Poor people and poor fields?

Integrating legumes for smallholder soil fertility management in Chisepo, central Malawi

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Bernard Chizengo Gomezgani Kamanga

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Dedication:

To

My Dear Wife, Juliana Tayungwa NyaBanda Kamanga

My Two Boys
Gomezgani Junior Kamanga
Suzgo Blessings Kamanga

My Father, Brighton Suzgo Fataleza Kamanga
My Mother, Tafwanji Banda

My Father in-law, Late Henriko David Banda, and
My Mother in-law, Josephine Efrina Nkosi

“… whoever could make two ears of corn or two blades of grass to grow upon a spot of ground where only one grew before, would deserve better of mankind, and do more essential service to his country than the whole race of politicians put together….”

Jonathan Swift

Preface

This doctoral dissertation has been a journey of many steps, sometimes in rough terrain, sometimes with smooth horizons, but finally travelled through. During this journey, I interacted with countless friends who helped in one way or the other. It is impossible that I can mention all of them here, but many thanks to you all.

This study was one of the projects under the Participatory Approaches and Up-scaling (PAU) programme at Wageningen University coordinated by the Technology and Agrarian Development (TAD) Chairgroup. Financial support came from the Rockefeller Foundation (for my stay at Wageningen and field work), and the Australian Centre for International Agricultural Research (ACIAR) through the CIMMYT Risk Management Project (RMP) for much of my field data collection. I wish to express my heartfelt gratitude to all of them.

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Secondly, I express my thanks to Professor Paul Richards for his critical and thought-provoking comments. He instilled in me right from the beginning of the journey at Wageningen University the idea that to find solutions to social problems requires a social model of analysis. The technography courses and his explanations of the Durkheim and other theories - (Appadurai, “Disjuncture and difference..,” Mary Douglas, “How institutions think”…; Pawson and Tilley, “Realistic evaluation…”; and many more) were all just a beginning, but spiced up how I now think towards the situations I face. This has been critical in my life. My deepest appreciation to you Paul.

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Dr. Stephen Waddington has been exceptional in this work. It started when I was working under him in CIMMYT in the late 1990s up to 2005. Stephen was at that time the CIMMYT Regional Maize Agronomist for Southern Africa, based in Harare, Zimbabwe, where he was closely involved in much of the earlier work of this study. During those years, I remember how he used to hold my hand in the art of writing scientific articles, after field activities. In this thesis, he has helped me to shape a massive amount of material for journal accessibility and for the finalisation of the thesis. He has all along been my source of inspiration. Stephen, receive heartfelt thanks from me. *E. Khristu!*

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Dr. Larry Harrington, who was Director of the Natural Resources Group in CIMMYT in Mexico, helped me a lot in my career as an employee for CIMMYT. He authorised and secured my leave of absence from work for my studies at Wageningen University, and accepted, out of his kindness, to provide support to my family while I was away in the Netherlands. He was instrumental in the development of my proposal and contributed enormously in guiding my initial research activities. In addition, Drs. Pat Wall and the late Zondai Shamudzarira (both with CIMMYT), Anthony Whitbread and Michael Robertson (both of CSIRO, Australia), the late Webster Sakala and Todd Benson (Chitedze Research Station, Malawi), among others, are particularly thanked for different research roles they played in complementing my study.

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My sister Lugede Chiumya and colleagues at DanChurchAid Malawi in particular Lennart Skov Hansen, Katrine Lorentzen, Carl Gustav, Mercy Kambwiri, Agnes Banda, George Vilili, Innocencia Chirombo, Etness Kayoyo, Thandizo Kadzamira, Levie Chandiyang'ana, James Milanzi, Osman, Wilson and Della Chiwayu are appreciated for the support and enthusiasm. Lennart will remain my "role model" as far as DanChurchAid is concerned and should receive heartfelt thanks from me. Special and sincere appreciation to Ole Dahl Rasmussen from GFU for the support, inspirations and encouragement on my work as GFU officer and on the PhD. Particular reference is on micro-finance –village savings and loans, GFU work and your efficiency in management of issues. You are one in a million Ole.

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Abstract

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Soil infertility undermines the agriculture-based livelihoods in Malawi, where it is blamed for poor crop yields and the creation of cycles of poverty. Although technologies and management strategies have been developed to reverse the decline in soil fertility, they are under-used by smallholder farmers. This study was conducted to assess with farmers the performance of a range of maize-legume technologies and their benefits on soil fertility management in central Malawi. Farmer participatory experimentation was a focus of the study. The aim was to facilitate learning and the interpretation of experiences, improve the communication of information about the concepts and technologies to farmers, and provide insights for researchers.

Using a combination of survey and participatory methods, 136 smallholder farmers from Chisepo were grouped into four resource groups (RGs), comprising better-resourced (RG 1 with 6 farmers), medium resourced (RG 2, 14 farmers), less well-resourced (RG 3, 64 farmers) and least-resourced group (RG 4, 52 farmers). Analysing their livelihoods for their relation with soil fertility revealed that soil fertility management is a complex activity which is influenced by ownership of assets. Farmers from RG 1 and RG 2 owned more resources including cattle, had larger fields, hired-in labour for timely farm operations, earned more income and invested far more in soil fertility improvement. Farmers from RG 3 and 4 (who are the large majority) were resource constrained and did not invest adequately in improving soil fertility. They had large food deficits due to poor crop yields. *Ganyu* labour (casual work done for other farmers for food or cash) was their main strategy to reduce food deficits. Farmers from all the four RGs were interested in working with researchers to explore strategies to improve soil fertility. They tested various grain- and green manure-legumes, and mineral N and P fertiliser on maize and the legumes for effects on crop productivity and soil fertility. Associated production risk and interest in technology adoption were assessed.

On-farm evaluation was done on maize cv. MH18 in rotation with pigeonpea cv. ICP 9145 and intercropped with groundnut cv. CG 7, (Mz/Pp+Gn); intercropped with tephrosia (Mz+Tv); intercropped with pigeonpea (Mz+Pp) and in rotation with mucuna (Mz/Mp). These technologies were compared with sole crop maize without fertiliser (Mz-Ft) or with 35 kg N ha^{-1} (Mz+Ft) in experiments with 32 farmers from the four RGs over four years. Economic and risk assessments were made. Maize grain yields (accumulated over the four years) were greater for farmers from RG 1 and 2 than RG 3 and 4. Mz+Pp and Mz+Tv gave greater cumulative yields than Mz/Pp+Gn and Mz/Mp. The legumes improved maize grain yields by between 0.2 and 4 t ha^{-1} ($P < 0.001$) over Mz-Ft and additionally they gave legume grain to the household. Mz+Pp was less risky to all RGs, and applying 35 kg N ha^{-1} to the legumes resulted in Mz+Tv, Mz/Pp+Gn and Mz/Mp being least risky to RG 1, RG2 and RG 3. Farmers in RG 1 had the highest returns to labour (US$0.8 day^{-1} with Mz-Ft and US$1.1 day^{-1} with Mz+Pp) and these increased to 1.9 and 1.7 respectively with 35 kg N ha^{-1}. Mz+Pp intercrop gave consistent positive returns across the RGs and was the only technology to provide positive returns to labour in RG 4. Use of pigeonpea was overall the least risky option, and was especially suited to least-resourced farmers.

Application of phosphorus fertiliser (0, 20 kg P ha^{-1}) to legumes significantly ($P = 0.05$) increased grain and biomass yields for mucuna, groundnut, soyabean, Bambara groundnut and cowpea by 1.0, 0.8, 0.5, 1.0 and 0.3 t ha^{-1} compared with unfertilised plots. Cowpea and fertilised groundnut had larger yields in the home fields than middle fields, but other legumes performed better ($P = 0.05$) in the middle fields.

Maize responses to small amounts of fertiliser (0, 15, and 30 kg N ha^{-1} and 0, 20 kg P ha^{-1}) in two weeding regimes showed that weeding twice significantly ($P < 0.001$) raised maize yields by 0.4 t ha^{-1} over weeding once (0.9 t ha^{-1}). Stover yields (significant at $P < 0.001$) were 2.3 and 1.6 t ha^{-1} respectively. Mean grain N (kg ha^{-1}) was 17.1 and 9.8 for plots weeded twice and once respectively while that of stover were 10.1 and 5.6 kg N ha^{-1}. Applying N at 15 kg N ha^{-1} increased maize yields, but the 30 kg N ha^{-1} increased yield only on more clayish soils due to the effects of mid-season dry spells on sandy soils. Except for the physiological efficiency of N (PE_N), all agronomic indices of N-use showed significant differences due to weeding (agronomic efficiency of applied fertiliser N (AE_N) at $P < 0.001$, recovery efficiency of applied N (RE_N) and partial factor productivity for N (PFP_N) at $P < 0.01$. The average PE_N of 40.7 and PFP_N of 78.8 in plots weeded twice were within the common ranges of 40–60 kg grain kg^{-1} N and 40–80 kg grain kg^{-1} N applied respectively. AE_N and RE_N values of 38.7 and 0.9 respectively were above the common range of 10-30 kg grain kg^{-1} N applied and 0.3-0.5 or 0.5–0.8 kg N kg^{-1} applied. Mean indices from plots weeded just once were all within the ranges stated above but lower than indices from plots weeded twice; suggesting the unsustainability of the use of fertiliser without raising its efficiency through better management or combination with organic resources. Weeding twice gave higher returns to labour (US\$0.30 day^{-1}) than weeding once (US\$0.05 day^{-1}) and resulted in gross margins of US\$35.00 and US\$4.00 with labour taken into account respectively. Farmers need to ensure timely weeding to optimise efficiencies and returns from the fertiliser, especially in drier cropping seasons.

Using surveys, focus group discussions and the analytical hierarchy process (AHP), adoption of the ten legumes introduced to farmers in Chisepo was assessed among 136 farmers in 2004 and 84 farmers in 2007. Thirty-five percent of the farmers in 2004 and 22% in 2007 had adopted at least one of the legume technologies, with food grain legumes predominantly soyabean, groundnut, pigeonpea and to a lesser extent Bambara groundnut and cowpea being most adopted. Mucuna and tephrosia were adopted by few farmers while sunnhemp and grahamiana were not adopted at all. Farmers from RGs 1 and 2 adopted more of the legumes than those from RG 3 and 4. Lack of consistent markets, a lack of seed for planting, as well as land and labour shortages explained weak adoption.

Soil fertility management by smallholder farmers is influenced by ownership of assets and the majority poorer farmers fail to invest adequately in improving soil fertility. In the absence of such resources, grain legumes can play an important role as a source of both food and organic matter to improve soil fertility. The participatory methods used in the study helped farmers better understand some of the soil fertility concepts and options, including the legumes. However, much as farmers understand these concepts, they are constrained to use the technologies and concepts because of poverty and may not be possible to do so without external assistance. There is need to focus on how to assist farmers with practical knowledge to help them best combine organic and mineral fertiliser resources for improving soil fertility, and to develop and promote new dual-purpose legume options that feed humans and the soil.

Key words: *Adoption, analytical hierarchy process, crop yield, financial returns, food security, household assets, legume integration, livelihoods, NP fertiliser, nitrogen use efficiency, production risk, resource groups, smallholder, soil fertility, weeding.*

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Chapter 1

General introduction

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General introduction

1.1 The state of soil fertility in Malawi

Low agricultural productivity is one of the main reasons for widespread food insecurity problems in sub-Saharan Africa (SSA). Poor soil fertility is central to the issue of low agricultural productivity (Smaling *et al.*, 1997; Sanchez, 2002). Smallholder farmers are faced with complex interactions among social, bio-physical and economic factors that govern their soil fertility management (Zingore *et al.*, 2007a). In Malawi, the high human population density (currently 13.1 million people with an annual growth rate of 3% on about 4.001 million ha of arable land (NSO, 2008)) has created considerable pressure on land for agricultural production. Smallholder farmers have thus been forced to cultivate small fields and bring marginal land into use. Management of these fields has been characterised by continuous cultivation and little or no use of external inputs, leading to an imbalance between nutrient inputs and nutrient removals through harvesting, soil erosion and leaching (Zingore *et al.*, 2005). Drechsel *et al.*, (2001) reported that in SSA crop harvest (product and residues) plus erosion constitute about 70% of all N losses, nearly 90% of all K losses, and 100% of the P losses from soils. However, the depletion rates of specific nutrients depend on several factors including management, soil type and climate (Wopereis *et al.*, 2006; Tittonell *et al.*, 2007b; Zingore *et al.*, 2007b). Nitrogen (N) and phosphorus (P) have become the most limiting nutrients for crop productivity as a result of the factors above (Giller *et al.*, 1997; Sanchez, 2002).

Soil fertility decline and droughts are the main factors in trapping smallholder farmers into poverty. Eighty percent of the farmers in Malawi are subsistence farmers and have limited access to external resources for improving soil fertility. The odds with low soil fertility in smallholder agriculture have often been that more than 60% of smallholder farmers do not produce enough to meet their food self-sufficiency, and end up seeking *ganyu* for food. The time spent in *ganyu* in other farmers' crops mean a delay in their own farm operations such as planting, weeding and fertilising. Late planting and poor weeding lead to a poor harvest, and once again the farmers may find themselves without food before the next crop comes in (Kumwenda *et al.*, 1996).

Maize-based technologies to improve crop yields should therefore aim at breaking this cycle of low productivity through improving soil fertility among other factors. Mineral fertilisers play a major role in maintaining or increasing soil fertility, but farmers in smallholder agriculture use around 8 kg N ha^{-1} (AFS, 2006) which is below crop and soil maintenance requirements. In addition, smallholder farmers' management of fertiliser is characterised by late application, poor weeding and wrong methods which further reduce the fertiliser efficiency. Even when fertiliser is used, there are still low use efficiencies (kg grain kg^{-1} N applied) of around 14 kg grain kg^{-1} N (Chisinga, 2008). However, smallholder agriculture has the potential to raise the efficiencies with improved fertiliser application, improved timing and application methods to over 25 kg grain kg^{-1} N applied (Kumwenda *et al.*, 1996). Fertilisers alone may not be able to achieve this especially on severely depleted soils in smallholder agriculture, and thus a combination of both organic and inorganic inputs are needed. Several options that broadly put emphasis on a combined use of organic and inorganic inputs to improve soil fertility are potentially available (Kumwenda *et al.*, 1996, 1997b; Waddington *et al.*, 1998), and evidence is there that the most promising route to improving inorganic fertiliser efficiency is by adding small amounts of high-quality organic matter to tropical soils (Snapp, 1995) as they help to improve soil health. However, extremely very few farmers have access to adequate organic inputs to maintain soil organic matter (SOM). Malawi's low livestock densities (Benson *et al.*, 2002) limit the potential for significant fertility inputs from manure, and where available its use is constrained by shortage of labour. Availability of crop residues in smallholder agriculture offers an opportunity to improve soil fertility, but its management for soil fertility remains poor (ICRISAT/MAI, 2000). The other option available is to capitalise on the biological fixation capacity of legumes which can sustain tropical agriculture at moderate levels of output, often double those currently achieved (Giller *et al.*, 1994; Giller 2001) but use of legumes by farmers is low. It remains unclear why 'promising' or 'best fit' solutions have not been fully absorbed by farmers. Where lies the problem? It is important to closely look at the circumstances under which smallholder farmers operate and work with them in the process of technology development and evaluations and scale out those attractive and suitable to their livelihoods. This study was therefore designed to work with smallholder farmers in evaluating maize-based technologies for soil fertility improvement. It used an on-farm experimentation and evaluation of maize-legume and mineral fertiliser technologies for soil fertility management in central Malawi.

1.2 Potential of legumes in improving soil fertility and maize yields

Legume production in Malawi remains low (Phiri, 1999; Snapp *et al*., 2002), despite smallholder farmers diversifying into legumes (Mataya and Chulu, 1998). This has provided an opportunity for agricultural experts to closely examine and design with farmers better ways of integrating legumes for soil fertility improvements. Legumes are able to biologically fix atmospheric nitrogen into the soils. This trait is important for maintaining soil fertility through net N contributions (Giller and Wilson, 1991; Giller *et al*., 1994; Peoples *et al*., 1995) and hence offers a practical compliment to mineral fertilisers (Blackie and Jones, 1993; Giller and Cadisch, 1995). There is an increasing effort to enhance the soil biological processes that optimise nutrient cycling as well as minimise and efficiently utilise external inputs (Anderson and Ingram, 1993; Giller and Cadisch, 1995; Kumwenda *et al*., 1996). As components of integrated soil fertility management (ISFM), legume biomass improves soil quality which increases mineral fertiliser use efficiency and may reduce fertiliser N needs (Mwandemere, 1985). While legumes are a source of food, another direct contribution of legumes to soil fertility management is through selling of grain whose income can be used to buy mineral fertilisers for crop production or invest in other soil fertility management options such as transporting manure to the fields.

1.3 Rationale of the study

Minimal use of legumes for soil fertility improvement in smallholder agriculture remains an issue to be well understood in the technology development process. What is the problem? Many feel that the link between technology development and farmers has not been fully exploited or realised (Ashby 1990; Van Veldhuizen *et al*., 1997; Mnyulwa and Mugwagwa, 2005), others feel that the technologies being developed are good but other factors play a role (Ashby and Sperling, 1995; Roling and Wagemakers, 1998; Freeman *et al*., 2002), while others think that technologies do not offer useful products or effects (Gilbert, 2004; Snapp *et al*., 2002a) and still others think that it is the superior nature of scientific knowledge that makes farmers not to adopt the technologies (Kinderlerer and Adcook, 2005). These issues provide a platform for critical assessment of the entire technology development process in the smallholder agriculture context. The assessment should seek to know whether with ‘farmer participation’ there is i) better tailoring of the technologies to the farmers’ needs and ii) support to the farmers’ decision-making capacity on adoption of technologies. This needs to include gaining knowledge about what actually drives smallholder agriculture. The assessment should lead to minimising the challenges of developing strategies which can bring about a convergence between the short term food security and socio-economic interest and the long term societal interest in maintaining the environment for future generations (Norman, 1993). In the case of this thesis, focus was to seek an understanding of the influence poverty and poor fields have on soil fertility management. With widespread soil infertility, it focussed on working together with farmers to find attractive methods for building the N capital of the soils (Giller *et al*., 1997).

Since legumes are important in improving soil fertility in smallholder agriculture, increasing their productivity is a concern that requires further efforts to promote and support them. In addition to the concern of integration of legumes, use of fertiliser continues to give low use efficiencies of about 14 kg maize grain kg^{-1} fertiliser N (Chisinga, 2008; GoM, 2008). Given the current investment by the Government of Malawi in the fertiliser programmes (Dorward and Chirwa, 2011), low fertiliser use efficiency may threaten food security of the country and it needs more efforts for improvement. Finding better strategies of combining mineral fertiliser and organic sources of nutrients including legumes would improve soil fertility and lessen the problem of food insecurity. Given that maize remains the staple food crop for Malawians, a maize self-sufficiency policy is implemented in Malawi. The widespread low soil fertility and the unpredictable high prices of mineral fertiliser have remained major concerns to increasing maize production. However different strategies to improve soil fertility including maize-based technologies are in place (Kumwenda *et al.*,1996, Harrigan, 2008; Dening *et al.*, 2009), and the only problem is their low use by farmers. While the technology approach to improving maize productivity is taking place, the assumption in this thesis is that different technologies affect farmers differently depending on their resource endowment. The other assumption is that farmers are likely to adopt those technologies that perform well under their conditions when they are involved in the experimentation process. This study was developed to evaluate with farmers a range of mainly annual legumes for soil fertility in relation to resource endowment. In addition, the study focused on working with smallholder farmers to improve N and P fertiliser use efficiency in their fields.

1.4 Methodological approach

The study used both quantitative and qualitative methods of data collection to understand agro-ecological and socio-economic features of the smallholder agriculture in the area. Quantitative methods included surveys and measurements of field data such as yields of crops, labour used, soil parameters, rainfall, seed volumes and distribution channels, marketing, and other related data to assess resource endowment of farmers and establish input-output relationships. Qualitative methods collected information on socio-economic aspects of farmers' livelihoods, perceptions, explanations to actions and feedback. Qualitative research used open and semi open questions in surveys, focussed group discussions, interviews (narrative, semi-structured and key informants) and observations. The study used an experimentation approach with farmers where it focussed on maize-legume technologies and mineral fertiliser use in improving soil fertility and crop productivity. Farmer participation was an important feature in the experiment process.

1.5. Location of the study site in Malawi

The study was conducted in Chisepo in Dowa district, in central Malawi. Chisepo is in the mid-altitude zones (around 1100 m asl) of the Lilongwe-Kasungu Plains, 120 km northwest of Lilongwe city at a latitude of 13'32'' S and longitude of 33'31'' E. It is in Kasungu Agricultural Development Division (KADD) and Dowa West Rural Development Programme (RDP). Annual rainfall ranges from 400 – 1100 mm with annual mean temperature of 24 ^{0}C. The soils are generally described as sandy and ferralitic clay loams with a miombo woodland climax vegetation. Agriculture dominates the farmers' livelihood strategies in the area with maize as the dominant food crop and tobacco as a cash crop. Poor soil fertility and erratic rainfall are the major biophysical constraints to smallholder agricultural production in the area. The soils hardly produce adequate crops without soil fertility interventions. Maize yields range from as low as 0.1 t ha^{-1} to 2.5 t ha^{-1} and legume production is still infrequent and yields are low. Chisepo was originally matrilineal with inheritance rights reserved for the female child, but now patrilineal system is more common and practiced.

This study was part of the Risk Management Project implemented by CIMMYT in Malawi and Zimbabwe from 1998-2004. The project focussed on using an innovative new approach of featuring a combination of simulation modelling and farmer participatory research in solving problems of soil fertility, climatic variability and low and unstable agro-ecosystem productivity in drought-prone rain-fed areas of Southern Africa where maize systems are fundamental to food security.

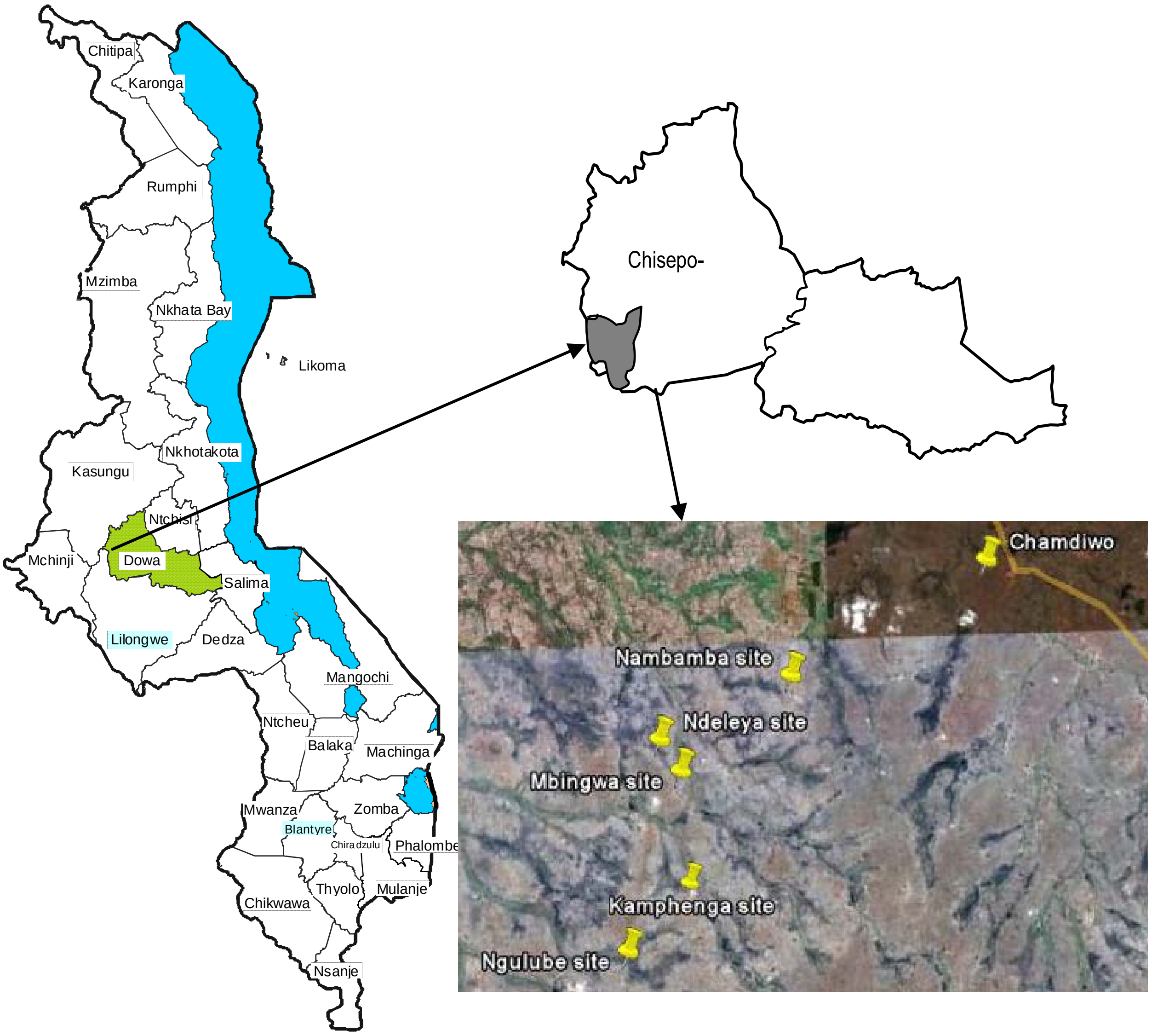

Fig. 1.1. Map of Malawi showing Dowa district, and Dowa district showing the study site- Chisepo. Plate 1. Chisepo showing the village sites for the experimentation with yellow pin marks.

1.6 Objectives of the study

The aims of the study are to analyse technology development from farmers' perspectives and identify factors that explain current farmers' management of soil fertility and technology adoption in the maize-based cropping systems of Chisepo in central Malawi. The study has five objectives to achieve:

1. Identify and analyse farmers' livelihood strategies, coping strategies and their implications for soil fertility management (Chapter 2).
2. Assess the risk and contributions of legume technologies to soil fertility improvements, maize yields and food security of farmers (Chapter 3)
3. Assess the effects of P fertiliser use with legumes and farmer perceptions of the practice to legume production (Chapter 4)
4. To increase farmers' knowledge about N and P fertiliser management with maize and assess their perceptions on food security (Chapter 5)
5. Assess the extent of integration of legume based technologies (adoption) into farmers cropping systems (Chapter 6)

1.7 The thesis structure

The thesis has seven chapters. It has begun with the general introduction in Chapter 1 which has additionally given a brief profile of the study site with map illustrations (Fig. 1.1). This has been followed by the theme or rationale and objectives of the study, and the methodology of the thesis. Chapters 2 to 6 present issues around soil fertility management by smallholder farmers and the technological evaluations that were conducted together with farmers in Chisepo, central Malawi. Chapter 2 provides more details on the context of the communities studied, with a specific focus on soil fertility management as shaped by divergent livelihood strategies and risks. Farmers were grouped into four types based on resource endowment, which I used in the thesis to understand how the soil fertility technologies affect each type of farmer. This was based on the assumption that farmers belonging to different resource categories in the typology are affected differently by various soil fertility improving technologies. Chapter 3 presents a comprehensive risk analysis of several legume-maize technologies used in a series of on farm 'mother-baby' experiments with farmers. The chapter showed yield results from the technologies which were used to explain the risks associated with the technologies to farmers in each resource category. In Chapter 4 an account of the legume response to fertiliser P is given. The chapter focused on improving legume production in smallholder agriculture. Chapter 5 describes the results of small amounts of fertiliser applied to maize and the effects of weed management by farmers, and discusses how the fertiliser can be efficiently used. Chapter 6 presents an assessment of the dynamics of the adoption of legume technologies by farmers in Chisepo. It has shown the actual adoption by the four types of farmers and tries to explain why these outcomes have happened. This chapter measured the social acceptance of the legumes through the extent of legume technology adoption by farmers. Chapter 7 provides a synthesis of the findings and the implications of the research for future rural development in Malawi. The thesis structure is presented in Fig. 1.2 below

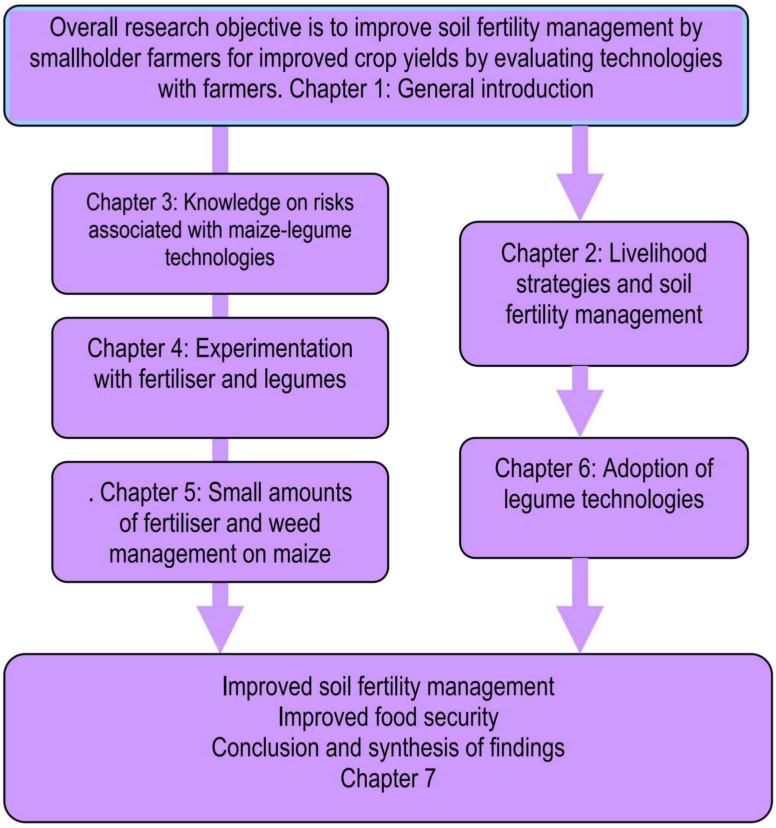

Figure 2.2. Structure of the thesis

Chapter 2

Soil fertility management by smallholder farmers in Malawi: can household livelihoods help to explain it?

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Chapter 2

Soil fertility management by smallholder farmers in Malawi: can household livelihoods help to explain it?

Abstract

Raising agricultural productivity in African smallholder agriculture systems requires understanding how a complex array of household and livelihood socioeconomic factors relate to soil fertility. This chapter examines the effects of asset holding on agricultural practices and farmers' soil fertility management in central Malawi using the household livelihood analysis, while arguing that uneven distribution of wealth results in differential social and soil fertility management outcomes. Using agricultural data from 136 households in Chisepo, four farmer groups were identified based on wealth levels: the better-resourced, medium-resourced, less well-resourced and least-resourced. Eighty-five percent of the farmers belonged to the less well- and least-resourced groups and these farmers were less educated than those in the other groups. Land ownership did not seem to be a main limiting factor for crop production, but capacity of farmers to replenish the lost soil fertility was. The average farm size of 1.4 ha was adequate for food security with necessary input resources. However, most fields had poor soil fertility and the least well-resourced farmers had the least fertile fields. Management of soil fertility was dictated by the assets held by the households, and better and sustainable soil fertility management skewed more towards the better-resourced (4%) and medium-resourced farmers (11%). The resources held by these farmers enabled them to access mineral fertilisers and use manure. The few resources controlled by the majority poorer farmers meant they could employ only small amounts of soil fertility inputs and management on their fields. Since the difference in productivity between the better-resourced and least-resourced farmers was largely a function of soil fertility inputs and management, soil fertility is the issue that needs attention through appropriate technology and support targeted to the resource-poor.

Key words: *Asset, diversification, income, livelihoods, poverty, production, resource group, soil fertility and yield.*

2.1 Introduction

Most of us like to know that our next meal will arrive. The better off we are, the smaller amount of our income we actually spend on food and greater the certainty of a decent meal in the near future; and food becomes relatively less important in our scale of priorities (Blackie, 2005). Smallholder farmers face a blanket of uncertainties about their next meal, especially during off harvest periods. Agriculture is their main endeavour, manipulating soils and plants in a complicated environment to sustain life and support their households (Ramisch, 2002). Non-farm activities are frequently another important source of food and livelihoods. In Malawi, the immediate priority of smallholder farmers is to grow enough food to meet their home consumption needs (Snapp *et al*., 2003; Blackie, 2005). Dominant cropping systems therefore remain those that have a large emphasis on production of maize, the staple food. Thus food security (and the potential prosperity) of most smallholder households in the country is critically dependent on the productivity and sustainability of maize-based cropping systems. Poor soil fertility and lack of inputs are considered major problems threatening the sustainability of food production in these systems (e.g. Kumwenda *et al*., 1996). As the depletion of the soils continues, subsistence farmers are finding that their options to deal with the crisis are severely limited (Uttaro, 2002).

Development of technology interventions to address soil fertility depletion has often not defined the target groups of farmers that are meant to use them (Snapp *et al*., 2003). The conventional wisdom of rural equality in Africa has been challenged vividly by the low farmer integration of numerous soil fertility interventions in the cropping systems, leading to emerging views that socio-economic differentiation among rural households plays a leading role in understanding soil fertility management (Giller *et al*., 2011). The lack of uptake of technologies by farmers therefore may require a socially differentiated view of rural livelihoods (DFID, 1999). Such analysis provides insights into the likely responses to the effect of policy and program interventions in the socially differentiated communities, and as a consequence, may lead to effective targeting of development interventions.

Simler (1994), Adams *et al*. (1997), and Barrett and Reardon (2000) have described the utility of a socially differentiated view of rural livelihoods in Africa. However, few of the many studies on soil fertility in Malawi have linked household differentiation to soil fertility management for sustainable agricultural production. Most have neglected the social context underlying the complexity of soil fertility management by farmers, whose understanding helps to identify promising strategies for farmers to integrate soil fertility improvements into their farms. Therefore, in this chapter I present the results of a survey that was conducted to assess household access to assets and diversity in livelihood strategies and how they influence soil fertility management in central Malawi. The study developed typologies of resource groups (described in this thesis) of rural households and used them to provide empirical evidence on diversity in livelihood strategies among farmers and links with investments in soil fertility management. It assesses the livelihood outcomes in terms of food security and sustainable agricultural production. It also attempts to explain factors that shape and identify who could be the clients for soil fertility improvement technologies proposed by researchers. Broadly, the study attempts to answer the questions “why do farmers manage soil fertility the way they do?” Does soil fertility vary among wealth classes? Is there a relationship between soil fertility decline and poverty?

2.2 Drawing on a livelihoods approach to explain soil fertility management

Soil fertility is usually seen as equivalent to the capacity of the soil to supply nutrients to the plant. The debate on soil fertility decline in Africa has focused on ‘soil nutrient mining’ with evidence that the nutrient capital is declining (Sanchez *et al*., 1997; Wopereis and Maatman, 2002). In its broadest sense soil fertility can be seen as a mixture of soil chemical, physical and biological factors that affect potential for crop production (Wopereis and Maatman, 2002; Misiko, 2007). In smallholder agriculture, the flow of wealth creation is inevitably from farming outwards, and primacy is given to options that can bring more income to farm households. I therefore assume that differences in soil fertility management result from failure by agriculture to support certain households’ needs which push them to increase participation in non-farm activities. I have used the livelihood approach, which is based on the assets of the households, and is fundamental to understand the options open to farmers, the options they use to survive and the outcomes they aspire to obtain within their vulnerability context.

Chambers and Conway (1992) defined a livelihood as comprising the capabilities, assets and activities required for a means of living. The concept of livelihoods revolves around the opportunity offered to an individual or household by their asset endowment and their chosen allocation of those assets across various activities to generate a stream of benefits (Barrett and Reardon, 2000). “A livelihood comprises the assets (natural, physical, human, financial and social capital), the activities and the outcomes from undertaking such activities that together determine the living gained by the individual or household” (DFID, 2001). The concept can best be understood by thinking of one's own family. Any family may have some years when illness, natural disaster or tragedy forces it to spend more than its income and also draw down on its assets, for example, selling off livestock or land (Frankenberger, 1992). A livelihood is sustainable when it can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, provide sustainable opportunities for the next generation, and contribute net benefits to other local and global livelihoods in the long and short term. The starting point of the livelihood framework is the capital assets owned, controlled, claimed, or by some other means accessed by the household. The framework seeks to bring together the critical factors that affect the vulnerability or strength of individual or family survival strategies. As articulated by Moser (1998) it seeks “to identify what the poor have rather than what they do not have”. In the context of soil fertility management, understanding livelihoods would help to understand the options open to farmers for improving soil fertility and also other constraints they face. It will also help to assess whether depletion and repletion of soil nutrients are dependent on poverty dynamics.

2.3 Research Approach

2.3.1 The study area

The study was carried out in Chisepo (13’32’’ S and 33’31’’ E), a farming community in Dowa district, located on the mid altitude plains (ca 1100 m asl) in the central region of Malawi. Chisepo is strategically placed in the ‘bread basket’ area of Malawi about 120 km northwest of Lilongwe, the nation’s capital. Chisepo receives a mean of 800 mm annual rainfall, falling from November to April. Soils are sandy ferralitic with pH of 4.9 to 6.0. They are low in organic matter and water holding capacity and are prone to leaching. The region has a history of large-scale tobacco production which offers paid employment. Additionally, smallholder tobacco production has allowed some farmers to become much wealthier. Most farmers in the area are considered to be poor or very poor, although within villages there are often significant differences among farmers. These differential levels of wealth are important in determining the vulnerability of the farm households and also enable farmers to undertake different practices that have implications for environmental quality, productive capacity and household livelihoods (Gray, 2005). The dominant rain-fed dryland cropping systems are based on maize. Some cultivate *dimba* fields for winter cropping. *Dimba* fields are wetlands or low-lying fields which have residual moisture to allow crop production in the dry season. The attainment of food security involves the deployment of family labour on food production over much of the year.

2.3.2 Data collection and management

A list of all villages was obtained from the Agricultural Development office at Chisepo Extension Planning Area (EPA). A simple random sampling technique was used to choose 21 villages from the 47 villages in Chisepo. A list of households was obtained for the selected villages. Sample households were drawn using random sampling, giving a total of 136 farm households in Chisepo. A household survey questionnaire was developed and pre-tested in a village outside the study area. The survey was conducted in 2004 and followed by several farmer group discussions, wealth ranking, farmer interviews and participant observation in 2006 and 2007. The wealth ranking exercise built on one done in the area in 1998 (Kamanga, 2002a). The survey questionnaire included variables on household demography, resource endowments, economic activities, income, and grain yields. Data were cross-tabulated using the Statistical Package for Social Scientists (SPSS) version 11.1

2.3.3 Development of household typologies

In rural areas of Malawi, all households are dependent on agriculture and what distinguishes between them is their asset base or wealth. Within the framework of livelihood studies, there is growing interest in social heterogeneity and the identification of people at risk. The vulnerable population is identified by gender, age, ethnicity, household size, wealth and education. Wealth is subjectively defined as one farmer will explain it differently from another. Wealth influences opportunities for adoption of agricultural technologies (Gilbert and Smale, 1993; Jeffries *et al*., 2000). In smallholder agriculture, variations in wealth affect accessibility to inputs and the ability to adopt proposed technologies. It is important to understand those variations that affect soil-fertility-management behaviour by farmers.

Wealth ranking (Adams *et al*., 1997; Jeffries *et al*., 2000) was used to characterise farm households and develop resource groups in relation to the level of indigence (poverty) in Chisepo. Wealth of a household is at the heart of rural socio-economic differentiation. Wealth ranking is an important Rapid Rural Appraisal (RRA) tool used to assess practical needs, opinions, attitudes and behaviour of development clients in the complex context of the peoples' personal organisational and social realities (Adams *et al*., 1997). By using locally defined criteria for wealth, it helps to understand the concepts of wealth, ownership or user rights of productive assets, stratification at the community level and the economic and well-being profile of a community. In wealth ranking, knowledgeable community members use a set of pre-established criteria where relative socioeconomic status in the context of the criteria set are observed (Chambers, 1994) to provide rough approximates of socio-economic status of households in the villages. Despite its limitations (which include its inability to show the dynamics of poverty and the distribution of well-being within the households), it is probably the most widely employed method and has increasingly been an accepted means of categorising community members involved in applied research projects and development programmes (Chambers, 1994). Levy (2003) has used this approach to understand project targeting among the rural poor in Malawi. Bond *et al*., (2007) used a similar methodology to identify socioeconomic categories while tracking livelihoods in Malawi and India. Belsky (1984) cited in Emtage (2004) used wealth ranking to establish three classes of farmers based on rice self-sufficiency in the Philippines. Key questions in wealth ranking analysis ask about local perceptions of wealth, well-being and inequality, local terms for poverty and well-being and how diverse or narrow they are; socio-economic groupings in the community and who belongs in which group, what one group has and others not; how households are currently distributed between the different categories, and what distinguishes community members that make decisions.

This study used the key informant method where key informants or local analysts with extensive knowledge of the villages were identified and separately interviewed for their own ideas of wealth, and what makes one person better off than the other. Information from key informants was used to develop wealth criteria which included the level of resource endowment by a household, the level of education, number of months that a household has maize from its own harvest, housing quality, access to inputs and influence in the society. In focus groups, community members then discussed and elaborated four local terminologies describing wealth classes, giving the distinctive characteristics of each category. In this thesis the classes are described as resource groups (RG). *Anamadyabwino* are the better-resourced households (RG 1), *olemerako* are the medium-resourced (RG 2), *osauka* the less well-resourced households (RG 3) and *osauka kwambiri* are the least-resourced households (RG 4). The key informants were then given the sampled households and they each separately subjected the household names to the criteria and their judgement to establish its RG category. They later compared their classifications and after agreement the results were further subjected to focus group discussions with all participants for consensus. During the discussions in focus groups, the classifications were related to additional types of data such as level of remittances. Table 2.1 presents the summarised characteristics and the farmer groups (RGs) as defined by the communities. Results were organised according to the five types of capital (human, physical, natural, social and financial) frequently identified in a livelihoods analysis (e.g. DFID, 2001).

2.4 Results

Results of wealth ranking (Table 2.1 and 2.2) indicated that out of 136 households sampled from Chisepo, only 15% were in the medium (10%) and better-resourced (5%) groups while the majority (85%) were in the poorer less well-resourced (47%) and least-resourced (38%) groups. The classification was largely based on ownership of assets but also included level of education and knowledge, level of use of production inputs and their associated outcomes. Inherent in most of the classifications are common socioeconomic variables such as age, gender, education, wealth, access to inputs and level of general knowledge (Table 2.2).

Table 2.1. Wealth parameters and characteristics of four farmer groups as identified by local communities during 1998 and 2004 in Chisepo, Malawi

Resource Groups (RG)	Indicators or Attributes
Better-resource endowment (*n* = 6)	• Have iron sheet roofed houses, many household assets, some luxuries, e.g. car • Own large fields (>5 ha), grow more tobacco for commercial purposes • Buy and use more fertilisers, hire in *ganyu* (labour), have servants • Food secure (bumper yield every year); any shortage is mild and is temporary • Earn more than MK100, 000 per year • Own more livestock e.g. cattle, goats, pigs and oxen for oxcarts • Own a forest with mixed planted and natural trees • Have good toilets with good sanitation measures
Medium-resource endowment (*n* = 14)	• Have brick house, grass thatched or iron roofed, household assets (for all necessities) • Own large fields of approximately 5 ha, grow tobacco for income • Use fertiliser on valuable crops such as tobacco and maize, hire in labour • Food secure; may experience periodic or seasonal food insecurity • Earn a little more money, approximately MK40, 000 per year • Own livestock e.g. cattle, goat and chicken • Own some forest • Have good sanitation facilities
Less well-resource endowment (*n* = 64)	• Have grass thatched houses, few necessities • Little land (<3 ha) and grow mostly food crops such as maize, sell off labour • Occasionally uses fertiliser (about 10 kg N/ha) • Limited food (lasts up to August), involved in work for food programmes • Earn little money, approximately MK7, 000 per year • May rear goats, normally have chickens • Have poor sanitary facilities • They grow less tobacco with minimal use of fertiliser and it is sold locally
Least- resource endowment (*n* = 52)	• Have thatched houses, no household necessities • Illiteracy very high • Have <2 ha land, sometimes grow some tobacco without fertiliser • Generally use no fertiliser, if do comes from hand-outs and in small quantities • Chronic food insecure, survive on kinship and *ganyu* • Earn least amounts of money from different livelihoods; about MK1,000 per year • No livestock; if do it is a chicken or a goat given by others or through *ganyu* • No sanitation facilities

Table 2.2. Mean household assets by farmer resource groups in Chisepo, Malawi in 2004

Variable	Resource Groups (farmer $n = 136$)				
	RG 1	RG 2	RG 3	RG 4	Average
Number of farmers					
Participatory wealth ranking	5	15	63	53	
Consensus	6	14	64	52	
Human Capital					
Household size	5 (3.4)	5.1(2.3)	4.8(2.1)	5.6(2.2)	5.1 (2.2)ns
Age of head (years)	41.5 (14.6)	32.7(10.7)	45.1(11.9)	48 (14)	40.8(14.2)***
Education level [a]	3.3 (0.8)	2(0.5)	1.7(0.5)	1.0(0.5)	1.8(0.6)***
Gender (1 = male)	1.0 (0.5)	1.1(0.3)	1.1(0.6)	1.2(0.4)	1.1(0.3)ns
Physical Capital					
Livestock: cattle	3.1(1.1)	1.3(2.1)	0.1(0.3)	0.0(0.0)	0.2(0.3)***
goat	3.8(2.8)	2.3(2.7)	1.2(2.7)	1.2(2.3)	1.4(2.6)ns
Farm equipment	7.5 (4.7)	3.5 (1.5)	3.4 (2.2)	3.3 (2.1)	4.4(2.2)**
Natural capital					
Farm size (ha)[1]	9.1(6.5)	6.9 (4.9)	3.5 (3.6)	1.4(2.1)	3.2(2.4)**
Per capita land	1.8	1.4	0.7	0.3	0.9**
Labour count	2.5 (0.8)	3.1(1.6)	3.1(1.5)	3.6(2.0)	3.2(1.6)*
Land: labour ratio	3.6	2.2	1.1	0.4	1.4
Social capital					
Group membership [b]	1.5(0.5)	1.5(0.5)	1.6(0.5)	1.5(0.5)	1.6(0.5)ns
Financial capital					
Access to credit [c]	2.0(0.8)	1.7(0.5)	1.9(0.3)	1.9(0.3)	1.9(0.2)ns
Hired labour [d]	3.8(0.6)	3.5(0.6)	1.9(0.8)	1.2(0.4)	3.3(0.9)***

* ** *** means variable significant at 10%, 5% and 1% respectively. ns means not significant

a: education levels 1 = none, 2 = primary, 3 = secondary, 4 = tertiary; b: membership 1 = No; c: access to credit 1 = No; d: hire labour 4 = always, 3 = likely, 2 = sometimes, 1 = not at all. [1] considered home and middle fields only.

Values in brackets are Standard deviations

Source: Household Survey, 2004.

2.4.1 Household assets in Chisepo

Access to assets is linked to timing of farm operations, ease of performance and level of education and knowledge. It is associated with the level of input used, types of crops grown and the influence one has in the society. There were major differences in asset ownership among the groups and these are described below.

Human capital

Human capital is described here by household size, age of the household head, education level and gender variables (Bates, 1990; Clay *et al.*,1998; Nguthi, 2007). Age of the household and education of the household head showed significant differences ($P < 0.001$) among resource groups while no significant differences were observed in household size and gender (Table 2.2). Age is linked to ownership of assets, increased knowledge and experience. Older farmers were considered more experienced and knowledgeable. Table 2.3 shows the frequencies of the variables of human capital. A majority of household heads were within the economically productive age range (20 – 64 years) of the country, indicating that most of the households were economically valuable. As elsewhere, Malawi's social welfare is determined by the performance of the economic age group in agricultural production (Sahn *et al.*, 1990). Households from RG 1 tended to be better educated than the other groups. Many people attended school at least to primary level meaning they were able to read and write. Education of a household increases security of access to land by both men and women. Educated farmers are often rational in decision making and often belong to wealthier groups. Education and knowledge determine the timeliness of farm operations as well as synchronisation of major practices such as fertiliser application and weeding to crop growth stages. The majority of the households had a male head of household with only 14% female-headed households. In Malawi a household consists predominantly of a husband with his wife (wives) and their children but with strong links to an extended family. Household sizes ranged from 1-11 people with an average of 5.2, which indicates the average labour supply potential by the households. Most household heads were married. Polygamy was reported in 6.6% of the households, with other household heads being widows or divorced.

