	Output markets and prices												
11.	Input markets and prices												
12.	Collective action/farmer organization												
13.	Livestock production												
14..	Family health												
15.	Tree planting												

CODE 1	**CODE 2**	**CODE 3**			
1= Had enough information/knowledge 2= Not aware about the issue before 3= **Other (specify)…………**	1=Self 2=Spouse 3=Self and spouse jointly 4=Other household member 5=Self and other household member(s) 6=Spouse and other household member(s)	1=Government extension service 2=Spouse 3=Other household members 4=Farmer Coop or groups 5=Neighbour farmers	6=Seed traders/Agro-dealers 7=Relative farmers 8=NGOs 9=Other private trader 10=Private Company	11=Research centre 12=Farmer business school 13=Radio/TV 14=Newspaper 15=Mobile phone	16=NASFAM 17=Farmer Field School 18=Farmer training centre 19= **Other (specify)**

MODULE 4: HOUSEHOLD ASSETS, ACCESS TO CAPITAL AND INFORMATION

PART D: Production equipment and major household furniture *Household ID……… Respondent ID……..*

Asset Category	Asset type	Does the household own [...]: 1= Yes 0=No	No. owned	Current Value each (MK)	Who would you say owns most of the […]? **CODE 1**	Who would you say can decide to sell […] most of the time? **CODE 1**	Who would you say can give away […] most of the time? **CODE 1**	Who would you say can decide to mortgage or rent out […] most of the time? **CODE 1**	Who would you say would keep majority of […] in case a marriage is dissolved due to divorce/separation? **CODE 1**	Who would you say would keep majority of […] in case a marriage is dissolved due to death of spouse? **CODE 1**	Who contributes most to decisions regarding a new purchase or construction of [….]? **CODE 1**
	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11
Farm implements	Sickle										
	Hoe										
	Spade or shovel										
	Axe										
	Knapsack sprayer										
	Slasher										
	Panga knife										
	Wheelbarrow										
	Ox-plough										
	Water pump										
	Tractor										
Transport	Push cart										
	Bicycle										
	Motorbike										
	Donkey/oxen cart										
	Car										
Household Furniture	Improved charcoal/wood										
	Kerosene stove										
	Water carrier										
	Fridge,										
	Table, sofas, chairs, and beds										

MODULE 4, PART D (CONTINUED) ***Household ID……… Respondent ID……..***

Asset Category	Asset type	Does the house hold own [...]: 1= Yes 0=No	No. owned	Current Value each (MK)	Who would you say owns most of the […]? **CODE 1**	Who would you say can decide to sell […] most of the time? **CODE 1**	Who would you say can give away […] most of the time? **CODE 1**	Who would you say can decide to mortgage or rent out […] most of the time? **CODE 1**	Who would you say would keep majority of […] in case a marriage is dissolved due to divorce/ separation? **CODE 1**	Who would you say would keep majority of […] in case a marriage is dissolved due to death of spouse? **CODE 1**	Who contributes most to decisions regarding a new purchase or construction of [….]? **CODE 1**
	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11
Communication	Radio										
	Mobile phone										
	Cassette or CD player										
	TV										
Jewellery	Gold,										
	Silver,										
	Wristwatch										
Trees	Fruit trees										
	Other trees (e.g. eucalyptus)										
Land	Land owned (acres)										
House	House										

CODE 1			
1. Self **2.** Spouse **3.** Self and spouse jointly	**4.** Other household member **5.** Self and other household member(s) **6.** Spouse and other household member(s)	**7.** Whole family owned **8.** Someone outside the household **9.** Self and other outside people	**10.** Spouse and other outside people **11.** Self, spouse and other outside people **12.** Other (specify)……

MODULE 5: LIVESTOCK PRODUCTION ACTIVITIES DURING 2012/13 CROPPING YEAR ***Household ID……… Respondent ID……..***

PART A: Livestock production activities during 2012/13 cropping year

	Animal type	Does the household own […]? 0=No; 1=yes	No. owned	Current Value each (MK)	Who would you say owns most of the […]? **CODE1**	Who would you say can decide whether to sell […] most of the time? **CODE 1**	Who would you say can decide whether to give away […] most of the time? **CODE 1**	Who would you say can decide to hire out […] most of the time? **CODE 1**	Who would you say would keep majority of […] in case a marriage is dissolved due to divorce/separation **CODE 1**	Who would you say would keep majority of […] in case a marriage is dissolved due to death of spouse? **CODE 1**	Who contributes most to decisions regarding a new purchase of […]? **CODE 1**
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**	**A11**
1	Indigenous cows										
2	Cross bred/exotic										
3	Oxen										
4	Bulls										
5	Steers										
6	Heifers										
7	Calves										
8	Small livestock (goats/sheep)										
9	Pig										
10	Donkeys										
11	Horse										
12	Mule										
13	Poultry										
14	Bee hives with colony										
15	Rabbits										