Table 2.3. Frequency distribution for the human capital variables by resource groups in Chisepo in 2004

Variable	Chisepo (*n* = 136)				
	RG 1	RG 2	RG 3	RG 4	% distribution
Number of farmers	6	14	64	52	
Household size					
Range	2 – 11	2 - 9	2 – 11	1 – 11	
1- 2	2	1	10	3	12
2-5	1	7	30	26	48
>5	3	6	24	23	40
Age of head (yrs)					
Range	23 – 60	21 – 60	18 - 75	22 –85	
<15	0	0	0	0	0
16 - 50	4	13	55	31	76
51 - 60	2	1	7	11	15
>60	0	0	2	10	9
Gender of head					
Male	6	13	58	40	86
Female	0	1	6	12	14
Education level					
None	1	2	8	25	26
Primary	2	11	48	27	65
Secondary	3	1	8	0	9
Tertiary	0	0	0	0	0
Marital Status					
Single	0	1	1	1	2
Married	6	11	53	35	77
Polygamy	0	2	3	4	7
Divorced	0	0	1	4	4
Widow	0	0	5	5	7
Widower	0	0	0	3	2
Separated	0	0	1	0	1

Source: Household Survey, 2004. Numbers in bold are % of total rate of participation

Physical capital

Significant differences (at $P < 0.001$) were observed in the number of cattle among households, but there were no differences in the number of goats and pieces of farmer equipment. Table 2.2 shows that livestock and equipment ownership were highest in RG 1 households and it decreased progressively to RG 4 households. Cattle ownership[1] ranged from nil in RG 4 to 3.1 cattle in RG 1 households, with intermediate numbers in RG 2 and RG 3. Goats were common with farmers in all resource groups, with RG 1 having 2.6 more goats than

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[1] For comparison of cattle herds with different composition, different weights were used to construct oxen equivalent value based on the prevailing monetary value of animals in Malawi in 2004. The weights were 1 for a trained ox, 0.74 for a cow, 0.52 for a heifer, 0.57 for a young ox, 0.24 for a calf.

RG 4. Pigs are a good source of manure for those that own them. One farmer in RG 4 reported owning one pig which was with a relative elsewhere. Cattle ownership is an indicator of manure availability and use. Access to oxen indicates timely farm operations such as transportation of farm produce to home and manure to fields. Livestock is also important for averting risks.

Table 2.4. Frequency distribution for the physical capital variables across resource groups in Chisepo in 2004 (All variables expressed in number of households, except % distribution)

Variable	Resource Groups (*n* = 136)				
	RG 1	RG 2	RG 3	RG 4	% distribution
Number of farmers	6	14	64	52	
Livestock					
Cattle	5	3	1	0	6
Oxen	2	3	0	0	4
Goat	6	8	20	19	39
Sheep	1	0	0	1	2
Pig	4	4	3	1	9
Chicken	6	12	45	34	71
Pigeon	2	0	4	0	4
Guinea fowl	2	2	2	0	4
Rabbit	1	1	1	1	3
Duck	0	1	5	0	4
Farm equipment					
Hoe	6	14	64	52	100
Plough	0	0	0	0	0
Ridger	0	0	0	0	0
Axe	6	10	47	37	74
Ox cart	4	2	0	0	4
Tobacco shed	6	12	49	4	52
Mud thatch house	0	2	63	52	86
Iron roofed house	6	7	1	0	10
Generated lights	1	0	0	0	1
Television	2	1	0	0	2
Radio	6	7	4	0	13
Vehicle	2	0	0	0	2

Numbers in bold are % of total rate of participation
Source: Household Survey, 2004

Farm equipment units reported in Table 2.4 showed a hand hoe and an axe to be the main implements owned by the households in rural Chisepo. Households from RG 1 had more equipment than the other groups. Farm equipment frequencies in Table 2.4 indicate that all households in Chisepo had a hoe and the majority had an axe. Apart from ox-carts, there was no other animal-drawn equipment such as a plough and a ridger despite a few farmers having oxen. Ownership of an ox-cart reflects availability of transport and opportunity for hiring this out to earn extra income. Availability of transport means timely delivery of inputs as well as ease of transporting manure to the fields where available. Most houses were made of mud and thatch; only 10.2% had permanent structures with brick walls and iron roofs. Less than one percent had access to solar electricity and few had televisions and radios. One household owned a pick-up truck. Tobacco sheds were another important structure, owned by 52.2% of households.

Natural capital

Natural capital was described through farm size, per capita land and land to labour ratio variables (Table 2.2). Land (farm size), per capita land and labour count showed significant differences ($P = 0.05$). Members of RG 1 had more land than other farmer groups. RG 1 had 7.7 ha more land than RG 4 whose members held an average 1.4 ha. RG 2 had double the amount of land compared with RG 3, while the difference between RG 1 and RG 2 was small (2.1 ha). Size of the land influences the choice and spatial arrangements of the crops in the fields. Land-to-labour ratio, measured as a ratio of the land area cropped to the number of family members engaged in farming on full-time basis, is used to indicate the household labour supply potential. It was higher in RG 1 and lower in RG 4 indicating that there was insufficient family labour to work all the land owned by the better-resourced groups while labour availability was more in the poor-resourced households. This is why hired labour is sought by farmers from RG 1 and 2 who also have the resources to do so. It should be noted that agriculture is a pursuit involving all members of the family where everyone turns out to labour in the fields. It is common to see men, women and children all hard at work in the rainy season. Table 2.5 shows the frequencies of the natural capital variables. The majority of the farmers belonged to the category that had 1-5 ha of land and only 14% had more than 5 ha. The dominant form of land acquisition was through inheritance and few households had borrowed or purchased land. Land is passed through the daughter or son, accessed upon marriage and used jointly with the spouse. Distribution of land types indicates that large amounts of fields close to home were owned by wealthier households. RG 1 owned more land near home clusters and in the middle fields than other groups. The distances also vary from home fields to remote fields (Plate 2.1; Table 2.7). Distance to the fields determines allocation of resources, including manure and type of crops. It also affects timeliness of conducting farm operations. Although RG 3 and RG 4 farmers had all field types, their fields were smaller than the fields from RG 1 and 2. The distance to the *dimba* field depended on the position to the wetland or *dambo*. In some cases it was close and in others it was more than 2 km.

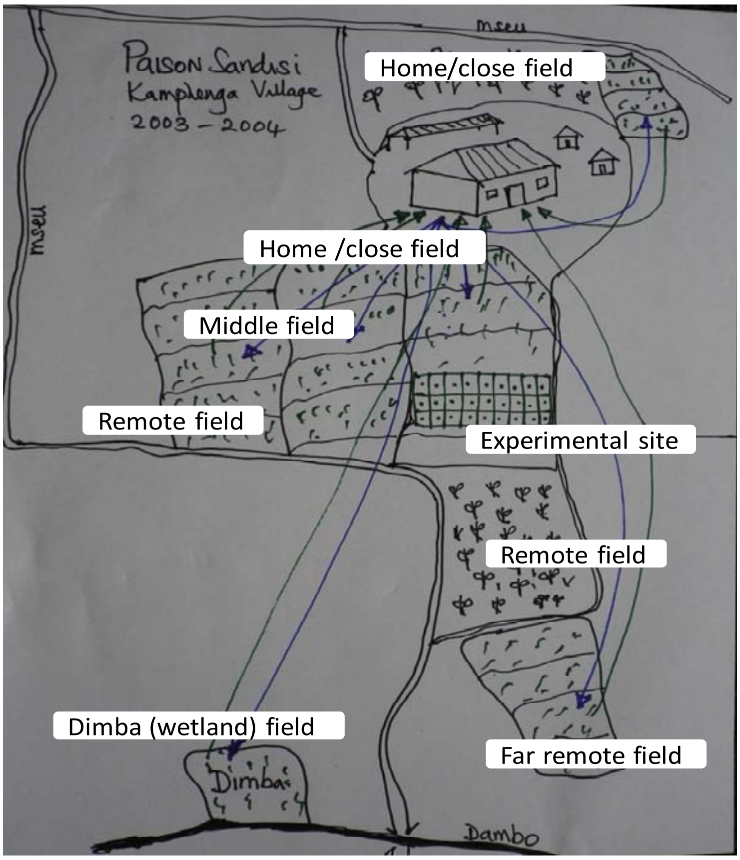

Plate 2.1. Farmer resource allocation map showing location of field types in relation to the homestead

Table 2.5. Frequency distribution for the natural capital variables and individual field size (ha) across farmer defined resource groups in Chisepo in 2004

Variable	Chisepo (*n* = 136)				
	RG 1	RG 2	RG 3	RG 4	% distribution
Number of farmers	6	14	64	52	
Farm size (ha)					
<0.5	0	0	0	0	0
0.5 – 1	0	0	15	21	26
1- 5	1	5	44	31	60
>5	5	9	5	0	14
Land acquisition					
Family land	4	13	59	46	90
Borrowed	0	0	5	6	8
Purchased	2	0	0	0	1
Rented	0	1	0	0	1
Ind. field size (ha)					
Home field	3.9	2.4	1.1	0.4	2.0
Middle field	4.5	4.0	2.1	0.6	2.8
Far away field	0.5	0.3	0.1	0.3	0.3
Dimba	0.2	0.2	0.2	0.1	0.2

*Farmers had more than one type of field. For this work each farmer was recorded once despite having mentioned other fields. Numbers in bold are % of total rate of participation

Source: Household Survey, 2004

The individual field sizes showed that the middle fields were larger than the home fields and the remote fields were smaller (see Table 2.7 for description of field types). Field sizes tended to decrease in the poorer farmer groups with RG 4 having an average field size of just 0.4 ha. The *dimba* fields are important for supplementing the harvests from upland fields. Winter cropping takes place in *dimba* fields and farmers in Chisepo use them for planting vegetables, maize and sometimes rice.

Social capital

In this study membership of rural organisations or institutions was taken to measure the social capital. The term institution refers to formal and informal organisations that interact with farmers and in various ways influence their livelihoods. It also encompasses their associated norms, rules, and values which define the roles of the members of the institutions and their responsibilities and relationships within the community. The importance of an institution is defined by its relationship with members of the community. Farmers identified eight main types of organisations in which household heads participated (Table 2.6). Social capital, as indicated in Table 2.2, was defined partly by this membership and participation in various community institutions.

Table 2.6. Social capital as measured by farmer participation in community organisations in Chisepo in 2004 (Multiple answers were allowed)

Institutions	Responses (*n* = 136)
Kinsmen/neighbourhood	100
Religious/church group	78
Marriage counsellors	57
Farmer group	44
Community development committee	28
Community HIV/Aids committee	25
Local business group	7
Orphan group	1

Source: *Focus Group Discussions* 2004, 2006

Kinsmen/neighbourhood network was ranked number one in importance in day-to-day life of individuals. Kinsmen groups are sources of family security to farmers in matters concerning an individual's livelihood. In crisis situations such as famine, illness, or death, they help each other with food, farm inputs, care, and comfort. Matters of community welfare such as security, funerals, illnesses and caring for the elderly were reported to be the responsibilities of kinsmen or neighbourhood networks. These groups are helpful, understanding, and dependable. Farmers mentioned that there is great interdependence among the households through kinsmen and neighbourhood relationships. For example, those that have enough food, seed or other resources share with those that don't have, mainly through *ganyu* or gifts such as of seed. Poor-resourced households depend more on better-resourced households for immediate food and cash needs and *vice versa* for labour. However, socially related activities such as digging graveyards were reported to be done by people from poor-resourced groups. The second ranked institution was the religious group which undertake counselling and promote peace among farmers. Religious bodies have also provided services such as hospitals, relief and agricultural projects, schools and water sanitation. It was reported that frequently the services provided by religious bodies had more female participation than by male household heads, especially in services such as nutrition and food security projects.

Farmer groups were ranked third, although participation varied among the resource groups. Farmer groups were formed around commodity crops or livestock, for example tobacco and small ruminants, or around loan facilities. Farmers indicated that their organisation into groups gives them more chance to access finance loans. Malawi Rural Development Fund (Mardef) is one of the most important finance institutions that provide credit to farmers through clubs. Mardef loans enable farmers to start small businesses or invest in agriculture, and farmers considered this as economic empowerment to them. Through such groups, farmers sometimes accessed loans for farm inputs. Discussions revealed that men from medium- and better-resourced groups participated more in activities that related to financial loans than did the other groups. Female headed households participated more in activities covering food processing for nutrition. The fourth ranking institution was the community development committee. These committees are concerned with the general status of development of the village such as the construction and maintenance of roads, bridges, schools and other community infrastructure.

Community AIDS committee was the fifth ranking organisation. It looks into the welfare of people living with AIDS and households that had been severely affected by the pandemic. HIV/AIDS has become a critical constraint to agricultural production in Chisepo as with many other rural communities in Malawi. The effects are felt through the loss of family members who worked in towns or elsewhere and sent remittances to rural areas, or through direct loss of labour in the villages. AIDS illnesses are prolonged, and caring for the sick is costly to affected households.

Financial capital

Access to credit was not different among the households (Table 2.2). Access to credit is associated with the ability to purchase inputs, including hiring of labour when needed and choice of crops to be grown. It may link to intensification and diversification to high paying microenterprises. All households accessed credit but what differed were the amounts, types and sources of the credit. Better-resourced farmers obtained credit from established micro-finance institutions while poor-resourced farmers accessed small loans through rural farmer groups such as Mardef. In Mardef and similar financial institutions, collateral is guaranteed by the collective productivity of the group which may buffer the failure of some members to repay credit in farmers' clubs. Repayment is either through crops produced or cash. The better-resourced households tend to access larger loans and rarely look for credit from Mardef collective-credit programmes. Households from RG 1 significantly ($P < 0.001$) hired-in more labour than RG3 for farm operations and farmers in RG 4 group never hired labour.

2.4.2 Household livelihood activities

Households in Chisepo derived their livelihoods from several sources. In this study these sources were broadly grouped into those that are based in agriculture and various non-farm activities. Agriculture-based livelihoods included growing crops and keeping animals. Main crops were maize, tobacco and groundnut while the common livestock were goats and chicken. Cattle remained the property of a few better-resourced farmers. Non-farm activities ranged from selling labour to owning a pick-up truck for transporting goods and people to markets and to the main road.

Main crops grown by farmers

Farmers reported that maize remained the most important crop in their households because it was the main staple food crop and also provided cash income. Its availability is a measure of food security in the community. Maize was often grown in association with other crops such as common bean, soyabean, groundnut and pumpkins. Tobacco is the main cash crop, and it is the second most important crop in both the area planted and number of households that grew the crop. Farmers followed tobacco with maize in rotation to capitalise on the residual fertility in tobacco fields. Tobacco receives most fertiliser nutrients because of its economic importance. The other common crop found in Chisepo was groundnut; frequently planted in association with maize and common bean. Soyabean was another cash crop grown by some farmers after recent initiatives to promote it for market sale, local nutrition and the maintenance of soil fertility.

Participatory field classification and field soil properties

In the focus group discussions with farmers, four field types were identified based on distance from the homestead rather than on soil type (Table 2.7, Plate 2.2). Farmers felt distance was more important than type of soil (which often features in such classifications by farmers elsewhere) because distance influenced type of crop inputs, soil fertility inputs and management intensity (such as plant spatial arrangements, amount of manure used and weeding) while similar soils were found on most fields except the *dimba* fields. Farmers indicated that all fields with the distance of 0 – 50 m from the homestead were home fields (type 1), and fields within 50 m - 100 m were middle fields (type 2). Those beyond 100 m were remote or away fields (type 3). The fourth type was a *dimba* field which is located in the *dambo* (low-lying wetland) areas. The classification did not vary much among the farmers, although there was an additional field-type called 'rented' fields that was identified by some of the farmers. This was not included in the classification because rented fields could either be near homes, in middle or in remote areas.

Table 2.7. Field description by farmers in Chisepo, Malawi in 2004

Fields	Characteristics of fields and criteria for demarcations
Field type 1	*Home/close field:* Near homestead (within 50 m) high soil fertility, preferred for high value crops such as maize and tobacco and give high yields, receive a lot of attention. Fertility is high close to home and decreases as one moves away from home
Field type 2	*Middle field*: Outfield, within 50 m – 100 m away from homesteads, usually used for moderate value crops, has low soil fertility
Field type 3	*Remote or away field*: Any field beyond 100 m from homestead and are usually least fertile
Field type 4	*Dimba field*: Wet land for winter cropping, small in size, fertile and seasonally used

Source: Farmer Group Discussions, 2004

Soils had similar texture across the field types of particular areas in the soil catena. The majority of farm fields had sandy soils, with a small portion of sandy clay soils (e.g. Kamanga, 2002a). Soils were poor in nutrient content as shown in Table 2.8. Soil fertility decreased from home fields to remote fields in each farmer group and it also decreased from fields belonging to RG 1 to those in RG 4. The fields belonging to households in RG 1 were generally more fertile than fields from RG 4. The soil nutrient properties for home fields in RG 4 were similar to the soil nutrient properties measured for the remote fields held by farmers from RG 1. This is a worrisome picture since the many households represented in RG 4 rely principally on their home fields for their crop production with little or no external nutrient inputs. Middle fields are their second important field type. This suggests that for households in RG 4 to raise production and become food secure, they need to apply much larger amounts of manure or fertiliser on their home fields. However, it remains difficult for these farmers to access manure or fertiliser; they usually leave the fields without fertility inputs other than crop residues incorporated during re-ridging. The number of households with remote fields was small, reportedly due to population pressure and the scattering of villages.

Table 2.8. Soil properties by field type for the better-resourced and the poor-resourced households in Chisepo, Malawi

Resource groups and field type	Soil properties							
	% Sand	% Silt	% Clay	pH	% C	% N	% K	Available P (Bray) (ppm)
Resource Group 1 (*n* = 3)								
Home	53	23	23	6.1	1.6	0.14	0.9	9.9
Middle	63	23	13	5.3	1.3	0.11	0.7	4.7
Remote	77	10	13	5.5	0.9	0.08	0.5	3.2
Resource Group 2 (n = 6)								
Home	53	15	32	5.4	1.2	0.10	0.7	7.0
Middle	61	14	25	5.5	0.9	0.07	0.5	4.9
Remote	65	10	25	5.7	0.7	0.05	0.3	3.1
Resource Group 3 (n = 6)								
Home	50	10	34	5.6	1.1	0.08	0.8	7.7
Middle	56	12	38	5.5	0.7	0.05	0.5	3.0
Remote	63	13	25	5.3	0.6	0.04	0.2	2.4
Resource Group 4 (n = 6)								
Home	60	27	13	5.6	0.62	0.08	1.1	6.7
Middle	73	7	20	5.5	0.46	0.03	0.9	3.8
Remote	67	7	27	5.4	0.34	0.04	0.8	3.6

Source: Author from farmer resource allocation maps, 2002

Distribution of crop activities by field types

Figure 2.1 shows the distribution of crops across different land types held by farmers in Chisepo. Households from RG 1 allocated more land to tobacco, maize and groundnut across the field types, with almost equal shares in home and middle fields. The remote fields had only 0.5 ha of maize often growing crops like sweet potatoes, cassava and chickpea. Sometimes these minor crops were planted on other field types, but only main crops were reported. Farmers in RG 2 also used more land from home and middle fields for maize and tobacco while their remote field was planted to tobacco and groundnut. Those in RG 3 planted about the same amount of maize to home and middle fields, which also had tobacco but fewer groundnuts. Households in RG 4 grew a greater proportion of their crop area in the home field, with maize on 0.2 ha but only 0.1 ha of tobacco. Additional maize and tobacco were planted on the middle land. Some households in all four resource groups had *dimba* fields available for cropping rice, vegetables and sugar cane. Dimba gardens are pieces of land which due to proximity to some source of water (a stream or a spring), retain their moisture for all or most of the year. They are a very valuable asset as they allow households to grow vegetables out of season, which can either be consumed or sold. Even in households where husbands are present, women seem to retain firm control over the sale of *dimba* produce, and this seems to be directly connected to their labour contribution on these plots. Dimba gardens are 'women's' gardens, and the proceeds of sales of *dimba* produce usually accrue to them (Hirschmann and Vaughan, 1983). However, the status is now changing in the sense that *dimba* farming has now become a common practice with the introduction of the treadle pumps which have reduced the problem of watering using canes. The main crops such as vegetables and green maize have become market commodities in semi-urban areas and more men are securing their income from this field. They are also very important for the tobacco nurseries in Chisepo. *Dimba* fields are normally small in size because of the wetland scarcity in Chisepo.

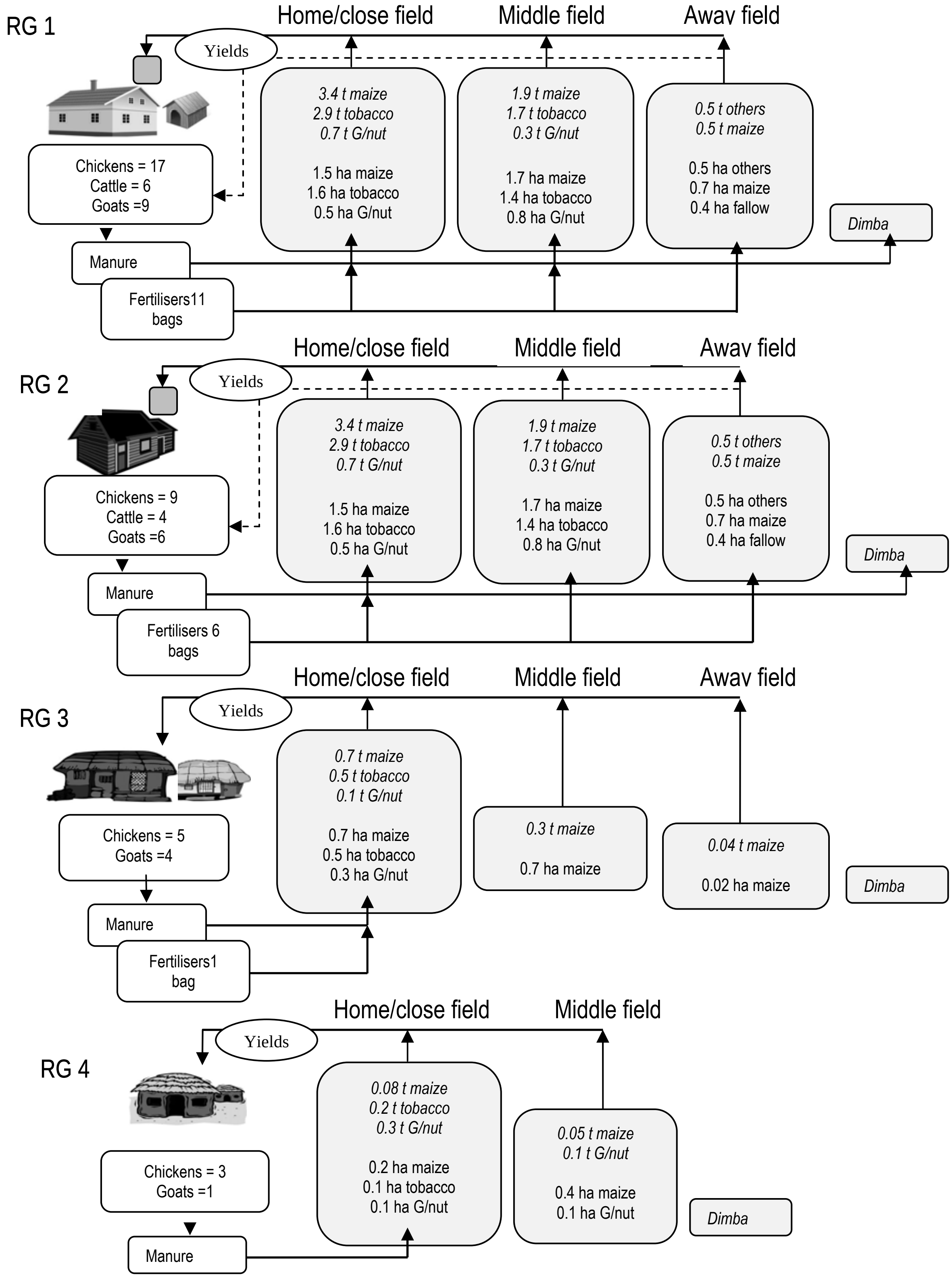

Fig. 2.1. Diagrammatic representation of fields and crops for four farmer resource groups in Chisepo, central Malawi ($n = 3$ in each resource group). Numbers in italics are crop yields. The dotted line is for crop residues fed to livestock. Source: Scheme adapted from Tittonell *et al*., (2005a) and Ncube, (2007). The houses shown are proxy indicators for comparison and not exactly as in field.

Use of manure by farmers

Manure application across the RGs is shown in Fig. 2.2b. Farmers applied more manure to home fields than to the other field types, consistent with findings by Zingore *et al*., (2007b) in north-central

Zimbabwe. RG 1 applied manure to home and middle fields while other RGs applied to the home field only. RG 1 applied a total of 5 t of manure; 3 t ha^{-1} to the home field and 1.5 t ha^{-1} to the middle field. RG 2 applied a total of 2.3 t ha^{-1} in the home field while RG 3 used 0.8 t ha^{-1} and RG 4 only 0.3 t ha^{-1}. Compared with the 13 - 25 t ha^{-1} manure recommendation in Malawi (see Kumwenda *et al*., 1996), the amounts applied by all households were small and likely of poor quality due to inadequate management of manure before application (Rufino *et al*., 2007). Depending on the volume of manure collected each year, application was done to different parts of the fields, sometimes sparingly. Poor management of manure and limited volumes applied mean that soil fertility may continue to decline resulting in decreasing agricultural productivity. Depending on the state of soil fertility depletion, small amounts of manure may not be effective. Kapkiyai *et al*., (1999) observed that even under relatively high manure application rates, significant positive change in soil fertility may not occur on such highly degraded soils. This could explain why farmers in RG 4 were unable to get good crop yields (see Fig. 2.2a) despite manure application to their home fields. Use of manure was also reported for *dimba* fields, but amounts applied to *dimba* fields were not recorded. RG 2 had allocated its manure only in the home fields while fertiliser was spread to all the fields. No manure was reported being used in the remote fields. For RG 3 and RG 4, the little manure they collected was all applied to their home fields. Farmers said that manure was primarily applied to tobacco fields and that maize crops benefit from that manure in the second season. Almost all the manure applied was reported to have come from livestock. However, with the scarcity of manure, many farmers had started to learn how to make compost from crop residues and other materials. Farmers that did not use manure cited lack of livestock as a main constraint, while lack of labour was mentioned to constrain compost making. Even the wealthier farmers indicated that low stocking rates for cattle was the main constraint in manure production since cattle gives more manure than other farm animals.

Use of mineral fertiliser by farmers

Mineral N fertiliser use (Fig. 2.2c) was variable among the farmers. The common nitrogen fertilisers used by farmers in Chisepo were calcium ammonium nitrate (CAN) (27% N) for tobacco or urea (46% N) for maize. Farmers in RG1 applied more nitrogen fertiliser than the other RGs in all fields. The average nitrogen application was 44 kg N ha^{-1} for a home field in RG 1 and but only about 10 kg N ha^{-1} in the same field in RG 3. Farmers in RG 4 applied no fertiliser at all. The fertiliser rates used decreased for middle and remote fields in all RGs. Middle fields in RG 1 received twice as much fertiliser as those in RG 2, with none applied in RG 3 and RG 4. Application of phosphorus was done by farmers in RG 1 and RG 2 (Fig.2.2d). RG 1 applied slightly more (11 kg P ha^{-1}) than RG 2 (9 kg P ha^{-1}) (Fig. 2.2d). Farmers in RG 3 and RG 4 did not apply phosphorus fertiliser. Home fields received more phosphorus fertiliser than middle fields, while away fields received none. Phosphorus was applied as a basal dressing to both maize and tobacco. Where manure was adequately applied, the rate of phosphorus on tobacco was reduced. Very few farmers applied basal fertiliser to maize across the RGs.

Few farmers from RG 1 and RG 2 applied combined basal and top dressing fertiliser to either maize or tobacco. Farmers also reported using some fertiliser for winter cropping in their *dimba* or wetland fields. Winter cropping as a risk averting strategy was increasing due to availability of treadle pumps. RG 1 and RG 2 farmers accessed treadle pumps through loans and were able to purchase some fertiliser for their winter cropping. Those that did not access fertiliser cited lack of cash to purchase the fertiliser as well as segregative distribution of targeted farm inputs which left them out.

Non-farm activities

Farmers reported engaging in numerous non-farm activities as well as farming (Table 2.9). Apart from agricultural based livelihoods, many households in RG 1 and RG 2 reported that they engaged in general businesses (e.g. selling second hand items). RG 3 and RG 4 reported that they engaged more in *ganyu* labour of different types (see the high percentages in Table 2.9).

Plate 2.2. Satellite map for Mbingwa village in Chisepo, Malawi showing intensity of cultivation. Maize crop residues very close to the home (left top end of homestead) and fewer residues as one goes away from the houses

Ganyu was reported the main strategy for many rural households suggesting that such households did not keep much of their family labour on their fields. Formal employment was another reported source of non-farm income. There were household heads who were employed but at the same time were farmers. In addition, there were many small local businesses reported by farmers. Examples included selling firewood and selling wild natural resources such as mushroom, fruits, edible ants, brooms and thatch grass. These are seasonal but contribute to the income of the households and are especially important for those in RG 3 and RG 4. Some farmers from RG 3 reported distilling local gin called *kachasu* which has become one of the main sources of income. The distillation is dependent on availability of maize and thus the business is also seasonal. Better-resourced households diversify to non-farm activities to smooth consumption and increase income while the poor-resourced engage in non-farm activities to access food and cash income in difficult times. Relatively high paying micro-enterprises for the better-resourced farmers included owning small grocery shops and involvement in trading in high value crops such as tobacco. One farmer with a pick-up truck provided transport to the people and their merchandise to the markets and to the main road, over 21 km away. Common low paying micro-enterprises included brewing of beer and the local gin, selling of vegetables and other commodities. In peak periods, *ganyu* formed the main non-farm source of income, and this was common for the poorer farmers. Asked why they were not involved in relatively high paying activities, they often cited lack of start-up capital.

Table 2.9. Frequency distribution (%) of households involved in non-farm activities in Chisepo (Multiple answers were allowed)

Activity	Chisepo (n = 136)			
	RG 1	RG 2	RG 3	RG 4
Ganyu	0	0	87.7	94.8
Trade business	4.2	1.5	0	0
Remittance	25.6	45.9	8.1	4.4
Petty trading	1.4	14.4	12.4	1.4
Firewood	0	0	2.1	4.9
Brick making	0	0	2.9	3.2
Rural crafts	0	0	5.1	13.2
Formal employment	10.2	4.4	6.6	2.9

Source: Household Survey, 2004

Migration

Remittance was dependent on whether the households had members in informal or formal employment, either locally or internationally. Prominent was temporary employment on tobacco estates within the region. A small proportion of households had at least one member working elsewhere within Malawi or a neighbouring country. For example, households that have relatives in South Africa received remittances in goods and cash. Farmers mentioned that in most cases remittances were fertiliser, seed or cash, especially when it came from within Malawi. Most of monetary income from remittances was used to purchase farm inputs, pay school fees and for other household needs.

2.4.3 Household livelihood outcomes

Crop yields and income

Figure 2.2a shows maize grain yields for the resource groups across different field types. Home fields performed better than the middle fields. On home fields, RG 1 obtained 2 t ha^{-1} more maize than RG 4 and 1.3 t ha^{-1} more than RG 3, but only 0.3 t higher than RG 2. In middle fields, RG 1 had 1 t ha^{-1} higher yield than RG 4 and 0.7 t ha^{-1} higher than RG 3. RGs 1, 2 and 3 grew maize in remote fields and obtained less than 1 t ha^{-1} grain each while RG 4 did not grow maize in remote fields. Better-resourced farmers attributed their higher yields to the use of fertiliser and manure, and to timely farm operations such as weeding and fertiliser application. All better-resourced farmers mentioned hiring-in labour during peak periods to assist with timely farm operations. The poorer farmers planted small areas and did not pay adequate attention to fertiliser, manure and weeding. However, poor farmers mentioned that even though they have inadequate inputs, they would not stop growing maize because doing so would not justify them when they request for assistance from relatives.

Table 2.10 shows income from selling crops. For RG 1 and RG 2, crop production provided a major share of their total income, followed by non-farm activities. Access to cash is associated with timely performance of farm operations and ability to purchase inputs and labour. Livestock did not contribute much to the total household income. RG 1 received more money from tobacco than from maize and other crops. RG 2 also obtained more income from crops, particularly tobacco that gave the households more income of MK87, 600. The income from RG 3 and RG 4 together was MK158, 200 less than income from RG 1 farmers alone and MK79, 300 less than RG 2 in tobacco income. RG 1 got almost twice the income than RG 4 from groundnut. Households in RG 3 and RG 4 reported selling more of the other crops.

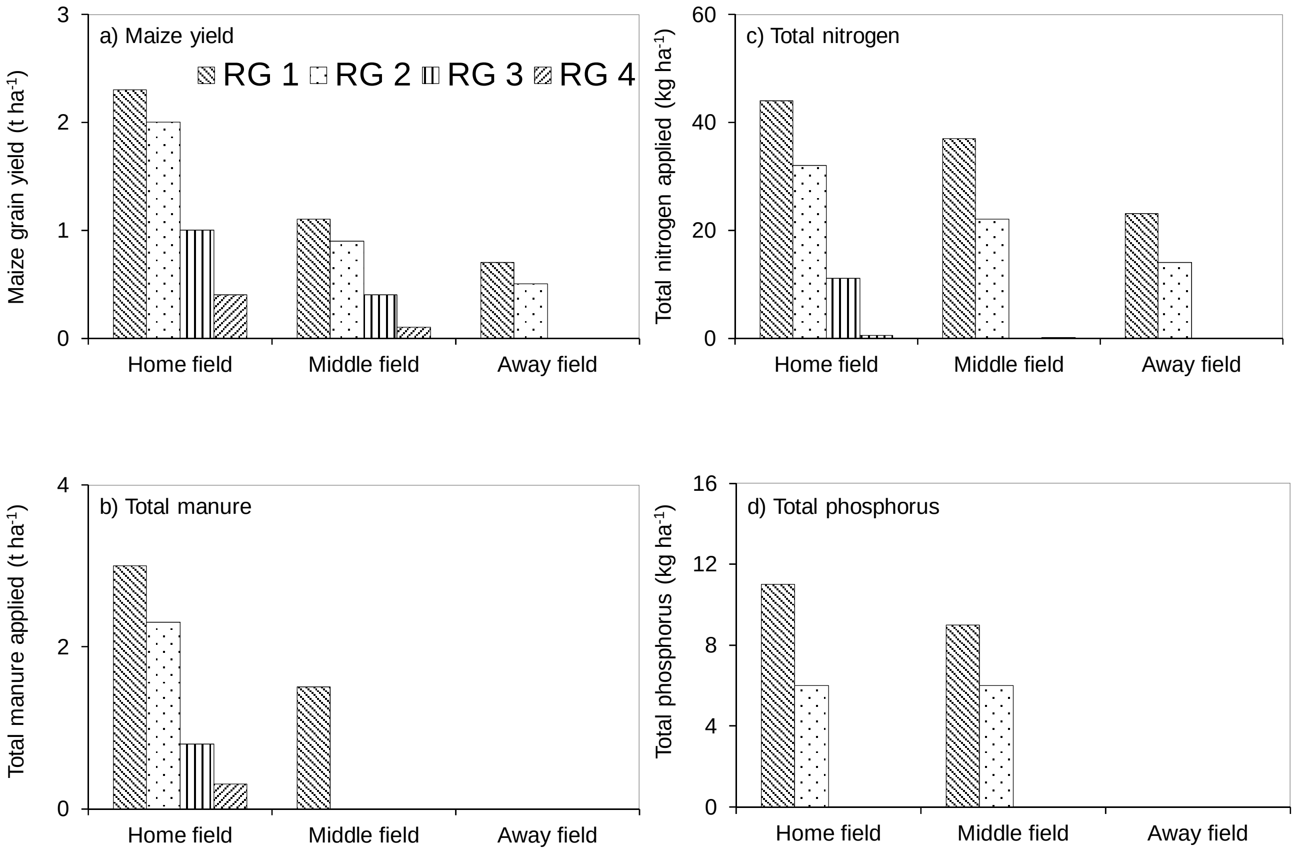

Fig. 2.2. Mean values for (a) maize grain yield (t ha^{-1}), (b) manure (t ha^{-1}), (c) nitrogen (kg ha^{-1}) and (d) phosphorus (kg ha^{-1}) by field type and farmer resource group in Chisepo, Malawi in 2004.

Income from livestock

Livestock is another important asset, providing food, manure and direct income (Table 2.10). Sources of income are from milk, hiring for transport or sale of manure. Most livestock-related income came from poultry with all resource groups, with RG 1 obtaining higher income than other groups. Income from cattle was recorded for RG 1 and RG 2 only. Poultry brought more income than cattle and goats in RG 1 and RG 2. Cattle and goats contributed even less to the total household income in RG 3 and RG 4 probably because of the limited numbers kept by the farmers and the tendency by farmers to “hold on” to assets for future security purposes. One farmer from RG 1 reared free range cross-bred chickens (black australopes) which provided him with an additional source of income as well as manure.

Income from non-farm activities

Non-farm income was a second major source of income to the farmers. RG1 and RG 2 had more income from non-farm sources than the other RGs. Farmers of RG 1 had MK117, 300 more income than RG 4, and MK67, 500 higher than households in RG 2. Non-wage employment was the main source of non-farm income for RG 1 and RG 2 while *ganyu* was the main source for RG 3 and RG 4 households. Remittances were another important source of income. In most cases this was in-kind in the form of fertiliser and seed. Self-employment brought to RG 1 households MK111, 900 more than total non-farm income for RG 4, and MK71, 400 more than for RG 3. There was a difference of about MK63, 000 between RG 1 and RG 2 from both total non-farm income and income from employment. Two farmers were retired, from primary teaching and extension. Farm income decreased from RG 1 (53% of total income) to RG 4 (20%) and at the same time non-farm income increased towards RG 4 (78%).

Table 2.10. Mean annual income (MK'000) from different livelihood strategies in Chisepo, Malawi in 2004

Variable	Chisepo (*n* = 136)				
	RG 1	RG 2	RG 3	RG 4	% total
Crops					
Maize	3.5 (8.1)	2.3 (0.6)	0.7 (2.0)	0.9 (3.2)	1.3
Tobacco	176.5 (81.4)	87.6 (75.4)	15.1 (9.7)	3.2 (1.3)	47.8
Groundnut	2.7 (2.8)	1.2 (2.2)	0.9 (2.0)	0.9 (1.5)	1.0
Soyabean	0.2 (0.6)	0.6 (0.4)	0.2 (0.4)	0.0	0.2
Bean	0.0	0.4 (0.1)	0.2 (01.0)	0.2 (0.5)	0.1
Other legumes	0.0	0.8 (0.6)	1.1 (1.4)	0.0	0.3
Other crops	0.0	0.4 (0.6)	2.1 (1.1)	0.4 (0.7)	0.5
Total income crops	182.9	93.3	20.3	5.6	51.2
Livestock					
Cattle	4.3(11)	1.5 (5.6)	0.0	0.0	1.0
Goat	4.3(8.8)	0.4 (1.6)	0.2 (0.7)	0.0	0.8
Poultry	13.4(10)	0.8 (1.7)	0.9 (2.7)	0.4 (1.2)	2.6
Others	1.6 (1.9)	0.5 (1.9)	0.4 (0.1)	0.2 (1.3)	0.4
Total income l/stock	23.6	3.2	1.5	0.6	4.8
Non-farm activities					
Ganyu	0.0	0.0	16.6 (3.8)	17.8 (1.8)	6.0
Self-employment	133.5 (26.5)	70.5 (21.8)	7.6 (2.7)	0.7 (1.2)	36
Remittance	3.0	0.8 (2.7)	1.9 (3.7)	0.3 (1.4)	1.0
Employment	0.0	0.1(2.4)	1.6 (2.2)	2.8 (1.6)	1.0
Total income non-farm	138.9	71.4	27.7	21.6	44
Per capita income	69.1	32.9	6.9	5.0	29.0
Proportion of income					
Total crop income	0.53	0.56	0.41	0.20	0.53
Total livestock income	0.07	0.02	0.03	0.02	0.05
Total non-farm income	0.40	0.42	0.56	0.78	0.42
Total h/hold income	345.4	167.9	49.5	27.8	100

Source: Household Survey 2004. Numbers in brackets are standard deviations (US$1 = MK108).

2.5 Discussion

The results show that farmers operate consistently and rationally as influenced by the level of capital or asset ownership. There were major differences in level of resources between the resource groups and these differences are important for understanding farmers' soil fertility management. Ownership of assets had an influence on level of use of inputs on crops and their associated yields. For instance, older age of a household head reflects high experience and knowledge and coupled with relatively better education, farmers of this type are able to understand information and better-interpret some complex situations (World Bank, 2002). Timely farm operations such as weeding and fertiliser application, frequently observed for farmers in RG 1 and RG 2, could be explained by their understanding of the importance of timeliness and synchronisation of operations such as planting, fertiliser application and weeding to crop growth. Timing is a major constraint in uni-modal rainfall cropping systems and delay in the main operations and ignorance of correct scheduling of farm activities lead to decreased productivity (Epulani, 2003). Delays in farm operations were common with farmers from RG 3 and RG 4. However, farmers mentioned that the delays resulted from lack of adequate assets that could enable them to carry out farm operations on time. As with other farm operations, education helps to understand the importance of proper soil fertility management. Educated farmers may have the zeal to use different options to improve soil fertility. Generally, a lack of education has a negative impact on development since people who are illiterate take time to understand or adopt different initiatives. These results are consistent with the findings that differences among households in education, land, labour availability, and resource endowments gave rise to different practices for soil fertility management in sub-Saharan Africa (Orr and Jere, 1999 in Malawi; Ayayi *et al*.; 2006 in Zambia; Tittonell *et al*., 2007a in Kenya).

Access to land, which is another important asset affecting agricultural productivity, was skewed towards the better-resourced farmers. The larger fields available to farmers from RG 1 and RG 2 allowed them to grow more crops of their choice such as tobacco (Fig. 2.1). Farmers from RG 1 and RG 2 could grow larger areas of food crops than farmers from RG 3 and RG 4 (Fig. 2.1) and this probably increased labour needs for the better-resourced farmers. Unlike farmers from RG 3 and RG 4, better-resourced farmers were able to fallow some fields, which is one way of restoring soil fertility. More land under maize and tobacco likely resulted in increased fertiliser demand in these crops. The average farm size of 1.4 ha for RG 4 (Table 2.2) was more than the estimated 1.0 ha required to produce enough food for a household of five people in Malawi (World Bank, 1990). However, because land held by RG 3 and RG 4 farmers is of low fertility and received few soil fertility inputs such as manure and mineral fertiliser, it is increasingly difficult for them to raise crop productivity (Orr and Jere, 1999). In labour intensive hoe-based systems, soil fertility is the most important factor limiting production per unit land area because farmers can only effectively cultivate small areas of land – they cannot raise production by planting larger areas (even if they had them).

Access to livestock determined the level of manure use. Farmers in RG 1 and RG 2 who had some cattle, goats and pigs used manure to improve soil fertility. It was not surprising that farmers in RG 1 applied a total of 5 tonnes of manure (Fig 2.2) per year although this was far much below the recommended rate of 13 t ha^{-1} manure for Malawi (Kumwenda *et al*., 1996). Those households with oxen and ox-carts had an additional source of labour for transporting agricultural produce, including manure. Application of manure to home and mid fields by farmers from RG 1 was likely because of availability of ox-carts and capacity to hire them in. Hiring out the oxen to perform tasks for other farmers was an extra source of income. Unlike better-resourced farmers, poorer farmers from RG 3 and RG 4 had no cattle and fewer goats and chickens, and associated manure production was low. Chickens are normally in free range systems and the low stocking rates for other livestock such as goats resulted in low manure production and use by RG 3 and RG 4 farmers. In addition, farmers from RG 3 and RG 4 did not make compost to supplement manure from livestock. The general low use of manures and lack of access to mineral fertiliser by farmers in RG 3 and RG 4 implied few options for soil fertility improvement and cropping with little or no external amendments to improve yields.

The differences in access to income impacts on timeliness of farm operations, level of use of inputs and intensification (Orr and Mwale, 2001). Tobacco formed a large component of the large farm incomes for RG 1 and RG 2 and this alone is enough to explain differences in input purchases among the farmer resource groups. Tobacco is a labour and input intensive crop with high income, justifying the large amounts of inputs. Since tobacco was the main cash crop, almost all farmers who grew it applied manure to it. Maize follows tobacco to take advantage of the residual fertility to increase maize yield. It was observed that even farmers from RG 3 and RG 4 applied manure to tobacco to improve its yields, and this shows the importance the farmers attach to the crop. The diversification of farmers from RG 1 and RG 2 into relatively high-paying non-farm sources of income might have increased their capacity to access more fertiliser and hire-in labour during peak farming periods. This corroborates with Orr and Mwale (2001) who found that farmers who diversified into other relatively high paying micro-enterprises such as selling high value vegetable crops in the Shire Highlands in Southern Malawi purchased more fertiliser, hired in labour for the main agricultural season and were able to invest in other soil fertility replenishing practices. Unlike RG 3 and RG 4, non-farm income for RG 1 was reported to have come from relatively high-paying micro-enterprises such as grocery shops and provision of transport to the rural population. Thus the difference in proportion of non-farm and farm income among the groups seems to reflect the varying importance of the livelihood activities to the farmers. The better-resourced farmers value both farm and non-farm sources of income as indicated by their share of the total income, whereas farmers from RG 4 may attach more importance to non-farm source of income because their fields are so poor (Table 2.10).

Thus RG 1 and RG 2 were able to improve productivity of their fields as a result of higher income compared to farmers in RG 3 and RG 4. They invested in fertilisers, manure and hiring in labour which may result in timely and possible synchronisation of farm activities with crop growth. In contrast, farmers from RG 3 and RG 4 obtained such low income from on-farm production that they diversified into low paying non-farm micro-enterprises including beer brewing and *ganyu*. The proceedings from these enterprises were small for investment soil fertility improvement even where they acknowledged soil infertility. Thus, failure to replenish soil fertility is in this case determined by the differential access to opportunities to do so which in turn is determined by the economic status of a household (Barrett *et al*., 2006). These opportunities are often scarce (Thangata *et al*., 2007) and where available, they are not even adequate to meet immediate needs such as food (Whiteside, 2000), and that may compromise investment in soil fertility which is often not an immediate need to poor farmers (Orr and Jere, 1999).

The varying input uses by farmers result in varying crop yields. With resources, farmers from RG 1 and 2 obtained the largest yields of maize and tobacco. On the contrary, farmers from RG 3 and RG 4 obtained lowest yields of maize and tobacco. Given their small average farm sizes, these farms are routinely in food deficit. For instance RG 4 would require 1,400 kg maize to be food self-sufficient against own production of only 500 kg of maize (Fig. 2.2). The deficit of 900 kg maize has to be met from other sources and this is a big challenge. As described earlier, one common option is to sell their labour to better-resourced farmers in exchange for food. At the same time the majority (85%) of the farmers sampled in Chisepo came from RG 3 and RG 4 and this shows that most farmers will likely remain in a maize-focused poverty trap as has been described recently for many areas of Malawi (Dorward and Chirwa, 2011).

What then could be done to best help RG 3 and 4 farmers produce more maize food from their little land? Almost three quarters of the maize produced by RG 3 and RG 4 came from home fields and the mid field contributed less, showing the importance of home fields to the poor. Any effort to raise agricultural productivity for farmers in RG 3 and RG 4 should therefore target raising productivity of the home fields first. Some of the available options are integration of legumes, production of manure and compost from locally available resources including crop residues and increasing knowledge and efficiency in fertiliser use especially in line with the huge recent government investments in fertiliser (Cronwell and Kyegombe, 2005; Harrigan, 2008). Many legumes are especially attractive in increasing soil fertility (Kumwenda *et al*., 1997b) and they provide direct food to the households.

Farmers are now able to access small amounts of fertiliser through the fertiliser input subsidy programmes at affordable prices. They only need right information about fertiliser use to maximise benefits, and integrating legumes to complement the fertiliser accessed would be important. This thesis therefore has focused on evaluating these options with farmers. Firstly it looks at risks associated with legume technologies in order to identify suitable legumes that may not add risks to the poorer farmers. This is important in designing future legume-based technologies for improving agricultural productivity for the poorer farmers. Second, the thesis looks at how farmers can gain knowledge on use of small amounts of fertiliser to improve maize productivity, and finally it looks at uptake and adoption of the various legumes since they are the most appropriate with minimal production costs.

2.6 Conclusion

The purpose of the study reported in this chapter was to find out whether there is a relationship between poverty and the way soil fertility is managed in Chisepo, Malawi. The study has found out that farmers' soil fertility management is directly determined by the level of assets of a household, which influence the amounts of resources such as mineral fertiliser and manure a household can use. Ownership of assets determines the level of poverty and explains the relationship between poverty dynamics and soil fertility decline in smallholder agriculture in Chisepo. Inability to replenish soil fertility may result in dismal yields which may lead to a vicious circle of poverty. The poorer households who are in the large majority may not be able to escape from the maize-focussed poverty trap under their current livelihoods if nothing is done to improve their food productivity. Crop products from their agricultural activities are vital to food security, livelihoods, well-being and life. With home fields being the most important to the poor, improving soil fertility for food production in these fields will directly improve their lives. This is why the thesis is focused on several promising soil fertility technologies, including integration of annual legumes for soil fertility and their risks, small amounts of fertiliser and adoption by farmers to target the vitally important home and middle fields for the majority of poor farmers. The better-resourced farmers, who remain very few, engage more in commercial agriculture and off-farm enterprises, obtain adequate monetary profits and are able to take care of themselves.