CODE 1			
1=Self 2=Spouse 3=Self and spouse jointly	4=Other household member 5=Self and other household member(s) 6=Spouse and other household member(s)	7=whole family owned 8=Someone outside the household 9=Self and other outside people	10=Spouse and other outside people 11=Self, spouse and other outside people 12= Other (specify)…………

MODULE 6: HOUSEHOLD INCOME ACTIVITIES DURING 2012/13 CROPPING YEAR

Household ID……… Respondent ID……..

PART A: What was your household's income from the following sources during the past 12 months? (*Include the income of all household members listed*)

Income source	Who earned income? **Use NA if none** **Code 1**	Income for the past 12 months		
		Cash (MK)	In-kind (cash equivalent in MK)	Total
Income from salaried employment				
Income from machinery services for other farms (ploughing etc.)				
Income from casual labour (on-farm)				
Income from casual labour (off-farm)				
Income from own **non-agricultural** businesses (shops, saloons etc)				
Income from non-farm agribusiness (grain milling, grain trading etc)				
Selling charcoal, brick making, selling firewood etc				
Pensions				
Remittances from family members/friends who do not live in the household				
Revenues from leasing out land				
Other sources (specify)…………				

Code 1
1=Self
2=Spouse
3=Self and spouse jointly
4=Other household member
5=Self and other household ember(s)
6=Spouse and other household member(s)

MODULE 7: IMPROVED CROP VARIETY KNOWLEDGE AND ADOPTION/ DIS-ADOPTION ***Household ID……… Respondent ID……..***

PART A: Maize variety knowledge, sources of information and seed adoption and dis-adoption

		Code	**Response**
A1	In your household, who makes the decision on which improved maize varieties to use and dis-adopt?	1=Self; 2 =Spouse; 3=Self and spouse jointly; 4= other household members	
A2	In your household, who mostly acquires maize seed from different sources?	1=Self; 2 =Spouse; 3=Self and spouse jointly; 4= other household members	
A3	How certain are you about the origin and purity of the improved maize varieties that you have grown?	1= Very; 2= Modest; 3= Not sure	
A4	In your household, who mostly acquires extension services related to new maize varieties	1=Self; 2 =Spouse; 3=Self and spouse jointly; 4= other household members	
A5	In your household, who mostly acquires credit (cash or in kind) services for purchase of maize seeds both improved and local varieties and other inputs (fertilizer, herbicides)	1=Self; 2 =Spouse; 3=Self and spouse jointly; 4= other household members	

PART B: Legume variety knowledge, sources of information and seed, adoption and dis-adoption

		Code	**Response**
B1	In your household, who makes the decision on which improved legume varieties to use and disadopt?	1=Self; 2 =Spouse; 3=Self and spouse jointly; 4= other household members	
B2	In your household, who mostly acquires legume seeds from different seed sources?	1=Self; 2 =Spouse; 3=Self and spouse jointly; 4= other household members	
B3	How certain are you about the origin and purity of the improved legume varieties that you have grown?	1= Very; 2= Modest; 3= Not sure	
B4	In your household, who mostly acquires extension services related to new legume varieties	1=Self; 2 =Spouse; 3=Self and spouse jointly; 4= other household members	
B5	In your household, who mostly acquires credit (cash or in kind) services for purchase of legume seeds both improved and local varieties and other inputs (fertilizer, herbicides)	1=Self; 2 =Spouse; 3=Self and spouse jointly; 4= other household members	

MODULE 8: CLIMATE CHANGE AND ADAPTATION OPTIONS

Household ID……… Respondent ID……..

PART A: CLIMATE CHANGE PERCEPTION

		CODE	Response
A1	If you compare the number of hot days in a year now and 10 years ago, do you feel that the number has---?	1= Remained the same 2= Increased; 3= Declined; 4= Do not know	
A2	Please explain what you observed? **(Enumerators let farmers try first & then probe by reading the codes) RANK MAIN 3**	1= Average temperature increasing 2=Average temperature decreasing 3= Prolonged drought 4= Frequent drought 5= Hot months are getting hotter 6= Pest and diseases increase 7= Other, specify……	
A3	What adjustments in your farming have you made to these long-term shifts in temperature? **(Enumerators let farmers try first & then probe by reading the codes)**	Code 1, below (enumerators multiple responses possible)	
A4	Over the last 10 years, has the number of rainfall days per year…?	1= Remained the same 2= Increased; 3= Declined; 4= Do not know	
A5	Please explain what you observed? **(Enumerators let farmers try first & then probe by reading the codes) RANK MAIN 3**	1= Late start of rains 2= Early start of rains 3= Early stop of rains 4= Later stop of rains 5= More overall rainfall 6= Less overall rainfall 7=More frequent floods 8= Hailstorm 9=In-season dry spells	
A6	What adjustments in your farming have you made to these long term shifts in rainfall? **(Enumerators let farmers try first & then probe by reading the codes)**	**Code 1, below (enumerators multiple responses possible)**	
A7	Do you get information on expected rainfall and temperature?	1= yes>> A7; 0=no	
A8	Source of information on expected rainfall and temperature (multiple response possible)	1=Government; 2= Radio/TV; 3= Fellow farmer; 4=NGO; 5=Other, specify……..	

CODE 1			
1. Change crop varieties	4. Crop diversification (e.g. intercropping + rotation)	7. Migrate to urban areas	11. Box ridges
2. Early planting	5. Planting trees (fruit + others)	8. Minimum tillage	12. Savings
3. Change from crop to livestock production	6. Find off-farm income	9. Stone and soil bunds	13. None
		10. Terraces	14. Other (specify)…………

MODULE 9: HOUSEHOLD FOOD INSECURITY ACCESS SCALE (HFIAS) ***Household ID……… Respondent ID……..***

PART A: FOR EACH OF THE FOLLOWING QUESTIONS, PLEASE CONSIDER WHAT HAS HAPPENED IN THE PAST 12 MONTHS.

No.	Question	Response options (mark where applicable)
1.	During the last 12 months, did you worry that your household would not have enough food?	0 = Never
		1 = Rarely (in one or two months during the last year)
		2 = Sometimes (in 3 to 10 months during the last year)
		3 = Often (in more than 10 months during the last year)
2.	Were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?	0 = Never
		1 = Rarely (in one or two months during the last year)
		2 = Sometimes (in 3 to 10 months during the last year)
		3 = Often (in more than 10 months during the last year)
3.	Did you or any household member eat just a few kinds of food day after day due to a lack of resources?	0 = Never
		1 = Rarely (in one or two months during the last year)
		2 = Sometimes (in 3 to 10 months during the last year)
		3 = Often (in more than 10 months during the last year)
4.	Did you or any household member eat food that you preferred not to eat because of a lack of resources to obtain other types of food?	0 = Never
		1 = Rarely (in one or two months during the last year)
		2 = Sometimes (in 3 to 10 months during the last year)
		3 = Often (in more than 10 months during the last year)
5	Did you or any household member eat a smaller meal than you felt you needed because there was not enough food?	0 = Never
		1 = Rarely (in one or two months during the last year)
		2 = Sometimes (in 3 to 10 months during the last year)
		3 = Often (in more than 10 months during the last year)
6.	Did you or any other household member eat fewer meals in a day because there was not enough food?	0 = Never
		1 = Rarely (in one or two months during the last year)
		2 = Sometimes (in 3 to 10 months during the last year)
		3 = Often (in more than 10 months during the last year)
7.	Was there ever no food at all in your household because there were no resources to get more?	0 = Never
		1 = Rarely (in one or two months during the last year)
		2 = Sometimes (in 3 to 10 months during the last year)
		3 = Often (in more than 10 months during the last year)
8.	Did you or any household member go to sleep at night hungry because there was not enough food?	0 = Never
		1 = Rarely (in one or two months during the last year)
		2 = Sometimes (in 3 to 10 months during the last year)
		3 = Often (in more than 10 months during the last year)
9.	Did you or any household member go a whole day without eating anything because there was not enough food?	0 = Never
		1 = Rarely (in one or two months during the last year)
		2 = Sometimes (in 3 to 10 months during the last year)
		3 = Often (in more than 10 months during the last year)

PART A: FOR EACH OF THE FOLLOWING QUESTIONS, PLEASE CONSIDER WHAT HAS HAPPENED IN THE PAST 12 MONTHS (CONT'D)

Household ID……… Respondent ID……..