Chapter 3

Risk analysis in maize legume technologies for smallholder maize yield improvement in Malawi: a farmer typological approach

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Chapter 3

Risk analysis in maize legume technologies for smallholder maize yield improvement in Malawi: a farmer typological approach

Abstract

Using farmer resource typologies, adaptability analysis and an on-farm mother and baby trial approach, I evaluated the production risks of alternative maize-legume crop combinations for smallholder farmers in Chisepo, central Malawi between 1998 and 2002. Production benefits and risks of four soil fertility and food legumes, pigeonpea (*Cajanus cajan*), groundnut (*Arachis hypogaea*), tephrosia (*Tephrosia vogelii*) and mucuna (*Mucuna pruriens*), intercropped or rotated with maize, were compared by 32 farmers in 4 farmer resource groups (RGs) of different wealth status. The calculation of lower confidence limits was used to determine the production risk of the crops. Alternative crop technologies presented different risks to farmers of different wealth status, and the degree of risk affected their choice of soil fertility management strategy. The better-resourced farmers (RG 1) had larger yields with all crop combinations than the poorly resourced farmers (RG 4). Legumes integrated with maize significantly ($p < 0.001$) raised maize grain yields by between 0.5 t ha^{-1} and 3.4 t ha^{-1}, when compared with sole unfertilised maize crop. Fertilised maize was less of a risk for the better-resourced farmers (RG 1 and RG 2), and it yielded well when combined with the legumes. Maize-legume intercrops yielded more and were associated with less risk than the maize-legume rotations. Maize intercropped with pigeonpea was predicted overall to be the least risky technology for all RGs. I conclude that new crop technologies may pose more risk to poorly resourced farmers than to wealthier farmers.

Key words: *Confidence limit, food security, minimum acceptable yield, legume technology, probability, risk and vulnerability*

3.1 Introduction

Maize (*Zea mays*) is life in Malawi, and its availability is a measure of both food supply and social security nationally and for the household. *Per capita* calorific consumption of maize in Malawi is the highest in the world (Smale and Heisey, 1997). However, maize grain yields in the dominant smallholder sector declined in recent decades (Kumwenda *et al.,* 1997a; Blackie *et al.,* 1998) until 2005 when a fertiliser subsidy programme was re-introduced. Depletion of soil fertility is one major factor that has led to low agricultural production in Malawi (Kumwenda *et al.,* 1997a; Blackie *et al.*, 1998; Snapp, 1998).

Lack of access to sufficient mineral fertilisers limits opportunities for soil fertility improvement in African smallholder agriculture. Recent efforts to replenish and maintain soil nutrients in southern Africa have included the use of legumes as one of the most practicable and cost effective means of improving the soil fertility of smallholder farms (Kumwenda *et al.,* 1997b; Snapp *et al.,* 2002a; Waddington *et al.,* 2004; Mafongoya *et al.,* 2006).

Research in Malawi, as elsewhere, has demonstrated that integrating more legumes into cropping systems provides a cheap source of nitrogen (N) for the soil, as well as producing grain to fortify diets (Snapp *et al.,* 1998; 2002a; Waddington *et al.,* 2004; Bezner-Kerr *et al.,* 2007). Although legume technologies cannot generally produce enough N for maximum maize yields in the short term, they provide limited but significant amounts of soil N that can increase maize yields, and arrest depletion of soil fertility at a low cost and at low risk for the poor farmer (Giller, 2001; Waddington *et al.,* 2004; Giller *et al.,* 2006a). Researchers in southern Africa have generated substantial information on soil fertility benefits from legumes in research stations, but less is known about the feasibility of these options on smallholder farms. There has been limited adoption of new legume technologies for soil fertility improvement by smallholder farmers in Malawi (Kumwenda *et al.,* 1997; Snapp *et al.,* 2002a; 2002b), but long-term engagement between researchers and smallholders there has been shown to raise uptake (Bezner-Kerr *et al.,* 2007).

Risk and vulnerability analysis can help fit technologies to classes of farmers differing in resource endowment (Legesse and Drake, 2005). Vulnerability here refers to things that are outside farmers' control but influence their capacity to cope with risk (Patt, 2001). Successful reduction of risk increases or stabilises incomes, which can then reduce vulnerability. Legume-related technologies can often reduce vulnerability by raising crop yields. However, sometimes they may reduce maize yields and thus increase vulnerability, as may occur when legumes replace a maize crop in rotation, or if there is excessive competition between intercrops in dry years (Adato and Meinzen-Dick, 2002). Few studies have attempted to evaluate maize-legume technologies in terms of their impact on risks of meeting household food security for farmers varying in resource (land, labour, draught power, off-farm income) availability. Differences in resource endowment (Wellard, 1996) are influential in decision-making processes for household livelihoods. Thus the identification of resource groups among target farmer communities can help the understanding of differences in farmers' behaviour and preferences, perceptions of risks and their interest in the adoption of new technologies.

This chapter reports an agronomic and economic evaluation of the risks and potential relevance of legume-based soil fertility technologies to different resource groups of smallholder farmers in central Malawi. I examined the link between soil fertility technologies, the magnitude of associated risk and the feasibility of the technologies under smallholder farming conditions. I focused on maize-legume combinations because farmers showed interest in experimenting with legumes to improve soil fertility.

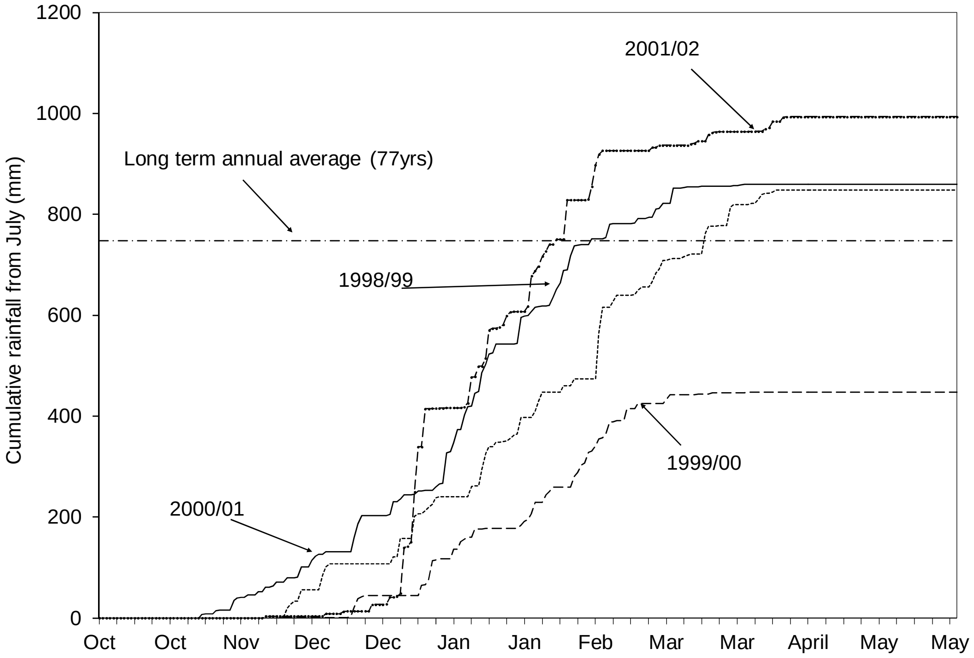

Fig.3.1. Cumulative distribution of rainfall (mm) for each of four years in Chisepo, central Malawi from 1998/99 to 2001/02

3.2 Materials and Methods

3.2.1 Site description

The study was conducted from 1998 to 2002 in Chisepo, Dowa district, situated 120 km northwest of the capital Lilongwe in the mid-altitude plateau of central Malawi (13'32''S, 33'31''E., elevation 1100 m asl). The climate is semi-arid to sub humid, characterised by a unimodal pattern of rainfall from November to April, with a 10–20% chance of either prolonged dry spells or flooding. The 77-year average seasonal rainfall is 748 mm, with an annual range from 400 mm to 1100 mm (Fig. 3.1). Mean temperature is 22 ^{0}C. Soils are predominantly Alfisols of low to moderate fertility and sandy loam to loamy sand textures underlain by laterites, which impede drainage (Wendt, 1993). Chisepo soils are generally poor in soil organic carbon (C) (0.7% on average) and N (0.06%) (Table 3.1). The main crops in Chisepo are maize and burley tobacco (*Nicotiana tabacum*), with maize yields ranging from as low as 0.1 t ha^{-1} to 2.5 t ha^{-1} (Kamanga, 2002b). Legumes grown by farmers include: groundnut (*Arachis hypogaea*), common bean (*Phaseolus vulgaris)*, Magoye – a promiscuously nodulating variety of soyabean (*Glycine max*) (see Mpepereki *et al.,* 2000), a bunch-type of cowpea (*Vigna unguiculata*) and Bambara groundnut (*Vigna subterranea*).

Table 3.1. Soil physical and chemical properties for the 0–20 cm soil layer in legume-maize mother and baby trial fields belonging to farmers from four resource groups (RG) in Chisepo, central Malawi. *n* = 8 farmers per RG.

Resource Group	% sand	% clay	% silt	% C	% OM	% N	P (avail) Bray (ppm)
RG 1	48.2	39.7	12.1	1.2	2.1	0.1	8.4
RG 2	46.3	42.3	11.4	0.9	1.5	0.08	5.5
RG 3	49.7	36.3	14.0	0.5	0.9	0.05	2.4
RG 4	55.7	33.9	10.4	0.3	0.5	0.02	0.7
Mean	50.1	38.0	11.9	0.7	1.3	0.06	4.3
s.e.	3.4	3.8	1.3	0.05	0.1	0.005	0.3

3.2.2 Farmer resource groups

Four groups of farmers, varying in their level of resource endowment, were identified in Chisepo in 1998 (Kamanga, 2002a). Wealth ranking (Jeffries *et al.,* 2000) was used to characterise the farm households into relatively homogeneous groups with similar resources, constraints and degree of poverty. Key informants, with an intensive knowledge of the area, helped to develop the grouping characteristics and the groups. Information used included the resource endowment of a household, number of months that a household had maize grain from its own harvest, housing quality, access to inputs and influence in the community. Farmers from 136 households in seven villages around Chisepo were assigned to the appropriate resource groups by key informants (see Chapter 2 this thesis). Farmers in Resource Group (RG) 1 were 'better resourced' and had enough food throughout the year, adequate farm tools and livestock, iron-roofed houses and sufficient land (Table 3.2). They also could afford enough fertiliser and to hire-in labour. RG 2 farmers were 'medium resourced'. They had enough food almost throughout the year, enough farmland, good thatch houses and were able to buy some fertiliser and hire labour. Farmers in RG 3 were 'poor' or 'less well-resourced' and cultivated small pieces of land, had little to harvest, relied on casual labour, used no fertilisers and had poor houses. RG 4 farmers were the 'poorest' with few resources for agriculture, and they largely relied on the sale of casual labour for survival. Soil fertility improvement was a main challenge for RG 3 and RG 4 due to lack of adequate resources to do so. Their crop yields were poor and had large food deficits which pushed them to sell their labour for food.

Table 3.2. Wealth parameters and characteristics of farmers in four resource groups in 1998 in Chisepo, Malawi.

Wealth	Resource group 1 (better resourced)	Resource group 2 (medium resourced)	Resource group 3 (poor resourced)	Resource group 4 (poorest)
Farm size	More than 4 ha of land	Around 4 ha of land	Around 2 ha of land	Have less than 1 ha land
Livestock	Have more than 3 cattle, 2 oxen and more than 4 goats	Had less than 3 cattle and some goats	Had no cattle but a few goats or chickens	No cattle
Food security	Have enough food throughout the year	Have food lasting more than 9 months a year	Food for 3 months a year and rely on casual labour	Rely on food from casual labour
Farm	Had major implements, including ox-carts. Two farmers had pick-up vehicles	Rarely have ox carts, but have all other implements	Have small implements such as hoes, axes and sickles	Have small implements that are not enough for family
Key crops	Produce tobacco for cash, maize for food. Other crops were legumes (groundnut and soyabean) and vegetables	Focused on tobacco for sale and maize for food and sale. Grew groundnut, beans and soyabean for food and sale	Focus on immediate needs. Maize and legumes were important source of food and income	Focus on immediate survival. Maize and grain legume production were very important food source
Fertiliser use	Used 10, 50 kg bags (1000 kg) of fertiliser (4 compound and 6 straight fertiliser) and manure	Used about 6 bags (300 kg) of fertiliser (2 compound and 4 straight fertiliser)	Used 50 kg of straight fertiliser, but regularly do use less than this amount	Did not use fertiliser
House type	Burnt brick walls with either iron roofs or well thatched roofs	Burnt or un-burnt brick walls or mud walls with well grass thatched roofs	Mud walls and grass thatched houses	Mud walls with grass thatched roofs
Labour use	Hire in labour	Occasionally hire in labour	Sell out labour	Sell out labour

3.2.3 Design and implementation of mother and baby trials

An on-farm mother and baby trial approach (Snapp, 1999; Snapp *et al.,* 2002b) was used as an evaluation and extension tool. Replicated and researcher-managed mother trials are used to test many different crop technologies on a few farms and associated baby trials (not replicated and farmer-managed) test subsets of the technologies on many farms. Mother and baby trials ran for four seasons from 1998/99 to 2001/02 on sandy, sandy loam and loamy sand soils, the main soil types in the area. They were located within a radius of 6 km.

During an initial participatory planning session, 32 farmers, comprising eight from each resource group, were selected at random to be involved in the mother-baby trial programme. In each resource group, two farmers were selected to host mother trials and six farmers agreed to conduct single replicate baby trial plots. Analysis of mother and baby trials showed few differences in results. Thus, this chapter reports the full results from mother trials and draws comparisons, where relevant, with results from the baby trials.

Participatory planning sessions were held with the farmers in 1998 to determine the experimental treatments and trial management. Farmers expressed interest in testing maize-legume combinations on fields that had different management histories. Four maize-legume technologies, along with two concerning fertiliser inputs on sole maize, were identified for testing in the mother-baby trials (Kamanga 2002b). Pigeonpea (*Cajanus cajan*) and groundnut were given high priority because, in addition to improving soil fertility, farmers stated that they could get edible grain from them. The maize legume technologies were: maize (cv. MH18) in rotation with pigeonpea (cv. ICP 9145) intercropped with groundnut (cv. CG 7) (Mz/Pp+Gn); maize intercropped with tephrosia (*Tephrosia vogelii*) (Mz+Tv); maize intercropped with pigeonpea (Mz+Pp); and maize in rotation with mucuna (*Mucuna pruriens*) (Mz/Mp). In the intercropped treatments (Mz+Tv and Mz+Pp), the legumes were grown and harvested in each of the four years, whereas the legumes in the rotational treatments were grown only in the first and third years. The four maize-legume technologies were compared with sole crop maize without fertiliser (Mz−Ft) and sole maize with half (i.e. 35 kg N ha^{-1}) the national fertiliser recommendation of 69 kg N ha^{-1} (Mz+Ft). Urea was used to supply the N and was applied once when the maize was knee-high. No other nutrients were applied.

Experimental treatments for mother trials were laid out in a randomised complete block design with three replicates on each farm and a plot size of 10 m × 10 m with a 1 metre path between plots (Fig. 3.2). Legumes and maize were planted with recommended plant spacing (Government of Malawi, 1996) giving the following plant population densities: 37 000 plants ha^{-1} for maize and pigeonpea in both systems and 74 000 plants ha^{-1} for mucuna and groundnut. In the fourth year, a split-plot design was used. Plots were split into two, where half of each plot received 35 kg N ha^{-1} and the other half did not. The Mz+Ft treatment received a full fertiliser recommendation of 69 kg N ha^{-1}. Yields from plots that received N fertiliser in the 2001/02 season were used to compare the riskiness of technologies when fertiliser was applied in addition to organic sources of N from legume biomass.

Mz/Pp+Gn	Mz/Mp	Mz+Tv	Mz - Ft	Mz + Ft	Mz+Pp
Mz + Ft	Mz+Pp	Mz+Tv	Mz/Pp+Gn	Mz - Ft	Mz/Mp
Mz+Pp	Mz - Ft	Mz/Mp	Mz + Ft	Mz+Tv	Mz/Pp+Gn

Mz/Pp+Gn - 35 kg N ha^{-1}	Mz/Mp - 35 kg N ha^{-1}	Mz+Tv - 35 kg N ha^{-1}	Mz – Ft - 35 kg N ha^{-1}	Mz + Ft - 35 kg N ha^{-1}	Mz+Pp - 35 kg N ha^{-1}
Mz/Pp+Gn +35 kg N ha^{-1}	Mz/Mp + 35 kg N ha^{-1}	Mz+Tv + 35 kg N ha^{-1}	Mz – Ft + 35 kg N ha^{-1}	Mz + Ft + 35 kg N ha^{-1}	Mz+Pp + 35 kg N ha^{-1}

Fig. 3.2: Plot layout in Mother experiments. In the fourth year, the plots were split to halves and one half received 35 kg N ha^{-1} as shown on the separate right scheme

Overall implementation (plot size, experimental treatments, time of planting, seeding rates, harvest) of the trials was the responsibility of the researchers. Farmers in the RGs provided management decisions and inputs (such as labour) on non-experimental practices such as ridging, weeding and banking. Thus crop management and yields reflected some investments the RG farmers gave to the trials.

Baby trials were planted in plots of 10 m × 10 m each on individual farms by farmers belonging to the RGs and managed according to their individual preferences. Legume pods from grain legumes were harvested, and all remaining biomass from all legumes was incorporated after samples from net plots of 5 m × 5 m were taken and weighed. Maize stover was removed for domestic use. At several times each season, farmers in each RG visited their mother trials and assessed the treatments together, providing information to researchers on performance and preferences, and used this information to compare with their baby trials. Theft and human consumption of grain, mainly of pigeonpea and groundnut before data measurement and animal grazing were reported in the second and third years. These contributed to low or no yields measured in a few cases.

3.2.4 Measurements and analysis

Soil samples were collected from the eight fields of each RG that hosted mother and baby trials from 0–20 cm soil depth to establish initial soil fertility status. Samples were analysed for soil texture, organic C, N and phosphorus (P) using standard methods for tropical soils (Anderson and Ingram, 1993) (Table 3.1).

Maize and legume grain yields from mother and baby trial net plots of 25 m^2 were harvested at maturity. A moisture meter was used to determine grain moisture content at harvest and maize grain yields were adjusted to 12% moisture content; all legume grain yields were adjusted to 10% moisture content. All plant samples were sun-dried and recorded at the Soils and Plant Laboratory, Bunda College of Agriculture. Shoot biomass N was calculated from the measured legume biomass, which was then returned into the soil at harvest in each year. Sampling for biomass N was done from the net plot at peak flowering and at harvest. Biomass N was plotted against the corresponding maize grain yield in the following season to determine if maize yield responded to incorporated biomass.

Yield data from mother and baby plots were analysed separately by analysis of variance using GenStat Release 9.1. When a split-split plot design was used in the fourth year, resource groups were considered as blocks, farmers were main plots, the replicates sub-plots and experimental treatments sub-sub-plots.

3.2.5 Risk analysis

Calculation of lower confidence limits as described by Hildebrand and Russell (1996) was used to assess risks of technologies. This technique requires that 'recommendation domains' are determined and a minimum acceptable yield limit established for each domain. Our focus was on the risks associated with the legumes for each RG, thus the RGs formed the socioeconomic environments or recommendation domains. Production risk analysis of the technologies was based on the yields obtained from each treatment in the mother and baby trials belonging to each RG. Mean maize grain yields from mother and baby trials were calculated for each RG and used as environmental indices (EIs). An EI is the average of all the observed maize yields from each treatment in a field and indicates the capacity of the field to produce the crop.

We used the EI to establish the minimum acceptable yield levels for each resource group. Evaluation of risk was done on the average minimum maize food requirement of 1.3 t per household per year considering a basic requirement of 250 kg of maize per adult per year in Malawi to sustain a healthy diet (Peter and Herrera, 1989) and at the area average family size of 5.2 people. Considering that farmers grow maize primarily for household food, for income when there is a true surplus and also use it for distress sale[2] in time of emergency, the lower confidence limits were adjusted upwards to ensure that the households still remain food secure even after occasional distress sale of maize to meet emergency household needs. Thus for RG 1 and 2 the adjusted lower confidence yield limit was set at 2 t ha^{-1}, and for RG 3 and 4 it was 1.5 t ha^{-1}. RG 1 and RG 2 had the same minimum acceptable limit of 2 t ha^{-1} because farmers from these groups had a similar behaviour pattern of food utilisation, as did farmers from RG 3 and RG 4 (e.g. Fonte, 2002).

Riskiness of the technologies to farmers as assessed in this chapter is the probability that the technology will give a yield below the minimum acceptable yield (Foti *et al.,* 2003). If the maize-legume technology gave a maize grain yield below the minimum acceptable limits, it was considered risky and not attractive to the RGs for which the technology was assessed, since it may not offer the farmers expected returns. Since we were interested in the risks associated with the technologies to individual farmers and farmer risk aversion varies depending on socioeconomic status (Legesse and Drake, 2005), the confidence limits were varied from 75% (p = 0.25) to 95% (p = 0.05). The value p = 0.25 indicates the minimum maize yield that an individual farmer could expect to obtain one in four years (i.e. more frequently), and p = 0.05 estimates the minimum maize yield a farmer could expect only once in twenty years (i.e. which may be encountered less frequently). The lower confidence yield limits (risks) were calculated using a formula in Hildebrand and Russell (1996) as:

Risk (lower confidence limit) = mean − $(t_{d.f.} = n - 1, p)(S_d)/n^{1/2}$
where:

n = the number of observations used to calculate the mean of the group
t = values from one tailed t-table
$d.f.$ = degrees of freedom associated with that mean
S_d = standard deviation associated with the mean
p = the chosen probability level in a one tailed t- table.

Lower confidence limits were then plotted against the probabilities to show the risks associated with the technologies for the farmers in each RG.

Farmers in each resource group were subjected to vulnerability analysis in group discussions to determine their response to perceived risks. Vulnerability analysis for the farmers in the study used local socioeconomic indicators and also through use of literature (e.g. Carter 1997, Mosley and

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[2] Farmers sell maize even if they don't have enough for consumption. This is done to offset immediate cash needs e.g. for illnesses and other pressing issues. Locally there is exchange of maize grain with items such as salt, dried fish, vegetables and other tradable items, especially with people who ply between rural and urban for trade.

Verschoor 2005). The analysis was based on four risk factors which included aversion to variable dominant cropping systems, ability by the household to purchase fertilisers associated with the proposed technologies, importance of secondary use of proposed crops and labour constraints to the households (Sirrine *et al*., 2010). Farmers typically respond to perceived risks in different ways which include entering into low risk activities or diversifying into portfolios of activities with differing profiles (DFID, 2004. This was done to categorise farmers to identify the levels of risks each group would face, and how they might be vulnerable to them. Four risk aversion criteria or socioeconomic vulnerability levels were defined (Table 3.3).

Table 3.3. Risk, vulnerability and sources of risks to farmers

Resource Groups (RG)	Risk factors	Sources of risk (as described by farmers in focus group discussion)
Better-resourced Least Vulnerable	• Maximise yields • Avoid short terms risks • Focus on use of fertilisers and manure • Role of technologies such as mucuna not clear, however it is means of food fortification • Labour costs not an issue at all • Focus on cash crops such as tobacco	• Market risks: Low prices when selling produce • Production risks: Poor yields, theft, droughts, storage losses, strong winds, pests and diseases • Social risk: Deaths, HIV/AIDS, crimes, violence • Institutional risk: Marriage breaking • Technology risk: Use of fertilisers in relation to climate, new crops, droughts
Medium resourced Moderately Vulnerable	• Maximise yields • Avoid long term risks • Technologies useful sometimes • Labour costs may be an issue • Technologies as means of food fortification	• Market risks: Low prices when selling produce • Production risks: Poor yields, theft, droughts, storage losses, pests and diseases • Social risk: Deaths, HIV/AIDS, violence • Institutional risk: Marriage breaking • Technology risk: Use of fertilisers, new crops, climatic variability
Less-resourced Vulnerable	• Focus on short term risks, i.e. focus on immediate needs • Legumes are important source of food and income • Use technologies with no fertiliser • Labour costs very high	• Market risks: High prices when buying things, unavailability of commodities, distances to markets • Production risks: Food insecurity, labour use • Human risk: Sickness, HIV/AIDS • Institutional risk: Death of spouse, Loss of land • Technology risk: often none
Least-resourced Most Vulnerable	• Focus on immediate survival (short term risks), reason to sell labour for survival in hard times • Focus on alternative cheap means of income sources • Legumes very important food source • Additional labour from legumes too costly • Technologies very important for soil fertility	• Market risks: High prices when buying produce, scarcity of high return off farm activities, • Production risks: Food insecurity, lack of land, no fertilisers, no money, soil infertility • Human risk: Sickness, witchcraft • Institutional risk: Death of husband • Technology risk: Often none, but due to labour demands for *ganyu*, technology may offer risks

3.2.6 Financial analysis

A financial analysis of the technologies for each RG was performed on the four-year (1998–2002) maize grain yield averages from the mother trials belonging to each RG to compare performance and complement the risk analysis of the technologies. Total variable costs included those for labour, fertiliser applied, and maize and legume seed. Labour was valued at a minimum wage of MK56.00 (US\$0.53) day^{-1} (Chirwa *et al.,* 2004). Urea fertiliser had a selling price of MK86.70 (US\$0.81) kg^{-1} and maize seed cost was MK70.00 (US$0.65) kg^{-1}, while legume seed sold (on average) at MK20.00 (US$0.19) kg^{-1}. Benefits were calculated using the average farm gate price of MK7.00 (US$0.1) kg^{-1} maize grain in Chisepo and the value of legume grains in local markets.

Maize prices were obtained through survey questions to farmers about the maize they sold. The technology recommendations for each RG in Table 3.5 were identified using different thresholds. Agronomic risk assessment used minimum acceptable yields for each RG (see Fig. 3.8). A US$0.53 day^{-1} threshold for labour was used, which is the minimum wage rate for Malawi that rural people got when they sold their labour in *ganyu* (i.e. temporary off-farm casual labour for income, food or other materials). The threshold for returns to total costs was calculated using the average minimum maize requirement of each RG. If all returns to total costs in each RG were invested in obtaining the minimum maize requirement, then it would need not less than 15.3 kg maize per US$ invested to achieve the minimum maize requirement goal.

3.3 Results

3.3.1 Soil fertility status

Soil analysis in Table 3.1 showed significant differences in physical and chemical properties of soils among the RGs. Soils from RG 1 farms had 0.9% more C, 0.8% more N and an additional 7.7 ppm available P (Bray) than soils from RG 4. These differences were reflected in the maize and legume grain yields in the RGs in the four years (see Fig.3.3, 3.4, 3.5 and 3.6).

3.3.2 Maize productivity

Cumulative maize grain yields from mother trials over four years (Fig. 3.3) were greater in those experiments located on RG 1 and 2 farms and less for RGs 3 and 4. In all the groups, Mz+Ft significantly ($p < 0.001$) outperformed all the other treatments with the highest cumulative grain yield of over 14 t ha^{-1} in RG 1. The response of maize to fertiliser in mother and baby plots showed a similar trend, although baby plots (15.2 t ha^{-1} for RG 1 and 5 t ha^{-1} for RG 4) had slightly higher cumulative maize grain yields than mother plots (14.5 t ha^{-1} for RG 1 and 4.6 t ha^{-1} for RG 4).

Maize grain yield ranged from 0.9 t ha^{-1} in the second year for RG 1 and 0.1 t ha^{-1} in the third year for RG 4 without fertiliser to 4.4 t ha^{-1} in RG 1 and 1.3 t ha^{-1} in RG 4 with fertiliser (both in the fourth year). All treatments gave lower maize yields in the second year when there was poor rainfall (Fig. 3.1). The growing season of 2001/02 experienced good rainfall and that was reflected in large yields and responses of maize to legumes and fertiliser. Maize intercropped with pigeonpea or tephrosia gave greater cumulative yields than maize in rotation with mucuna or the pigeonpea/groundnut intercrop. In general, maize grain yields in mother plots improved with the introduction of legumes by between 0.2 and 4 t ha^{-1}, in comparison with yields from the Mz-Ft treatment.

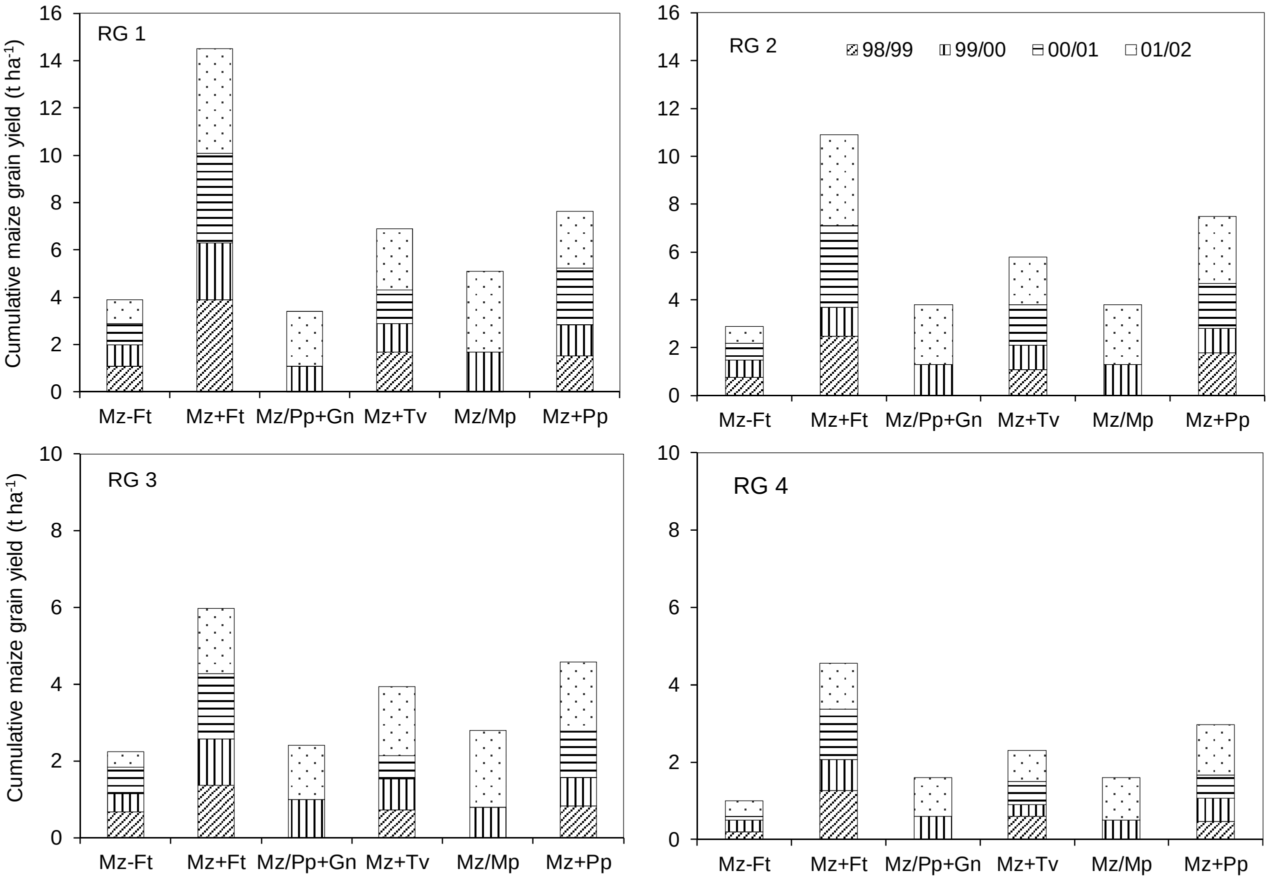

Fig. 3.3. Maize grain yield (t ha^{-1}) from mother plots in Chisepo, central Malawi from 1998 to 2002

Cumulative maize yields from baby trials displayed a similar pattern. The maize grain yields in baby plots improved with the introduction of legumes from 0.1 to 2 t ha^{-1}. Fig. 3.4 show that Mz+Ft significantly (*P* = 0.001) out performed all treatments in all groups, followed by the intercrops. Although the yield levels in each year were smaller, the overall contribution to food security of the households was relatively better when compared to rotation systems. Maize yields from the fertilised baby plots were similar to those in mother plots. Farmers were generally pleased with the performance of maize in their baby plots in the final year of experimentation after being grown with legumes and fertiliser.

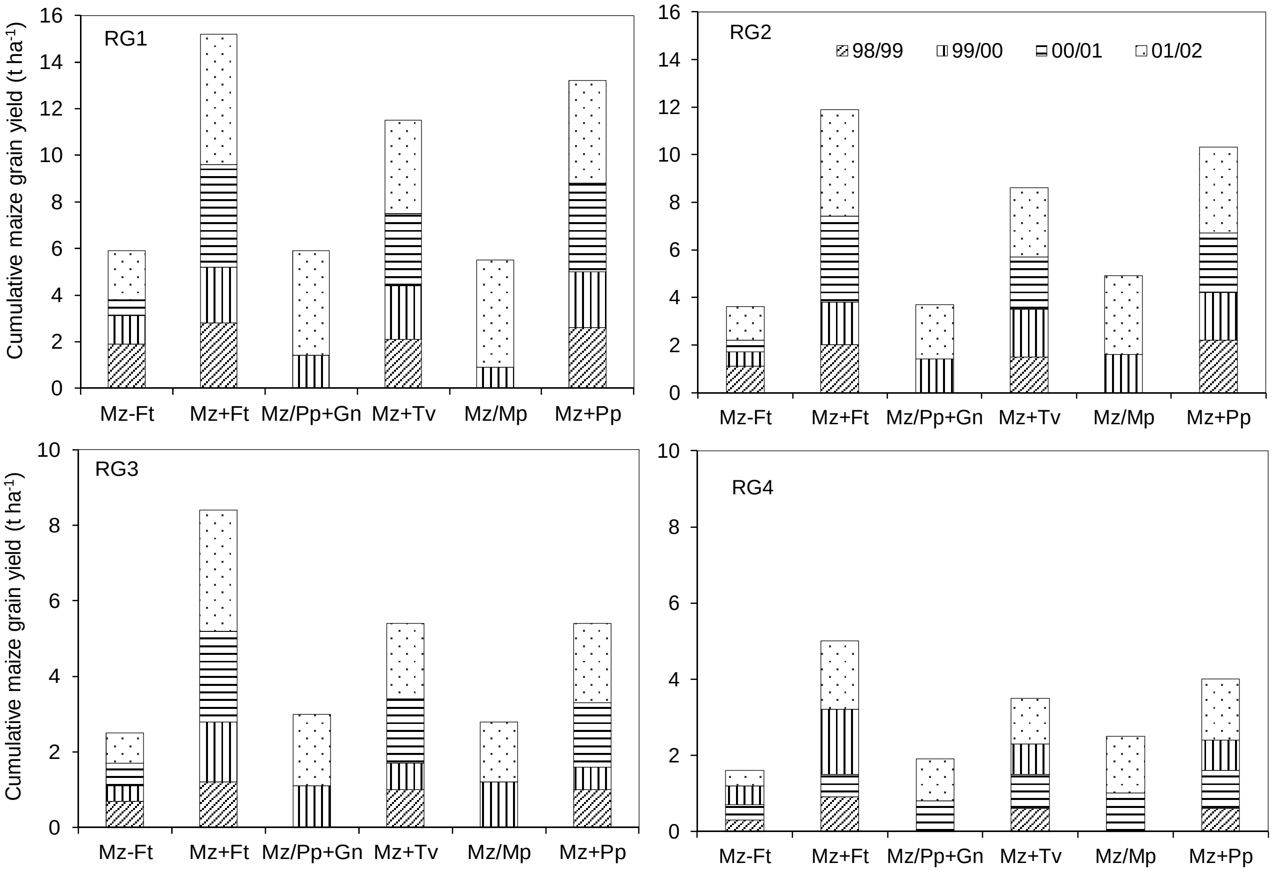

Fig.3.4. Maize grain yield (t ha^{-1}) from baby plots in Chisepo, central Malawi from 1998 - 2002

3.3.3 Legume productivity

Groundnut and pigeonpea in the Mz/Pp+Gn treatment in mother and baby plots were harvested separately, and grain yields are shown separately (Fig. 3.5). Both groundnut and pigeonpea yielded poorly in all treatments in all years. The largest yield of groundnut was 1.2 t ha^{-1} of grain in the mother plots of the RG 1 farmers in the first year and 1.4 t ha^{-1} in the first year from RG 1 in baby plots. The largest yield of pigeonpea (1.5 t ha^{-1} grain) in mother plots was found with RG 2 in the fourth year and 1.8 t ha^{-1} in baby plots of RG 1 farmers in the first year. Yields of the green manure legumes were larger, with tephrosia achieving almost 3 t ha^{-1} in plots of the RG 4 farmers in the last year, and mucuna yielding up to 6 t ha^{-1} of grain in the third year. Both tephrosia and pigeonpea yielded little grain in the second (dry) year.

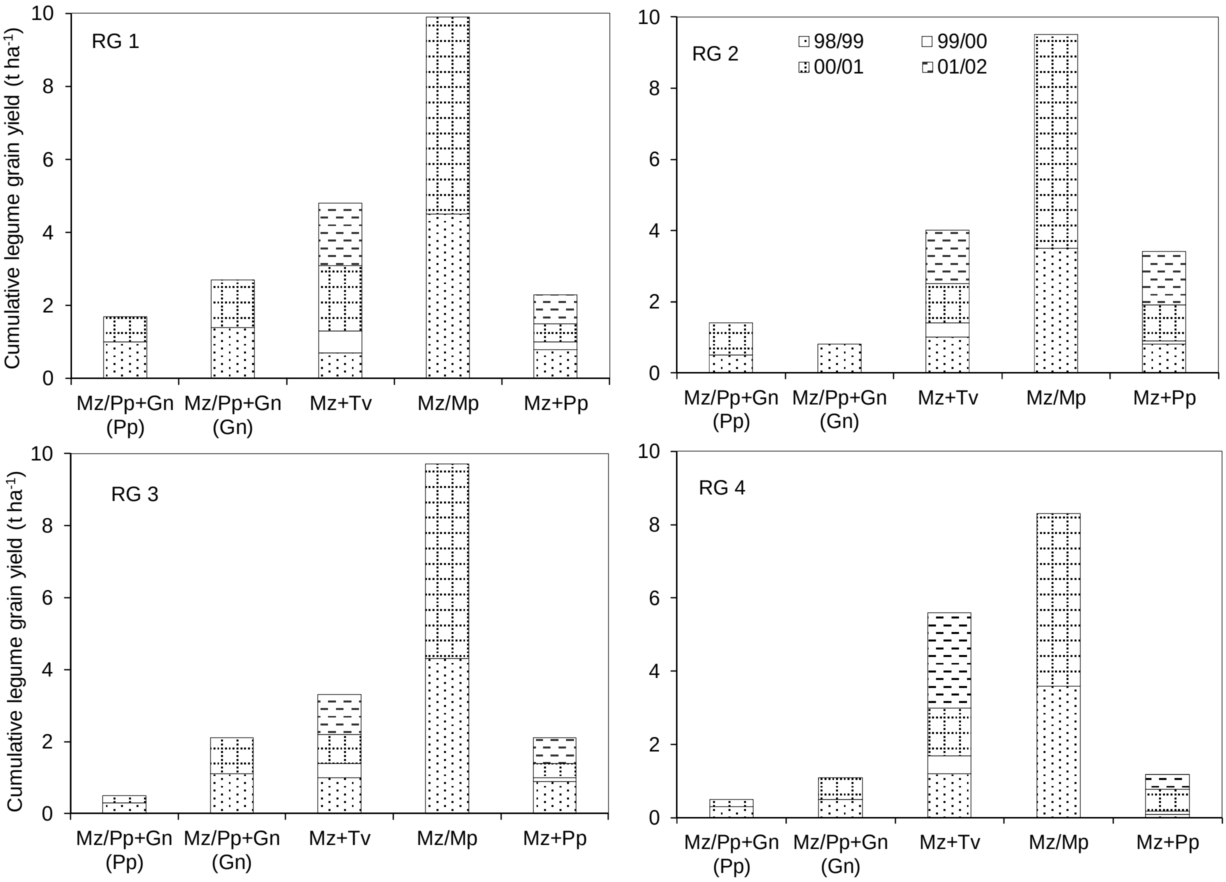

Fig.3.5. Legume grain yields (t ha^{-1}) from legume mother plots in Chisepo, Malawi 1998-2002

Overall, the legumes yielded most grain in the plots of the RG 1 farmers, followed by RG 2 and least with the RG 4 farmers. Cumulative grain yields were greatest in Mz/Mp (about 10 t ha^{-1}) for RG 1 and poorest in the RG 4 farmers' plots. Pigeonpea yields in RG 2 were higher than RG 1 whose yields were almost the same as RG 3. Pigeonpea yielded less in all cases than groundnut in the mixed legume treatment. There was no yield of groundnut for RG 2 in the third season because of theft of grain and animal damage. The total grain yield across the two legumes, however, in these treatments was more than with Mz+Pp alone. The RGs selected different legumes for evaluation in the baby trials. Farmers of RG 1 and RG 2 expressed most interest in growing Mz/Mp and Mz+Pp based on their experiences with the baby trials. RG 4 farmers preferred growing Mz+Pp to other maize-legume combinations. RG 1 and RG 2 farmers mainly selected Mz/Mp, Mz+Pp and Mz+Tv from their mother trials to test in their non-experimental plots outside baby trials. RG3 farmers selected Mz+Pp and Mz/Pp+Gn, and RG4 farmers preferred Mz+Pp for testing.

Legume yields from baby trials showed little difference from the mother trials (Fig. 3.6). Mz/Mp and Mz+Pp legume grain yields for RG 1 were 0.6 and 1 t ha^{-1} more than in the mother trials in the first year. Cumulative yield over the four years was 0.5 t ha^{-1} smaller for Mz/Mp, and 3.3 t ha^{-1} more than in the mother trials for the same RG. Cumulative legume grain yields for Mz+Tv and Mz/Pp+Gn in baby plots were 0.9 and 0.8 t ha^{-1} smaller, respectively, than in mother plots. Cumulative legume grain yields from baby plots for RG 4 were the same at 1.2 t ha^{-1} for Mz+Pp and 0.4 t ha^{-1} for Mz/Pp+Gn. Mz/Mp and Mz+Tv were 2.6 and 2.1 t ha^{-1} less than in the mother plots for the same RG.

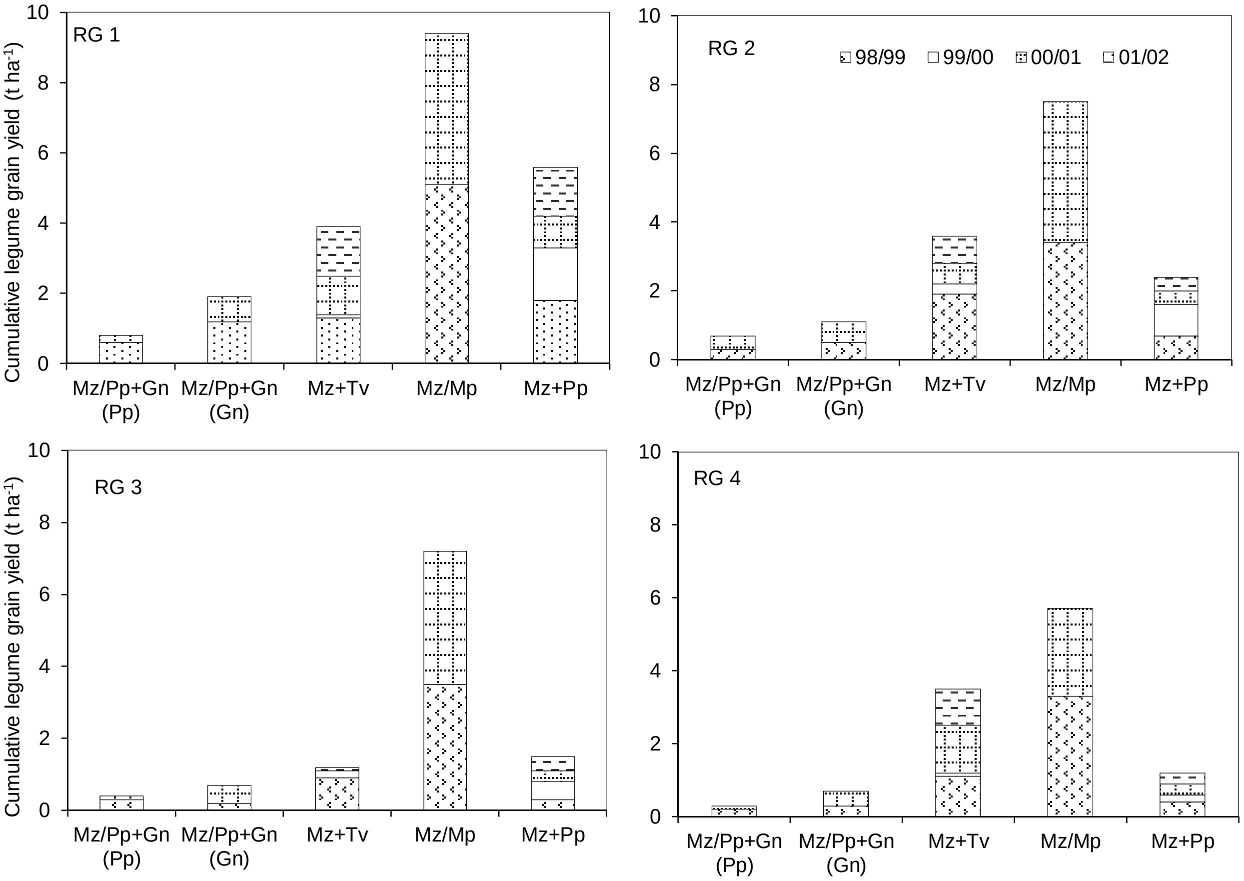

Fig. 3.6. Legume grain yield (t ha^{-1}) from baby plots in Chisepo, central Malawi 1998-2002

Biomass N from the legumes ranged from 12 to 223 kg N ha^{-1}. Maize grain yields without fertiliser (that ranged from 0.6 to 3.4 t ha^{-1}) in the year after legume biomass incorporation was correlated positively with the amount of incorporated biomass N in the previous season (Fig. 3.7). Mz+Tv and Mz/Mp had a higher correlation and greater response of maize yield to legume N inputs than Mz/Pp+Gn and Mz+Pp.

The risks associated with the legume technologies and farmer vulnerability were analysed by comparing the yields obtained from mother trials with the minimum acceptable yield and risk factors for each farmer RG. Minimum acceptable yield limits or confidence yield limits were established and adjusted to reflect consumption and distress sale of maize by farmers. RG 1 and RG 2 had minimum confidence yield limits of 2 t ha^{-1}, while 1.5 t ha^{-1} was adjusted from 1.3 t ha^{-1} for RG 3 and 4 to take into account distress sale of maize for immediate cash needs and consumption.

The risk probability (%) for Mz+Pp, which crossed the threshold line at p = 0.05, means that a farmer using this technology in RG 1 could expect a yield below 2 t ha^{-1} once in 20 years. For RG 1 farmers, three of the maize-legume technologies (Mz+Ft, Mz+Pp and Mz+Tv) had lower frequencies of risk occurrence (Fig. 3.8) than other technologies. Mz+Ft crossed the threshold line for minimum acceptable yield at p = 0.04 and Mz+Tv at p = 0.17. Mz+Pp had the least frequency of risk occurrence of the legume treatments for the better-resourced RG 1. A similar frequency of riskiness was observed in RG 2 where Mz+Pp, Mz+Ft and Mz+Tv were equivalent in yield (Fig. 3.6). Mz+Pp crossed the threshold line at p = 0.075, Mz+Ft at p = 0.1 and Mz+Tv at p = 0.12. Other technologies had a high frequency of risk occurrence for RG 2 where none of them crossed the threshold line. When 35 kg N ha^{-1} fertiliser was applied to the treatments, Mz+Ft, Mz+Pp, Mz+Tv, Mz/Pp+Gn and Mz/Mp had a lower frequency of risk at both p = 0.05 and p = 0.25. Mz/Pp+Gn crossed the threshold line at p = 0.07 and had a lower frequency of risk. With those technologies combining legumes with N fertiliser, the expected risk of yields less than 2 t ha^{-1} was reduced to below 1%.

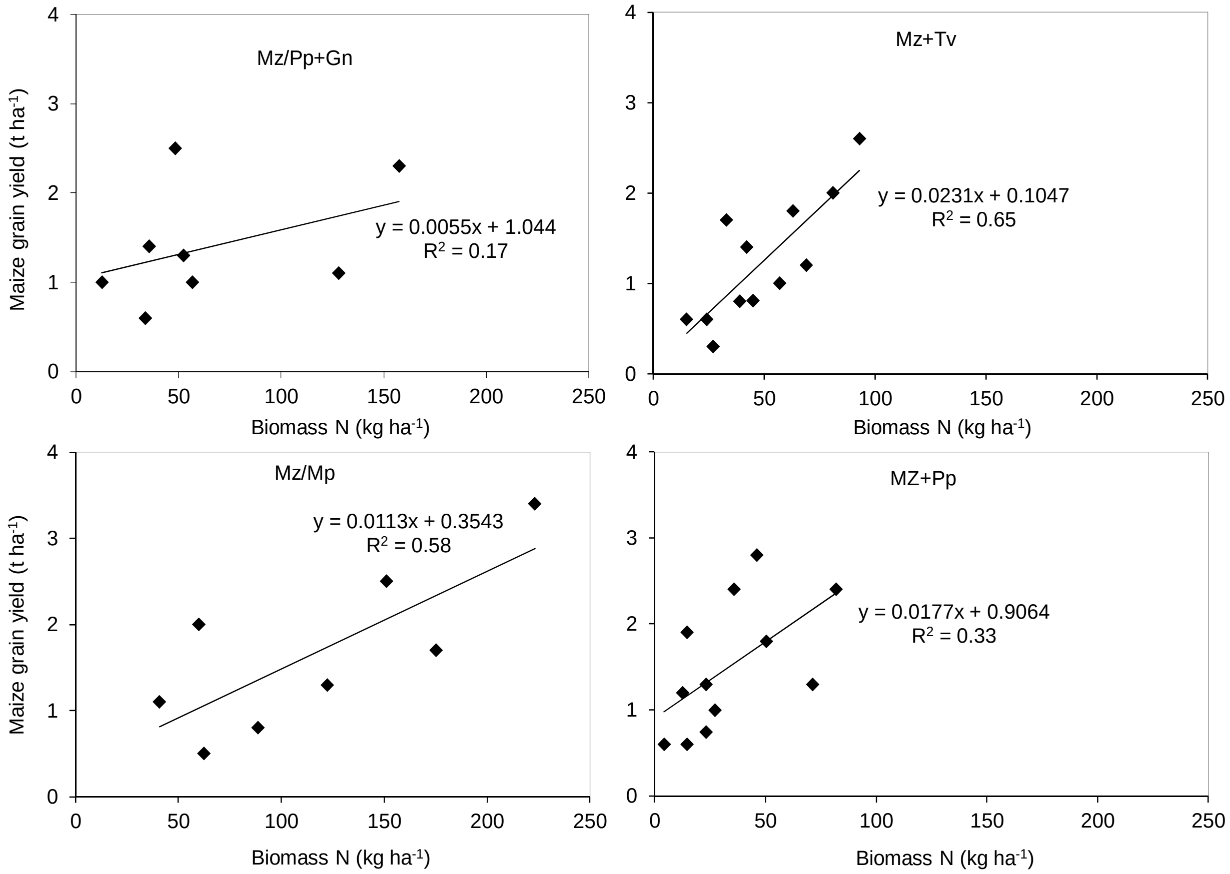

Fig. 3.7. Maize grain yield (t ha^{-1}) response to biomass N (kg ha^{-1}) incorporated in farmers' fields in Chisepo, central Malawi from 1998 to 2002

Considering the minimum acceptable yield of 1.5 t ha^{-1} for RG 3 and RG 4, all the treatments gave far below the threshold yield. All the treatments had a high frequency of risk occurrence for members of RG 3, but relatively better than for RG 4 whose yields were constantly below 1 t ha^{-1}. However, RG 3 and 4 farmers were still able to benefit from fertiliser. With RG 3, when fertiliser was applied to the treatments, all except Mz−Ft became less risky at varying probabilities. Mz+Ft, Mz+Tv, Mz+Pp and Mz/Mp had low frequencies of risk occurrence at both probability intervals while Mz/Pp+Gn crossed the threshold line and became not risky at p = 0.04. Mz+Pp and Mz+Tv became equivalent in yield and least risky at p = 0.25 and p = 0.05. Results for RG 4 were no better in terms of riskiness. None of the treatments gave yields closer to the threshold yield of 1.5 t ha^{-1} with legumes alone. When 35 kg N ha^{-1} was applied, Mz+Ft, Mz+Pp and Mz/Mp became less risky at p = 0.25. Mz+Ft crossed the threshold line and had a lower risk frequency at p = 0.07, Mz+Pp at p = 0.175 and Mz/Mp at p = 0.20.

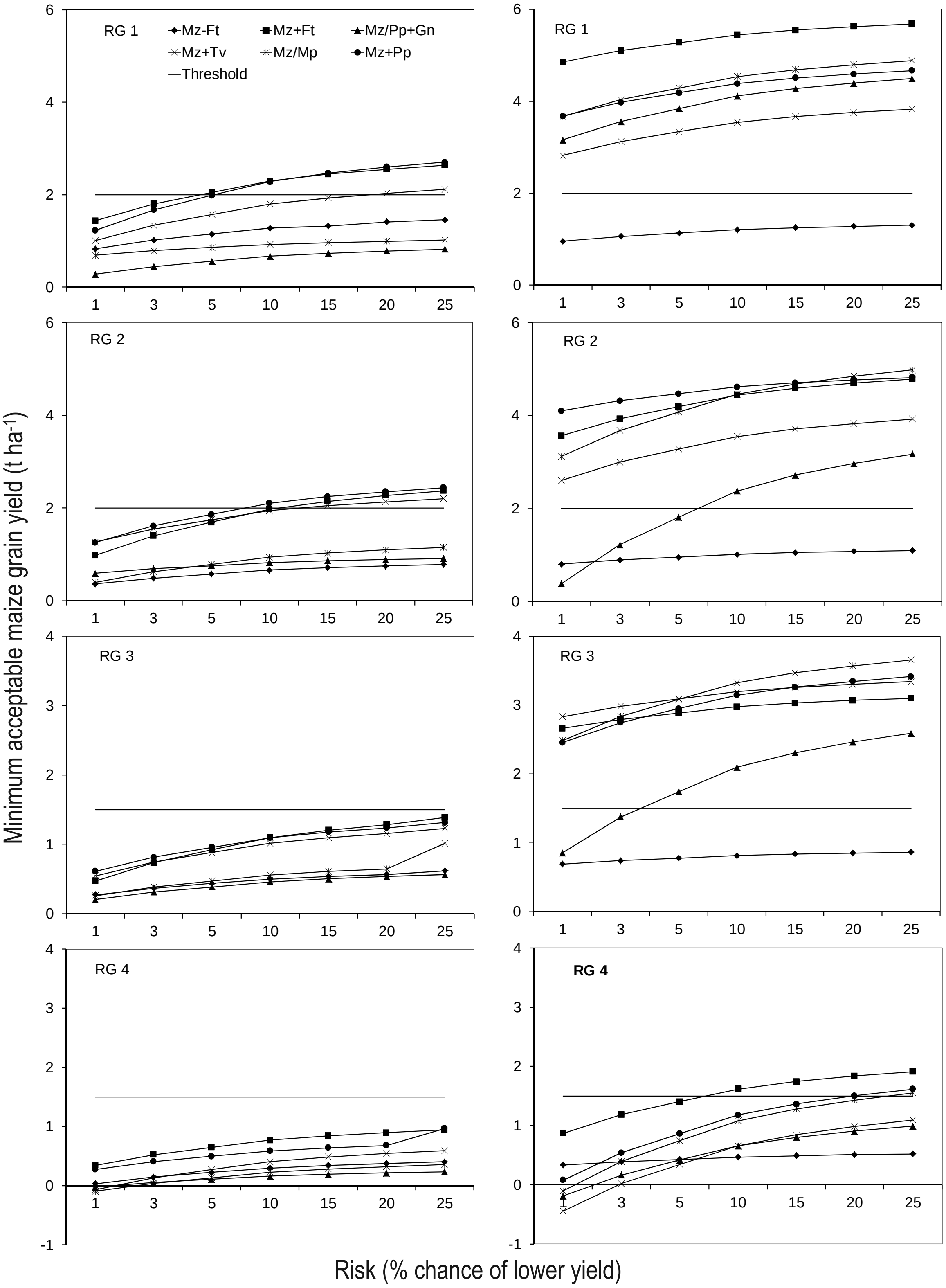

Fig. 3.8. Minimum acceptable maize grain yield (t ha^{-1}) at different levels of risk (probability of occurrence) in Chisepo, central Malawi. The left column shows level of risk as influenced by legumes only while the right column shows level of risk as influenced by legumes added together with 35 kg N ha^{-1}

3.3.4 Economic performance and recommended technologies

Financial returns were highest when 35 kg N ha^{-1} fertiliser was used with maize in combination with legume biomass in all the RGs (Table 3.4). RG 1 had the highest returns while RG 4 had least. Market returns to labour and total variable costs showed the same trend but varied from one resource group to the other. Mz+Pp intercrop had consistent positive returns across the farmer RGs indicating its suitability to a wide range of environments and for the poorer farmers. The rotation systems were variable, with more-negative returns in the less well-resourced groups.

Table 3.5 proposes maize-legume technology (with and without fertiliser) recommendations for the RGs. Mz+Pp and Mz+Tv were observed to meet almost all the criteria for RG 1 and 2 with or without N fertiliser. In addition, Mz/Mp and Mz/Pp+Gn met the criteria only when N fertiliser was applied. For RG 3 and 4, Mz+Pp and Mz+Tv met some of the criteria for recommendation without N fertiliser. The application of N fertiliser to maize-legume combinations made almost all technologies meet the criteria for recommendation toRG3 and 4. Thus the Mz+Pp technology met many of the evaluation criteria for RGs, suggesting it is suitable for widespread use in central Malawi.

Table 3.4. Economic risk assessment of legume-maize technologies for four resource groups (RG) of smallholder farmers in Chisepo, Malawi; without N fertiliser and with 35 kg N ha^{-1} applied.

	RG 1		RG 2		RG 3		RG 4	
Crop technology	Returns to labour $(\$\ \mathrm{day}^{-1})$	Returns to total costs $(\mathrm{kg}\ \$^{-1})$	Returns to labour $(\$\ \mathrm{day}^{-1})$	Returns to total costs $(\mathrm{kg}\ \$^{-1})$	Returns to labour $(\$\ \mathrm{day}^{-1})$	Returns to total costs $(\mathrm{kg}\ \$^{-1})$	Returns to labour $(\$\ \mathrm{day}^{-1})$	Returns to total costs $(\mathrm{kg}\ \$^{-1})$
Without N								
Mz-Ft	0.8	31.4	0.2	18.4	0.0	14.3	– 0.2	12.3
Mz+Ft	0.7	27.1	0.7	26.7	0.2	17.9	– 0.2	12.4
Mz/Pp+Gn	– 0.2	9.8	– 0.2	11.0	– 0.3	7.5	– 0.5	3.8
Mz+Tv	0.6	28.5	– 0.7	30.4	0.3	21.5	– 0.1	12.8
Mz/Mp	– 0.1	12.7	0.1	16.8	– 0.2	10.9	– 0.3	7.2
Mz+Pp	1.1	40.2	1.0	37.5	0.6	26.7	0.2	18.3
With 35 kg N ha^{-1}								
Mz-Ft	1.9	41.1	1.5	35.4	1.0	28.4	0.4	19.5
Mz+Ft	1.6	39.5	1.4	36.0	0.6	23.4	0.1	17.2
Mz/Pp+Gn	1.2	38.4	1.0	33.4	0.8	28.4	– 0.1	13.4
Mz+Tv	1.1	33.4	1.3	36.6	1.2	33.0	0.0	15.7
Mz/Mp	1.6	45.5	1.9	50.8	1.4	39.6	0.5	22.7
Mz+Pp	1.7	44.9	2.0	48.2	1.6	39.5	0.7	24.0

Table 3.5. Legume-maize technology recommendations based on yield level risk and returns to the farmers in Chisepo, Malawi from 1998 to 2002. Thresholds shown in bold.

		Criteria variables for maize-legume technology recommendation					
		Without N fertiliser			With 35 kg N ha^{-1}		
		Agronomic risk	Returns to labour	Returns to total costs	Agronomic risk	Returns to labour	Returns to total costs
Threshold		**2 t ha^{-1}***	**\$0.53 /day****	**>15.3 kg\$$^{-1}$ *****	**2 t ha^{-1}**	**\$0.53 day^{-1}**	**>15.3 kg \$$^{-1}$**
	RG 1	Mz+Pp (5) Mz+Tv (17) Mz+Ft (4)	Mz+Pp Mz+Tv	Mz+Pp Mz+Tv Mz+Ft	Mz+Ft (1) Mz/Pp+Gn (1) Mz+Tv(1) Mz/Mp (1) Mz+Pp (1)	Mz+Pp Mz+Tv Mz+Ft Mz/Mp Mz/Pp+Gn	Mz+Pp Mz+Tv Mz+Ft Mz/Mp Mz/Pp+Gn
	RG 2	Mz+Pp (7) Mz+Ft (10) Mz+Tv (12)	Mz+Pp Mz+Tv Mz+Ft	Mz+Pp Mz+Tv Mz+Ft Mz/Mp	MZ+Pp (1) Mz+Ft (1) Mz/Mp (1) Mz+Tv (1) Mz/Pp+Gn (7)	Mz+Pp Mz+Tv Mz+Ft Mz/Mp Mz/Pp+Gn	Mz+Pp Mz+Tv Mz+Ft Mz/Mp Mz/Pp+Gn
Threshold		**1.5 t ha^{-1}**	**\$0.53 day^{-1}**	**>15.3 kg \$$^{-1}$**	**1.5 t ha^{-1}**	**\$0.53 day^{-1}**	**>15.3 kg \$$^{-1}$**
	RG 3	None	Mz+Pp	Mz+Pp Mz+Tv Mz+Ft	Mz+Pp (1)* Mz/Mp (1) Mz+Ft (1) Mz+Tv (1) Mz/Pp+Gn (4	Mz+Pp Mz+Tv Mz+Ft Mz/Mp Mz/Pp+Gn	Mz+Pp Mz+Tv Mz+Ft Mz/Mp Mz/Pp+Gn
	RG 4	None	None	Mz+Pp	Mz+Ft (7) Mz+Pp (10) Mz+Tv (20)	Mz+Pp Mz/Mp	Mz+Pp Mz+Tv Mz+Ft Mz/Mp
Overall		Mz+Pp, Mz+Tv and Mz+Ft (if accessed fertiliser)			Mz+Pp, Mz+Tv, Mz/Mp and Mz+Ft		

* Used in risk analysis as the minimum maize required for the RG 1 and RG 2 farmers. ** Minimum agricultural wage rate for Malawi. Returns to labour should exceed the minimum agricultural wage rate. ***Assuming the total returns are invested to obtain minimum maize requirement of 2 t ha^{-1} for the household, then needs not less than 15.3 kg for every dollar investment to meet the goal. Figures in brackets are probability level of risk.

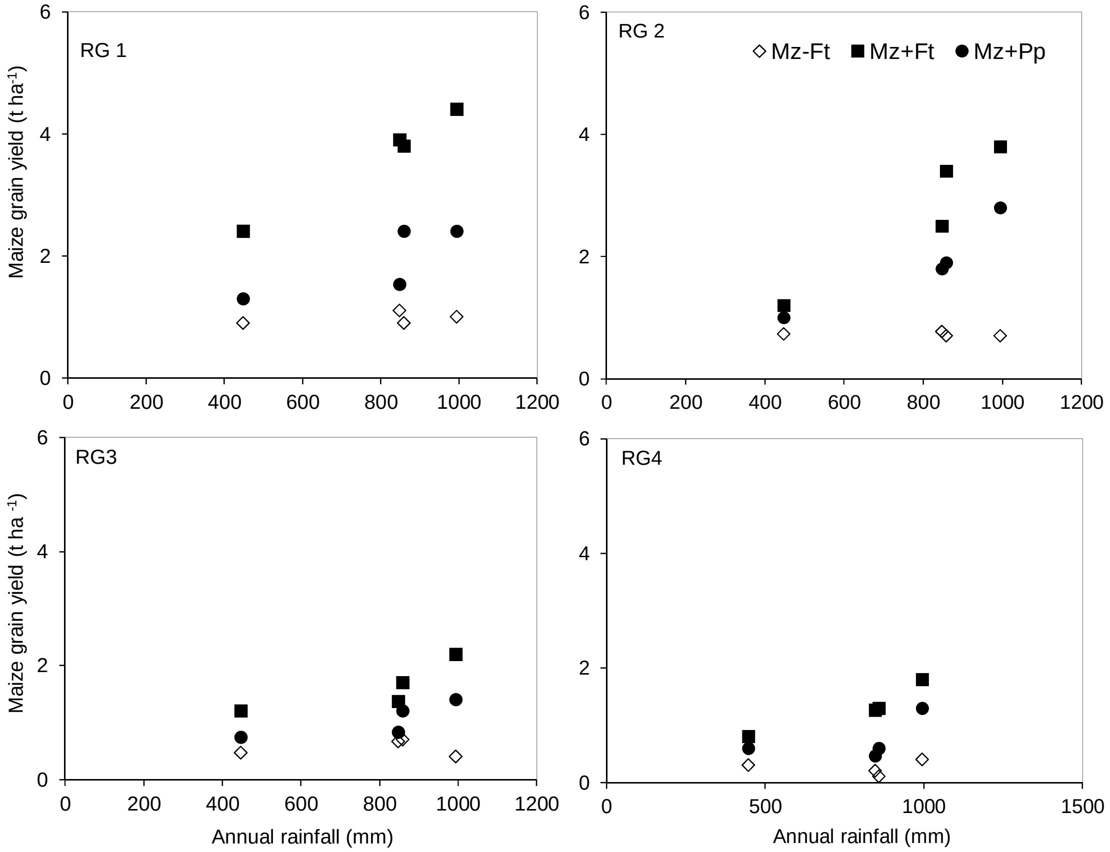

Fig. 3.9. Relationship between maize grain yield (t ha^{-1}) from mother trials and annual rainfall in Chisepo, central Malawi from 1998 to 2002

3.4 Discussion

3.4.1 Maize production and risks

Both seasonal variation in rainfall and differences in previous field management and soil fertility are likely reasons for differences in technology performance between RGs. With low rainfall the maize grain yield from the soil fertility technologies was poor and the yields increased with higher rainfall (Fig. 3.9). Maize yields increased when legumes were integrated in the crop system. Maize yield response was better with normal rainfall and in the better-resourced groups (Fig. 3.9). Maize grain yields were consistently poor on control plots (Mz−Ft) and best with N fertiliser, while maize yields in maize-legume mixtures were intermediate in all the RGs.

Differences in field management between better-resourced and poorly resourced households before the experiment probably contributed to the yield variations. Low yields in less well-resourced groups was likely associated with previous continuous cropping of fields without adequate soil fertility inputs thus reducing their inherent soil fertility (Kumwenda *et al.,* 1997a). RG 3 and RG 4 farmers had a long history of using less fertiliser and, less labour in their own agriculture and more interest in off farm income generation activity (see Table 3.2; Kamanga, 2002a). Additionally, our soil analysis results showed their fields contained less N, soil organic matter and P (Table 3.1). The findings of this study on maize grain yield increments with legume biomass incorporation confirm the findings of earlier studies on maize-legume interactions (e.g. Waddington *et al.,* 2004).

Bringing vulnerability analysis to technology assessment helps fit technologies to different classes of farmers. In our study, most of the maize-legume technologies were less risky for the better-resourced farmers. Maize-legume technologies alone were risky to RG 3 and RG 4 and made poor farmers more vulnerable to maize food shortage. Better-resourced farmers had the capacity to maintain the fertility of their fields while less well-resourced farmers did not (Kamanga, 2002a), and that might have contributed to the yield variations and the risks the technologies gave them. In this case, legume maize technologies that give low maize yields may actually increase vulnerability for poorly resourced farmers in RG 3 and RG 4 while the better-resourced farmers with higher yields are less vulnerable. The low yields and high frequency of risk experienced by the least resourced groups may indicate the difficulties those farmers have to realise better maize yields by just integrating legumes in their fields for soil fertility.

3.4.2 Legume grain, biomass production and soil fertility

Legumes were incorporated into the maize cropping combinations assessed here as a strategy to increase overall crop yields, crop diversity and the stability of crop production. Farmer choices of the legumes studied here were based on their desire to experiment on how best to use the legumes to improve their maize yields. Farmers were especially keen to test Mz+Pp, Mz+Tv and Mz/Mp in baby trials on their farms. RG 3 and 4 farmers were happy with Mz+Pp, RG 1 and 2 with Mz+MPp and Mz/Mp. Apart from mucuna, all the legumes had low grain yields. These probably resulted from poor and variable management of legumes in the field, especially in RG 3 and RG 4, and lack of adequate residual moisture in the case of pigeonpea after maize harvest. Pests such as pod sucking bugs (*Nezara viridula*) and pod borers (*Helicoverpa armigera*) also contributed to the low legume yields during the four years. Reports of theft of legume grain, especially in the third year, contributed somewhat to low yields.

Legume grain offers important food and income benefits to farmers, including fortifying their diets with protein (e.g. from pigeonpea and groundnut). Mucuna gave higher yields because of its high yield potential, good adaptability to poor soils and resistance to pest attack. Mucuna is considered a ‘hunger crop’ in Malawi and farmers mentioned its use for food during the 2001/02 famine when it saved the lives of many people in Chisepo. Generally in Malawi the use of mucuna grain as human food is associated with poverty, although in areas of southern Malawi where this crop is more of a traditional food, the grain is marketable. Where markets are available, farmers easily integrate legumes in cropping systems especially when legumes are a marketable commodity, not grown only for soil fertility. A deliberate policy to develop formal markets for legumes from smallholder farming would help three-fold by improving soil fertility, income and food fortification.

Effective use of legumes to improve soil fertility depends on the amount of biomass produced and the amount of N_2 fixed (Giller, 2001). As a rule of thumb, legumes have to produce at least 2 t ha^{-1} of dry matter biomass that provides about 50-60 kg N ha^{-1} to show measurable impact on maize yield. The positive response of maize to retained biomass in Fig. 3.4 may indicate that most of the legumes were able to supply adequate biomass N over the years. Unlike pigeonpea and groundnut, little biomass of mucuna and tephrosia was grazed by livestock and so more biomass returned into the soil. Thus, although the accumulation of residual nutrients through use of legumes is a slow process (Giller, 2001), continuous use of legumes has additive effects on soil fertility (Shepherd *et al.,* 1997). A 6 year average N contribution by the legumes from both mother and baby plots from 1998-2004 in the area is presented in Table 3.6. Average net N inputs were encouraging although the benefits varied with resource endowment, and the better-resourced farmers obtained an additional 60 kg N ha^{-1} from the largest value of net N input for the least-resourced farmers. The nitrogen left for the maize varied from 0 to 163 kg N ha^{-1} depending on species, giving an average urea equivalent of 2 bags.

Table 3.6. Contribution of legumes in terms of fertiliser equivalents to smallholder fields in Chisepo, central Malawi

	RG 1				RG 2			
Legume	Dry Matter (t ha^{-1})	Net N input (kg ha^{-1})	Urea Equivalent (50 kg bag)	Costs saved (US\$ ha^{-1})	Dry Matter (t ha^{-1})	Net N input (kg ha^{-1})	Urea Equivalent (50 kg bag)	Costs saved (US\$ ha^{-1})
Groundnut	4.3	103	4.5	148	3.3	80	3.5	114
Soyabean	4.7	113	4.9	161	4.4	106	4.6	151
Pigeonpea	4.1	98	4.3	141	3.7	90	3.9	128
Bambara	3.4	82	3.5	117	3.2	77	3.3	110
Cowpea	3.4	80	3.5	115	2.6	61	2.7	88
Mucuna	6.8	163	7.1	233	6.2	148	6.4	212
Tephrosia	4.4	106	4.6	151	2.9	71	3.1	101
	RG 3				RG 4			
Groundnut	2.9	71	3.1	101	2.6	62	2.7	88
Soyabean	3.8	91	4.0	130	2.8	67	2.9	96
Pigeonpea	2.6	63	2.7	90	2.5	61	2.6	87
Bambara	2.5	60	2.6	86	2.1	50	2.2	72
Cowpea	1.8	42	1.8	60	1.9	44	1.9	64
Mucuna	4.5	107	4.7	154	4.2	102	4.4	145
Tephrosia	2.1	51	2.2	73	2.0	48	2.1	68

Although, not all the N applied to the soil can be available for crop use in a season, the useable fraction of the N from legumes in Table 3.6 combined with small amounts to fertiliser that farmers usually access plus timely field management such as weeding could profitably contribute to the household and national food security. The savings in terms of the urea equivalency was something that farmers could utilise and gain in improvement of maize yields. For instance, where households access free fertiliser from government programmes, or accessed fertiliser from the subsidy programmes, it would make a bigger impact if such farmers would apply the fertiliser to maize that has either been planted with legumes or has followed a rotation legume crop. Many studies (de Sornay, 1918; Davy, 1925; Rattray and Ellis, 1952; Edje, 1984; Palm *et al.,* 1997; Giller *et al*., 1997 Giller, 2001) have reported the benefits of these legumes in improving soil fertility and crop yields, but it is the adoption of the same by farmers that is still minimal (Kumwenda *et al*., 1997b, Blatner *et al*., 2000) and this masks the potential contribution of these legumes in soil fertility amelioration.

Small yields in the first years of legume integration in some cases may reduce farmers' interest in legumes, when additional labour of planting a legume and also harvesting are considered. However, the benefits of integrating legumes in the cropping systems should not only be considered in terms of increased maize yields, but also should take into account other useable benefits such as a bonus grain which fortifies farmers' diets. Where legumes are well integrated in the maize cropping systems such as in the southern parts of Malawi, it is a long term strategy to increase crop yields, crop diversity and the stability of crop production, and also to satisfy dietary requirements, while spreading labour peaks, risks caused by weather, pests and disease attack or market fluctuations (Willey, 1979).

3.4.3 Economic performance, risks and technology recommendations

The risks of technologies as identified by the calculation of lower confidence limits (minimum acceptable yield) assist in technology choice for integration in farmers' fields. From an agronomic perspective the domain for technologies in each resource group was identified based on their vulnerability and riskiness. The economic analysis furthered the assessment by incorporating costs of inputs used, labour and land in producing the crops. Results showed that some technologies recommended to RGs based on the lower risk (lower confidence levels) were not viable when costs of inputs were factored in (Table 3.4). Mz+Pp, Mz+Tv and Mz+Ft were all recommended for RG 1 when analysis was based solely on lower confidence limits, but when returns to land and labour were used Mz+Pp became the most attractive technology. This was the same with RG 2 where Mz+Pp and Mz+Tv satisfied most of the criteria. For the poorest farmers (those in RG 4), no technology was chosen because none met the minimum food requirement. However, considering returns to labour, Mz+Pp was found to be suitable also for both RG 3 and RG 4. Mz+Pp was the only maize-legume technology assessed suitable for all the RGs, albeit using different criteria for assessing its suitability.

Return to labour is an important criterion for most farmers in Malawi, especially the less well-resourced farmers from RG 3 and RG 4. Since they get inadequate yields from their fields, these poorer farmers sell their labour to other farmers (known as *ganyu*) to supplement food supplies and income. Mz+Pp has been shown here to be one such agricultural technology that less well-resourced farmers could rely on. It has high stable yields and good returns on small land areas.

Better-resourced farmers have several options. In addition to Mz+Ft, we recommend Mz+Pp, Mz+Tv and Mz/Mp for farmers in RG 1 and RG 2. Farmers in these groups have a high probability of purchasing inputs such as fertiliser and hiring in labour for timely farm operations. They also tend to have more land and may be able to afford to practice crop rotation. For less well-resourced farmers in RG 3 and RG 4, Mz+Pp is recommended. In cases where less well-resourced farmers access fertiliser either through public work programmes or through charitable organizations, the fertiliser would be more profitably used in the longer term in a maize-legume cropping system involving pigeonpea than on short-term sole-crop maize.

With chronic low yields as a result of depleted soil fertility, non-farm activities become more beneficial, and the benefits make sense where risk aversion is high (Kydd *et al.*, 2002). Farmers with chronic low yields have a greater need to engage in non-farm activities, but at the same time have more difficulties to engage in higher return non-farm activities (Kydd *et al.*, 2002). Thus the poorest (e.g. RG 4) may tend to crowd into low return and seasonal labour selling activities. These conditions make farmers such as those from RG 4 most vulnerable to soil fertility depletion and low yields. Perceptions of risks by farmers from this group are likely to be those of “take less” rather than “take more” and may likely not be willing to incorporate the legumes in their fields. Thus would only engage in a technology that is really rewarding to their needs with immediate effects, as explained by the theory of risk aversion. On the other hand, well-off farmers (RG 2) have the capacity to gain more from farm activities, and may not engage in low non-farm activities. Compared to poor farmers, these farmers are least vulnerable to soil infertility and low yields, and their attitude may be that of “take more” risks, as they have the capacity to buffer shocks in case of failure of one enterprise. In between are farmers who are vulnerable (RG 3) and moderately vulnerable (RG 2), and their risk perceptions would tend to follow the same patterns.

3.5 Conclusions

New maize-legume technologies bring more risks to less well-resourced farmers than to better-resourced farmers. Better-resourced farmers in central Malawi had larger maize grain yields than less well-resourced farmers. As often reported, use of N fertiliser is the most rapid way to increase maize yields but is suitable only for better-resourced households. The integration of legumes in maize-based systems reduces the level of risk to farmers compared with continuous maize without fertiliser, and contributes to improvement of soil fertility. In assessing crop technologies for farmer suitability or recommendations, a combination of agronomic and economic criteria provides useful insights. An agronomic risk assessment showed that maize with N fertiliser is least risky to farmers, the inclusion of costs of inputs at current retail prices in the risk analysis showed that it was still risky to farmers. I recommend a maize + pigeonpea intercrop for soil fertility and maize yield improvement for most poorly resourced farmers in Chisepo and similar areas of central Malawi. Continuous use of legumes such as pigeonpea in maize systems should be encouraged in smallholder agriculture. Long-term policy support is needed in central Malawi to help the poorer farmers to access seed of food legumes (especially pigeonpea) as well as N fertiliser for maize.

Chapter 4

Participatory evaluation of the effects of phosphorus on legume grain and biomass yields: tapping on farmers' knowledge in legume production in Chisepo

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Chapter 4

Participatory evaluation of the effects of phosphorus on legume grain and biomass yields: tapping on farmers' knowledge in legume production in Chisepo

Abstract

Building from the perception that farmers have an intimate knowledge of their local environment, production problems, crop priorities and criteria for evaluation, an on-farm experiment was conducted with farmers in 2003/4 in Chisepo, central Malawi, to evaluate the response of six annual legumes to phosphorus (P) (20 kg P ha^{-1} or no P fertiliser) application. The legumes were velvet bean, pigeonpea, soyabean, groundnut, bunch-type cowpea and Bambara groundnut. Twelve farmers hosted the experiments and each farmer formed a group of at least 4 other farmers to evaluate the legumes. Farmer participatory monitoring and evaluation of the legume and P combinations was conducted during the experiment to determine farmer preferences and acceptance of the technology. Measured grain yields, returns to labour and total costs of the P-fertilised legumes were compared with those for the unfertilised legumes. The application of P fertiliser significantly ($P = 0.05$) increased legume grain yields, particularly with velvet bean, and soyabean. However, use of P was not financially attractive and farmers were not interested to use P at the time. Farmers were more interested to maximise legume food production from their labour investment. Soyabean, groundnut and pigeonpea, grain legumes with high value as food, were considered to be priority crops by farmers over velvet bean, cowpea and Bambara groundnut.

Key words: *Grain legume, farmer participation, soil fertility, phosphorus, monitoring and evaluation, financial analysis.*

4.1 Introduction

The incorporation of legume residues is often proposed as a way to improve the productivity and sustainability of cereal-based cropping systems in smallholder fields in Africa (e.g. Snapp *et al*., 1998; Giller, 2001; Mafongoya *et al*., 2006). In Malawi, common annual grain legumes include pigeonpea, groundnut, soyabean and common bean (*Phaseolus vulgaris*) and examples of green manure legumes are velvet bean and fish bean (*Tephrosia vogelii*). Soil fertility is in a slow general decline in sub-Saharan Africa and this poses a special threat to the future of smallholder agriculture where limited options to improve soil fertility are available (Smaling, 1998). To arrest the decline in soil fertility and improve crop yields in southern African smallholder agriculture, research has widely promoted the use of annual grain legumes that also provide food for humans (Waddington *et al*., 2004; Whitbread *et al*., 2004a). Nevertheless, in Malawi, many farmers grow few legumes, and on small land areas (Phiri, 1999; Snapp *et al*., 2002a). The improvement of soil fertility therefore requires an integrated approach that includes increased production of legumes by farmers using inputs, such as mineral fertilisers, that help the legumes to grow well. One way to do that is for farmers to work together with research and extension staff to learn about various legume and fertiliser options and benefits.

The maintenance of soil organic matter (SOM) is crucial to the management of soil fertility in the tropics (Woomer *et al*., 1994). Therefore farmer's perceptions about biomass and SOM from legumes (and cereals) and the management of legumes are relevant to improving soil fertility. In addition, legumes improve soil fertility through biological N_2-fixation, additional carbon inputs and by conserving nutrients (e.g. Giller, 2001). However, farmers may neglect the effect of these legumes as the benefits often are not obvious in the short run. Farmers have an intimate knowledge of their local environmental conditions, production problems, crop priorities and criteria for evaluation, and many actively engage in experimentation as part of their farming routine (Sumberg *et al*., 2003).

However, this knowledge, experience and experimentation are often ignored by researchers, who commonly give farmer perceptions little attention in their research (Bellon, 2001; Tripathi and Ellis-Jones, 2005). At the same time, the results of formal research are often not accessible and inappropriate for resource-poor farmers. To bring these components of knowledge together requires that the local knowledge with farmers be taken as a basis or keystone for a collegial relationship between farmers and researchers where significant extra benefits may accrue to both (Quansah *et al*., 2001; Sumberg, *et al*., 2003). While legumes can improve soil fertility, prevailing low soil fertility limits N_2 fixation by legumes and the overall growth and yield of legumes grown on many smallholder farms. Phosphorus (P) deficiency is one often important factor (Whitbread *et al*., 2004b). P is needed in relatively large amounts by legumes for growth and nitrogen fixation and their effectiveness in soil improvement is hindered by P deficiency (Giller and Cadisch, 1995). P deficiency can limit nodule, leaf area, biomass and grain development in legumes.

The application of P fertiliser can overcome the deficiency on soils that do not strongly adsorb P (Giller, 2001). In Malawi, low yield of legumes grown by smallholder farmers may be strongly linked to minimal use of P fertiliser (Mwalwanda *et al*., 2003) among other factors, and this was also identified during simulation modelling of the response of maize to legumes and N fertiliser in central Malawi (Robertson *et al*., 2005). In recent efforts to increase the production of legumes by smallholder farmers, the notion of 'trialability" has been emphasized where end users (farmers) contribute their knowledge and experiences effectively and modify where necessary the innovations during the process of adoption (Sumberg *et al*., 2003). It is important that participatory assessment is used to capitalise on farmer knowledge to identify opportunities and constraints, understand farmers' use of technologies, and assist technology adoption. To evaluate the response of six annual legumes to P fertiliser application, I conducted an on-farm experiment with 12 host farmers in 2003 - 2004. To increase ownership and the usefulness of results from the experiment, farmers provided land and labour for all activities on the plots and made frequent visits as a group to the experiments. This chapter presents results from that study which established the response of the legumes to P fertilisation, identified constraints and farmer concerns about the technologies, and recorded farmer modifications to the use of P fertiliser on the legumes.

4.2 Materials and Methods

4.2.1 Profile of the study site

The study was conducted in Chisepo, Dowa district in the central region of Malawi (13'32" S and 33'31" E), located 120 km northwest of Lilongwe City at an average elevation of 1100 m above sea level. Annual rainfall in Chisepo ranges from 600 - 1100 mm (Fig. 4.1) with an annual mean temperature of 22°C. In the 2003 – 2004 growing season, rainfall was not well distributed from November to April and the annual total (670 mm) was below the long term average of 748 mm. Below average rainfall adversely affects crops such as long duration pigeonpea which require more residual soil moisture before maturity in July. Soils in the area are generally sandy and ferralitic clay loams (Young and Brown, 1962). Most of the area was formerly a miombo woodland ecosystem. Agriculture dominates the farmers' livelihood strategies in the area. Maize is the predominant food crop and tobacco the most important cash crop. Other crops include traditional legumes such as groundnut and common bean. Low soil fertility and erratic rainfall are the major constraints to increased smallholder agricultural production. The soils produce inadequate crops without soil fertility interventions, resulting in relatively high levels of poverty in the area (Snapp *et al.*, 2002b).

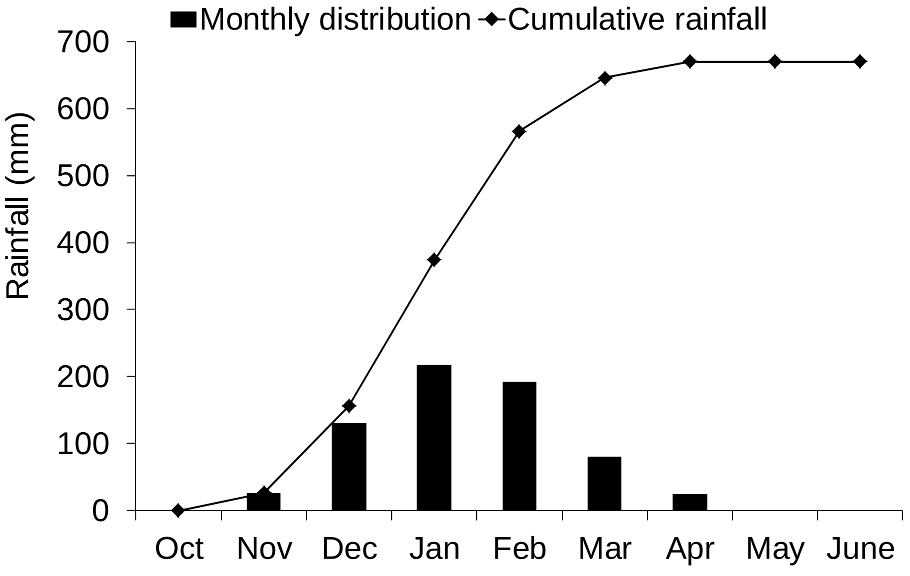

Fig.4.1. Rainfall (mm) at Mbingwa in Chisepo in 2003/04

4.2.2 Selection of farmers hosting legume experiments

Prior to this study, farmers in Chisepo had experience with conducting on-farm experiments on maize-legume technologies beginning in 1998 by working as research groups over four years. These previous participatory studies involved over 52 farmers in the village area. In a pre-season workshop with farmers in 2003, discussions on the results of APSIM crop system simulation model predictions on yield of legumes

(Robertson *et al*., 2005) led to the decision to evaluate P fertiliser application to legume performance under farm conditions. Twelve farmers were randomly selected by the researchers to host the experiments. Each farmer formed a group of at least four farmers. Although many of the farmers had received previous training on field experiment management, farmers were reminded about the principles of conducting research. Many farmers were familiar with at least the following ten legumes: pigeonpea (ICP 9145) (*Cajanus cajan,* (L.) Millsp.), Magoye soyabean (*Glycine max* (L.) Merrill), groundnut (*Arachis hypogaea* L.), Bambara groundnut (*Vigna subterranea* (L.) Verd), velvet bean (*Mucuna pruriens* (L.) DC), cowpea determinate-habit (*Vigna unguiculata* (L.) Walp.), cowpea indeterminate-habit (*Vigna unguiculata* (L.) Walp*.)*, fish bean (*Tephrosia vogelii* Hook. F.), sunnhemp (*Crotalaria juncea* L.) and grahamiana (*Crotalaria grahamiana* Wight and Arn.*)*. From these, farmers selected six annual legumes for the experiment based on their expectations of food, soil and financial benefits. Responsibilities for implementing the experiments were discussed during the workshop. The agreement was that researchers would provide P fertiliser, seed and field notebooks while participating farmers would provide land and labour. All farmers would make observations and help with recording, and participate in all activities from planting to harvest with the help of a field assistant. At the end of the experiment all farmers and researchers jointly evaluated the results.

Sb-P	Cp+P	Bn+P	Pp+P	Gn-P	Bn-P	Mp+P	Sb+P	Cp-P	Pp-P	Gn+P	Mp-P
Mp-P	Bn-P	Sb+P	Cp-P	Pp+P	Pp-P	Sb-P	Bn+P	Gn+P	Mp+P	Cp+P	Gn-P
Gn-P	Pp-P	Mp-P	Bn+P	Cp+P	Mp+P	Cp-P	Pp+P	Bn-P	Sb+P	Gn+P	Sb-P

Fig. 4.2: Plot layout for legume experiments in farmers' fields. Pp is pigeonpea, Mp is *Mucuna pruriens*, Sb is soyabean, Gn is groundnut, Cp is cowpea, Bn is Bambara groundnut and –P or +P is without or with phosphorus fertiliser

4.2.3 Experimental design and implementation

The experiment consisted of 12 experimental treatments. Plots were allocated to six legumes: velvet bean, pigeonpea, soyabean, groundnut, cowpea bunch-type and Bambara groundnut. Each legume received no P fertiliser or 20 kg P ha^{-1} as triple super phosphate (TSP). The experiment was laid out in home fields adjacent to the homestead buildings (within 50 m) and in middle fields that were over 50 m away from homes. The experiment was hosted by 12 farmers, but one farmer discontinued involvement during the study because the family had to look for a temporary employment on a tobacco estate in the area as a means of finding food. Each farmer had all 12 experimental treatments which were replicated three times in each field in a 6 × 2 × 3 randomised complete block design giving a total of 396 data points (Fig. 4.2). Legumes were planted following standard farmer plant spacing targeting plant population densities of 74,000 ha^{-1} for velvet bean, groundnut, Bambara groundnut, and bunch cowpea, 444,000 ha^{-1} for soyabean and 37,000 ha^{-1} for pigeonpea (GoM, 1996). P fertiliser was applied once at planting at the rates given above, and either banded or dolloped on the soil surface on top of the ridges. All management activities with the experiment were the responsibility of the farmers, field assistant and researchers.

4.2.4 Data and methods for collection

Baseline soil samples were collected from a soil depth of 20 cm just before planting the legumes. The samples were analysed for pH (in H_20), soil texture, % organic matter, % nitrogen and available phosphorus (Bray) using standard methods for tropical soils (Anderson and Ingram, 1993). Legume grain and yield components were measured after crop maturity at the end of the season. Crop samples were harvested for above-ground non-grain biomass analysis from the legumes in net plots of 3 × 3 m at the end of the season. Samples were analysed for nitrogen (N) and phosphorus (P) content in DM at Bunda College Soils and Plant Laboratory. Farmers and the field assistant periodically recorded their practices and observations from the experiments, including operations such as date of planting, weeding, flowering and the incidence of pests and diseases. Labour use on different operations was monitored by the host farmer and the field assistant and records kept of the time taken for each operation. This included land preparation, planting, fertilising, weeding, and harvesting. Incorporation of crop residues was left to the host farmers to perform. Training events, farmer workshops, field days, exchange visits and farmer evaluation of the legumes were done with all participating farmers at appropriate times throughout the season. Proceedings of each meeting were recorded by farmers and the field assistant. Because experimental management was left with the farmers, rather than be tightly controlled, management practices and standards were variable as were the fields where the experiments were conducted. This resulted in a large range of yields achieved in the experiments.

4.2.5 Preference ranking of technologies by farmers

Farmers monitored the performance of legume technologies throughout the season and regularly observed and recorded their observations in field notebooks and on resource allocation maps. Crop performance at each stage was evaluated against their criteria for selection of the technology and that was used to judge farmers' final assessment of each technology. In a final evaluation, farmers looked at crop growth parameters like the amount of biomass, grain yields and ease of management, including suitability for intercropping. Intercropping became an important selection factor because it is increasingly used by farmers with legumes that are promising to restore soil fertility and also offer a bonus food crop. Farmers assigned ranks to each technology in a preference ranking based on their criteria. All observable aspects were aggregated by each farmer for each technology. After all farmers had ranked the technologies, the results were given by numbers for each technology and the final level of satisfaction were animated and presented in Table 4.3. Farmers were grouped into three categories based on how well they participated and responded to the needs of the experiments.

4.2.6 Economic analysis of the technologies

Costs and benefits were calculated on inputs and outputs in the experiments using prices prevalent in the 2003/4 season. Average farm-gate price for legume grain was MK20.00 kg^{-1} (US\$0.19 kg^{-1}). Labour cost was estimated using the opportunity cost of labour, based on the minimum agricultural wage rate of MK56 man-day^{-1} (US\$0.53) in 2003/4. Average labour requirement for the production of legumes for each field experiment (not including costs of residue incorporation) was 47 man-days including fertilising with P, and an average of 36 man-days in some legumes where fertiliser was not applied. Legume seed was priced at US\$0.56 kg^{-1}, which is lower than the normal price of US\$1.2 kg^{-1}. This was so because normally farmers plant legume seed from their previous harvests. Buying of new seed is not common for many farmers and if they buy it usually is from within the area from other farmers. Triple super phosphate-P was MK249.31 kg^{-1} (US\$2.33). Most economic analyses of agricultural experiments use three criteria for evaluation for financial or economic performance: returns to labour, returns to land and the benefit to cost ratio.

These criteria were used to evaluate the economic legume grain response to P fertiliser application under farmer conditions in Chisepo (Table 4.4). Labour is the main asset of smallholder farmers and their goal is to maximise returns to this asset. Returns to labour, calculated by dividing the net benefits by the total man-days, were used to compare the benefits in the economic analysis. Returns to land are represented by the Gross Margins (GM), and GM was calculated as;

$$GM = \sum_{i=0}^{n} (B-C)$$

Where B is the benefits accrued by using the land in that year, C are the costs associated with use of that land in the same period. The benefit-cost ratio (B/C) indicates the rate of return per unit cost. The B/C ratio was calculated as follows;

$$B/C \text{ ratio} = \sum_{i=0}^{n} B \,/ \sum_{i=0}^{n} C$$

A B/C ratio of greater than 1 indicates that the land use system is profitable.

4.2.7 Data management and analysis

All quantitative data from experimental plots and field based measurements were statistically analysed using an appropriate analysis of variance model in the Genstat statistical package. Field observations that farmers had recorded throughout the year were presented in a final workshop in June 2004 and were discussed to identify farmer perceptions.

4.3 Results

4.3.1 Farmers' rationale for selection of legumes used in the participatory evaluation

Farmers described five main criteria for evaluating a legume for their cropping systems (Table 4.1). Their rationale involved weighing the positive attributes against negative ones. The first positive attribute was the ability of a legume to produce useable grain for either human food or market. Farmers mentioned that although the project emphasised soil fertility improvements, for them the use of legumes for soil fertility improvement was a secondary benefit after food. The second attribute was the ability of a legume to be intercropped with maize.

Farmers explained that due to scarcity of land and increased labour demands for other activities, a legume that intercropped well with maize or other main crops was better than one that did not. The third attribute farmers gave was ability to improve soil fertility. This was assessed primarily through the level of biomass production by the legume, which they believed was the most important pathway for legume soil fertility improvements.

The fourth attribute was the ability to control weeds. Witch weed (*Striga asiatica*) was one of the most important weeds in the area, and most farmers agreed with researchers that some legumes reduce witch weed incidence on maize. Legumes with those characteristics would be preferred over others. The last attribute mentioned was the labour requirement for management of the legume. Negative attributes that farmers identified for velvet bean included lack of market for its grain, problems with cooking the toxic seeds and difficulties to intercrop with maize. Late maturity was the main negative attribute for pigeonpea because damage by livestock into the dry season reduces its ability to improve soil fertility or provide seed. Pests and diseases were recognised to reduce grain yields of pigeonpea. The method of harvesting soyabean, where the whole crop is uprooted for processing at home, reduces incorporation of biomass. The commonly used CG 7 groundnut was susceptible to pests and diseases and it easily gets mouldy when harvesting has delayed. Bambara groundnut and cowpea had several negative attributes including susceptibility to pests and diseases, limited biomass production, aphid attack and low yield expectation.

Farmers however said that they consider both positive and negative attributes for selection of a legume. If in their view, the positive attributes out-weigh the negative attributes then the legume has a higher priority over others. According to Estrella and Gaventa (1998), evaluation of legumes that centres on farmers own criteria reflect the value farmers put on the characteristics of technologies. Since the evaluation was done in a participatory manner, significant participation of farmers in legume evaluation was expected and it was made sure that such evaluation was based on their major problems such as soil fertility, and that farmers really understood the trial set up which they could monitor easily on their own. Good communication with the farmers and simple and straightforward trial lay-outs (in which they have participated to formulate) were critical tools to achieve significant participation.