10.	What is your own assessment of the adequacy of your family's food consumption over the past 12 months?	1=It was less than adequate for your family's needs 2=It was just adequate for your family's needs 3=It was more than adequate for your family's needs 4=Not applicable ''Adequate'' means no more nor less than what the respondent considers to be the minimum consumption needs of the family	
11.	What is your own assessment of the adequacy of your family's housing over the past 12 months?		
12.	What is your own assessment of the adequacy of your family's clothing over the past 12 months		
13.	What is your own assessment of the adequacy of the health care your family gets over the past 12 months?		
14.	What is your own assessment of the adequacy of your children's schooling over the past 12 months?		
15.	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 assess your family's food consumption in the past 12 months	1. Food shortage through the year, 2. Occasional food shortage, 3. No food shortage but no surplus, 4. Food surplus.	

PART A: ROLE IN HOUSEHOLD DECISION-MAKING on PRODUCTION, EXPENDITURE, AND INCOME GENERATION AND USE (If household does not engage in that particular activity, enter code for "Decision not made" and proceed to next activity)

Household ID……… Respondent ID……..

Decision on		Did you participate in (decision) in the last 12 months? **1. Yes** **0. No**	How much input did you have in making decisions about [ACTIVITY]? **CODE 2**	How much input did you have in decisions on the use of income generated from [ACTIVITY]? **CODE 2**
		A1	**A2**	**A3**
1	Food crop farming: crops that are grown primarily for household food			
2	Cash crop farming: crops that are grown primarily for sale in the market			
3	What type of seed to buy?			
4	What type of fertilizer to buy?			
5	When or who would take crops to the market (food crops)?			
6	When or who would take crops to the market (cash crops)?			
7	Livestock raising?			
8	When or who would take livestock to the market?			
9	Non-farm business activity			
10	Your own (singular) wage or salary employment?			
11	Major household expenditures? (such as a large appliance for the house like refrigerator)			
12	Minor household expenditures? (such as food for daily consumption or other household needs)			
13	Whether or not to use family planning to space or limit births?			

Code 2
1. No input 2. Input into very few decisions 3. Input into some decisions 4. Input into most decisions 5. Input to all decisions 98. No decision made

Part B: DECISIONMAKING (CONTINUED)

Household ID……… Respondent ID……..

ENUMERATOR: This set of questions is very important. I am going to give you some reasons why you act as you do in the activities I just mentioned. You might have several reasons for doing what you do and there is no right or wrong answer. Please tell me how true it would be to say: **If household does not engage in that particular activity, enter code for "Decision not made" and proceed to next activity.**		My actions in [DOMAIN] are partly because I will get in trouble with someone if I act differently. [READ OPTIONS] **CODE 1**	Regarding [DOMAIN] I do what I do so others don't think poorly of me. READ OPTIONS] **CODE 1**	Regarding [DOMAIN] I do what I do because I personally think it is the right thing to do. [READ OPTIONS] **CODE 1**
		B1	**B2**	**B3**
1	Agricultural production			
2	Getting inputs for agricultural production			
3	The types of crops to grow for agricultural production			
4	Taking crops to the market (or not)			
5	Livestock raising			
6	Nonfarm business activity			
7	Your own (singular) wage or salary employment			
8	Major household expenditures (such as a large appliance for the house like refrigerator)			
9	Minor household expenditures (such food for daily consumption or other household needs)			
10	What to do if you have a serious health problem			
11	How to protect yourself from violence			
12	Whether and how to express religious faith			
13	What kind of tasks you will do on a particular day			
14	Whether or not to use family planning to space or limit births			

CODE 1
1. Never true 2. Not very true 3. Somewhat true 4. Always true 98. Decision not made

MODULE 11: LEADERSHIP AND INFLUENCE IN COMMUNITY

Household ID……… Respondent ID……..

	Question	CODE 1
1	Do you feel comfortable speaking up in public to help decide on infrastructure (like small wells, roads, water supplies) to be built in your community?	
2	Do you feel comfortable speaking up in public to ensure proper payment of wages for public works or other similar programs?	

CODE 1		
1=No, not at all comfortable 2=Yes, but with a great deal of difficulty	3=Yes, but with a little difficulty 4=Yes, fairly comfortable	5=Yes, very comfortable

Time finished interview (24 HR) ……………………………………….

Thank you very much for your time and patience!