Table 4.1. Farmers' reasons for selection of annual legumes for the 2003/04 season in Chisepo, central Malawi.

	Positive attributes	Negative attributes	Supporting ethnographic quotes
Velvet bean	High biomass production and grain Good for soil fertility Helps in weed control e.g. *Striga* species Has few pest or disease problems Grows well in almost all soils Conserves soil	Difficult to cook (need alternative ways of processing) Poisonous Does not grow well with maize Difficult to incorporate	"Our soils are so poor, we can't find fertiliser, and maybe growing these bushes would help improve our maize" "… although we hear that it killed the Ngoni people, its grain helped many families here in Chisepo during the 2001/02 famine; that year we were dying"
Pigeonpea	Excellent grain and relish food Improves soil fertility Grows well with maize, hence labour and land saving Provides firewood Good to feed cattle and goats if wanted	Late maturing hence destroyed by livestock, goats like it Depredation by pests and diseases (beetles)	"*Ndiwo yake ya yiwisi ndiyokoma kwambiri* " (Its grain relish is very good)
Soyabean	Grain for food (flour makes local bread, porridge, milk, mix with relish) Grain for sale Improves soil fertility Grows well with maize, hence land and labour saving Grows well in almost all soils	Difficult to establish where seed-eating birds are common Difficult to incorporate due to harvesting method Poor germination	"I prefer growing soyabean because I understood from our field officers how to make milk and porridge from soyabean. The milk and porridge have helped keep my family healthy and I guarantee the family health for as long as I grow the crop"
Groundnut	Food Improves soil fertility Good animal feed	Susceptible to diseases and pests Becomes mouldy easily	"The new variety is sweet, although it does not make a good mixture for relish"
Bambara nut	Good relish Easy to manage	Limited biomass production Low yielding Susceptible to pests and diseases	"This crop has not been widely grown because we believed that only households who had lost at least one child should grow it. Using it in the experiment helps to clear this myth"
Cowpea bunch-type	Relish Easy to manage Matures faster	Aphid attack	"The traditional cowpea spreads a lot and we fail to plant more of it in maize. This new one maybe would replace that"

4.3.2 Soil properties of experiment sites

Initial soil properties in the farmers' fields where the experiments were hosted indicated that the soils had a slightly acidic reaction, and small concentrations of Bray available P (Table 4.2). The critical value for Bray available P ranges from 8 - 16 mg kg^{-1} for most soils in central Malawi. There was little difference in soil properties between the home and middle fields.

Table 4.2. Soil properties at 20 cm soil depth for selected farmers' fields in Chisepo, central Malawi in 2003.

Farmer	pH	% Sand	% Silt	% Clay	% OM	% N	Bray avail. P (mg kg^{-1})
			Home field				
G. Mbingwa	5.6	53	13	33	1.3	0.06	4.1
B. Banda	5.4	63	10	27	1.7	0.08	7.0
L. Mwenda	5.1	67	17	17	0.8	0.04	9.9
M. Samson	5.6	63	10	27	1.9	0.10	9.0
Mean	5.4	61	13	26	1.4	0.07	7.5
			Middle field				
P. Biliati	5.4	53	13	33	1.6	0.08	6.2
S. Kalivute	5.9	70	10	20	2.1	0.10	6.6
J. Mafuta	5.2	53	17	30	2.1	0.10	4.9
L. Basela	5.9	67	7	27	1.8	0.09	9.0
M. Jeremani	5.6	63	10	27	1.5	0.07	5.2
Mean	5.6	61	11	27	1.8	0.09	6.4
Overall mean	5.5	61	12	27	1.6	0.08	6.9

4.3.3 Legume response to P fertiliser

Effects of P fertiliser on legume grain yields

Grain yields of P fertilised legumes were higher (P = 0.05) than yields of unfertilised treatments for all legumes in the two field types, except for pigeonpea where yield was the same in the home field (Fig. 4.2). The mean grain yield of P-fertilised velvet bean was 1.0 t ha^{-1} higher than unfertilised. Similarly, P-fertilised groundnut, soyabean, Bambara groundnut and cowpea gave 0.8, 0.5, 1.0 and 0.3 t ha^{-1} extra grain yield (P = 0.05) than unfertilised plots respectively. Velvet bean gave the largest grain yield followed by groundnut, soyabean, Bambara groundnut and then cowpea (Fig. 4.2). Pigeonpea had the poorest yields on both field types. Velvet bean, pigeonpea, soyabean, unfertilised groundnut and Bambara groundnut had larger yields in middle fields (P = 0.05) than home fields. Cowpea and fertilised groundnut had better yields in the home fields than middle fields (Fig. 4.2). Except pigeonpea and cowpea, other legumes performed better than the national average grain yields of 400 - 800 kg ha^{-1}. In terms of percentage response, cowpea had the strongest response to applied P seconded by Bambara groundnut, and then groundnut, velvet bean and soyabean. Pigeonpea showed no response to P in the home fields. However, pigeonpea and cowpea had the strongest response to applied P fertiliser in the middle fields. Velvet bean and soyabean responded almost the same way to applied P fertiliser. Overall responses (mean of 11 farmers), indicate that cowpea responded more to applied P than any other legume, followed by Bambara groundnut, groundnut and soyabean. Pigeonpea responded least to P fertiliser.

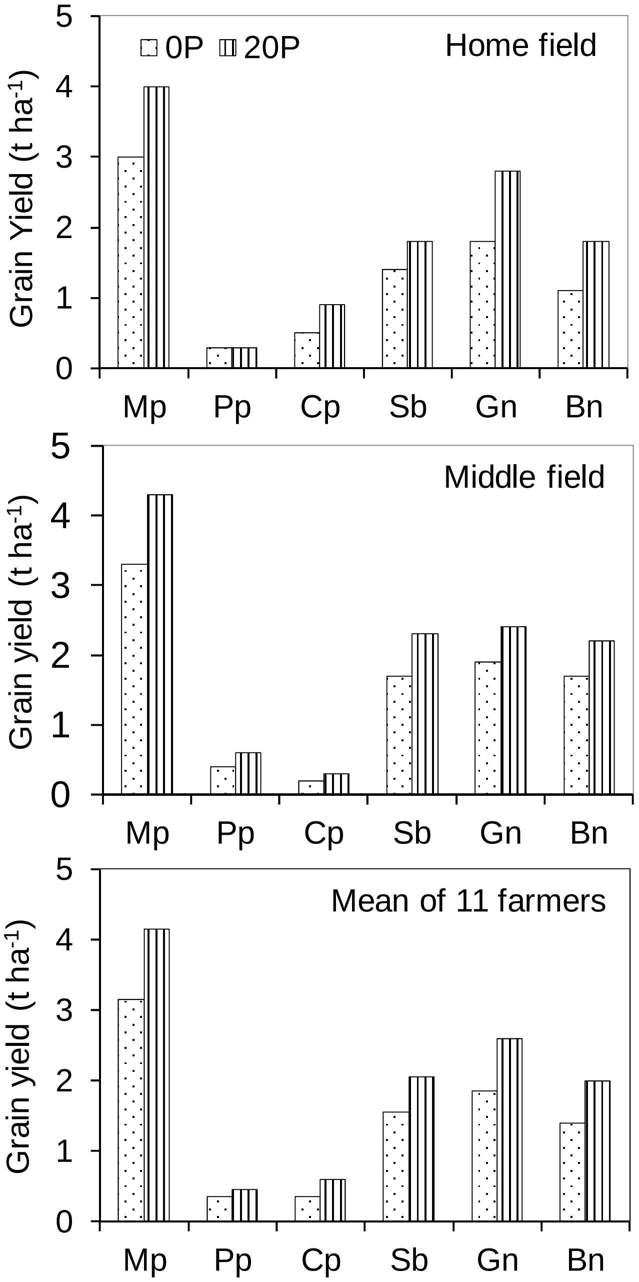

Fig. 4.2. Grain yield (t ha^{-1}) of legumes in Chisepo in 2003/04 (*n* = 11 farmers)

Effect of phosphorus on legume biomass yield and N and P leaf content

Legume biomass yields (DM) shown in Fig. 4.3 were significantly different at $P = 0.05$. Fertilised treatments gave higher biomass yield than unfertilised treatments for all legumes planted on both field types. Mean yield showed the same trend, with the fertilised velvet bean treatment yielding 2.2 t ha^{-1} higher biomass than the unfertilised treatment ($P = 0.05$). Fertilised soyabean had 1.5 t ha^{-1} of biomass on top of the unfertilised treatment. The least difference was from pigeonpea where the fertilised treatment raised yields only by 0.3 t ha^{-1} compared with the unfertilised treatment. Velvet bean gave the highest biomass yield of all legumes followed by groundnut, soyabean, Bambara groundnut and cowpea; pigeonpea was least (Fig. 4.3).

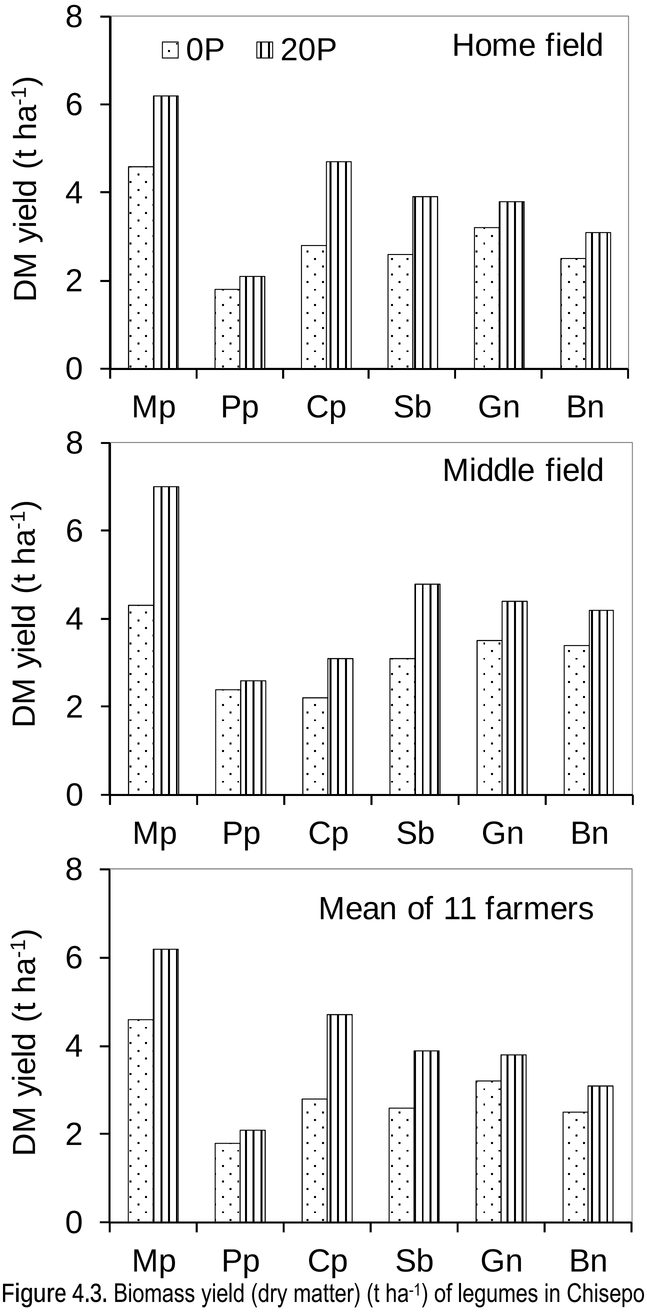

Figure 4.3. Biomass yield (dry matter) (t ha^{-1}) of legumes in Chisepo in 2003/04 (n = 11 farmers).

In home fields, velvet bean still produced the most biomass, followed by cowpea, groundnut, soyabean, Bambara groundnut and the pigeonpea, while velvet bean was followed by soyabean, groundnut and Bambara groundnut, cowpea and then pigeonpea in middle fields. The differences between home and middle fields were variable, with velvet bean, pigeonpea, soyabean, groundnut and Bambara groundnut giving better yields in middle fields than home fields.

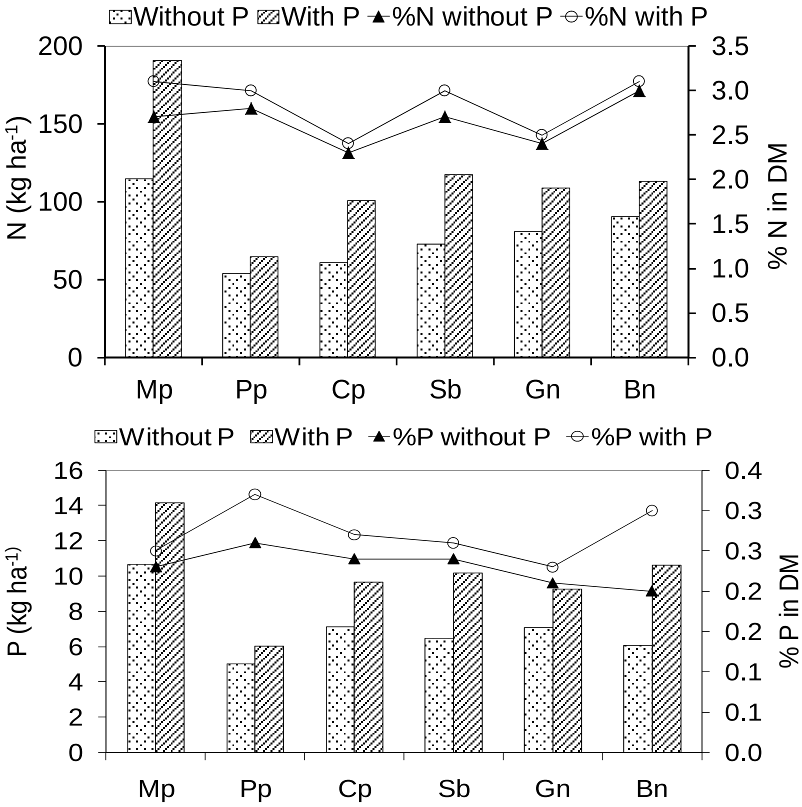

Fig. 4.4. Response of legume leaf N and P content (by difference method) and leaf concentration to applied fertiliser P in Chisepo, Malawi in 2003/04.

The effect of P fertiliser on legume leaf N and P content is shown in Fig. 4.4. There was a consistent increase in N content in all legumes with P fertiliser application with the highest response observed in velvet bean followed by soyabean, cowpea, groundnut, Bambara and pigeonpea. Mean % N content ranged from 2.0 to 3.2 across the legumes but was slightly higher within treatments that had received P. Leaf P content also increased with P fertiliser for all legumes with the exception of pigeonpea. The highest response came from Bambara groundnut followed by soyabean, velvet bean, cowpea and groundnut.

4.3.4 Participatory evaluation of legumes

Farmers' evaluation and preference ranking of the technologies

Farmers were asked to assess the legumes for different attributes with P fertilisation. Soyabean was the most preferred legume by farmers, followed by groundnut and cowpea. Velvet bean, pigeonpea and Bambara groundnut had lower scores (Table 4.3). Farmers observed that soyabean showed a better response to P for grain and biomass yields. They observed that it had the highest contribution to food security, had good germination and the grain is marketable. However, soyabean scored poorly on drought resistance. The second highest preferred legume by farmers was groundnut, which scored high on seed availability, marketability, storage and contribution to food security. Cowpea was preferred to velvet bean, pigeonpea and Bambara groundnut. Farmers were able to link legume response to its potential for soil fertility improvement and capacity to smother weeds. Farmers also noted that pigeonpea, velvet bean and soyabean grew well during the dry spells in the season. Labour for P fertilisation was perceived to be high for all the legumes except pigeonpea.

Table 4.3. Farmer score of legume response to P fertilisation in Chisepo, central Malawi in 2003/04 (n=48 farmers).

	Velvet bean	Pigeonpea	Cowpea	Soyabean	G/nut	Bambara
Grain yield response to P	☺	☹	☺	☺	☺	😐
Biomass yield response to P	☹	☹	☺	☺	😐	😐
Drought resistance	☹	☹	☹	😐	☹	☹
Germination	☺	☺	☹	☺	☺	😐
Pest attack resistance	☺	😐	☹	☺	☺	☹
Contribution to food security	☹	☺	☺	☺	☺	☺
Marketability	☹	☺	☺	☺	☺	☺
Seed availability	☹	☹	☺	☺	☺	😐
Storage	☺	😐	☹	☺	☺	☹
Rank	4	5	3	1	2	6
Over all rank	😐	☹	☺	☺	☺	☹

Note: 1 = most preferred, 6 = least preferred; 😐 = Not sure; ☹ = Not satisfied; ☺ =Very satisfied

4.3.5 Financial evaluation of legumes

A financial analysis of the legumes (Table 4.4) revealed that returns to labour were more than the minimum wage rate of $0.53 per day for agricultural labour for all legumes except pigeonpea with fertiliser and cowpea in both types of field. Gross margins were higher with P fertiliser application. A benefit/cost ratio of more than 1 indicates that the practice is profitable. Velvet bean, soyabean, groundnut and Bambara groundnut had positive B/C ratios greater than 1, indicating that production of these legumes under good rains was profitable to the farmer. Application of P however reduced the profitability of the legumes due to the cost of the fertiliser. Pigeonpea gave the lowest returns while velvet bean had the highest returns to labour, GM and also B/C ratios in both types of Malawi in 2003/04. B/C ratios with the fertilised treatments were lower than in unfertilised plots indicating that application of P fertiliser to legumes was not economic to farmers in Chisepo at present, although this assessment does not take into account any residual benefits to subsequent crops.

Table 4.4. Grain yield (t ha^{-1}) and financial returns (US$) from six legumes grown on home and middle fields in the experiment in Chisepo, central Malawi in 2003/04.

		Home fields					Middle fields				
Legume treatment		Returns to labour $/day	GM ($ ha^{-1})		B/C ratio		Returns to labour $/day	GM ($ ha^{-1})		B/C ratio	
			With labour	Without labour	With labour	Without labour		With labour	Without labour	With labour	Without labour
Velvet bean	-P	10.9	511.5	536.4	8.7	16.0	12.1	568.5	593.4	9.7	17.7
	+P	11.6	650.1	679.8	5.9	8.5	12.6	707.1	736.8	6.4	9.2
Pigeonpea	-P	0.6	27.6	52.5	0.9	11.7	1.0	46.6	71.5	1.6	16.0
	+P	-0.4	-26.4	5.9	-0.3	0.1	0.5	30.6	62.9	0.4	1.2
Cowpea	-P	0.8	36.5	61.4	0.6	1.8	-0.4	-20.5	4.4	-0.4	0.1
	+P	1.1	61.7	90.8	0.6	1.1	-1.0	-52.4	-23.2	-0.5	-0.3
Soyabean	-P	4.4	207.5	232.4	3.5	6.9	5.6	264.5	289.4	4.5	8.6
	+P	3.6	228.4	261.8	2.0	3.3	5.1	323.4	356.8	2.8	4.4
Groundnut	-P	5.6	261.1	286.0	3.2	5.1	6.0	280.1	305.0	3.5	5.4
	+P	5.8	393.4	429.4	2.8	4.2	4.7	317.4	353.4	2.3	3.4
Bambara	-P	3.2	150.5	175.4	2.6	5.2	5.6	264.5	289.4	4.5	8.6
	+P	3.7	228.9	261.8	2.0	3.3	4.9	304.9	337.8	2.7	4.2

4.3.6 Farmer learning and participation in legume experimentation and evaluation

Table 4.5 summarises what farmers learnt from the participatory evaluation of legumes. There were eleven groups with a total of 56 farmers. The results were divided into three categories of farmers based on their interest to participate, how well they managed the experimentation and their uptake of information. Category 1 had farmers who were very active in all the processes of on-farm experimentation, including recording their observations from the plots. This group also provided good guidance to other farmers. Six farmers from this category hosted the experiments, and provided better management than those in the other two categories. They were not doing this for recognition, but they had considerable interest in learning together to improve their farming.

Table 4.5. What farmers learnt from the field experiments (% of total farmers, n = 56) (multiple answers were allowed).

Things farmers learnt	Category 1 (49%)	Category 2 (35%)	Category 3 (16%)
Methods to apply fertiliser to legumes	73.9	21.1	5.0
That legumes grow better with fertiliser	65.6	24.1	10.3
Processing of legumes for consumption	37.0	51.3	11.7
Use of legumes to improve soil fertility	88.2	10.0	1.8
Planting patterns of legumes (incl. intercropping)	54.8	30.2	15.0
Frequent weeding of legumes	60.9	34.3	4.8
Data collection from experiments	55.6	43.4	1.0
Types of legumes and their benefits	67.0	18.3	14.7
Conducting and explaining experiments	67.4	30.6	2.0

Category 1 comprised just under half (47%) of the participating farmers. Category 2 farmers were those who were neither active nor passive; the average farmers. These were farmers with mixed feelings that did not want to take chances or be seen to be doing things out of nothing. They contributed to the study but were sometimes unavailable or absent. Category 2 consisted of 36% of the farmers; including three who hosted the experimental plots. The last category (Category 3) of farmers comprised those who required to be reminded of their role in the experimentation, contributing little. Their main reason for involvement was an expectation of receiving inputs such as seed or fertiliser. They comprised 17% of the total group and four of these farmers discontinued their participation. One of the farmers who dropped out of Category 3 hosted an experiment but declined to continue after the field was planted. Accordingly we ended up having eleven groups. The other two experiments from this category were poorly managed despite numerous visits and encouragement from the field assistant.

More farmers from Category 1 learned several things from the process as shown by high percentages for several practices especially the use of legumes for soil fertility (Table 4.5), indicating their confidence in legumes for soil fertility improvements. Percentages were also high for methods of fertiliser application to legumes, and conducting experiments. The average farmers in Category 2 learned more about the processing of legumes for consumption and also about data collection from experiments. Category 3 had few farmers that had understood these things well. They lagged behind in all steps in the process of participatory evaluation. The high confidence that legumes improve soil fertility was emphasised through lessons on management of subsequent crops (including timely planting and weed management) during follow-up meetings with farmers. Timely planting improves the synchronisation of nutrient release from incorporated biomass with maize growth. There is a flush of nutrients at the onset of rains and this can be used properly with timely planting of crops and proper weed management (Giller and Cadisch, 1995).

4.4 Discussion

4.4.1 Grain yields and farmers' rationale of legume selection for food

The difference in grain yields between home and middle fields (Fig. 4.3) could be attributed to human factors that included reports of consumption of some grain such as pigeonpea and cowpea before yields were measured and accidental feeding by livestock especially goats which were often tethered within the homes during the crop season. Although strong gradients of decreasing soil fertility are found with increasing distance from the homestead within smallholder African farms due to differential resource allocation (Tittonell *et al.*, 2005b), variable management of experiments by farmers is another critical factor. Poorly managed fields had lower overall yields. Pigeonpea yields were consistently low because of poor germination of seeds resulting in poor crop establishment, and this was more a problem in home fields than middle fields. Phosphorus is an essential element for plant growth and P deficiency is often found to limit legume growth and yield of legumes, depending on the ability of the soil to supply sufficient P. Responses of the legumes in growth and yield and nutrient uptake to P were observed in these experiments in farmers' fields (Fig. 4.3 – 4.5).

Since food production is the main objective of most of the farmers, food crops were given precedence over other crops. Selection of a crop for inclusion in the farming system therefore depends on whether or not it is a food crop. In addition, the crop has to be a marketable commodity. However, soil fertility was a concern for many farmers, and consequently their third criterion identified was the ability of a legume to restore soil fertility as observed through biomass production. Although crops like velvet bean gave the highest grain yields, they were not given priority over food legumes in the final score of legumes (Table 4.3). Velvet bean grain had small market value and is considered a "hunger crop" by most families. If the household was self-sufficient in maize, very little interest was given to velvet bean grain. On the other hand, groundnut, Bambara groundnut and cowpea were food legumes that were eaten in most households. Soyabean, pigeonpea and velvet bean, however, were relatively new legumes in the area and farmers still needed more technical support for production and utilisation. Soyabean, for example, is commonly used today by farmers to fortify their diets through production of local bread, preparation of porridge and milk extraction from the grain. Tethered livestock often fed on the biomass before harvest, contributing to low biomass yield.

4.4.2 Economic performance and phosphorus fertiliser application

Economic performance of the legumes was directly linked to legume grain yield since grain was the main source of financial return to the farmer in that year. Legumes that gave high yields had better returns than those that had low grain yields. Although velvet bean gave higher returns to labour, GM and B/C ratio in Table 4.4, the crop had no immediate food and market value. This reduced the importance of the crop to farmers. Other crops such as pigeonpea, soyabean, groundnut and Bambara groundnut were edible and marketable and returns from them were more meaningful to farmers. Application of P to legumes increased the yields and also improved financial returns, but not enough to cover its cost. The high price of P fertiliser and high cost of labour to apply it reduced its profitability with the legumes. Residual effects of the P fertiliser may continue to contribute yield and financial benefits in the following year or two and thus raise its attractiveness. Although its future is not certain, the Government of Malawi fertiliser input subsidy programme offers an opportunity to farmers to increase fertiliser use as well as increase food production at present (Denning *et al.*, 2009). The program has made fertiliser available to local markets at government subsidised prices for the production of maize and tobacco. Increased use of P fertiliser would directly increase legume food production especially where proper extension advice to farmers is given.

4.4.3 Farmer evaluation and acceptance of legumes

Farmer evaluation of legumes was based on the legume response to P fertiliser. Discussions below indicate the overall performance of legumes in relation to farmers' preferences. As with other studies in Malawi (Blatner *et al*., 2000; Snapp *et al*., 2002a), this work showed that to enhance the adoption of legumes in central Malawi, promotion should emphasise those legumes that have a dual purpose, such as soyabean, pigeonpea and groundnut. Future research in increasing farmer participation in legume production should concentrate on useable grain legumes that also contribute to soil fertility (Waddington *et al*., 2004). For example, farmers said that velvet bean seed is quite large and appetising to eat, but no one was doing so because of its troubled history and the poisonous nature of the grain (Gilbert, 2000). One farmer pointed out that velvet bean got a lower rank mainly because of the aggregated effects of its aggressive growth habit suppressing maize, the lack of a market for grain, and they rarely could consume it. The ranking of velvet bean at the fourth position emphasises a point, that research-driven farmer participation reveals a number of barriers to both local experimentation with and adoption of legumes such as velvet bean. Velvet bean has been a priority legume for promotion for soil fertility in Malawi following its undisputed improvement of soils on-station and on farm (e.g. Sakala *et al*., 2003; Waddington *et al*., 2004), but it has extremely limited end use by farmers and consumers.

This study has confirmed that for smallholder farmers, food production is given first priority over soil fertility issues. In one example of an ethnographic quote, Mr Kamangira said, "*nyemba za kalongonda zabwino mmaso, koma poti sitidya, ndibwino kukolora chimanga chochepa kusiyana ndikubyala nyembazi*" (velvet bean seed is good looking, but since we don't eat it, it is better to harvest little maize than to grow velvet bean). Farmers also noted that fertilising the legumes with P would require extra labour. It would require more time to fertilise a hectare of the legume crops than maize. Participating farmers realised from this study that growing legumes on fields with a good history of fertiliser application may increase legume grain yield. This was one reason legumes were evaluated for intercropping with maize, which is more beneficial to smallholder farmers (Willey, 1979). Although food production was the priority, farmers felt that soil fertility was an important issue to look at critically. Their high prioritisation of legumes that grow well with maize was based on the thinking that while they obtain legume grain, they also maintain the soil with the same legumes. Again, their choices might be influenced by a fast decline of landholding sizes which may call for intensification of agricultural production including better integration of legumes. Ruthenberg (1980) however found that as the population increases and land sizes decrease, rotations, ley farming, and green manures are not likely to be used.

Economic values of the different legume crops are important to the farmers to promote legumes in smallholder agriculture. Farmers also observed that velvet bean, with its heavy spreading biomass, forms living mulch which helped to conserve soil moisture until it was incorporated. They linked that to the fast decomposition of velvet bean leaf which they said was good for the soil. The dense biomass coverage over the soil surface was also reported to be excellent in weed suppression in the fields. While farmers' acceptance of legumes was largely based on their visual evaluation in this experiment, P application has other benefits to farmers. In addition to increasing grain and biomass yield, residual effects on subsequent crops have been demonstrated to be beneficial; e.g. Bationo *et al*. (1992) observed that the response of pearl millet to fertiliser N was higher where P was applied than where it was not. Osiname *et al*. (2000) showed significant maize yield response to residual P fertiliser in Cameroon. Thus, the application of P often has beneficial effects which farmers cannot observe in the year of its application.

4.4.4 Farmer's knowledge, participation and adoption of technologies

Farmers' knowledge is essential, and tapping into it leads to understanding farmer participation, and understanding farmers' perceptions about crop technologies (Richards, 1986; Bellon, 2001; Tripathi and Ellis-Jones, 2005). Experiments involving legume effects on soil fertility generate relatively complex system technologies that require end user (farmer) inputs for their modification and wider adoption. Thus the emphasis of our evaluation was to identify knowledge gaps and promote use of the experimental results by farmers. While soil fertility management remains a constraint to smallholder agriculture, the study showed that farmers seek to obtain a minimum maize harvest first, marketable food legume yield second and then benefits to soils. Their knowledge use was in line with realising that goal while remaining risk averse, over options that conflict with their goals.

Application of P fertiliser to legumes revealed to farmers that legumes do grow and yield better with fertiliser. An important follow on to this was the realisation that legumes would therefore likely do better in fields with a good history of fertiliser use. For example, more benefits would be realised if burley tobacco fields (that generally receive fertiliser) were followed by maize planted together with legumes rather than maize alone. Again although velvet bean was not edible, farmers were convinced that its ability to restore soil fertility was the highest among the legume options tested, suggesting that those with more land, and labour, would easily use it for improving soil fertility. Farmers' perceptions, needs and knowledge of legumes point out that there was a likelihood of more adoption of food legumes such as soyabean and groundnut on larger land areas, for reasons that they intercrop reasonably well with maize in addition to producing grain. For example, Mr. Kalivute observed that his maize was better where he continuously planted legumes with maize, and that encouraged him to incorporate more pigeonpea and soyabean into his cropping system as intercrops. Factors that led a few farmers to stop participating in this study were numerous, but the key one was their failure to observe immediate benefits to their soils or crops. One of these farmers had an extremely poor field, where legume growth was heavily limited by the infertility. His initial interest and participation in the project was in anticipation of improved soils at the end, and when he did not easily see that, he decided to pull out. Poor soils may not have a quick fix solution in smallholder agriculture, but continuous engagement with farmers, exploring their knowledge, perceptions and needs, is the only possible way of identifying alternative long term solutions that they are likely to use.

4.5 Conclusion

Phosphorus fertiliser increased legume grain and biomass yields in Chisepo. P fertiliser application to legumes likely would increase legume food production and directly increase food and nutrition security of households besides improving soil fertility. However farmers said that application of P fertiliser to legumes was not an immediate option to them because of the high cost of mineral fertiliser. Other major reasons farmers cited were the unavailability of P fertiliser in local markets, its limited profitability in the short term and the need for extra labour to apply P to legumes. Despite observations that P increased legume grain and biomass yields, farmers expressed little interest to adopt P fertiliser for their legumes at the moment. Low interest to adopt P application to legumes was a major reason that P fertiliser application to legumes had limited relevance to their priorities of maximising food security from their labour investment.

At present, farmers' priority of legume production is given for legume food production and legumes that provide multiple benefits are likely essential. However with recent changes in demand for legumes for industrial use in Malawi, the availability of P fertiliser in local markets at a relatively low price would attract some farmers to apply P to legumes to increase income as well as improve legume food production, soil fertility and overall cereal production. It is important therefore for government to deliberately support the supply of P fertiliser to local markets at attractive prices to increase legume food production. While many annual legumes show potential to improve soil fertility, their use by farmers is affected by many other factors including lack of seed, lack of markets for legume grains, lack of improved knowledge for proper production and variable performance of legume technologies. Farmers observed that grain legumes grow better in fields with a history of fertiliser use and this may influence field choice for legumes in the future. Thus farmers' participation in the evaluation of legumes helps to explore their perceptions, needs, knowledge and chances that farmers may increase legume food production.

Chapter 5

Improving the efficiency of use of small amounts of nitrogen and phosphorus fertiliser on maize through farmer-research partnership in central Malawi

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Chapter 5

Improving the efficiency of use of small amounts of nitrogen and phosphorus fertiliser on maize through farmer-research partnership in central Malawi

Abstract

Mineral fertiliser is a scarce input for smallholder maize farmers in Malawi. Recent provision of small packages of and the subsidised fertilisers by government programmes to farmers throughout Malawi has increased fertiliser access and raised maize production, but fertiliser management and yield responses frequently remain poor. To seek the more efficient use of the fertiliser, I analysed the effects of small rates of N (15 or 30 kg N ha^{-1}) and P (20 kg P ha^{-1}) fertiliser in combination with improved weed management on smallholder maize yields in experiments on eight farms in Chisepo, central Malawi. Several indices of N and P use efficiency were computed from the above ground yields and yield simulations conducted in APSIM. NP fertiliser significantly ($P < 0.001$) raised maize grain yield from 0.5 to 1.7 t ha^{-1}, and weeding fertilised-maize twice significantly ($P < 0.001$) raised maize yields by 0.4 t ha^{-1} over weeding once (0.9 t ha^{-1}) in the relatively dry conditions. The contribution of P to yield was larger with just one weeding. Agronomic efficiency of applied fertiliser N (AE_N) averaged 19.3 kg grain kg N^{-1} with one weeding and doubled to 38.7 kg with the extra weeding. Physiological efficiency of applied N (PE_N) was 40.7 kg grain kg^{-1} N uptake. With fertiliser obtained from market other than the targeted input programme in 2003-04 growing season, financial analysis showed that application of these small amounts of fertiliser was economic, and returns to limited cash and labour were especially attractive when extra weeding was done. The study helped farmers understand the increased fertiliser use efficiency available from more weeding but many farmers were unable to implement it due to competing demands on labour. The results of the study are important in relation to the frequent droughts affecting maize production in most parts of Malawi. The conclusion was that to raise the productivity and sustainability of fertiliser support programs in Malawi, they should be combined with initiatives to help farmers to manage the inputs more effectively.

Keywords: *Agronomic efficiency, dry spell, fertiliser indices, fertiliser use efficiency, financial returns, weeding, yield response*

5.1 Introduction

Maize (*Zea mays* L) is the most important staple food crop in southern Africa, but yields have stagnated, mainly due to low soil fertility (Carr, 1997; Sanchez, 2002). N and P deficiencies are of most concern with cereals such as maize (Wendt *et al*., 1996; Wendt and Jones, 1997; Nziguheba *et al*., 2002). Continuous cropping of land with little use of fertilisers or organic manures has led to decline in soil fertility and poor productivity (Kumwenda *et al.*, 1996; Blackie *et al.,* 1998). For example, current average fertiliser use in Sub-Saharan Africa (SSA) is estimated to be only 8 kg nutrients ha^{-1} of cropped land per year (African Fertiliser Summit, 2006), little changed from 1990 (Mwangi, 1996). In Malawi mineral fertilisers are expensive, a common situation for land-locked countries in SSA. All N fertiliser is imported and in 2005 its cost (US$1285 t^{-1}) constituted close to 50% of the total production costs of maize (DFID, 2005). P is available from local sources (Wendt and Jones, 1997) but is still expensive for resource-poor farmers.

Maize occupies 70% of the arable crop fields in Malawi, with tobacco as the most important cash crop (Sauer and Tchale 2009). Use of organic soil amendments is constrained by the small numbers of livestock that provide limited quantities of manure (Benson *et al*., 2002; NSO, 2009). Relatively small amounts of legumes are grown in these maize-dominated systems, though pigeonpea (*Cajanus cajan* (L.) Millsp.) is frequent in the south of Malawi (Kamanga, 2002a). Although legumes can provide substantial inputs of N from biological N_2-fixation, the other nutrients contained in their residues are obtained from available soil pools (Carr, 1997; Giller, 2001). The limited use of fertiliser or organic manures results in average maize yields on many fields in Malawi of below 1 t ha^{-1} (Kanyama-Phiri *et al*., 2008) and are much lower in many depleted fields (Kanyama-Phiri *et al*., 2000).

During the growing season in which the study was conducted, a national targeted input programme (TIP) was in place giving 12.5 kg each for NPK and urea for maize production. A bag of urea at the open markets was MK2,800 (US$25.9) which was quite high for most smallholder farmers to afford. The re-introduction of a fertiliser input subsidy programme (FISP) in 2005 benefited the rural poor and has improved access to fertiliser (Blackie, 2005) and also improved food security (Gum, 2008; Dorward and Chirwa, 2011). A household is given two fertiliser coupons; one for a 50 kg bag of urea and the other for 50 kg of 23:21:0+4S (NPK) for maize. This is enough to fertilise less than 0.3 ha of maize at the national recommended rate of 69 kg N ha^{-1} (Benson, 1998) and 0.25 ha at 92 kg N ha^{-1} (the older blanket application rate promoted by Sasakawa Global 2000).

While the current investment in the input subsidy programme has resulted in substantial increases in food production, the N use efficiency is estimated around 14 kg maize grain kg^{-1} N applied (Chisinga, 2008; GoM, 2008) and is much less than half the N use efficiency that can be achieved with good management (Heisey and Mwangi 1996; Snapp *et al*., 2001; Makumba, 2003). Authors report poor fertiliser management (inappropriate rates of input, late timing and poor placement) and poor field and weed management due to lack of proper information and knowledge (Mushayi *et al.,* 1999; Ruben and Lee, 2000; Dimes *et al.,* 2004) as part of the cause of fertiliser inefficiencies on smallholder maize (e.g. Zingore *et al.,* 2007b; Wopereis *et al.,* 2007; Giller *et al*., 2006b). Given current investments by the Malawi Government in fertiliser and the poor returns to this investment, there is an urgent need to assist smallholder farmers to use the little fertiliser they access as efficiently as possible.

I conducted a participatory study on the use efficiency of small amounts of N and P fertiliser on maize with a representative smallholder maize farming community in central Malawi. On-farm experiments, using a consistent and agreed design, were conducted together with 12 smallholder farmers in their fields during the 2003/2004 wet season. The objective of the experiment was to assess and learn from the responses of two maize varieties to small amounts of N and P fertiliser at two intensities of weed management together with the farmers. I included treatments to explore interactions between weeding and fertiliser and focused on farmer evaluation of the trial process.

5.2 Materials and Methods

5.2.1 Study site

The research was conducted during the 2003-2004 cropping season at Kamphenga in Chisepo, central Malawi (13’32” S and 33’31” E). Soils in the area are ferralsols (sandy loams) of low to moderate fertility, underlain by laterite which impedes drainage (Wendt, 1993). Rainfall is unimodal from November to April; in 2003/04, total annual rainfall was 492 mm (Fig. 5.1), below the long term average of 748 mm. The season was characterised by several dry spells, particularly during flowering when moisture is most critical for crop growth.

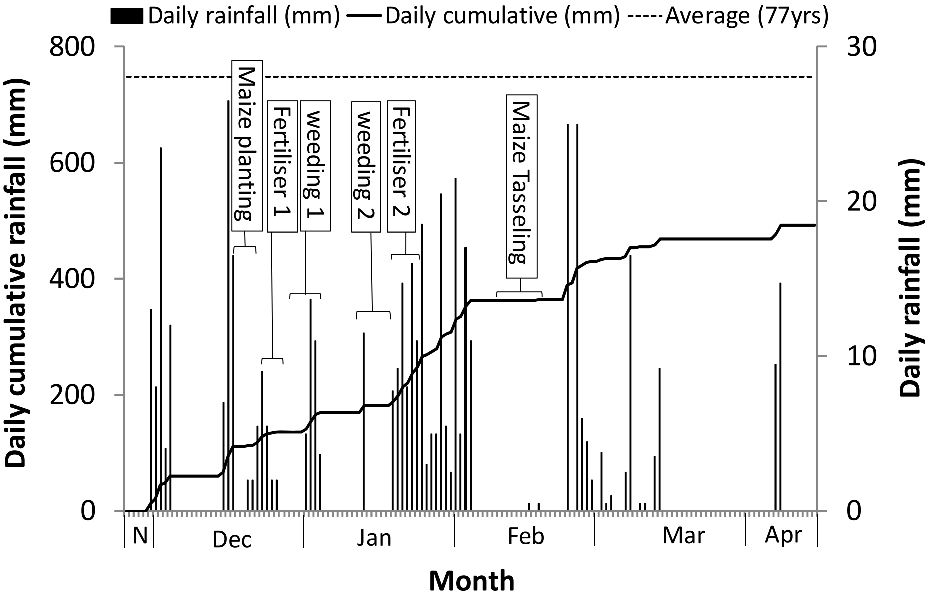

Fig. 5.1. Monthly and cumulative rainfall in Kamphenga, Chisepo in central Malawi during the 2003-4 growing season.

5.2.2 Farmer participatory experimentation

Initial group discussions focusing on use of the available fertiliser from the subsidy programme were conducted with farmers before the onset of the 2003-04 growing season. Together researchers and the participating farmers decided to assess the effects of small amounts of fertiliser and weeding on maize yields. Twelve farmers were selected randomly (from among those that expressed interest) to plant the trials. Design of the field layout, planting, fertiliser application and harvesting were jointly decided by researchers and farmers. The research team interacted with farmers at least once a month and with a research assistant stationed in the area on a weekly basis. The participating farmers monitored and evaluated the experiments using their own criteria for evaluation and they recorded their own observations as described below.

5.2.3 Experimental design

The experiments were laid out in a split plot design with a 3 N rates × 2 P rates × 2 maize varieties with three replicates on each of 12 farmers' fields. The three N-treatments (as urea) were 0, 15, and 30 kg N ha^{-1}, applied twice in equal splits at planting and when the maize was knee high. Two rates of phosphorus (0 and 20 kg P ha^{-1}) as triple-super phosphate (TSP) fertiliser were applied at planting. The two maize varieties were MH 18 and SC 627. MH18 is a semi-flint hybrid which is widely used in Malawi and SC627 is a relatively new hybrid release. Plot size was 5 m × 10 m with a net plot of 15 m^2. To compare the effects of weeding intensity across the 12 fields, six farmers were randomly selected to host plots that were weeded within 2-3 weeks after planting (WAP), and the remaining six fields hosted plots that were weeded within 2-3 WAP and 4-6 WAP. During trial establishment, one farmer had a land dispute and abandoned his trial immediately after planting. Three more farmers left for seasonal employment on a tobacco estate and management of their plots was poor. Eight farmers continued with the research: four farmers with plots that were weeded once and four farmers with plots that were weeded twice. All weeding was done by hand-hoe. The treatments are shown below.

T1: 0 kg N ha^{-1}, 0 kg P ha^{-1}, MH 18
T2: 0 kg N ha^{-1}, 0 kg P ha^{-1}, SC 627
T3: 0 kg N ha^{-1}, 20 kg P ha^{-1}, MH 18
T4: 0 kg N ha^{-1}, 20 kg P ha^{-1}, SC 627
T5: 15 kg N ha^{-1}, 0 kg P ha^{-1}, MH 18
T6: 15 kg N ha^{-1}, 0 kg P ha^{-1}, SC 627
T7: 15 kg N ha^{-1}, 20 kg P ha^{-1}, MH 18
T8: 15 kg N ha^{-1}, 20 kg P ha^{-1}, SC 627
T9: 30 kg N ha^{-1}, 0 kg P ha^{-1}, MH 18
T10: 30 kg N ha^{-1}, 0 kg P ha^{-1}, SC 627
T11: 30 kg N ha^{-1}, 20 kg P ha^{-1}, MH 18
T12: 30 kg N ha^{-1}, 20 kg P ha^{-1}, SC 627

5.2.4 Joint researcher and farmer data collection and analysis

Before the onset of rains and prior to planting, soil samples were collected from 3 points in each field and a composite sample was made for each of the twelve fields to a depth of 100 cm, incremented in 20 cm intervals. The soil samples were sieved to 2 mm and analysed for soil texture, pH, organic matter, %N and available P (Bray method) (Anderson and Ingram, 1993). At harvest, grain and stover samples were oven-dried at 60°C, weighed and sub-samples were collected for N and P analysis. Harvest index (the ratio of grain to total above ground biomass, expressed as a percentage) was calculated from the above ground dry matter yields. Agronomic indices for nitrogen and phosphorus use efficiencies were calculated (Cassman *et al.*, 1998; Dobermann, 2005) as follows: Agronomic efficiency of applied fertiliser N (AE_N) was calculated as yield gain from N application divided by N applied at different P rates (Y_N-Y_0/F_N). Partial factor productivity for N (PFP_N) and P (PFP_P) were calculated as yield per kg N (kg ha^{-1}) and P applied i.e. (Y_N/F_N) and (Y_P/F_P). Apparent recovery efficiency of applied N (RE_N) and applied P (RE_P) was calculated as kg nitrogen taken up by maize per kg N applied (U_N-U_0)/F_N, and as kg P taken up by maize per kg P applied (U_P-U_0/F_P). Physiological efficiency of applied N (PE_N) and applied P (PE_P) was calculated as yield gain from N application or P application divided by N or P uptake by maize (Y_N-Y_0)/(U_N-U_0) and (Y_P-Y_0)/U_P-U_0). Y_N or Y_P are maize yields (kg ha^{-1}) measured in plots with N and or P, Y_0 is maize grain yield (kg ha^{-1}) measured from plots with no N or P application. U_N or U_P are maize plant N or P uptake measured in above ground dry matter at harvest (kg ha^{-1}).

Data was subjected to an analysis of variance model using GenStat Discovery 3, Release 7.22 with a split plot design. To investigate further the factors influencing responses of maize, simulations of the trials using their agronomic management information, soil water and soil fertility characteristics of the sandy clay (red soils) (3 fields) and sandy soils (5 fields) of the Kamphenga area were performed using the maize component of the APSIM crop system simulation model (see Robertson *et al.*, 2005). Characterisation of the plant available water capacity of the sites using methods described in detail in Robertson *et al*., (2005) showed that using the crop lower limit (CLL) of maize, the sandy soil had a PAWC of 117 mm and the sandy-clay soil a PAWC of 157 mm.

The differences in yield were discussed with farmers in groups to understand what they had observed in the experiment and what they had learned during the research. Specifically, of importance was farmers' knowledge on fertiliser management to increase use efficiency, and the importance of weeding, the fertiliser and other factors they observed. Labour use (person-days) was recorded by farmers with the assistance of the field assistant on each activity for the main crops in field notebooks that had been provided and on resource allocation maps that they drafted.

5.2.5 Estimation of financial costs and benefits

Costs and benefits were calculated in the trials. The farm gate price for maize grain was Malawi Kwacha (MK) 7.00 kg^{-1} (US$0.1), seed of hybrid maize was MK70.00 kg^{-1} (US$0.65), urea-N fertiliser cost MK80.00 kg^{-1} (US$0.81) and triple superphosphate (TSP) was MK100.00 per kg (US$1.01). In this year most farmers who used fertiliser in the area bought it from the open markets as the targeted input programme did not reach them much, and thus the real fertiliser market prices were used in the estimation of the economic returns. Labour cost was estimated using the opportunity cost of labour, based on the minimum agricultural wage rate in 2004 of MK56 $man\text{-}day^{-1}$ (US$0.53). Returns to labour, gross margin and benefit to cost ratio were used to evaluate the economics of maize response to fertiliser application. Returns to labour were calculated by dividing the net benefits by the total man-days. Returns to land are represented by the gross margin (GM) and are calculated as GM = B-C, where B is the total benefit accrued by using the land, C are the costs associated with use of that land in the same period. The benefit-cost (B/C) ratio indicates the rate of return per unit cost and if it is greater than 1 then the land use system can be considered profitable. From the analysed grain yields, break-even prices for nitrogen were calculated using the generally accepted rule of thumb (Siegel and Johnson, 1991; Franzel, 2005; Dorward and Poulton, 2008) that for farmers to benefit, the benefits of extra production of grain kg^{-1} N applied has to be at least double the cost of that N. The break-even prices were calculated from the agronomic efficiency of nitrogen (kg grain kg^{-1} N) multiplied by the farm gate price of maize. Open markets prices of fertiliser were used in the analysis because farmers that used fertiliser accessed it from markets other than the targeted input programme. It was assumed that the extra grain kg^{-1} N was sold at the maize farm gate price (US$0.1) in 2004.

5.3 Results

5.3.1 Initial soil fertility

Initial soil fertility status of the host farmers' fields show that the soils were ferralsols (sandy loams) with a topsoil average pH of 5.4, %OM of 2.1, 0.1%N and considerable silt + clay content (36.7%) (Table 5.1). Of the fields that were analysed, only three were on dark brown soil (*Katondo*), and the rest were on sandy soils (*Mchenga*). These dark brown soils (classified as ferruginous/ferric rhodustalf) have a strong structure, low cation exchange capacity (CEC) of about 5.44 cmol/kg soil and low available P, but are considered more productive than other local soils. The sandy soils (classified as ferrallitic soils), have a loamy texture, low organic matter, low water holding capacity and are prone to leaching of nutrients below the rooting zone.

Table 5.1. Soil properties (20 cm depth) of plots weeded twice or once in Kamphenga, Chisepo, Malawi in 2003-04 season.

Farmer	Soil properties						
	pH	% OM	%N	Avail. P - Bray (mg kg^{-1})	% Sand	% Silt	% Clay
Plots weeded twice							
GVH Kamphenga	5.2	1.8	0.09	6.3	60	13	27
Liwichi	5.4	2.2	0.11	7.3	57	17	26
Paison	5.4	1.2	0.06	7.0	70	7.0	23
VH Chamadenga	5.4	1.9	0.09	8.2	60	13	27
Mean	5.4	1.8	0.09	7.2	62	12	26
Plots weeded once							
Dete	5.3	2.3	0.12	5.8	58	17	25
Kachere	5.8	2.0	0.10	6.5	67	10	23
Mbanga	5.7	1.7	0.08	3.8	67	13	23
Ngulube	4.9	2.0	0.10	4.4	70	13	17
Mean	5.4	2.0	0.10	5.1	66	13	21

5.3.2 Maize yields

Weeding twice resulted in significantly ($P < 0.001$) more maize grain yield (overall increase of 0.4 t ha^{-1}) than weeding only once (Table 5.2). N fertiliser at a rate of 30 kg ha^{-1} raised the grain yield by 0.6 - 1 t ha^{-1} on plots weeded twice but only by 0.2 - 0.4 t ha^{-1} on plots weeded once. There were significant differences ($P < 0.01$) between maize varieties and SC627 variety yielded slightly more than MH 18 maize especially with weeding twice. Stover yields in both weeding treatments followed the same trend. Plots with both N and P produced the most stover (2.1-2.3 t ha^{-1}) and the poorest stover production (0.6 t ha^{-1}) was measured in the plots weeded once with no fertiliser. In both weeding regimes, a combination of N and P gave stronger yield responses compared with plots where only N or P was applied. The maize yield response was greater with additional weeding (0.5 t ha^{-1} and 0.2 t ha^{-1} in plots weeded twice and once respectively), and show complementary benefits of N and P.

Maize grain yields at individual fields weeded twice however showed that fields in better sandy clay soils (GVH and Liwichi - Magadalena) responded significantly to 15 kg N ha^{-1} and at Liwichi site, there was a continued large and significant response in grain yield to 30 kg N ha^{-1} (Fig. 5.2a). There were no significant differences in grain yield at the sandy sites (Chamadenga and Paison). Maize yield responses in sandy-soil fields that were weeded once showed no significant differences (Fig. 5.2b), indicating presence of a limiting factor in sandy soils. The maize yields responded to 15 Kg N ha^{-1} at all sites, but there was no significant response to N at 30 kg N ha^{-1}, except at David. The APSIM simulation of grain yields of a sandy soil site soil plant-available water-holding capacity (PAWC = 117 mm) in the 2003/04 season showed a positive response to the application of P where 15 kg N ha^{-1} or 30 kg N ha^{-1} was applied (Fig. 5.3a), and there was little difference in grain yield by increasing N from 15 to 30 kg N ha^{-1}. Using a sandy-clay soil type (PAWC = 157 mm) for the same simulations resulted in a positive response to increasing N fertiliser, but no response to P fertiliser (Fig. 5.3b). There was a marked difference in the response to P fertiliser between the two soils types (Whitbread *et al.*, 2004b; Oliver *et al.*, 2009). Harvest index ranged between 39 to 50% and did not differ significantly across the three N rates (Table 5.2). Cobs were longest in the well-weeded treatments when fertilised with N and P – on average the cobs were 2.6 cm longer in plots weeded twice than those weeded once.

5.3.3 Indices for fertiliser use efficiency in maize

On average, maize in plots weeded twice took up 7.3 kg N ha^{-1} more than plots weeded once. The range in the plots weeded twice was 6.7 - 26.2 kg N ha^{-1}, and 4.1 - 18.1 kg N ha^{-1} in those weeded once (Table 5.3). Grain N uptake generally increased when 30 kg N ha^{-1} was added, although the largest value (26.2 kg N ha^{-1}) was obtained with 15 kg N ha^{-1} and 20 kg P ha^{-1} in the plots weeded twice. Maximum N uptake in the grain was 8.1 kg N ha^{-1} larger in the plots weeded twice than in plots weeded once. Stover N uptake ranged from 2.2 - 14.8 kg N ha^{-1}. It increased with increased N rates, and, plots weeded twice yielded 6.2 kg N ha^{-1} more stover N than plots weeded once.

Agronomic efficiencies of N was 19.3 kg grain kg^{-1} N with one weeding and it significantly doubled to 38.7 kg grain kg^{-1} N with second weeding.(Table 5.3), and the efficiencies improved with P. Although the AE_N from weeding twice may save as a reasonable indicator of what can be targeted with good field and fertiliser management, both AE_N values indicate that there is room for improvement in optimising maize production in smallholder farmers. Except for PE_N, RE_N (0.9 kg N kg^{-1} N applied) and PFP_N (78.8 kg grain kg^{-1} N applied) were higher in plots weeded twice than those weeded once. In general, all the indices indicate the benefit of extra weeding, and these were better where N+P were applied indicating a beneficial interaction effect of fertiliser and proper weed management.

SC627 took up significantly more P ($P < 0.005$) than MH18 in both grain and stover (Table 5.4). P uptake in grain was on average 1.5 kg P ha^{-1} greater in plots weeded twice than those weeded once. The PE_P was much large in plots weeded once suggesting strong dilution of P in the grain. RE_P and PFP_P were higher in plots weeded twice than in plots weeded once, suggesting a significant interaction between P and weeding in all the indices. The relationship between inherent soil fertility, rates of fertiliser and maize yields was displayed using a 3 quadrant figure (Fig. 5.4) (Wit, 1992). Yield responses to fertiliser are a function of the fertiliser uptake by the crop, which, are influenced by the crop's recovery efficiency (RE_N) of the nutrients. The N sources in the soil (indigenous supply of N) without addition of fertiliser play a substitution effect to the applied N and both influence the RE_N for the crop. Using Fig. 5.4 the N supplied from the soil other than the applied N was estimated to be higher at 19 kg N ha^{-1} and 7 kg N ha^{-1} for the plots weeded twice, while it was 13 and 4 kg N ha^{-1} for the plots weeded once, and this suggest a high substitution effect of the indigenous supply of N (Cassman *et al.*, 2002).

Table 5.2. Response of agronomic yield components to N and P in Plots weeded twice weeded twice (*n* = 4) and plots weeded once (*n* = 4) in Chisepo, central Malawi in the 2003-04 season.

			Agronomic components			
	Factors		Grain	Stover	Harvest Index	Cob length
N (kg ha$^{-1)}$	P (kg ha^{-1})	Maize Variety	(t ha^{-1})	(t ha^{-1})	(%)	(cm)
		Plots weeded twice				
0	0	MH18	0.7	1.0	41.5	15.5
0	0	SC627	0.8	1.2	41.3	15.7
0	20	MH18	0.8	1.3	41.0	16.2
0	20	SC627	0.9	1.5	41.0	16.5
15	0	MH18	1.3	1.9	43.5	18.2
15	0	SC627	1.6	1.9	45.8	16.8
15	20	MH18	1.7	2.3	44.3	17.4
15	20	SC627	1.7	2.3	45.0	15.3
30	0	MH18	1.4	1.8	43.4	15.7
30	0	SC627	1.6	1.8	47.1	18.1
30	20	MH18	1.6	2.1	45.1	18.9
30	20	SC627	1.7	2.1	44.3	17.6
		Mean	1.3	1.8	43.6	16.8
		Plots weeded once				
0	0	MH18	0.5	0.6	49.4	13.1
0	0	SC627	0.6	0.8	44.0	13.6
0	20	MH18	0.7	1.0	42.5	12.5
0	20	SC627	0.8	0.8	49.7	14.2
15	0	MH18	0.8	1.1	45.7	14.3
15	0	SC627	0.8	1.2	40.5	15.3
15	20	MH18	1.3	1.4	48.6	14.7
15	20	SC627	1.3	1.3	49.1	14.3
30	0	MH18	0.7	1.1	39.4	15.0
30	0	SC627	0.7	1.1	38.4	14.2
30	20	MH18	1.4	1.5	49.7	13.2
30	20	SC627	1.3	1.6	45.4	16.5
		Mean	0.9	1.1	45.2	14.2
		SED				
		Nitrogen	0.04^{***}	0.08^{***}	1.3^{ns}	0.7^{*}
		Phosphorus	0.03^{***}	0.07^{***}	1.1^{*}	0.6^{ns}
		Maize Variety	0.03^{**}	0.07^{ns}	1.1^{ns}	0.6^{ns}
		Weeding	0.03^{***}	0.07^{***}	1.1^{ns}	0.6^{***}
		N×P	0.06^{***}	0.11^{ns}	1.9^{ns}	1.0^{ns}
		N ×W	0.06^{***}	0.11^{ns}	1.9^{*}	1.0^{ns}
		P ×W	0.05^{***}	0.09^{ns}	1.6^{*}	0.8^{ns}
		V × W	0.05^{**}	0.09^{ns}	1.6^{ns}	0.8^{ns}
		N × P × W	0.08^{**}	0.16^{ns}	2.7^{ns}	1.4^{ns}
		N×P ×V × W	0.11^{ns}	0.23^{ns}	3.8^{ns}	2.0^{ns}

SED = Standard error of the difference; Significance: *** *P*<0.001, ** *P*<0.01, * *P*<0.05, ns = not significant

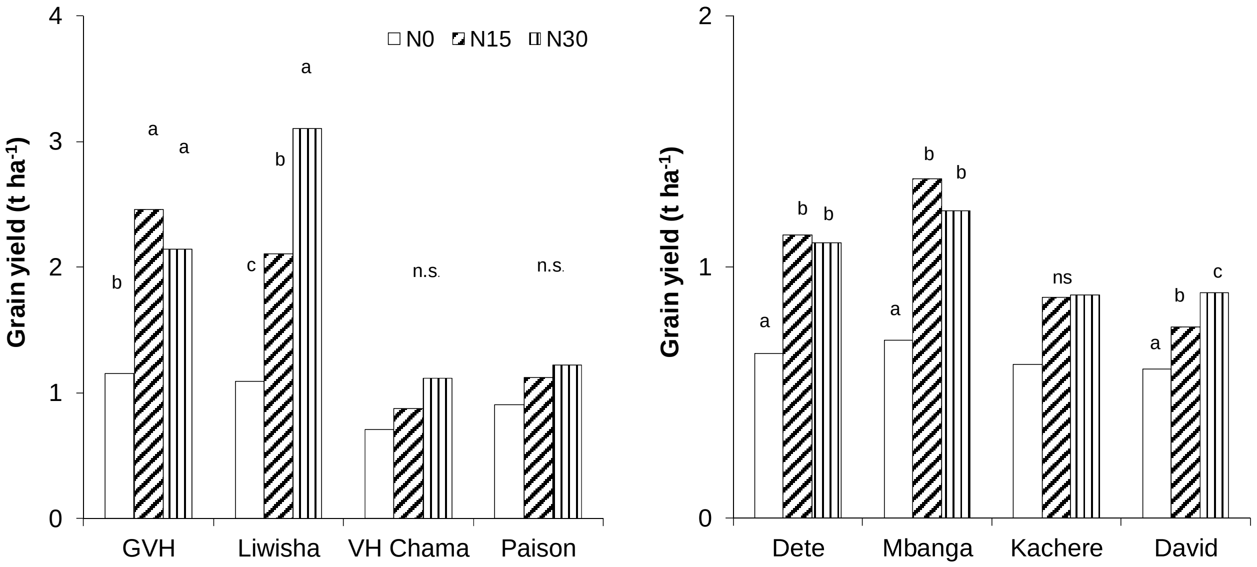

Fig. 5.2. Maize yield responses to N on individual farmers (a) Plots weeded twice (b) Plots weeded once in Chisepo, central Malawi in 2003-04.

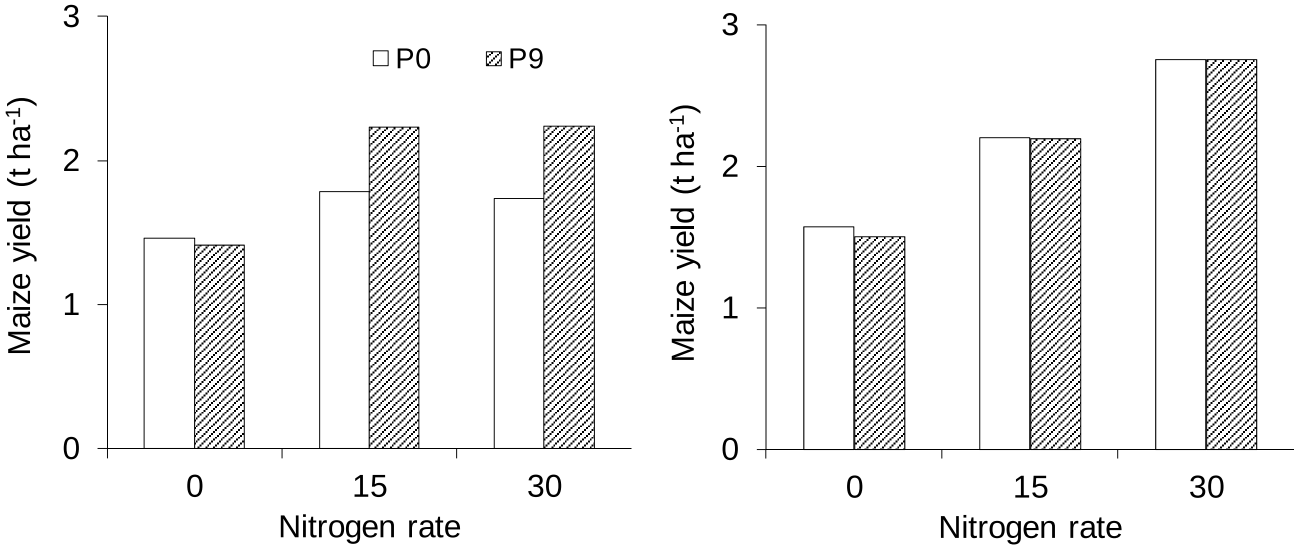

Fig. 5.3. Simulated maize grain yield of (a) sandy soil (PAWC=117 mm), (b) sandy-clay (PAWC=157 mm) in Chisepo, central Malawi in 2003-04.

Table 5.3. Indices of nitrogen use efficiency as affected by N and P application, variety and weeding in Chisepo, central Malawi in 2004-05. (see text for explanation of the indices).

Factors			N efficiency Indices					
N (kg ha^{-1})	P (kg ha^{-1})	Maize Variety	Grain N (kg ha^{-1})	Stover N (kg ha^{-1})	AE$_N$ (kg grain kg^{-1} N applied)	PE$_N$ (kg grain kg^{-1} N uptake)	RE$_N$ (kg N kg^{-1} N)	PFP (kg grain kg^{-1} N)
Plots weeded twice								
0	0	MH18	6.7	4.4				
0	0	SC627	7.0	5.5				
0	20	MH18	7.8	6.2				
0	20	SC627	9.9	7.3				
15	0	MH18	16.3	10.1	42.3	40.7	1.0	87.8
15	0	SC627	20.9	10.7	54.0	43.2	1.3	106.5
15	20	MH18	24.2	13.6	57.3	38.6	1.6	111.1
15	20	SC627	26.2	14.8	54.3	36.4	1.6	116.3
30	0	MH18	18.6	10.4	23.1	37.3	0.6	45.8
30	0	SC627	20.8	10.7	25.8	49.3	0.6	52
30	20	MH18	21.7	12.9	26.2	44.7	0.7	53.1
30	20	SC627	24.8	14.0	26.8	35.7	0.7	57.8
		Mean	17.1	10.1	38.7	40.7	0.9	78.8
Plots weeded once								
0	0	MH18	4.1	2.2				
0	0	SC627	4.6	3.1				
0	20	MH18	5.8	3.9				
0	20	SC627	6.3	3.8				
15	0	MH18	8.1	4.7	18.2	28.4	0.5	43.5
15	0	SC627	7.4	6.4	11.2	36.5	0.4	43.8
15	20	MH18	14.3	8.2	40.3	50.0	0.9	84.6
15	20	SC627	16.7	7.8	33.5	36.8	1.0	83.5
30	0	MH18	8.3	5.0	5.9	34.3	0.3	23.4
30	0	SC627	7.2	5.5	1.3	54.8	0.2	22.2
30	20	MH18	18.1	7.5	25.8	54.6	0.5	48.0
30	20	SC627	17.2	8.8	18.1	32.3	0.5	43.1
		Mean	9.8	5.6	19.3	41.0	0.5	49.0
	SED	Nitrogen	0.6***	0.5***	2.0***	2.4***	0.04***	2.1***
		Phosphorus	0.5***	0.4***	1.6***	2.0^{ns}	0.03***	1.7***
		Variety	0.5**	0.4**	1.6^{ns}	2.0^{ns}	0.03^{ns}	1.7^{ns}
		Weeding	0.4***	0.4***	1.5***	4.9^{ns}	0.06**	4.0**
		N × P	0.9***	0.7^{ns}	2.9**	3.4^{ns}	0.06***	2.9***
		N × W	0.8***	0.7**	2.7***	5.7^{ns}	0.07***	4.7***
		P ×W	0.7**	0.5^{ns}	2.2***	5.3^{ns}	0.07^{ns}	4.4***
		V ×W	0.7**	0.5^{ns}	2.2*	5.3^{ns}	0.07^{ns}	4.4*
		N × P × W	1.2**	0.9^{ns}	3.9*	6.6^{ns}	0.1^{ns}	5.5**
		N ×P × V × W	1.7^{ns}	1.3^{ns}	5.4^{ns}	8.2^{ns}	0.13^{ns}	6.9^{ns}

SED = Standard error of the difference; Significance: *** $P<0.001$; ** $P<0.01$, * $P<0.05$, ns = not significant

Table 5.4. Indices of phosphorus use efficiency as affected by N and P application, variety and weeding in Chisepo, Central Malawi in 2003-4. (see text for explanation of the indices).

Factors			P efficiency indices				
			Grain P (kg ha^{-1})	Stover P (kg ha^{-1})	PE$_P$ (kg grain kg^{-1} P uptake)	RE$_P$ (kg P kg^{-1} P applied)	PFP (kg grain kg^{-1} P)
N (kg ha^{-1})	P (kg ha^{-1})	Maize Variety					
Plots weeded twice							
0	0	MH18	1.0	0.8			
0	0	SC627	1.2	1.1			
0	20	MH18	2.6	1.3	60.7	0.14	40.3
0	20	SC627	3.3	1.9	78.3	0.15	46.5
15	0	MH18	2.1	1.0			
15	0	SC627	2.4	1.1			
15	20	MH18	6.3	2.6	67.6	0.29	83.3
15	20	SC627	7.0	3.2	52.0	0.33	87.2
30	0	MH18	2.5	1.0			
30	0	SC627	2.9	1.0			
30	20	MH18	6.1	2.3	76.4	0.24	79.6
30	20	SC627	6.8	3.1	83.4	0.30	86.8
		Mean	3.7	1.7	69.7	0.20	70.6
Plots weeded once							
0	0	MH18	0.8	0.2			
0	0	SC627	1.3	0.3			
0	20	MH18	1.6	0.7	172.5	0.07	33.3
0	20	SC627	1.8	0.7	123.0	0.08	37.6
15	0	MH18	1.2	0.5			
15	0	SC627	1.3	0.7			
15	20	MH18	3.9	1.2	151.2	0.16	63.5
15	20	SC627	3.9	1.3	185.0	0.16	62.6
30	0	MH18	1.2	0.5			
30	0	SC627	1.2	0.5			
30	20	MH18	4.1	1.4	215	0.20	71.9
30	20	SC627	4.3	1.7	148.9	0.22	64.7
		Mean	2.2	0.8	165.9	0.10	55.6
	SED	Nitrogen	0.20 ***	0.11 ***	6.8 ^{ns}	0.01 ***	1.6 ***
		Phosphorus	0.16 ***	0.09 ***	5.5***	0.01 ***	1.4 ***
		Variety	0.16 **	0.09 **	5.5^{ns}	0.01 ^{ns}	1.3 ^{ns}
		Weeding	0.14 ***	0.10 ***	6.0 **	0.01 **	1.8 ***
		N×P	0.28 ***	0.15 ***	9.6 ^{ns}	0.01 **	2.3 ***
		N×W	0.26 ***	0.16 ^{ns}	9.8 ^{ns}	0.01 **	2.6 **
		P×W	0.21 ***	0.13 ***	8.1 ***	0.01 ***	2.2 ***
		V×W	0.21 ^{ns}	0.13 ^{ns}	8.1 ^{ns}	0.01 ^{ns}	2.2^{ns}
		N×P×W	0.36 ^{ns}	0.22 ^{ns}	13.7 ^{ns}	0.02 *	3.4 ^{ns}
		N×P×V×W	0.52 ^{ns}	0.32 ^{ns}	19.3 *	0.03 ^{ns}	4.7^{ns}

SED = Standard error of the difference; Significance: *** $P<0.001$; ** $P<0.01$, * $P<0.05$, ns = not significant

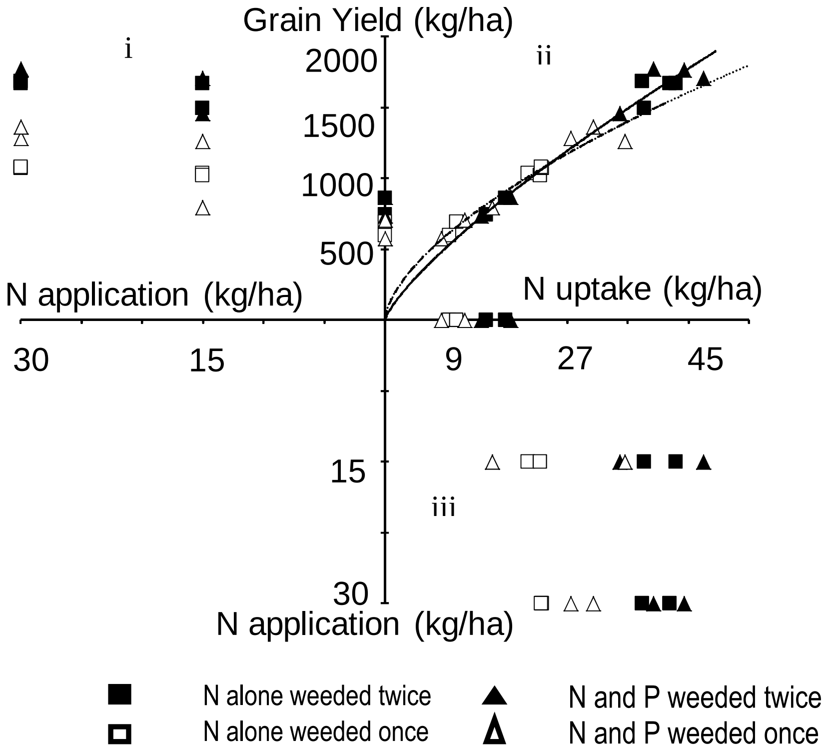

Fig. 5.4. Three quadrant diagram showing relationship between rate of fertilisation, uptake of nutrients and maize grain yield for plots weeded twice and weeded once: (i) Yield (kg ha^{-1}) against N fertiliser rates (fertiliser use efficiency), (ii) Yields against N uptake (Physiological N use efficiency), (iii) N uptake against fertiliser application rates (Recovery efficiency of N) grain against total N uptake. Dotted line (-----) is linear relationships for N, and N and P weeded once, bold (—) line is for N and N and P weeded twice

5.3.4 Financial analysis and maize responses

Financial analysis using the break-even price for fertiliser showed that returns to fertiliser were more than twice the cost ($0.81) of a kg N applied, but were better with second weeding (US$2.67) than weeding once (US$1.67 kg grain kg^{-1} N applied). It was highest at 15 kg N ha^{-1} (US$5.33) than with 30 kg N ha^{-1} ($2.67) in plots weeded twice. Break-even prices in plots weeded once were US$2.00 kg grain kg^{-1} N applied lower than plots weeded twice with 15 kg N ha^{-1}. Financial analysis using an opportunity cost of farm household labour equal to the local labour rate in Malawi of US$0.53 man-day^{-1} showed that investing in extra weeding[1] was equally profitable to household sale of labour (Table 5.5). The smallest return to labour was observed without N fertiliser. Applying N increased the returns to labour by US$0.52 man-day^{-1} with 15 kg N ha^{-1}, and US$0.45 with 30 kg N ha^{-1}. With labour costs included, the gross margins was US$43 more with 15 kg N ha^{-1} and US$39 more with 30 kg N ha^{-1} in plots weeded twice than the control. These figures were more than double when family labour was not considered. In plots weeded once both with and without opportunity cost of household labour, a positive gross margin was obtained with 15 kg N ha^{-1} only. A B/C ratio above 1 is often said to indicate that an enterprise will be attractive for smallholders (Mangisoni, 2000). Although all treatments had B/C ratios above 1 in plots weeded twice, 15 kg N ha^{-1} gave the highest B/C ratio of 1.6 when family labour was considered. This value more than doubled when family labour was not taken into account. In the plots weeded once only, 15 kg N ha^{-1} had a B/C ratio of greater than 1 with labour.

Table 5.5. Financial performance of combinations of N and P fertiliser in fields weeded twice and fields weeded once in Kamphenga, Chisepo, Malawi 2003-04 season.

N rates (kg ha^{-1})	Financial indicators					
	Returns to labour ($/man-day)	Gross Margin ($)		B/C ratio		Break-even price ($ kg grain kg^{-1} N)
		With labour	Without labour	With labour	Without labour	
Plots weeded twice						
0	0.04	3.83	53.7	1.07	3.45	0
15	0.53	59.64	119.0	1.61	4.30	5.33
30	0.33	41.13	106.9	1.36	3.21	2.67
Mean	0.30	34.87	93.2	1.35	3.65	2.67
Plots weeded once						
0	-0.03	-2.29	32.7	0.973	2.72	0
15	0.2	18.01	66.5	1.19	2.75	3.33
30	-0.03	-2.87	51.9	0.95	1.97	1.67
Mean	0.05	4.28	50.37	1.04	2.48	1.67

5.3.5 Farmer participatory learning and evaluation of N and P fertiliser in maize

Several observations were made independently by farmers. Almost all farmers said that they did not know that small fertiliser amounts would be profitable, although they stated that in their experience small amounts of fertiliser gave significant increases in yields. They observed that using small amounts of fertiliser would allow them to spread the fertiliser to cover a larger area and still obtain high yields. Farmers stated that in the trials fertilisers were applied well and in good time which contrasted with their normal practice. Many farmers said they were afraid of using the fertiliser in some fields due to the fear that fertiliser would damage their soils. Reference was made to ammonium sulphate (SA) which was commonly used earlier and is still available, but is less used for maize for fear of "*making their soils hard*". Farmers described the types of fertiliser by names, indicating that they knew the fertiliser either from contact with extensionists or from fellow farmers, but some of them could not identify samples of fertiliser correctly. They differentiated the fertiliser for basal dressing as "*wachitowe*" and for top dressing as "*wobereketsa*" using colour and size of granules. Although, the farmers could differentiate these types of fertiliser, they usually applied whichever fertiliser they find only once; at tasseling. The type of fertiliser they apply depends on what they access, and in this year, farmers said that most of them did not use the fertiliser because it was very expensive. They also said that the targeted input fertiliser that was operational did not reach them adequately, and it came late. Farmers observed that maize grew more poorly and yielded less in plots that had P only compared with those that received both N and P. Farmers said that maize grew with vigour in all plots that were weeded twice. They observed that maize growth was generally reduced by the dry spells that occurred in the season. Finally farmers reported that in most fields maize was attacked by *Chiwawu* (grey leaf spot caused by *Cercospora zeae-maydis),* but SC627 was less affected by the disease than MH18.

At harvest, maize yields were expressed graphically on flip charts as 50 kg bags of maize. Plots weeded twice gave 15, 34, and 33 bags of maize with no N, 15 kg N ha^{-1} and 30 kg N ha^{-1} respectively and that additionally received 20 kg P ha^{-1}. On average, an extra weeding gave an additional 8 bags of shelled maize ha^{-1}, which was adequate to cover about 4 months of maize for food for an average household (5.2 people) in Chisepo. Farmers noted that the same plots gave higher returns to labour and costs invested and they were optimistic that they would grow their maize the same way should they obtain fertiliser, and pay attention to extra weeding. The displays increased understanding of comparisons on the effects of weeding and small amounts of fertiliser. Farmers observed higher yields from plots weeded twice than those weeded once, however they said weeding for the second time was rarely done because of competing demands for their labour. This coincides with a peak labour demand for processing tobacco (the main cash crop for most farmers) from December to April (Fig. 5.5). Farmers that did not grow tobacco were involved in its processing on a *ganyu* basis (casual work done for other smallholder farmers for food or cash) or employed in nearby estates to cover the hunger period. Farmers observed that both maize varieties yielded well in both weeding regimes. Of the two varieties, farmers preferred SC627 because they said it yielded higher than MH18, had harder grain than MH18 and was less affected by grey leaf spot. Farmers however mentioned that fertiliser remained an expensive input to them and they wished the project would continue to offer fertilisers for use in the trials in their fields. The situation slightly changed from 2005 because of the fertiliser input subsidy programme which made fertilisers available at affordable price of MK950 (US$7.68) per 50 kg bag and each household was given two coupons to purchase the NPK and urea for maize. The subsidised fertiliser price has changed from MK950 to MK500 in 2010, but the critical issue is the distribution of the coupons and the fertiliser which does not reach farmers adequately.

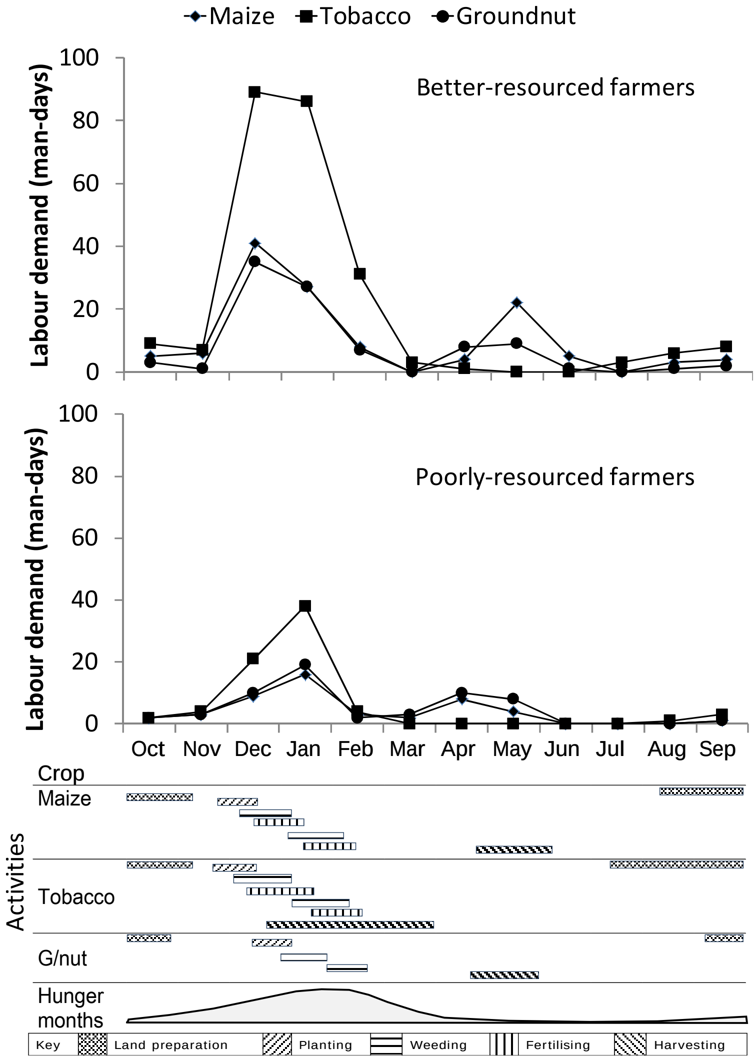

Fig. 5.5. Crop labour calendar and hunger months shown by cumulative grey-shaded shape in Chisepo, central Malawi.

5.4 Discussion

Overall yield responses especially at 30 kg N ha^{-1} were lower than expected and several reasons might have constrained the maize responses to fertiliser. There was low and poorly distributed rainfall during the maize growth in this particular season (see Fig. 5.1). A dry spell at tasseling and anthesis stage for maize occurred and this induced moisture stress to maize and limited maize responses to fertiliser especially in the sandy soils where five of trials were sited. The constrained yield response to N fertiliser on the sandy soil is attributed to that dry period resulting in water stress during maize tasselling (Fig. 5.1). On the sandy-clay soil which held an additional 30 mm of soil moisture, the maize was less water stressed during this period and responded to the additional N. In normal rainfall years, high maize response to fertiliser rates used in this study is expected and with proper weeding, application of small amounts of fertiliser would have high payoffs. This in conclusion is supported by APSIM simulations of maize growth which also show the same small response to N on the sandy site and responses on the sandy-clay (Fig. 5.3a, b)

(Unpublished data, Risk Management Project) although the APSIM over-predicted the unfertilised maize. Other authors have observed similar effects of dry spells in maize response to N (Keating *et al.*, 1999; Shamudzarira and Robertson, 2002; Whitbread *et al.*, 2004b). The results however show that if the season is dry, it is important to do extra weeding to get more from the small amounts of fertiliser.

The different nitrogen use efficiencies (NUEs) indicate three important factors: the soil N-supplying capacity, the recovery fraction of applied N in the crop, and the use of plant N to produce harvestable dry matter, i.e., the physiological N use efficiency (Wit, 1953). Soil N supplying capacity is a function of indigenous and applied N, which is influenced by the level of field, crop and fertiliser management (Dobermann, 2005). The low values of AE_N, PE_N, PFP_N and the high values of for RE_N might have been influenced by the weeding as well as effects of drought on synchronising N supply and crop demand of N, which affect the efficiency of applied N (Nhlane, 2001). Other studies obtained similar high values of RE_N (71-129%) in Zimbabwe (Whitbread *et al.*, 2004a) and this may confirm the importance of other sources of N in the soil such as from organic matter. Similar trends were observed for agronomic indices for P (Table 5.4). The results corroborate with on-farm studies in Malawi where average NUEs of 19 to 30 kg grain kg^{-1} N were obtained (Kumwenda *et al.*, 1996; Benson, 1997; Blackie *et al.*, 1998).

Higher maize yield responses and better nitrogen use efficiencies in plots weeded twice than those weeded once reflect the need for extra weeding. Weeding improves uptake and utilisation of N and P. It eliminates competition, and increases the water use efficiency and the rate of photosynthetic activity in the maize (Onken and Wendt, 1989). However, weed build up may be high under one weeding (and may reduce the fertiliser uptake by the crop and may result in as much as 26 to 33.6% crop yield reduction in maize (FAO, 2000) and this explain the lower responses in plots weeded once. Additionally, it was likely that because of the relatively dry season, there was competition for moisture between the weeds and maize. This may have increased the benefits for maize yield and N use from additional weeding. Nevertheless, because relatively dry years are common in Chisepo (one in 3 years is as dry as 2003-4), the benefit from extra weeding should be achieved in many of the years. Although farmers acknowledge the importance of extra weeding to crop yields, they often do not perform second weeding. The main reason is that second weeding coincides with other important activities such as tobacco harvesting. At the same time, a large majority of smallholder agriculture have food deficits (Fig. 5.5). Where there are no other sources of income, their labour is primarily used in *ganyu* in tobacco processing and weeding for the wealthier farmers to solve the food deficit problem (Whiteside, 2000). Although it is rational and economical for farmers to invest their labour at this time in *ganyu* (Alwang and Seigel, 1999), it has far reaching implications, in that those farmers in *ganyu* neglect their fields and end up having low maize yields. However, if they invest in second weeding, there may be an assurance of high maize yields and that may imply reduction in time for *ganyu* in the following season, unlocking labour for own food production. The point here is that although farmers should find it attractive to invest in more weeding of maize when using small amounts of fertiliser in dry years, the lucrative alternative sources of food through *ganyu* may mean it remains even more attractive and rational to offer their labour on other farms.

To improve the fertiliser the benefits from the national fertiliser subsidy programme in Malawi, there is need to improve the indigenous supply capacity of N by focusing on judicious use of organic matter, weeding and use of varieties of crops that have high ability to convert N to economic yields. Even if farmers access fertiliser, if poor field management continues, greater variability in factors controlling RE_N, PE_N and PFP_N will remain (Cassman *et al.*, 2002). Emphasis on integrated soil fertility management may improve indigenous N supply and timely field operations may enhance greater synchronisation between crop N requirements and N supply from all sources including fertiliser, organic inputs, and indigenous soil N. It is important to encourage farmers to explore different ways of adding more organic matter to the soil through composts, animal manure and integration of legumes.

The emphasis of this study was to explore the feasibility of improved management together with farmers. The study generated useful practical knowledge on farmers' practice of applying fertiliser far too late at tasseling where fertiliser use efficiency is reduced (Zambezi and Jones, 1992). Most farmers said that they believe that maize needs its fertiliser food most at tasseling and thus they apply it around that time. Others mentioned being constrained by late access of fertiliser, and uncontrollable social encumbrances such as tobacco *ganyu*, funeral and illness. Farmers' observation of fertiliser hardening the soil became an entry point for researchers to explain it on the basis of good soil management through organic matter (Vanlauwe and Giller, 2006). Farmers learnt from researchers that organic matter had the buffering effect on soils in reducing the effects of acidification from ammonium sulphate and hence the importance of judicious use of crop residues, application of manure and inclusion of legumes in the farming systems.

5.5 Conclusion

From this study we found that small amounts of NP fertiliser raise maize yields, are used relatively efficiently, and are financially attractive even when the fertiliser is valued at market rates. This is even the case in a relatively dry year such as the one encountered in the on-farm experiment. In such conditions, yields and N use efficiencies are greatly improved when farmers invest in additional weeding. In maize production, these small gains at the individual smallholder household level can represent a huge increase in efficiency and returns at national level to the subsidy programme. Timely fertiliser and field management are critical and the current Malawi input subsidy programme would have more national impact if farmers are able to invest in extra weeding. Given the labour shortages identified by farmers, support programs should consider helping farmers to access better hand-hoes and push-weeders so that fertiliser can be used efficiently with maize.

Chapter 6

Evaluation, adoption and non-adoption of annual legumes by smallholder maize farmers in central Malawi

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Chapter 6

Evaluation, adoption and non-adoption of annual legumes by smallholder maize farmers in central Malawi

Abstract

I studied the testing and adoption of ten grain legumes and green-manure legumes by smallholder maize farmers differing in resource endowment in Chisepo, central Malawi. Farmers (*n* = 136) were surveyed at the end of a programme of legume promotion on their farms in 2004 to assess the degree of uptake of the legumes and the reasons for farmers' adoption. A follow-up survey was conducted in 2007 among a broader sample of Chisepo farmers (*n* = 84) to measure the persistence of adoption. An Analytical Hierarchy Process (AHP) was used in 2004 to create scales of priority and predict adoption of the legumes. The actual adoption of food grain legumes reflected predictions by the AHP but the AHP over-predicted uptake of the non-food legumes. The AHP enhanced the understanding of farmer perceptions and needs in influencing adoption. Suitability for food was the most important criterion that farmers identified for adoption, followed by contribution to soil fertility and the suppression of weeds. On average, 35% of the farmers sampled in 2004 had adopted one or more of the food grain legumes; principally soyabean and CG7 groundnut, followed by pigeonpea or Bambara groundnut. This fell to 22% among the farmers surveyed in 2007. Somewhat greater uptake was noted for the better-resourced farmers (and women) than those with fewer resources. There was very little adoption of green manures by any of the farmers. There is a need to improve the food value of alternative multi-purpose legumes – such as mucuna – to raise the interest of farmers to use them.

Keywords *Analytical hierarchy process, benefit, grain legume, green manure, smallholder farmer, soil fertility management*

6.1 Introduction

Malawi faces numerous challenges related to poverty, increasing population pressure, a low-income base and the effects of an HIV/AIDS pandemic. Most of the population depends directly for their food on production from smallholder agriculture. Around 70% of Malawian smallholder farmers cultivate less than one hectare of land (the average is 0.5 ha) devoting 70% of their arable land to maize production (Alwang and Siegel 1999; Chirwa, 2003). Poor and declining soil fertility is one of the greatest biophysical constraints to increasing agricultural productivity in Malawi and elsewhere in eastern Africa (Bekunda *et al*., 1997; Smaling, 1998; Sanchez, 1999, 2002). Widespread soil fertility decline in Malawi results in average crop yields that are well below 1 t ha^{-1} (Blackie, 1994; Chirwa, 2003, 2005; Denning *et al*., 2009), leaving the majority of farm households food insecure and poor.

A wide range of low-cost technologies, including various types of annual legumes, have been proposed to improve the soils on which Malawi farmers grow maize (Blackie, 1994; Kumwenda *et al*., 1997b; Waddington *et al*., 1998, 2001). The biophysical performance and relevance of many of these legume-based technologies has been evaluated in Malawi and throughout the region (e.g. Kamanga *et al*., 1999, 2010; Kanyama-Phiri *et al*., 2000; Waddington *et al*., 2004). In addition to food-value/diet diversification and marketed income, smallholder farmers in general and in Malawi have shown interest in these crops for a range of other benefits; principally soil fertility maintenance and weed suppression (e.g. Giller, 2001; Gilbert, 2004; Snapp *et al*., 2002b, 2010).

Production and use of legumes has to increase in general because of their potential to improve food availability and soil fertility. However, their adoption has been limited in Malawi (Kumwenda *et al*., 1997b; Snapp *et al*., 2002a; Waddington *et al*., 2004). Recent studies suggest improved adoption particularly of grain legumes such as soyabean (Giller *et al*., 2011), groundnut and pigeonpea (e.g. Bezner-Kerr *et al*., 2007; Freeman *et al*., 2002) and perhaps agroforestry systems (Sirrine *et al*., 2010). But most legumes remain confined to very small land areas or are planted as sparse intercrops in the maize-dominated systems of central Malawi (Blackie *et al*., 1998; Snapp *et al*. 2002a; Bezner-Kerr *et al*. 2007).

Relatively few studies are available on the process of legume adoption by smallholder farmers in Malawi. Shortages of land, seed and labour; resource access, properties of the technologies, and farmers' lack of credit facilities are among the factors cited to limit widespread use of legumes in Malawi (Shaxson and Bentley, 1991; Blatner *et al*., 2000; Simtowe, 2006). Snapp *et al*., (2002a) reported that Malawian farmers weigh the benefits of weed suppression and potential cash earnings from legumes against the costs of seed, problems of seed access, labour requirements and problems of grain market access and price. Economic benefits were critical for poor farmers to adopt technologies (Blatner *et al*., 2000). The implication of inadequate knowledge of the factors limiting technology adoption is that development of unattractive technologies is perpetuated and, consequently uneven weak adoption continues.

This study was conducted to assess and understand the adoption of a range of grain and green manure legumes by smallholder farmers in central Malawi. Data were collected through two surveys, in 2004 and 2007, to look at the adoption of legumes that were introduced to farmers in participatory trials beginning in 1998. The Analytical Hierarchy Process (AHP) (Saaty, 1990; Byun, 2001; Karami, 2006) was used to assess farmers' preferences for the different legumes that they had been exposed to. The data from this ranking were compared with actual adoption of legumes by the farmers to better understand farmers' decision-making and the limited adoption of legume technologies.

6.2 Initial legume research and promotion activities

Ten annual legume crop technologies were introduced to smallholder farmers in the pilot-area of Chisepo, central Malawi through a CIMMYT-led ‘Risk Management project’ from 1998 to 2004 (Table 6.1) (see Kamanga, 2002b). Chisepo is in Dowa district within the Kasungu mid-altitude plain at 13’ 32” S and 33’ 31” E and an elevation of 1240 meters above sea level (Fig. 6.1). It has a total area of *c.* 300 sq km with around 1180 households spread over 47 villages and 95% of the land is suitable for agriculture.

Over the six years of the project (1998 to 2004), farmer participatory experimentation in Chisepo evaluated spatial and temporal variability in legume production, including the probability of yield losses in bad seasons, through simulation modelling and risk assessment (Kamanga, 2002b; Robertson *et al*., 2005; Kamanga *et al*., 2010). A major aim of the work was to identify and promote the most promising legumes to improve soil fertility in farmers’ fields (Kamanga, 2002b). A mother-baby trial approach was used (Snapp, 1999; 2002b; Kamanga *et al*., 2001) for participatory evaluation of the legumes, with a total of 14 farmers hosting a similar number of mother trials, and over 134 farmers hosting individual sets of baby trials across an area of 8 - 15 km radius.

Of the legumes, a variety (ICP 9145) of pigeonpea (*Cajanus cajan* (L.) Millsp.), soyabean (*Glycine max* (L.) Merrill), mucuna (*Mucuna pruriens* (L.) DC), determinate (bunch-type) cowpea (*Vigna unguiculata* (L.) Walp.), grahamiana (*Crotalaria grahamiana* Wight & Arn), sunnhemp (*Crotalaria juncea* L.), a new improved variety (CG7) of groundnut (*Arachis hypogaea* L.) and tephrosia (*Tephrosia vogelii* Hook. F) were all crops or varieties not commonly grown in the area. Bambara groundnut (*Vigna subterranea* (L.) Verd.) and indeterminate (spreading) varieties of cowpea had been grown locally by farmers. The legumes were grown either in rotation or as intercrops with maize (see Table 6.1). Based on substantial amounts of previous research, most of these legumes were considered to be broadly suitable for widespread promotion in the maize-based farming systems of central Malawi (see Waddington *et al*., 2004; Gilbert, 2004). All of these legumes have the potential to fix atmospheric nitrogen and produce biomass that can help to rehabilitate degraded soils (Giller, 2001). Throughout the years of research, farmers were supported with additional seed of those legumes that they liked, so that they could plant them on larger areas, and advice was given on their cultivation.

The potential adoption domain for the legumes is the area with similar conditions as Chisepo: it covers the entire Lilongwe-Kasungu Plain (see Fig. 6.1). It is estimated to comprise 46% of the total 3.3 million people of the Kasungu-Lilongwe plain of central Malawi, and a further 6.2 million who live in zones with a similar climate and cropping pattern elsewhere in Malawi. To promote the legumes in some of these areas beyond Chisepo, multiple dissemination channels and strategies were used, including the official extension services, farmer workshops, field days and partnership with non-governmental organisations (NGOs). Participation of traditional and public sector authorities, including the chief, in the field days encouraged farmers to try legumes and share information and seed with others. Developing partnership with organisations working in areas with similar climatic and socio-economic conditions was an additional strategy to scale out the technologies. Thirty farmers from the Soils, Food and Healthy Communities project in Mzimba visited Chisepo in 2000, Care Malawi International brought 11 farmers from Dowa East in 2000, and 27 farmers from Concern Universal in Dedza visited the trials in 2003. Concern Worldwide bought 547 kg of mucuna, 60 kg of tephrosia and 23 kg of pigeonpea seed from the area for distribution to over 200 farmers in Lilongwe West in 2002 (see Fig. 6.1).

Table 6.1 Legume-based technologies that were used in the programme of farmer participatory experiments in Chisepo, Malawi from 1998 to 2004 (adapted from Kamanga, 2002b; Snapp *et al*., 2002)

Technology	Population density (x 1000)	Description	Code
	Maize-legume technologies in rotations		
Maize and Mucuna	Maize: 37; Mucuna: 74	Maize follows mucuna in the following year, maize (MH 18 hybrid).	Mz/Mp
Maize and Ppea+G/nut	Maize: 37; Pigeonpea: 37; Groundnut: 74	Pigeonpea and groundnut (CG 7) are intercropped as 'double-up' legumes followed by maize	Mz/Pp+Gn
Maize and Soyabean	Maize: 37; Soyabean: 222	Magoye nodulates with indigenous rhizobium. Higher population densities of soyabean are possible.	Mz/Sb
Maize and Cowpea D	Maize: 37; Cowpea D: 80	Maize follows determinate cowpea in the second year	Mz/CpD
Maize and Groundnut	Maize: 37; Groundnut 74	CG 7 groundnut variety	Mz/Gn
	Maize-legume technologies in intercrops		
Maize and Tephrosia	Maize: 37 Tephrosia: 20 kg ha^{-1} seed	Tephrosia grows slowly at initial stages of development	Mz+Tv
Maize and Cowpea I	Maize: 37 Cowpea I: 10-22	Cowpea spreads, however the effects is less than mucuna	Mz+CpI
Maize and Pigeonpea	Maize: 37; Pigeonpea: 37	Pigeonpea and maize at same population densities	Mz+Pp
Maize and Sunnhemp	Maize: 37; Sunnhemp: 20 kg ha^{-1} seed	Sunnhemp either broadcast or in lines with maize	Mz+Sh
Maize and Grahamiana	Maize: 37; Grahamiana 20 kg ha^{-1} seed	Crotalaria grahamiana either broadcast or in lines with maize	Mz+Gh
Maize and Bambara	Maize: 37; Bambara: 74	Bambara groundnut between maize stations	Mz+Bn

D = determinate; I = indeterminate

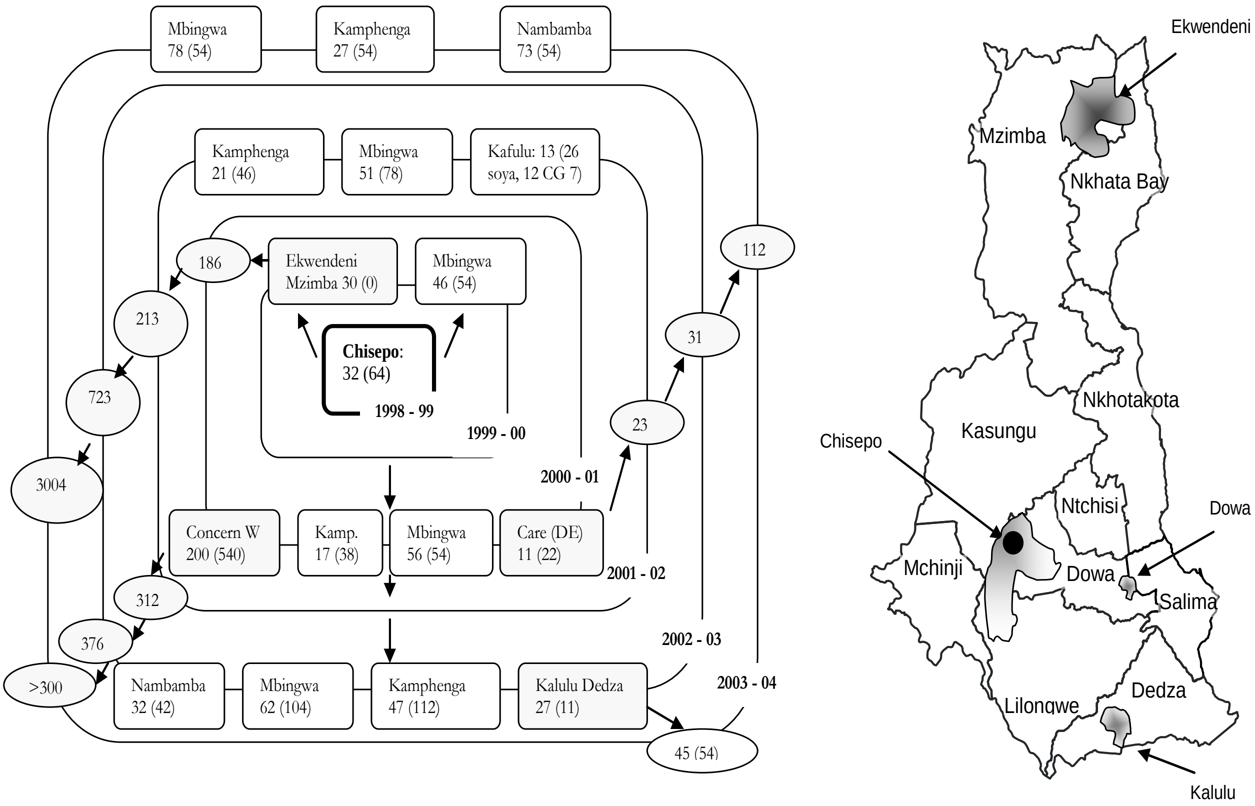

Fig. 6.1. Diagram (left) and map (right) showing the spread of legume seed and knowledge transfer through central and part of northern Malawi from 1998 through 2004. Shaded parts on the map are areas where legumes and knowledge spread to by NGOs. Numbers in parenthesis in boxes are amounts of seed of legumes shared from Chisepo, and numbers (not in parenthesis) under each name in the boxes are the number of farmers growing the legume at each site. Numbers in oval or circles on Concern Worldwide, Care Dowa East, Ekwendeni, and Kalulu are number of farmers growing the legumes in each year.

6.3 Assessment of legume adoption

6.3.1 The adoption process and surveys

I assessed the adoption process of legumes by distinguishing three stages; (1) awareness of the technology (% of all households sampled), (2) evaluating the technology by trying it (% of those aware), and (3) actual adoption (% of those that tried) (Floyd *et al*., 2003). Evaluation of legumes at each stage was guided by farmers' judgement of the attributes of the technology and was differentiated on the basis of the farmers' resource endowment (Kamanga *et al*., 2010). Dissemination and adoption pathways were identified using information from farmers on how they obtained seed and shared seed with other farmers. Data for the three stages were collected through two surveys which are described below.

The first survey was undertaken at the end of the promotion activities in 2004 in the pilot area and the surrounding villages to assess initial adoption of legumes. From a list of 47 villages for Chisepo, 21 villages were randomly-selected. One hundred and thirty six farmer households were selected for the survey from the total of 634 households in the 21 villages using a systematic sampling technique to ensure representative sampling (Byerlee *et al*., 1980). The head of each household was interviewed using a semi-structured questionnaire. In addition, focus group discussions and one-to-one interviews were conducted to complement the survey data and the AHP.

Adoption of legumes was further assessed in 2007 in the second survey three years after the CIMMYT project had stopped. This survey involved 84 households that were randomly sampled and interviewed from 36 villages, including the 21 villages sampled in the first survey and 15 villages from areas not targeted by the earlier project. Twenty-eight percent of the surveyed households had participated directly in the legume promotion activities, 43% were from the pilot areas but had not directly participated, and 29% of the households were from outside the intervention area. The households were categorised into better-resourced (*n* = 21) and less well-resourced households (*n* = 63), using wealth ranking and farmers' own assessment (see Kamanga *et al*., 2010). The survey was followed by focus group discussions, one-to-one follow-up interviews and open observations from the involved researchers. Information from these sources was used to complement and interpret the data from the surveys. Data were analysed using descriptive and cross-tabulated statistics in the SPSS package version 14.1 for windows. In both of our surveys, adoption was considered to have taken place if a farmer confirmed that a legume had been, as a minimum, planted on more than the trial plot sizes of 50 m^2 for more than one cropping season with the farmer giving at least one reason for still growing it. All values related to adoption have been reported on total of households sampled and total of households in the better- and less well-resourced groups.

6.3.2 The analytical hierarchy process (AHP) in preference ranking

The Analytical Hierarchy Process (AHP) can be used to organise farmers' perceptions, feelings, and judgments into a hierarchy that assists to explain the factors that influence choices between multiple alternatives (Byun, 2001; Karami, 2006). It allows priorities to be made explicit and is used in situations where differences in opinion limit the identification of the best compromise (Saaty, 1980). It has wide acceptability and use in various types of research (Saaty, 1990; Triantaphyllou and Mann, 1995; Al-Harbi, 2001), including agriculture (Alphonce, 1997; Karami, 2006). I used the AHP in 2004 to assess priorities and expectations of farmers for the different legumes and to predict the likelihood of adoption of legumes by farmers after three years. Adoption immediately at the end of a promotion project has in some cases been described as 'forced adoption' as a result of the incentives offered by the project (see Douthwaite *et al*., 2002). I therefore assessed adoption three years after the project had stopped. The value of the AHP method to predict adoption by farmers in the post project period was evaluated.

Focus group discussions in 2004 were used to generate information for the AHP. This included the definition of legume traits that were of interest to the farmers and a pair-wise comparison by farmers to calculate proxy-adoption indicators. The same categorisation of better-resourced and less well-resourced farmers was used as in the surveys. My use of the AHP in six steps is described below.

Step 1. Defining the problem: The problem identified was lack of adoption of legume-based technologies, and this was structured in a hierarchy in order to show levels of assessing the low adoption problem.

Step 2. Structuring the hierarchy of goal, criteria and options: Focus group discussions helped develop a hierarchical network of goals to which the legumes contribute (adoption of legumes), the criteria (five attributes of the legumes were identified: food, labour, soil fertility, weed suppression and intercropping) and the alternatives (pair-wise comparison of the ten legumes) (Fig.6.2).

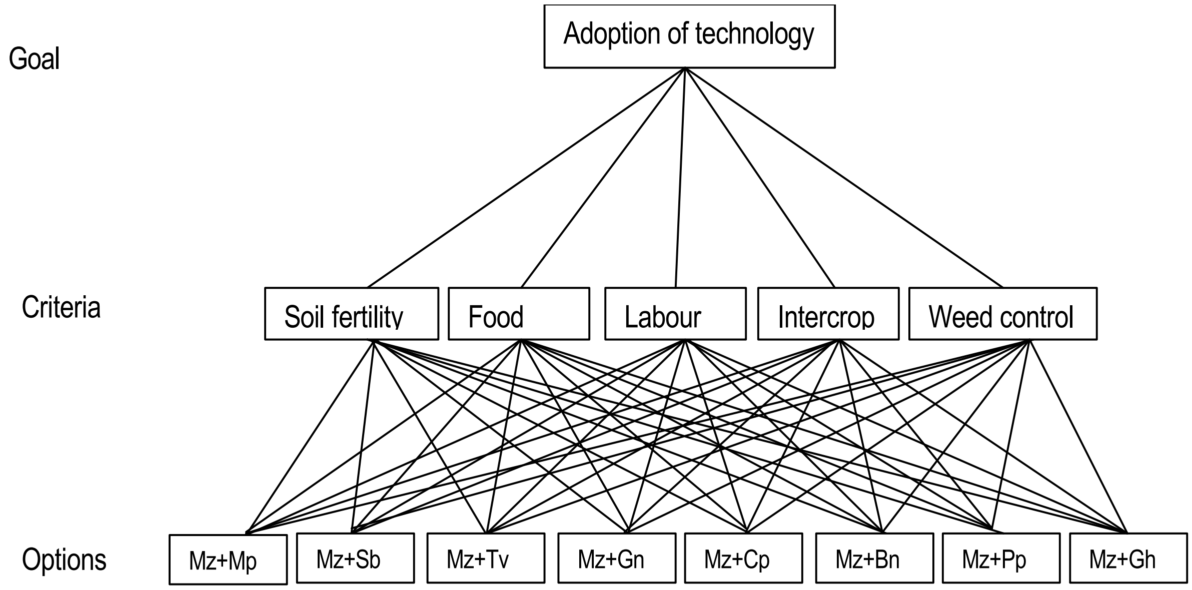

Fig. 6.2. Major criteria used by farmers to select technologies for adoption in Chisepo, central Malawi in 2004

Step 3. Construction of the pair-wise comparison matrix: This step involved development of a set of pair-wise comparison matrices (size *n* × *n*) using the relative scale measurement for each of 5 criteria (*n* × *n* = 5 × 5 matrices) for prioritising criteria and for each of the 10 legume options (*n* × *n* = 10 × 10 matrices) for pair-wise comparison of legumes (Al-Harbi, 2001). The pair-wise comparisons were based on which option or criterion dominates the other (Karami, 2006). Farmers evaluated each technology by reflecting on which of the two alternatives was more important with respect to the criterion, using a 9-point rating scale ranging from 1 (indifferent or equal importance) to 9 (extreme preference or absolute importance) (Karami, 2006).

Step 4. This identifies the judgements required from the set of the matrices developed in Step 3. For any set of matrices there are $n(n - 1)$ judgements, and for any judgement its reciprocal is automatically assigned in each pair-wise comparison. The judgement or comparison is the numerical representation of a relationship between two elements that share a common parent (Saaty, 1990). Each judgment represents the dominance of an element in the column on the left over an element in the row on top (Table 6.4a). If the element is less important than that on the top of the matrix, a reciprocal value is entered in the same position in the matrix. The lesser element is always used as a unit and the greater one is estimated as a multiple of that unit (Saaty, 1990). For instance using scales in Table 6.2, better-resourced farmers considered soil fertility more important than food security and it was given an absolute number 2 in the row under consideration, and in the column for food signifying that soil fertility was twice in importance than food security. Its reciprocal value of 0.5 was put in the row for food security in the column for soil fertility (Table 6.4a). Similarly, soil fertility was more important than intercropping and was assigned the absolute number 3 in the row for soil fertility, in column for intercropping and its reciprocal 0.33 was assigned to intercropping in its row, but in a column for soil fertility. This process allowed farmers to use their judgment and observations to conclude relations and strengths of relations of the alternatives and be able to predict the most likely preferred alternative.

Table 6.2. The scale used in a pair-wise comparison of legume technologies (aggregate judgement)

Importance	Definition	Verbal explanation
1	Equal importance	Two options contribute equally to the objective
3	Moderate importance of one over another	Slight favour on one over another
5	Strong or essential importance	Strong favour on one over another
7	Very strong importance	Strongly favoured and dominant
9	Absolute importance	Highest possible order of affirmation
2,4,6,8,	Separating values between two judgements	When compromise is needed
Reciprocals of above	If technology j^{th} has any of the numbers above when compared to k^{th} technology, then k^{th} has the reciprocal value when compared with j^{th}	

Source: Karami, 2006

Step 5 uses the hierarchical synthesis to weigh the eigenvectors (λ_{max}) by the weights of the criteria, and the sum is taken over all weighted eigenvector entries corresponding to those in the next level of the hierarchy (Al-Harbi, 2001). This involves simple mathematical calculations to use the hierarchical synthesis as described in the following sections.

Step 6 involves determining the consistency of the judgements made by using the eigenvalue, λ_{max}, to calculate the consistency index (CI) as: $CI = (\lambda_{max} - n) / (n-1)$, where n is the matrix size. The consistency ratio (CR) of CI (Table 6.4c) with corresponding average random consistency values (1.12 from matrix size of 5, and 1.49 for matrix size of 10 in Table 6.3) was used to check the consistency of the judgments. It is possible that judgements in a matrix are not consistent, especially where farmers are uncertain or have poor judgement in comparison with other elements. Inconsistency is inherent and may be considered a tolerable error only when it is a lower order of magnitude of 10% than the actual measurement itself (Saaty, 1990). Otherwise the inconsistency would bias the results if it is more than 0.10. The AHP shows where the inconsistency may arise in the judgement process and the closer the value is to zero, the more consistent the comparison.

Table 6.3 Average random consistency

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Following steps 1 – 6, the farmer preference matrix for the criteria in Table 6.4a is synthesised where in (a) priorities for each criterion are shown. The column priorities are added up to obtain a column total for soil fertility as shown below;

$$\text{Column total} = 1.0 + 0.5 + 0.5 + 0.3 + 0.3 = 2.6$$

This is repeated for the rest of the columns (Table 6.4a). Synthesising the pair-wise comparison matrix (b) is done by dividing each element of the matrix by its column total in (a). For example, value 0.385 in Table

6.4b is obtained by dividing 1 by 2.6, which is the sum of the column items in (a). The row average of 0.357 in (b) is the priority vector for soil fertility over the other criteria and is calculated as shown below;

$$\text{Priority vector} = \frac{0.385 + 0.488 + 0.345 + 0.316 + 0.250}{5} = 0.357$$

Repeating the process for other criteria gave priority vectors of 0.269 for food, 0.189 for labour, 0.109 for intercropping and 0.075 for weed control in Table 6.4b. At this point the priorities of farmers in terms of which criteria is the most important is known. However, it is important to check the consistency of the pair-wise ranking. To estimate the consistency ratio in Table 6.4c for the criteria, first the priority vectors are multiplied by the column items for each criterion in (a) gives 0.357 for soil fertility, 0.178 for food, 0.178 for labour, 0.107 for intercropping and 0.107 for weed control in Table 6.4 section (c). This is repeated for the rest of the priority vectors as below;

$$\begin{array}{l} \text{Soil fertility}\\ \text{Food}\\ \text{Labour}\\ \text{Intercropping}\\ \text{Weed control} \end{array} = 0.357 \overset{\text{Soil fertility}}{\begin{bmatrix}1.0\\0.5\\0.5\\0.3\\0.3\end{bmatrix}} + 0.269 \overset{\text{Food}}{\begin{bmatrix}2.0\\1.0\\0.5\\0.3\\0.3\end{bmatrix}} + 0.189 \overset{\text{Labour}}{\begin{bmatrix}2.0\\2.0\\1.0\\0.5\\0.3\end{bmatrix}} + 0.109 \overset{\text{Intercropping}}{\begin{bmatrix}3.0\\3.0\\2.0\\1.0\\0.5\end{bmatrix}} + 0.075 \overset{\text{Weed control}}{\begin{bmatrix}3.0\\3.0\\3.0\\2.0\\1.0\end{bmatrix}} = \underset{\text{Criteria weights}}{\begin{bmatrix}1.828\\0.380\\0.947\\0.542\\0.375\end{bmatrix}}$$

On each row (Table 6.4c) obtain criteria weights say 1.828 by adding up the values of the row. Second, divide all the elements of the criteria weights by their respective priority vector element to obtain the last column in Table 6.4c as shown below;

$$\frac{1.828}{0.357} = 5.126 \quad \frac{1.380}{0.269} = 5.124 \quad \frac{0.947}{0.189} = 4.998 \quad \frac{0.542}{0.109} = 4.960 \quad \frac{0.375}{0.075} = 4.977$$

To obtain λ_{max} compute the average of the values above as indicated below;

$$\lambda_{max} = \frac{5.126 + 5.124 + 4.998 + 4.960 + 4.977}{5} = 5.037$$

and once the $\lambda_{max} = 5.037$ in Table 6.4c is obtained, it is now possible to calculate consistency index (CI) by the formula below;

$$\text{CI} = \frac{\lambda_{max} - n}{n - 1} = \frac{5.037 - 5}{5 - 1} = 0.009$$

Where *n* is the number of criteria compared. Finally the consistency ratio (CR) is obtained by formula shown below;

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} = \frac{0.009}{1.12} = 0.008$$

This process was repeated for better-resourced and poor-resourced farmer groups separately (Table 6.5). After finding the priorities of the criteria, the pair-wise comparison matrices for the ten legumes were computed following the same procedures for better- and poor-resourced farmers and results are shown in Table 6.6.

6.4 Results

6.4.1 Initial adoption

The data from the first survey showed that the degree of awareness of the legumes varied from one technology to the other (Fig. 6.3a,b). There were no significant differences between well-endowed and less well-endowed households in 2004. In both categories of households, awareness levels of at least a legume averaged 77% of the all households sampled (*n* = 136), with greatest awareness (93%) of groundnut and least (38%) of grahamiana in 2004.

On average, the number of farmers reporting that they had tested at least one legume (% of total households) in 2004 was 62% with most testing groundnut (90%), and least grahamiana (27%), while 63% of the households in each of the categories had at least tried one or more legumes. Other legumes that were tried more by many farmers were soyabean (88%) and pigeonpea (76%). The number of farmers that still grew one or more legumes in 2004 was highest for groundnut and soyabean followed by pigeonpea, determinate cowpea, and least for tephrosia. Groundnut and soyabean were adopted more in both categories of households (Fig. 6.6a,b). Grahamiana and sunnhemp were not grown by any of the farmers in 2004, and tephrosia was only grown by better-resourced farmers. On average of all households sampled, 35% adopted at least one legume, 22% discontinued while 5% were not yet decided to discontinue or not and 38% had not tried any of the legumes at all. These variations indicate the different degrees of importance that farmers attach to each legume.

6.4.2 Reasons for growing legumes

In 2004, 58% of farmers that grew at least one legume in the better-resourced households mentioned contribution to soil fertility as the main reason for continuing with legume production while less well-resourced farmers gave contribution to food as the main reason for growing legumes (Fig. 6.4a). However, 49% of better-resourced farmers who were still growing one or more legumes mentioned food as their second main reason and 44 % of the less well-resourced farmers mentioned soil fertility as the second reason. Overall, food and soil fertility were the most common reasons farmers gave for continuing to grow legumes. Over 20% of better-resourced farmers reported that they had sold legumes to generate income as the third reason for continuing to grow legumes. Few of the less well-resourced farmers reported growing legumes for sale. A few farmers grew legumes such as mucuna and tephrosia for seed in anticipation of being able to sell the seed.

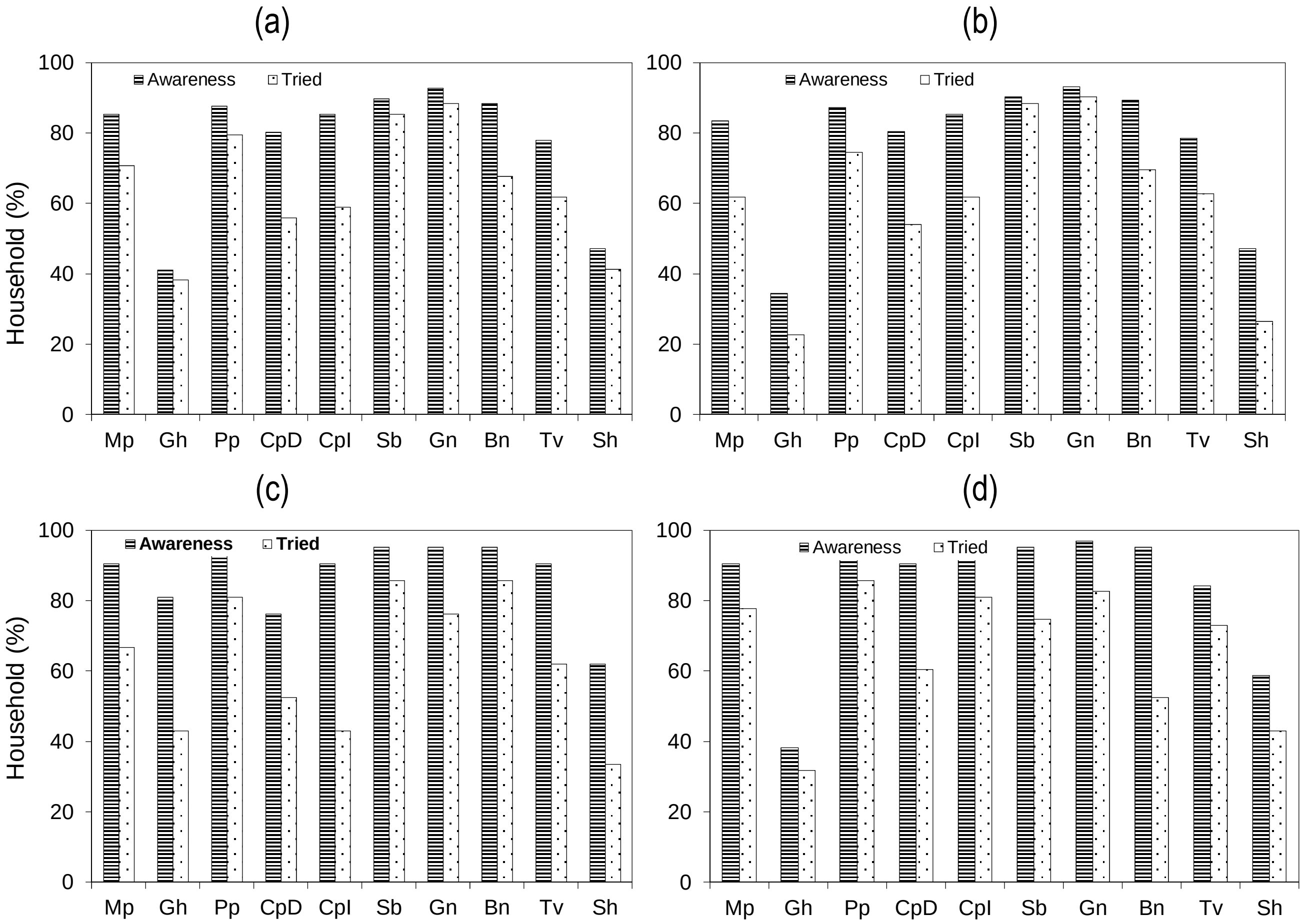

Figure 6.3. Household awareness of ten legumes in Chisepo, Malawi: % of total households in each group: In 2004 (a) better-resourced farmers (*n* = 34), and (b) less well-resourced farmers (*n* = 102). In 2007 (c) better-resourced farmers (n = 21) and (d) less well-resourced farmers (*n* = 63)

6.4.3 Sources of seed and information for farmers

Fellow farmers, the project and family were the main sources of seed and information, followed by market sources and NGOs (Fig. 6.4b). Farmers used more than one source of seed and NGOs contributed only a little less than 5%. Close to 60% of better-resourced farmers that were still growing one or more legumes depended on fellow farmers and the project for seed and information. The formal market was another main source of legume seed for better-resourced farmers in addition to buying it from fellow farmers. Over 60% of less well-resourced farmers that still grew one or more legumes relied more on fellow farmers and the family (38%) than NGOs and markets.

6.4.4 Non-adoption and dis-adoption of legume technologies

Fig. 6.4c shows the various reasons that households gave for abandonment of legumes. Of all farmers who stopped growing legumes, 21% of the better-resourced and 42% of the less well-resourced farmers reported lack of interest, 14% of better-resourced and 58% of less well-resourced households reported lack of seed as reasons to stop growing legumes. Others mentioned few benefits or low perceived profitability of the crop. Problems of labour were not cited a major reason for poorer farmers to dis-adopt legume technologies. However, better-resourced farmers cited no interest, no labour and little benefits as main reasons for discontinuing with legumes; none of the reasons clearly dominated. Other reasons collectively were for both groups of greater concern than labour availability.

In addition, farmers cited specific reasons for dis-adoption in relation to individual legume crops. The susceptibility of pigeonpea to insect pests such as pod sucking bugs (*Nezara viridula*) and pod borers (*Helicoverpa armigera*) was commonly cited. Farmers reported that the long-duration pigeonpea was often grazed by livestock and planting it close to their homes was one of the strategies to reduce damage. Farmers noted that although most households liked soyabean for fortifying their diets, its small grain size was a negative attribute in processing the crop for milk, flour and other products. Farmers said that although mucuna gave high yields of good grain, the reports of its poisonous effects (high concentrations of L-dopa in the grain) and lack of established formal markets contributed to its low adoption. Although they acknowledged declining soil fertility in their fields, and the difficulties they faced in accessing mineral fertiliser, farmers who did not try and adopt any of the legumes mentioned lack of interest in the legumes as a main reason. This lack of interest came from the lack of immediate returns among those that had been growing them. The numbers for non-adoption was lowest for soyabean, groundnut, and pigeonpea, and highest for grahamiana.

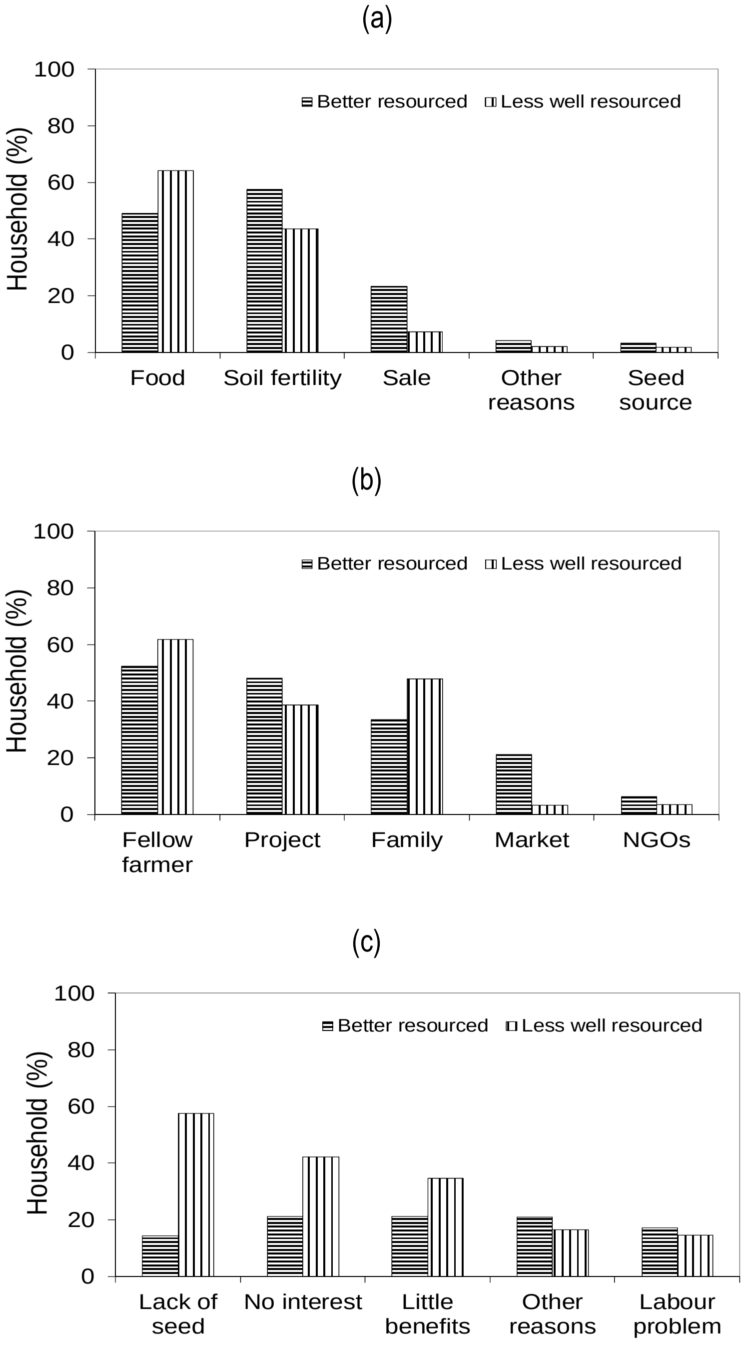

Fig. 4 (a) Reasons for still growing (% of still growing), (b) sources of seed and information (% of still growing) and (c) reasons for abandonment (% of dropped) of legume technologies among the better resourced and less well-resourced farmers in Chisepo in 2004.

6.4.5 Legume grain production and use

Cumulative grain produce and use for four seasons to 2004 are shown in Fig.6.5. Farmers reported selling grain-legume seed after the first year to fellow farmers outside the communities and NGOs. They also reported sharing grain among themselves for seed, which thus it enhanced spread of the legumes to nonpilot areas. Sales of mucuna in 2004 declined despite increased production of seed, due to the lack of markets. Farmers had increased production in anticipation of markets provided by NGOs. Absence of markets, as NGO interest in mucuna waned, resulted in the drastic reduction of mucuna production after 2004. Home consumption of grain was important from 2004 onwards for pigeonpea, soyabean, groundnut and Bambara groundnut.

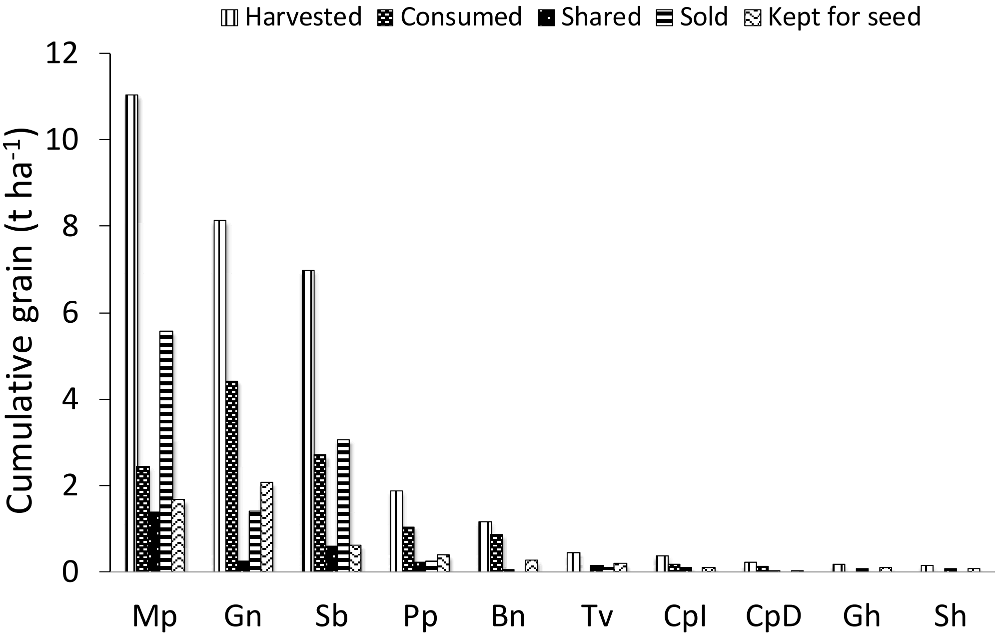

Fig. 6.5. Cumulative legume grain production and use of the harvest from 2001- 2004 by selected farmers in Chisepo, central Malawi (*n* = 36)

Fig. 6.1 shows the sites in central Malawi that accessed seed and knowledge from Chisepo, and in each site the number of farmers growing the legumes increased over the years. In Mbingwa, the number of farmers increased from 32 in 1998/99 to 78 in 2004. There were other villages around Mbingwa that grew legumes as shown in the figure. Thirty farmers from Ekwendeni visited Chisepo and accessed knowledge about legumes from farmers in the project, but not legume seed. The Soils, Food and Health Communities project under the Ekwendeni Mission Hospital who worked intensively to promote the legumes in Ekwendeni. By 2004, over 3000 farmers were growing legumes (see e.g. Bezner-Kerr and Chirwa, 2004; Bezner-Kerr *et al.*, 2007). Similarly information and seed from Chisepo helped other legume promotion projects such as those led by Care Malawi and Concern Worldwide.

6.4.6 The analytical hierarchy process (AHP) in 2004

Key criteria for assessing legumes for adoption

Results of farmer comparisons of criteria for assessing legumes for adoption in Table 6.5 show that food security had the highest priority weight of 0.495 for all farmers followed by soil fertility (0.312), intercropping, weed control and then labour. Better-resourced farmers indicated that soil fertility was their most important attribute for adopting legumes followed by food, intercropping and weed control. Less well-resourced farmers had food as the most important criterion, followed by soil fertility, intercropping and weed control. In the AHP, the consistency ratio (CR) limit is 0.1 (Al-Harbi, 2001), and CRs of 0.017 for all farmers, 0.008 for better-resourced farmers and 0.004 for less well-resourced farmers were obtained, indicating that their judgements for the criteria were consistent and acceptable.

Table 6.4. Farmer pair-wise ranking: (a), Comparison of criteria (b) synthesised matrix for criteria (c) computation of CI and CR in Chisepo, central Malawi in 2004 (n = 136 households)

	Criteria as defined by farmers							
	Soil fertility	Food	Labour	Inter cropping	Weed control	Row Total	Priority vector	Rank
			(a) Pair-wise comparison of matrix for criteria					
Soil fertility	1	2	2	3	3			
Food	0.5	1	2	3	3			
Labour	0.5	0.5	1	2	3			
Intercropping	0.3	0.3	0.5	1	2			
Weed control	0.3	0.3	0.3	0.5	1			
Column Total	2.6	4.1	5.8	9.5	12			
			(b) synthesised matrix for criteria					
Soil fertility	0.385	0.488	0.345	0.316	0.250	1.783	0.357	1
Food	0.192	0.244	0.345	0.316	0.250	1.347	0.269	2
Labour	0.192	0.122	0.172	0.211	0.250	0.947	0.189	3
Intercropping	0.115	0.073	0.086	0.105	0.167	0.547	0.109	4
Weed control	0.115	0.073	0.052	0.053	0.083	0.376	0.075	5
Column Total	1	1	1	1	1	5	1	
			(c) Computation of CI and CR					
Soil fertility	0.357	0.539	0.379	0.328	0.226	1.828	5.126	
Food	0.178	0.269	0.379	0.328	0.226	1.380	5.124	
Labour	0.178	0.135	0.189	0.219	0.226	0.947	4.998	
Intercropping	0.107	0.081	0.095	0.109	0.150	0.542	4.960	
Weed control	0.107	0.081	0.057	0.055	0.075	0.375	4.977	
						λ_{max}	5.037	
						CI=	0.009	
						CR	0.008	

Pair-wise ranking of legumes for adoption using the AHP

Results of pair-wise ranking of legumes showed that better-resourced household preferences were for soyabean followed by mucuna, CG7 groundnut, pigeonpea and grahamiana, and then the other legumes (Table 6.6). Sunnhemp and bunch-type determinate cowpea were the least preferred legumes by the better-resourced farmers. Similarly, less well-resourced farmers preferred CG 7 groundnut, soyabean and mucuna as a third important crop. Except for weed control for the better-resourced farmers and labour for the less well-resourced farmers, all consistency ratios were below 0.1, meaning that the pair-wise ranking by farmers were consistent to their choices and acceptable to the evaluation process. These preferences predict a strong adoption of soyabean, mucuna and CG 7 groundnut by farmers in the post evaluation period. However, these predictions of adoption by the AHP showed major differences with actual adoption. While mucuna was predicted to be readily adopted, its actual adoption was among the least (Fig. 6.6c, d) suggesting that other factors influenced adoption of the non-food legumes.

Table 6.5. Synthesised matrix for technology assessment criteria used by farmers in Chisepo, central Malawi in 2004 (n = 136 farm households)

Criteria	Soil fertility	Food	Labour	Intercrop	Weed control	Row total	Priority vector	Rank
All farmers (n = 136 farmers)								
Food	0.682	0.602	0.350	0.515	0.324	2.473	0.495	1
Soil fertility	0.227	0.181	0.350	0.368	0.432	1.558	0.312	2
Intercropping	0.045	0.060	0.150	0.074	0.162	0.491	0.098	3
Weed control	0.023	0.096	0.100	0.022	0.054	0.295	0.059	4
Labour	0.023	0.060	0.050	0.022	0.027	0.182	0.036	5
Better-resourced farmers (n = 34)								
Soil fertility	0.385	0.488	0.345	0.316	0.25	1.783	0.357	1
Food	0.192	0.244	0.345	0.316	0.25	1.347	0.269	2
Labour	0.192	0.122	0.172	0.211	0.25	0.947	0.189	3
Intercropping	0.115	0.730	0.086	0.105	0.167	0.547	0.109	4
Weed control	0.115	0.730	0.052	0.530	0.830	0.373	0.075	5
Less well-resourced farmers (n = 102)								
Food	0.465	0.392	0.286	0.455	0.241	1.838	0.368	1
Soil fertility	0.233	0.196	0.214	0.303	0.241	1.187	0.237	2
Intercropping	0.116	0.118	0.214	0.152	0.361	0.961	0.192	3
Weed control	0.116	0.196	0.214	0.045	0.120	0.693	0.139	4
Labour	0.070	0.098	0.710	0.045	0.036	0.321	0.064	5

All farmers: λ_{max} = 5.077, CI = 0.019, RI = 1.12, CR = 0.017 < 0.1 OK

Better resourced farmers: λ_{max} = 5.037, CI = 0.009, RI = 1.12, CR = 0.008 < 0.1 OK

Less well-resourced farmers: λ_{max} = 5.016, CI = 0.004, RI = 1.12, CR = 0.004 < 0.1 OK

Table 6.6. Priority matrix for legume contribution to farmer's goals in Chisepo, central Malawi in 2004 (*n* = 136 farm households)

	Overall	Soil fertility	Food	Labour	Intercrop	Weed control	Overall priority vector	Rank
				Better resourced farmers (*n* = 34)				
Soyabean	0.228	0.085	0.071	0.033	0.027	0.011	0.226	1
Mucuna	0.062	0.072	0.013	0.037	0.002	0.018	0.142	2
Groundnut	0.244	0.026	0.059	0.018	0.022	0.006	0.131	3
Pigeonpea	0.107	0.048	0.018	0.031	0.015	0.010	0.123	4
Grahamiana	0.028	0.036	0.007	0.027	0.005	0.012	0.086	5
Tephrosia	0.035	0.033	0.008	0.010	0.012	0.007	0.070	6
Bambara	0.182	0.015	0.032	0.010	0.006	0.003	0.066	7
Cowpea I	0.138	0.011	0.036	0.010	0.005	0.002	0.064	8
Cowpea D	0.073	0.012	0.020	0.007	0.005	0.001	0.045	9
Sunnhemp	0.024	0.020	0.005	0.006	0.009	0.005	0.045	10
λ_{max}	10.930	10.780	10.726	11.150	10.889	11.382		
CI	0.103	0.087	0.081	0.128	0.099	0.154		
RI	1.49	1.490	1.490	1.490	1.490	1.490		
CR	0.069	0.058	0.054	0.086	0.066	0.103		
< 0.1 >	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	> 0.1		
				Less well-resourced farmers (*n* = 102)				
Groundnut	0.244	0.049	0.092	0.014	0.035	0.013	0.204	1
Soyabean	0.228	0.050	0.083	0.013	0.042	0.006	0.194	2
Mucuna	0.062	0.035	0.018	0.010	0.005	0.034	0.101	3
Pigeonpea	0.107	0.034	0.024	0.003	0.020	0.017	0.098	4
Bambara	0.182	0.013	0.050	0.004	0.009	0.003	0.079	5
Grahamiana	0.028	0.023	0.011	0.002	0.008	0.041	0.085	6
Cowpea I	0.138	0.017	0.040	0.003	0.009	0.001	0.070	7
Cowpea D	0.073	0.008	0.034	0.003	0.008	0.003	0.056	8
Tephrosia	0.035	0.005	0.007	0.007	0.030	0.003	0.052	9
Sunnhemp	0.024	0.004	0.008	0.006	0.025	0.006	0.048	10
λ_{max}	10.930	10.539	10.592	11.444	11.169	10.870		
CI	0.103	0.060	0.066	0.160	0.130	0.097		
RI	1.49	1.49	1.49	1.49	1.49	1.49		
CR	0.069	0.040	0.044	0.108	0.087	0.065		
< 0.1 >	< 0.1	< 0.1	< 0.1	> 0.1	< 0.1	< 0.1		

6.4.7 Actual adoption of legumes by 2007

The data from the second survey show awareness levels (Fig. 6.3c,d) and adoption (Fig. 6.6c,d) of each of the legume technologies in 2007. Awareness levels of both the less well-resourced and better-resourced households were slightly higher in 2007 than in 2004 (Fig. 6.3a, b), averaging 84%. The number of farmers who had tried at least one legume by 2007 had increased to 65%, and all, but grahamiana, determinate cowpea and sunnhemp ranged from 60 - 85% for both household categories (Fig. 6.3c, d). Slightly more of the less well-resourced households had tried the legumes than better-resourced households. On average, 22% of households surveyed in 2007 had adopted at least one legume, much less than adoption in 2004.

Some 34% had discontinued, 9% were not yet decided to continue or not while 35% had not tried a legume at all (Fig. 6.6c,d). CG 7 groundnut and soyabean were highly adopted by the farmers in both households categories, but no household adopted grahamiana or sunnhemp. Adoption of soyabean and CG7 groundnut declined in both farmer resource groups with less adoption in less well-resourced households. Other crops following soyabean and groundnut were Bambara groundnut and pigeonpea, while mucuna was fifth and sixth in better- and less well-resourced households respectively. In both household categories, soyabean and CG7 groundnut were highly adopted and grahamiana and sunnhemp were not adopted at all in 2007. There were households that reported growing the legumes but were not sure they would continue to grow them or not. Area planted increased to an average of 0.4 ha from the original trial plot size of 0.01 ha. This was additional evidence for sustained adoption.

6.4.8 Farmer adaptation of legume technologies

Observations over the period 1998-2007 showed that farmers modified the planting patterns of legumes of the mother-baby trials. Over 80% of farmers who planted pigeonpea grew it more on homestead fields than outfields and intercropped it with maize or planted it as hedgerows. They said that these practices aimed at reducing damage by livestock, and did not mainly target soil fertility. Most of the farmers coppiced the pigeonpea plants for 2 or 3 years, and they said that this practice reduced the need for new seed and labour to plant a new crop each year. Although a few farmers planted mucuna in field boundaries, most farmers retained mucuna in their fields as a volunteer crop. They maintained it at low plant densities to reduce its aggressive competition with maize. This practice was a way to maintain its seed. Farmers planted tephrosia as a border crop of the fields and as hedgerows near the homesteads principally to provide leaf extracts as pesticide and fish poison. Farmers observed that tephrosia plants left to grow for two years gave more seed and biomass than the first-year crops. Farmers intercropped soyabean and CG 7 groundnut with maize at various population densities, and some farmers intercropped soyabean with tobacco as a way of improving soil fertility as well as to reduce labour shortages. This showed farmers' appreciation of soil fertility benefits from soyabean.

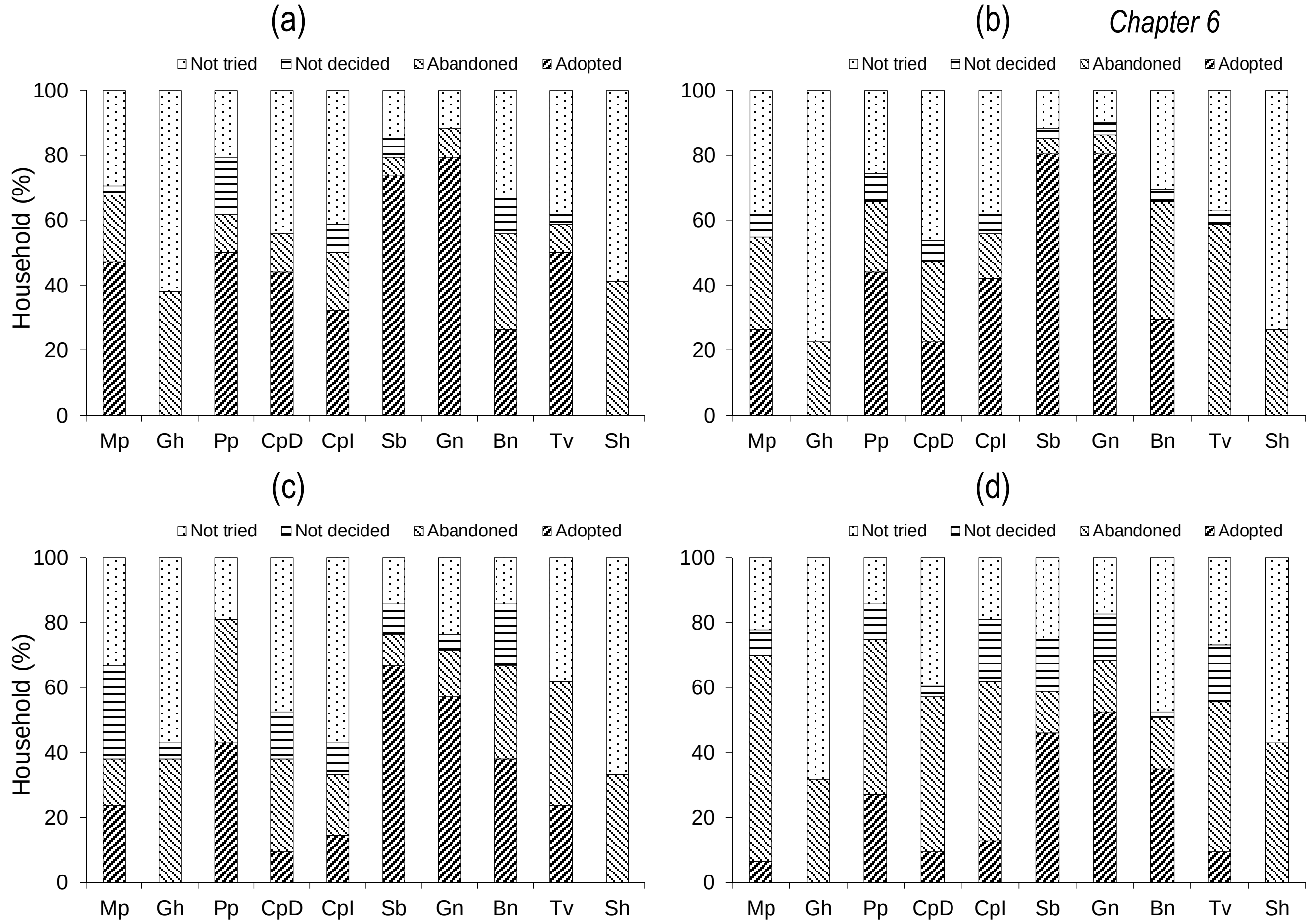

Fig. 6.6. Adoption of ten legumes, % of total households sampled in each group (a) = better-resourced farmers (*n* = 34) and (b) = less well-resourced farmers (*n* = 102) in 2004; % of total households for each group (c) = better-resourced farmers (*n* = 21) and (d) less well-resourced farmers (*n* = 63) in 2007 in Chisepo, central Malawi.

6.4.9 Farmer perceptions of the benefits of legumes

Farmers' assessment of what the technologies had contributed by 2007 (Fig. 6.7) indicated that 25% of the better-resourced farmers who had adopted one or more legume technologies saw that use of legumes continued to improve soil fertility in the fields, while (interestingly) 23% said that they noticed a decline. While there were positive indications of soil fertility improvements, the small numbers of farmers observing this impact may suggest the benefits of soil fertility improvements were small. This was observed more in less well-resourced households where only 14% of less well-resourced farmers saw that legumes improved soil fertility while 58% observed decrease in soil fertility improvements. Slightly over 50% of farmers in well-resourced farmers and 36% more farmers from less well-resourced farmers noted an increase in food availability. On average, 86% of the total households observed that intercropping legumes with other main crops was increasing in the area. The difference between the well- and less well-resourced households on contribution of legumes to food shows the differences in expectations in terms of food availability.

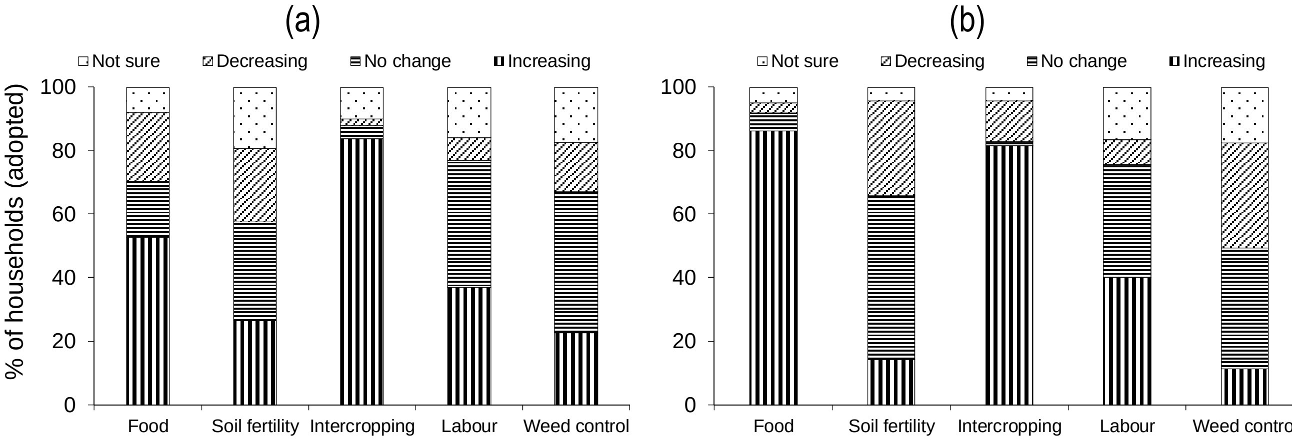

Fig. 6.7. Legume-adopting households reporting impact benefits of legume technologies in Chisepo, central Malawi in 2007. (a) better-resourced farmers (*n* = 21), (b) less well-resourced farmers (*n* = 63).

The agreement of both categories of households that intercropping is increasing either reflects the need to use it as a labour saving or weed suppressing technique or both. It may also suggest the strong degree to which farmers in the area prioritise maize production above other crops. Thirty-seven percent and 40% of better- and less well-resourced farmers observed that their needs for labour had increased due to the inclusion of legumes, whereas on average 38% considered no change. A little more than 20% of better- and 11% of less well-resourced farmers saw that weeds were still a problem even though legumes were used and about 15% of better- and 33% of less well-resourced farmers considered weed problems were reduced. On average 41% of all the farmers saw no any change.

In terms of area planted, most farmers that adopted soyabean and groundnut indicated an average of 0.4 ha expansion of crop area from the original trial plots of 0.005 ha. Assessment of the area of legume expansion by farmers who adopted them showed that expansion from the trial plots has been variable and limited (Table 6.7). Food grain legumes have been expanded more than non-food grain legumes. Thirty-six percent and 33% of those adopted groundnut and soyabean respectively out of the 84 farmers sampled in 2007 have expanded to more than one ha while non-food legumes which contribute more N to the soil have remained concentrated on small pieces of land. Both soyabean and groundnut are commonly intercropped with maize by smallholder farmers and better-resourced farmers additionally grow them in rotation.

Table 6.7. Area planted to legumes in Chisepo, central Malawi in 2007

	Legume							
Area planted (ha)	Groundnut	Pigeonpea	Soyabean	Mucuna	Bambara	Cowpea bunch	Cowpea spreading	Tephrosia
Up to	%							
0.1	7.1	46.2	8.3	66.7	70.0	87.5	91.0	72.7
0.2	16.7	23.1	14.6	33.3	30.0	12.5	9.0	27.3
0.5	19.0	15.4	14.6	-	-	-	-	-
1	21.4	11.5	29.2	-	-	-	-	-
>1	35.7	3.8	33.3	-	-	-	-	-
Number of farmers interviewed	42	26	48	9	30	8	11	11

6.5 Discussion

6.5.1 Adoption of legume technologies

The results of this study showed an average of 22% of the smallholder farmers surveyed in Chisepo in 2007 had adopted at least one legume technology. There was a high degree of acceptability and adoption of several of the food grain legumes among many of the farmers, as noted in earlier studies in Malawi (Bezner-Kerr *et al*., 2007, Freeman *et al*., 2002). Nevertheless, 34% of the farmers did not adopt any of the legume options that had been promoted. Adoption of the food grain legumes was strongest in the group of well-resourced farmers: soyabean was most frequently adopted, followed by CG7 groundnut, Bambara groundnut and pigeonpea. The adoption of the less well-resourced households showed a strong preference and acceptance for CG 7 groundnut and soyabean than mucuna, pigeonpea, and tephrosia, followed by Bambara groundnut and indeterminate cowpea. Farmers mentioned that CG 7 groundnut was highly preferred because of its high yield, cooking time, taste, drought tolerance and it intercrops well with maize, similar to earlier findings reported by Freeman *et al*., (2002). Soyabean was most preferred to other legumes because of good yield potential and multiple uses in diet fortification (Giller *et al*., 2011; Gilbert, 2004). This preference also suggested that the food grain legumes were consistent with their needs and were compatible with their land and labour resources. The less well-resourced households may have been more interested in CG 7 groundnut because it is a more common household food than soyabean, while the well-resourced households were interested more in soyabean as it is more marketable for income. The adoption pattern of food grain legumes suggested that while the better-resourced farmers would strive to be self-sufficient in food production (Sirrine *et al*., 2010), they also would be interested in selling the grain.

The adoption pattern of food crops is linked to that fact most food legumes are grown by women particularly for food availability to the households, good taste and easy of cooking and storage. In addition, these legumes are easy to manage in terms of production and do not need extra inputs such as pesticides. As such they are within the socio-economical realms of the women. Processing lessons for legumes for human consumption were often attended by women, and these lessons resulted in use of different recipes for soyabean and groundnut. Soyabean was particularly important for feeding children and directly helped to reduce malnutrition among them. The food grain legumes that were highly adopted exhibit characteristics that were pro-women and were hence preferred above the non-food legumes. The majority of farmers that adopted the food grain legumes including groundnut and soyabean were women farmers. In addition to food needs, the legumes offer an opportunity to women to access some income when the legumes have been sold. In contrast, men tend to focus on crops that are income-based (Bezner-Kerr *et al*., 2007).

Soil fertility benefit from legumes was initially another important reason for adopting legumes. Thus there was an early strong preference for mucuna, especially among the better-resourced households, who adopted it more than less well-resourced households. Interest in mucuna was probably also associated with a perceived lucrative market for seed created by NGOs. Interest fell as the market for mucuna seed declined, similar to findings elsewhere for legumes grown only for soil fertility (Ojiem *et al*., 2006, Giller, 2001). Farmers' assessments (Table 6.6) indicate that soil fertility contributions may have lost some importance as a reason to continue growing a legume crop as the project progressed, in particular with the well-resourced farmers. Beside providing food and improving soil fertility, other positive attributes of the legumes - particularly weed suppression effects by mucuna on *Imperata cylindrica* and S*triga* species - might have influenced farmer interest to adopt them.

Farmers gave several reasons for stopping to grow some of the legumes. Again for mucuna, its restricted use as a food grain and difficulties to cook made it unattractive to farmers. While some Chisepo farmers derived satisfaction from mucuna (many farmers in Malawi consider it a local crop since it is a traditional last resort food crop in some southern parts of the country), none of them contemplated to use it as a complete replacement for mineral fertiliser. Its aggressive, spreading habit prevents farmers from growing a companion crop with it, and it was not suitable with their systems of intercropping (e.g. Gilbert, 2004). Most farmers said they did not have seed, indicating they were not able to save seed from previous harvests for planting, either as a result of consumption needs or because they perceived that the project could give them fresh seed stock. It was not surprising that 36% of the farmers reporting lack of seed as a factor for dis-adoption of the legumes; and this was an especially important reason for 59% of the less well-resourced farmers.

Use of farmer groups in the experimentation process might have contributed to limited seed availability. These farmer groups tended to form social relations or identities around the legumes they were evaluating in trials and external access to seed and knowledge might have been restricted. The social relations might also explain the slow seed diffusion which was reported to mainly follow kinship lines or close social networks. Seed diffusion through these social networks often involved small quantities of seed with limited information on how to manage the legumes. It could also be that they did not share seed because they might have seen potential gains in the commercialisation of legumes when markets were available. Most of the legumes evaluated have a high seeding rate and this meant that, in absence of serious seed multiplication by farmers, farmer-to-farmer seed diffusion would take several years to meet the seed requirements.

The assortment of reasons for not adopting or dis-adopting legumes with potential to improve food availability indicates a complex of interacting factors that influence farmers' adoption. The weak adoption in 2007 raises the question of why the legumes are not attractive options. Thus the results of our study imply that any programme promoting legumes for soil fertility improvement needs to: a) identify legumes that also have high potential as food grain, b) improve the food value of legumes that have great value in maintaining soil fertility, and c) identify markets and link farmers to markets for legumes that may not be readily consumed locally.

Since farmers were often most interested in both food and soil fertility benefits from legumes, clearly those legumes best able to meet both of these needs may be particularly attractive for sustained adoption (e.g. Snapp *et al*., 1998; Waddington *et al*., 2004). Among the food legumes adopted by farmers in this study, pigeonpea and soyabean are probably those with the highest value for biomass and N input into the soil Gilbert, 2004; Waddington *et al*., 2004; Giller *et al*., 2011). Among the legumes principally used to improve soil fertility, mucuna is the one with the greatest potential to be converted into a food grain legume (Gilbert, 2004). If it were possible to select mucuna for a lower L-dopa content in its grain, it could be promoted as an attractive dual-purpose legume, with high grain yield for food and high N input and leaf biomass for soil fertility improvement (Buckles and Triomphe, 1999).

6.5.2 Use of the AHP in modelling adoption potential for legumes

The AHP was based on farmers' perceptions and experiences, but the final choices indicate that the soil fertility expectations that farmers had might not have been met. The AHP identified soil fertility as the attribute that farmers valued the most, thus indicating mucuna (the most attractive option among the green manures) to be the legume with most potential for adoption. However, the eventual limited adoption of mucuna and the later assessment of contributions of the legumes indicated that farmers had a stronger preference for food grains and less priority for soil fertility. Farmers' expectations of the impact on soil fertility may have been cultivated during the earlier Risk Management project that was especially interested in and promoted soil improvements from legumes (Kamanga, 2002b). It is also possible that the legumes did not perform as well as anticipated. During informal discussions in 2007, some farmers indicated that they had expected to see clearer effects of the legumes on the yields of their following crops. The differentiation for wealth status helped to show that social factors play a role in influencing rational decision-making and ultimate choices by farmers (Table 6.7 and Fig.6.6). It showed that although the less well-resourced farmers value food-grain for consumption more than better-resourced farmers, their eventual adoption behaviour was however quite similar.

Thus, while the AHP may not directly predict adoption, it proved to be a useful tool for ranking preferences among technologies and generating proxies. The AHP was most useful in relation to the deviations from the expected adoption. This was even more so because the information that farmers provided on the reasons for abandoning legumes was not precise (e.g. no interest, little benefits, lack of seed and high labour demands). This deviance between farmers' expectation and real adoption merits further research and may contribute to the understanding of opportunities to improve smallholder farmers' livelihoods and soil fertility through legume use.

6.6 Conclusion

The study has revealed that adoption of legume technologies is influenced by the contributions the legumes offer to the farmers' food needs and other livelihood pursuits. Farmers prefer legumes that contribute to their immediate food needs, and adoption of legumes by all farmers was largely limited to food grain legumes. Even though there was a high preference and acceptability of food grain legumes, the overall adoption rate of legume technologies was limited, and many of the farmers surveyed were aware of legume crop introduction but did not take up any of the legume options over the period of this study. The high difference of those that tried at least a legume and those that did not reflects among other reasons lack of seed as one of the limiting factors. The non-food value of some legumes such as mucuna, difficulties in finding seed, and lack of markets were some of the main reasons that contributed to low adoption. Adoption may be improved if future projects can offer new legumes that combine improving food and income security for the farmers with improving their fields' soil fertility and markets for excess produce.

Chapter 7

General discussion and conclusions

Poor people and poor fields? Integrating legumes for smallholder soil fertility management in Chisepo, central Malawi

7.1 Introduction

It is confirmed in the empirical chapters of this thesis that soil fertility is a critical factor for smallholder food productivity in Malawi. The improvement and sustainability of soil fertility depends on the use of an array of available options. Subsidies on mineral fertiliser are expensive and difficult to maintain. However where a subsidy is implemented, the way forward towards sustainable food production is for smallholder farmers to combine the use of mineral fertilisers with other fertility interventions, especially legumes and better fertiliser management. The thesis thus focused on on-farm evaluations with farmers of a) integrating legumes in farming systems with the purpose of improving soil fertility, b) using phosphorus fertiliser to improve legume productivity for grain and biomass for food, income and for improving soil organic matter, c) use of small amounts of NP fertiliser to increase farmers' knowledge on mineral fertiliser and d) their integration into smallholder farms through joint evaluation of the technologies with the farmers. In this chapter we discuss the main findings from the work, bring together the insights, ideas and knowledge and highlight the significance of farmer-participatory integrated soil fertility management (ISFM) and its way forward in the context of smallholder agriculture in Malawi.

7.1.1 Farmer participatory and joint learning in the study

Several participatory methods were used to facilitate co-learning from the experimentation. A mother baby approach was used to set up the on-farm experimentation process. The approach owes its name from a farmer in Malawi who named it "it is like a mother and baby" (Snapp, 1999). Using this approach, 14 farmers hosted the researcher and farmer managed mother trials with complete variety of technologies that farmers and researchers agreed to evaluate, and farmer managed baby trials had technologies chosen by farmers. On-farm experimentation systematically connected the farmer assessment of technologies with biological performance, and the basis for comparison was on farmers' insights and feedback. Communication and information flow among the participating farmers and the communities was encouraging in that farmers were able to see and ask questions where necessary as well as bring forth their views and knowledge to the process. Through the process farmers' interests in legumes developed, and that led to many non-participating farmers accessing small amounts of seed of non-traditional legumes such as mucuna for own experimentation, and also knowledge from participating farmers. Creation of temporary markets for legume seeds helped to spread the legumes further and farmers responded by producing a lot of legume grain, which was not adequately absorbed by the temporary markets. The effect of the temporary character of markets allowed pointing out that establishing and improving market opportunities can be a pull factor for adoption of legumes. I also observed that although the markets stopped, some farmers who tried the legumes continued with some of the legumes that they liked.

The on-farm experimentation allowed for a two-way communication between the farmers and the researchers, which allowed each of the parties to learn from each other, in particular where it concerned the thinking and reasoning around soil fertility and legume crops. Where field days and field tours were organised around the trials, farmers drove the events and exchanged their experiences and knowledge about the technologies with other farmers within and outside the area. Most likely the entire process strengthened their experimentation and innovative skills. This was reflected in Chapter 6 where it was observed that farmers modified the planting patterns to suit their labour conditions including coppicing pigeonpea, leaving tephrosia to grow for two years to accumulate more biomass and seed, and planting them as hedge fences around their homes. The intercropping soyabean and groundnut with maize today demonstrates the innovative thinking by farmers. One of the limitations of the approach though was that it was time consuming. In addition, the farmers' fears of being accused as a witch reduced observations and learning from the mother trials. It was not customary to visit ones field without permission from the owner. The approach provided the researchers however with a tool to collect data and quantifying feedback from farmers.

Focus group discussions were very useful and convenient in collecting data from several farmers simultaneously. The researchers used this approach in follow up studies on a number of issues such as the analytical hierarchy process (AHP), wealth ranking and evaluations. The approach was iterative as farmers were able to exchange their experiences and knowledge and even question what one thinks. It helped the researchers to explore farmers' knowledge and experience, how they thought and why they thought that way. It was one such approach that helped to explore and clarify views in ways that would have been difficult in a one-to-one interview. For instance, in the AHP, the approach helped to generate pair-wise rankings of five criteria and ten legumes through negotiations and agreements among the farmers themselves on particular ranks. It was a learning process to farmers and it strengthened farmers' thinking on importance of legumes. However, also this method was time consuming and in some cases it generated such critical thinking that some farmers became uncomfortable about the way things were discussed.

The resource groups (RGs) used in this thesis were generated by the wealth ranking method, based on farmers' local criteria of wealth in an iterative manner. Wealth ranking helped to understand the local perceptions of wealth in Chisepo but also helped to generate insights for developing and targeting technologies. The fact that farmers agreed on what wealth was and what it meant to them was a powerful starting point for participatory experimentation and assessments of the technologies. Differentiation of technology selection on the basis of these resource groups and comparisons among the groups were contributing to the understanding why legume technologies were attractive or not. However, the wealth ranking method was again time consuming and limited in scope for local knowledge.

7.1.2 The soil fertility situation and food security in Malawi

Soil fertility is the engine for agricultural productivity. For agriculture-based economies such as in Malawi, sustainability of soil fertility is critical and cannot be over-emphasised. However, soil fertility has declined especially in the smallholder sector and is associated with the decline in crop productivity in some years and leading to the creation of a poverty trap (Dorward and Chirwa, 2011). The deficiency of major soil nutrients, especially nitrogen and phosphorus, has been created through mining of soils by continuous cropping with minimal use of fertilisers or organic matter, and the situation poses serious threats to food production. The government's acknowledgment of the problem of poor soil fertility in smallholder agriculture (Malawi Government, 2009) have resulted in efforts to improve food production and were centred on the investment in the free and subsidised fertiliser programmes to increase maize productivity. The work presented in this thesis confirms that to improve benefits from the fertiliser input subsidy programme, innovative use of available organic and inorganic resources is needed; legumes offer potential in this respect. Legumes have long been considered as critical components of integrated soil fertility management and farmers need to be encouraged to use them in combination with mineral fertiliser where possible. The current fertiliser subsidy programme in Malawi offers a great opportunity to generate practical knowledge and guidelines in soil fertility management, particularly in line with combined use of mineral and organic fertilisers. This thesis offers some input in the generation of such knowledge and guidelines.

7.2 Main findings of the thesis

The process of evaluating technologies with farmers generated a number of finding and this section reports them in summary. Chapter 2 revealed that soil fertility management is complex, and the complexity can be understood by considering the context in which farmers plant their crops and use their fields. Households of similar resource endowments were clustered to help in describing and understanding between household variations. Four farmer types were described as resource groups (RG): the better-resourced households (RG 1), the medium-resourced (RG 2), the poor-resourced households (RG 3) and the least-resourced households (RG 4).

Current soil fertility management is driven by "pull and push" factors. For instance, the resource endowment gap between the less well- and the better-resourced groups of farmers skewed use of soil fertility improvement practices towards the better-resourced farmers. While the better resourced farmers used manure and mineral fertiliser, the less well-resourced farmers rarely did. This results in differentiated heterogeneity in soil fertility between and within fields in smallholder agriculture. Where the better-resourced farmers hire-in labour and perform their farm activities in a timely manner, the less well-resourced farmers supply *ganyu* labour to better-resourced farmers (Chapter 2). They are pushed away from intensive crop and soil fertility management by the need to solve an immediate food crisis, while the richer farmers are pulled by the need to maintain or increase returns from their main crops or enterprises. Less well-resourced farmers are thus locked in a low productivity trap and operate in the "*ganyu*-economy", especially in hunger months.

Findings of Chapter 3 show that legumes improve maize yields in continuous maize cropping systems. Under poor legume management, returns from incorporating legumes in maize-based systems are often not adequate to minimise the associated risks of getting low yields. Risks of lower yields as a result of legumes are a function of the performance of the legumes in smallholder farms. Lower risks of lower yields happen where legumes adequately contribute to food availability and soil fertility improvement. Heavily depleted soils (commonly farmed by less-resourced farmers) do not show attractive returns from legumes. Thus, the least-resourced are more affected by the risks from technologies than the better-resourced farmers. Findings of Chapter 4 show that the low legume yields experienced in smallholder agriculture are constrained by low soil P. At present, unless market outlets are sustainable, use of P for increasing legume yields will remain unattractive to farmers due to its high costs. However, those that use P-based fertiliser in tobacco may have the practical knowledge that P improves legume yields and rotating the tobacco field with a maize-legume intercrop will improve both maize and legume grain yields as well as biomass. That biomass, if well managed, can contribute to the soil organic matter.

In Chapter 5 it is shown that while poor soil fertility continues to constrain maize yields, mineral fertilisers remain an immediate solution to increase crop productivity. However, for the poor farmers the returns to use of fertiliser are constrained by several factors including inadequate weeding. Labour that can potentially be invested in extra weeding is often used to respond to immediate food and cash needs. Weeding and tobacco processing coincide with hunger periods and demand a lot of labour (Fig. 5.5 in Chapter 5). Poor farmers prefer to sell their labour for these activities to other farmers rather than invest it in weeding their own maize. Farmers' inability to acquire subsidy, to save or borrow money to access even small amounts of fertiliser is one of the main constraints to improving maize yields. Use of fertiliser remains an activity for the wealthier farmers and those able to save a little to access small amounts. Nevertheless, small amounts of fertilisers are the first step into integrated soil fertility management for smallholder farmers as demonstrated in Chapter 5 where maize yields increased by an average 62% as compared with no fertiliser.

Combinations of legumes with maize aim to improve soil fertility and to provide other benefits such as food, income and weed suppression. Farmers' assessments for adoption of legumes take these benefits into account and weigh them against the opportunity cost of labour. Although the integration of legumes in cropping systems is still weak (Chapter 6), the thesis shows that many farmers are willing to take up more grain legumes that provide principally food and some spin-off benefits to soil fertility. Weak uptake implies lack of appreciation or insufficient benefits from legumes, or conditions that constrain farmers' ability to use them. Lack of labour, seed and lack of interest were cited by farmers to limit adoption, but lack of a consistent market seems to be an important constraint as well because farmers planted more legumes when there was a prospect of markets created during the study period. The findings lead to the conclusion that improving crop production requires a focus on improving soil fertility in combination with other factors. The practical insights generated from this research are useful for guiding the targeting of legumes and other nutrient sources in complementing the fertiliser input subsidy programme (FISP) in Malawi. The next sections will give some opportunities and constraints in achieving high crop yields in smallholder agriculture in Malawi.

7.3 Maize production, opportunities and constraints

Maize production in Malawi is reported to account for over 70% of the crop-land and nearly 90% of the cereal area is for subsistence. It is the staple food and its consumption is estimated at 250 kg per capita per year, making Malawians the world's largest consumers of maize (GoM, 1995). Maize is at the centre of the food security equation and food security policy debates. Despite this central role of maize in food security in Malawi, its productivity declined since the early 1990s up to some years later, resulting in frequent food insecurity problems (Sauer *et al.*, 2007). From this period, maize production was variable and low until 2005 when the fertiliser subsidy positively increased average maize yields from 0.81 to 1.98 t ha^{-1} (Fig. 7.1). Smale (1991) and Douglas *et al.*, (1999) observed a decline in maize yield, and they reported falling agronomic efficiencies to fertiliser from 23 to 13 kg maize per kg of nitrogen in central region. Mwangi (1997) estimated fertiliser responses of 5-25 kg grain kg^{-1} N for southern Africa indicating that it was often uneconomic to use N fertiliser on maize. In Chapter 5, average fertiliser responses went from 13 to 26 kg grain kg^{-1} N with extra weeding and this showed a positive step that smallholder farmers need to take.

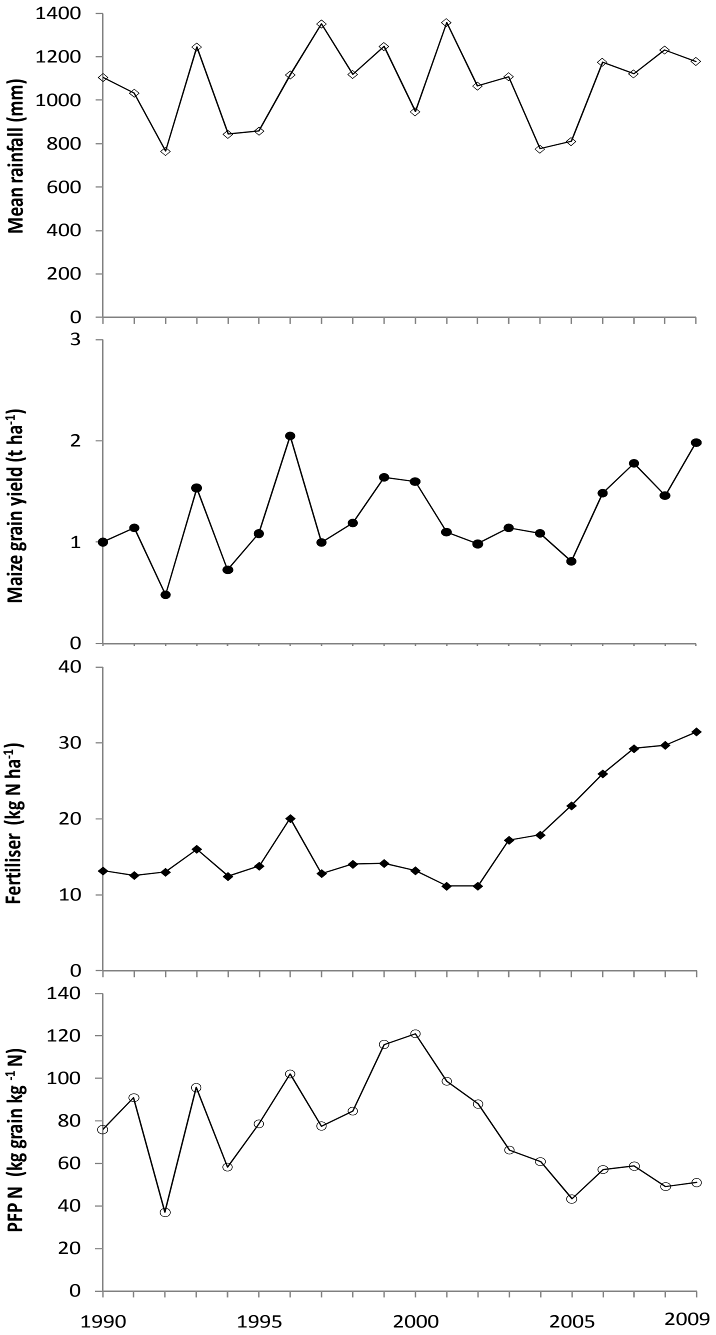

Fig.7.1. Maize grain yield, use of fertiliser N and partial factor productivity from fertiliser N applied in Malawi from 1990 – 2009. (PFP_N is kg grain yield kg^{-1} N applied). Source: Author calculations from MoAFS and FAO country statistics, 2010. Adapted from Cassman *et al*., (2002).

During the war in Mozambique in 1980s, there was a lot of donor support on food to Malawi to feed refugees and that boosted the food security and the economy of the country. Upon the end of the war and coupled with the World Bank inspired agricultural liberalisation, there were fewer inputs to agriculture and, consequently, food production declined over the years leading to food crises in mid 1990s (Blackie *a*nd Mann, 2005). Upon realisation that without fertiliser and improved maize seed the problem of food insecurity would continue, the Malawi Government in 1992 identified free distribution of inputs as one of the solutions to the food crisis. It then distributed free fertiliser and hybrid maize seed through a drought recovery input project to 1.3 million households. Following the success of the drought recovery project, a supplement project targeting less than 1 million households was implemented until 1996. With high fertiliser prices and the forecast collapse of maize production, the government with donor support implemented the starter pack programme from 1998 to 2000 targeting around 2.3 million beneficiaries with free inputs (5 kg urea and 10 kg fertiliser NPK, 2 kg of flint hybrid maize seed and 2 kg of legume seed). Because it covered most of Malawi, the starter pack programme was expensive and therefore targeted input programmes (TIP) were introduced between 2001 and 2005, giving similar amounts of inputs (5 kg of urea and 5 kg NPK, maize seed and legumes) but to very few beneficiaries. The current fertiliser input subsidy programme started in 2005 after experiences of more food crises. Each targeted household is given two coupons to purchase a 50 kg bag each of urea and NPK (23:21:0+4S), a coupon for hybrid maize seed and optional legume seed at subsidised prices. Apart from aiming at increasing the fertiliser use and improving crop yields, the free fertiliser and the subsidised programmes have been channels for distributing seed and disseminating information to farmers.

Despite the fertiliser programmes from 1992 onwards, fertiliser use was variable until 2004 when its use started to increase (Fig.7.1). The total N fertiliser use on maize and national maize yield data were used to calculate the PFP_N shown in Fig 7.1 for Malawi to give an estimate of the fertiliser responses at a national level. PFP_N is the ratio of crop grain per unit of applied N fertiliser and it is the most important measure of fertiliser responses for farmers because it integrates the use efficiency of both indigenous and applied nutrients (Cassman *et al*., 2002). From 1990 until 2000, the fertiliser responses as indicated by partial factor productivity for nitrogen (PFP_N) were variable and high and tended to vary with the variations of rainfall. High values of PFP_N of above 70 kg grain kg^{-1} N result from low use of fertiliser N and are indicative of soil N mining, typical of unsustainable production systems (Dobermann, 2005). Maize yields and fertiliser use in Fig.7.1 depict inefficient use of fertiliser for Malawi until 2003, despite presence of the fertiliser starter packs and targeted input programmes within this period (Blackie and Mann, 2005; Harrigan, 2008). From 2003 onwards the average rate of N fertiliser use in kg N ha^{-1} increased and that has resulted in an associated considerable decline in PFP_N. This is expected since PFP_N decreases when yields increase with increased fertiliser consumption, a case in Malawi now, as a result of the implementation of the current fertiliser subsidy programme (MoAFS, 2008). In addition rainfall conditions have been favourable in most of the years since 2005 (Fig. 7.1) and including the last two seasons with maize surplus as well. However, comparing with the common world optimal values of 40 - 80 kg grain kg^{-1} N applied (Dobermann, 2005), the PFP_N in Fig.7.1 suggest further that maize yields can improve much more if smallholder agriculture improves the fertiliser use efficiencies. This can be done through combined use of organic and inorganic fertilisers from replaceable sources and through use of efficient germplasm. Findings of Chapter 5 support the need to improve the fertiliser use efficiencies through improved field management such as timely and frequent weeding and use of more efficient maize varieties such as SC627 and MH18. At stake at the moment are three things: there is a widespread soil fertility problem in smallholder agriculture despite the increase in fertiliser use (Snapp, 1998; Kanyama-Phiri *et al*., 2002; Dorward and Chirwa, 2011), N fertiliser use is restricted and its management is poor (Mwangi, 1996; Snapp *et al*., 2002b; Minde *et al*., 2008) and local crop varieties that have weak fertiliser efficiency are often used (Thornton *et al*., 1995). If smallholder agriculture continues to use the fertiliser currently available without adequate addition of organic matter to the soil, there will be small gains in maize yields, since continued use of mineral fertilisers alone in fields with low soil fertility is not sufficient to sustain balanced crop productivity (Ladha and Reddy, 2003). Since PFP_N partly measures the use efficiency of N indigenous to the soil, the high PFP_N suggested that indigenous N available from the soil was limited (Dobermann, 2005). Indigenous N is a principal source of

N for most crops and comes from mineralisation of organic matter or from the residual effects of N_2 fixation and is constrained by absence of soil fertility replenishment practices. It is possible to associate high yields of maize in Chapter 3 with legumes alone over a period of time with the contribution of organic matter to the soil. Complementing the organic matter with mineral fertiliser increased maize yields in the experiments reported in the same chapter. However, depleted fields require improvements in soil fertility to increase indigenous N supplying capacity first before they can produce desirable returns (Sanchez *et al.*, 2009). In addition, while rates of N fertiliser used are increasing, optimum benefits in maize yields would result when the fertiliser applied combines with timely and quality crop management to synchronise it with the crops' demand (Chapter 5). Crop management to remove growth-limiting factors and synchronisation of applied fertiliser N with crop demand are main challenges under smallholder agriculture in Malawi (Zambezi and Jones, 1992), and thus explain the variable PFP_N obtained in Fig. 7.1. Most farmers who accessed the subsidy fertiliser often use it on local varieties that they perceive to store well and preferred for processing qualities but whose fertiliser efficiency is weak (Thornton *et al.*, 1995). These factors reduce fertiliser N use efficiency during the growing season and may increase N losses. The consequences are that maize yields remain just a fraction of their potential, food insecurity remains a challenge and development at national level is limited.

Considering the livelihood strategies analysed for Chisepo in Chapter 2, the large majority (85%) of farmers may continue to remain poor even with the current fertiliser subsidy. The reasons are that its pillars of operation are donor dependent, lack exit strategies that could gradually transfer the responsibility to producers and targeting of beneficiary farmers is poor (Dorward *et al.*, 2008; Chibwana and Fisher, 2010; Holden and Lunduka, 2010). In Malawi and elsewhere, the fertiliser subsidies have been shown to be non-sustainable and are disruptive since they are subjected to donor and government impulses. These factors threaten its sustainability and may imply that farmers may have false hopes about continued better maize yields in the following years. Coupled with the challenges just described, Fig. 7.1 points to the need for identifying and implementing complementary practices that are more sustainable under farmer conditions, and restore soil fertility and improve fertiliser use efficiencies. By not scaling up the use of alternative sources of fertilisers to complement the fertiliser subsidy programme, smallholder agriculture may be missing an opportunity for raising their food security in a sustainable manner. One option is scaling up use of legumes which may offer cheaper and environmentally friendly source of organic matter that can gradually replenish nutrients in smallholder fields. Use of legumes has been constrained by a number of factors which need to be minimised if smallholder agriculture has to benefit from legumes. The next section discusses legume production and their constraints for farmer use.

7.4 Legume production: Opportunity to improve soil fertility in smallholder fields?

Production of main legumes is limited in relation to maize production in Malawi. However, there has been an increase in production in recent years (Table 7.1). Legume productivity is on average less than 1 t ha^{-1} and the land area under legumes is proportionally small. Thus there is a minimal N contribution of legumes to the soil. At the moment, there is little attention from governments to promote legume productivity (Tripp, 2011), and they rarely form part of the food security policy debates despite the importance they have to the economy. Despite the lack of attention to promotion, legumes contribute a direct source of protein in the food and hence are important in fortification of diets both at household and industrial levels. Legumes especially soyabean and groundnut provide over 35% of the world's processed vegetable oils (Graham and Vance, 2003), and this directly points to a potential of oil processing in smallholder agriculture in Malawi. If the government capitalises on this potential, a market chain could be created for legumes which will stimulate production by farmers and gradually the soils can benefit from the residual N from legume production. Legumes are a source of fodder for improving livestock which may increase manure production, and additionally legumes have other health benefits especially soyabean isoflavones which reduce risks of cancer and lower serum cholesterol (Kennedy, 1995).

Table 7.1. Maize and legume production in Malawi from 1985/1986 to 2008/2009

	85/86	90/91	94/95	00/01	05/06	08/09
	Production (million t)					
Maize	1.395	1.589	1.793	1.713	2.612	3.583
Groundnut (all)	0.088	0.031	0.040	0.155	0.203	0.275
CG 7 Groundnut	0	0	0	0.041	0.096	-
Pigeonpea	0.015	0.029	0.065	0.105	0.131	0.184
Cowpea	0	0	0.022	0.026	0.020	0.028
Soyabean	0	0.013	0.042	0.037	0.055	0.080
Mucuna	0	0	0	0.003	0.002	-
	Land under crops (million ha)					
Maize	1.193	1.391	1.243	1.507	1.624	1.609
Groundnut (all)	0.132	0.043	0.072	0.189	0.245	0.267
CG 7 Groundnut	0	0	0	0.034	0.094	-
Pigeonpea	0.038	0.070	0.106	0.137	0.150	0.176
Cowpea	0	0	0.066	0.066	0.051	0.055
Soyabean	0	0.016	0.054	0.055	0.072	0.082
Mucuna	0	0	0	0.010	0.009	-
	Yield t ha^{-1}					
Maize	1.08	1.14	1.44	1.14	1.61	2.23
Groundnut (all)	0.67	0.72	0.56	0.82	0.83	1.03
CG 7 Groundnut	0	0	0	1.2	1.02	-
Pigeonpea	0.39	0.41	0.62	0.77	0.87	1.05
Cowpea	0	0	0.33	0.39	0.38	0.52
Soyabean	0	0.8	0.79	0.69	0.77	0.97
Mucuna	0	0	0	0.27	0.26	-
	% of total arable land (3.592 m ha)					
Maize	33.2	38.7	34.6	41.9	45.2	44.8
Groundnut (all)	3.7	1.2	2	5.3	6.8	7.4
CG 7 Groundnut	0	0	0	0.9	2.6	-
Pigeonpea	1.1	1.9	2.9	3.8	4.2	4.9
Cowpea	0	0	1.8	1.8	1.4	1.5
Soyabean	0	0.5	1.5	1.5	2	2.3
Mucuna	0	0	0	0.3	0.2	-

Source: Yield and area under crop from MoAFS and FAOSTAT, 2010. CG 7 groundnut variety is shown separately to compare it with other legumes used in the thesis.

A hallmark trait of legumes is their ability to fix atmospheric nitrogen and hence legume rotation and intercropping are important practices for maintaining soil fertility for farmers through net N contributions (Giller and Cadisch, 1995; Graham and Vance, 2003). Their ability to fix N in symbiosis makes them excellent colonisers of low-N environments (Giller, 2001). Grain legumes, for example, can fix substantial amounts of nitrogen (up to 250 kg N ha^{-1}) given favourable conditions and this can be useable to subsequent crops when retained in the field (Peoples and Herridge, 1990; Giller and Wilson, 1991).

However, legumes with a high nitrogen harvest index can lead to a decreasing soil fertility benefit for the subsequent maize (MacColl, 1988). This is translated into a general rule that the legumes with less high yield potential (low harvest index) are the ones with the greater benefit in terms of soil fertility (Giller and

Cadisch, 1995; Blackie *et al*., 1998). Legumes such as soyabean and groundnut have a high harvest index and the values of net N input obtained in Table 3.6 in Chapter 3 were a result of the high biomass accumulation. The N content in their above ground biomass which was used to calculate N contributions in Table 3.6 was on average 2% as compared with tephrosia which had an average of 2.6%. Although this is the case farmers still benefit from the N input from these high harvest index legumes if taken as part of the systems components with judicious use of the above ground biomass. The associated potential cost savings in Table 3.6 were relatively high especially to farmers who do not easily access mineral fertiliser.

Where possible, maize-legume rotation practices are better than intercropping practices in terms of net N input. Intercropped legumes in maize are often planted sparsely and contribute little N input (Waddington *et al*., 2007) while legumes in rotation add more N into the soil for the subsequent crop (Vanlauwe and Giller, 2006). N contributions by legumes in Chapter 3 support this finding and maize yields of subsequent crops were larger than in intercropping. Double up intercropping of legumes such as groundnut and pigeonpea are an option to increase N inputs. Due to competing labour demands and the increasing scarcity of land, intercropping of legumes in maize is increasing. What remains is to encourage farmers to recycle as much residues as they can to maximise on net N inputs from the legumes.

Most contribution of N fixation comes from plant matter decomposition and recycling above ground biomass is important. Legume litter can improve soil organic matter to replenish and build the nutrient reserve in the soil. Legumes can assist with weed control (ICRISAT/MAI, 2000) and through this litter, legumes such as pigeonpea additionally increase access to other nutrients such as P from deep soil horizons (Giller, 2001). With addition of compost or animal manure where it is available, availability of micronutrients which may not be supplied in commercial fertilisers is enhanced (Mughogho, 1992). The slow release of nutrients from organic manure reduces the risk of leaching, and manure improves soil water retention (Parr, 1986). It reduces soil erosion by improving rain water infiltration and water holding capacity and has the potential to raise soil pH in acid soils (Munthali, 2007).

Improved soil quality increases fertiliser use efficiency, which may lead to cutting down the fertiliser N volume considerably (Mwandemere, 1985). Findings in Chapter 5 on the fertiliser use efficiency call for other strategies for soil fertility, and legumes could form an excellent complement to small amounts of fertiliser where other sources of organic manure are not available. Chapter 3 further contributes to this practical knowledge that small amounts of N in combination with legumes improve maize productivity. Maize yield increments were averaging 25% following different legumes, and others also reported encouraging results for Malawi (Kumwenda *et al*., 1997b; Sakala *et al*., 2001; Snapp *et al*, 2002a). Given that soyabean and groundnut have a high harvest index (MacColl, 1988) and are often intercropped by farmers, their net N input is limited. This means that farmers have to combine legumes with other soil fertility management. Recycling crop residues through livestock systems can improve manure production. The small amounts of N contributed by cattle manure combined with mineral fertiliser improves maize productivity (Ncube *et al*., 2007). Where this section has discussed in some detail the potential role of legumes to complement the mineral fertiliser, the following sections discuss farmers' interests in using the legumes and explore some associated constraints.

7.5 Constraints reducing farmer uptake of legumes

7.5.1 Substitution effect on cropped land

Although legumes are an important component in the smallholder economy, Chapter 6 shows that adoption has been limited. The proportion of land under legumes is still too low to contribute considerable amounts of N to the soil (Table 7.1). Although there has been a lot of promotion of legumes, farmers are still not growing them as much as they could to benefit from their ability to fix atmospheric nitrogen. An example of low use of legumes is shown for the study area where only food grain legumes have been integrated to a larger extent (see Table 6.7 in Chapter 6). Findings of Chapter 3 and 4 and many other studies show the importance of legumes for longer-term sustainability of maize-dominated smallholder cropping systems (Blackie *et al*., 1998; Sakala et al., 2001; Waddington *et al*, 2007).

Major constraints that reduce farmers' use of the legumes are bio-physical problems (adaptation, droughts, poor soil fertility, susceptibility to pests and diseases), economic reasons (lack of cash to purchase inputs, lack of markets, and lack of seed) and social issues (lack of interest, lack of labour and cultural beliefs) (Ojiem *et al*., 2006; Ojiem, 2006). In Chapter 3, legumes grown under poor soil fertility management in RG 4 did not give higher grain and biomass yields and thus did not contribute much to improve crop yields. Under such conditions, the risk of a lower yield in maize-legume system was high due to poor performance of the legumes. However, in the same Chapter 3, legumes grown under better soil fertility management in RG 1 or 2 gave better maize yields indicating higher N contributions to the systems. Chapter 6 confirmed that lack of consistent markets for the grain and lack of food value in case of the green legumes such as mucuna constrain legume adoption. From the socio-ecological niche perspective the issue of substitution is a critical factor that farmers consider in integration of legumes (Ojiem, 2006). In the most densely populated areas, land scarcity prohibits the devotion of land to restoration of soil fertility as almost all of the organic sources of improving soil fertility involve either import of organic materials from surrounding land or allocation of land to produce organic materials (Giller *et al*., 1997; Giller *et al*., 2000; Ojiem, 2006). Farmers in Chisepo had land where maize-legume rotations could have been possible, but the limiting factor most cited was the competing demands for labour (Chapter 5). In addition, Chapter 3 showed that although maize-legume rotations gave higher yields, the loss in maize when a legume was planted posed a risk to poor farmers.

In Malawi, pigeonpea is mostly grown as an intercrop and hardly has a maize yield penalty since its growth is sufficiently slow to allow both crops grown at the same plant populations (Giller *et al*., 2000). This practice saves labour for weeding pigeonpea on sole cropping. An increasing practice in central and northern Malawi where pigeonpea is not traditionally grown is intercropping pigeonpea with groundnut at the same recommended density of 3 plants per station at 90 cm apart (see Bezner-Kerr *et al*., 2007). Apart from labour saving, there has been no study yet to establish whether there is yield penalty to CG 7 groundnut in this system. Groundnut production is characterised by poor yields of less than 1 t ha^{-1} resulting from a combination of poor seed quality, varieties used and poor management (Phiri, 1999). Farmers said that groundnut-maize rotation is common, but maize yields are often better when combined with fertiliser. This suggests that often the rotation systems do not add adequate N for the entire crop growth and needs additional N for high yields. This is possible because above ground biomass from groundnut is usually removed from the field and results in a considerable loss of N from the fields.

Green manures for soil improvement such as mucuna are not attractive for smallholder farmers. Growing mucuna in rotation gives the best biomass yields (Sakala *et al*., 2001; Kumwenda *et al*., 1997b; Giller *et al*., 2000) but that has an associated maize yield loss in that year. Due to poor management of biomass, the yield increments in farmers' fields have not convinced them to include mucuna in their cropping systems. Findings of Chapter 3 showed similar positive yields from maize mucuna rotation, but it was more risky to poor farmers due to the yield loss in one year. It was risky under RG 4 where yields of maize following mucuna were substantially poor.

7.5.2 Food security and labour demands

In Chisepo, 85% of farmers fell in the 'poor' category (Chapter 2) and their crop production is often creating varying food deficits for RG 2, 3 and 4 (Table 7.2). Using the five year average maize production by each of the systems in Chisepo, Table 7.2 shows the estimated yields farmers could obtain if they had used each of the technologies indicated in the table. The table shows that only RG 1 and RG 2 would be able to produce maize yields of over one tonne ha^{-1} from all the systems except maize and groundnut rotation for RG 2, while farmers from RG 3 and RG 4 rarely would reach that level. Annual maize and legume requirements on average in Table 7.2 were 1.28, 0.51 and 0.31 t household^{-1} for maize, groundnut and pigeonpea respectively. The surplus/deficit shows that farmers from RG 4 would be perpetually food insecure regardless of the cropping systems they could use. Farmers from RG 3 would be food secure if they had used maize-pigeonpea intercrop and complemented it with 35 kg N ha^{-1}. Farmers from RG 2 would not sustain their food requirements when they grow maize continuously and in rotation with groundnut, while farmers in RG 1 would always be food secure. They would harvest more than they need irrespective of the cropping systems. Household legume consumption requirements were not met with any of the technologies by farmers from RG 4 while the rest were self-sufficient in legume needs.

Table 7.2 shows that maize provision ability (MPA) for poor farmers is as low as 1.1 months after harvest between mid-April and June (Fig. 5.5 in Chapter 5). The number of farmers without maize in store increases as the season progresses and between October and February almost 80% has no food (Barbier, 1991; Whiteside, 2000). This period is a hunger season, locally called *'gwang'wang'wa' or 'kagalu kakuda'*.

7.5.3 *Ganyu* labour as hunger coping strategy

Another substitution effect is on labour which is one of the most important constraints in the adoption of legumes (Ojiem, 2006). This is explained in the previous sections in relation to the availability of maize to the households and why it becomes a major constraint to legume production. During the hunger period (Fig. 5.5 in Chapter 5), most common coping strategies available to households without food are (1) *ganyu,* casual work in other farmers' fields for cash or in kind, (2) reduction in number of meals per day, and other available means such as food gifts from relatives. In terms of *ganyu* labour, Fig 5.5 in Chapter 5 shows that better-resourced farmers have more labour demands than least-resourced farmers and hence opt to hire in labour to assist with timely field operation. This offers an opportunity to food deficit households to engage in *ganyu* labour.

G*anyu* labour therefore remains the most important coping strategy when a poor household runs out of food (Whiteside, 2000, Pircher, 2010). This peak period of *ganyu* labour employment relates with main agricultural activities of land preparation, ridging, weeding and tobacco processing. As high as 95% of households hire out labour within the hungry period spending on average 100 days per year (Sijm, 1990). Payments for this type of *ganyu* is often in kind (food) or cash, and a day's *ganyu* work often results in the payment of a day's food, the minimum necessary for survival (Pearce *et al*., 1996; Pircher, 2010).

Table 7.2. Household characteristics, total food production, food requirements, surplus/deficit and food self-sufficiency for the different resource groups in Chisepo (Calculation based on mean of actual yield ha^{-1} from each system from 1999 to 2003 for 3 farmers in each resource group)

	Farmer Resource Group			
Household characteristics	RG 1	RG 2	RG 3	RG 4
Family size	5.0	5.1	4.8	5.6
Land under maize (ha)	2.5	1.4	0.8	0.5
Family labour count (No working in field)	2.5	3.1	3.1	3.6
Actual maize production (t area cultivated^{-1})[1]				
Continuous maize no fertiliser	2.6	1.0	0.4	0.2
Maize and 35 kg N ha^{-1}	8.5	3.0	1.0	0.6
Maize and pigeonpea (intercrop)	5.2	2.2	0.8	0.6
Maize and groundnut (rotation)	2.0	0.6	0.2	0.1
Maize and pigeonpea + 35 kg N ha^{-1}	8.3	4.2	2.0	0.6
Legume production				
G/nut production (t ha^{-1})	0.68	0.35	0.53	0.28
Pigeonpea production (t ha^{-1})	0.58	0.85	0.53	0.30
Food requirement[2]				
Maize requirement (t yr^{-1})	1.25	1.28	1.20	1.40
G/nut requirement (t yr^{-1}	0.50	0.51	0.48	0.56
Pigeonpea requirement (t yr^{-1})	0.30	0.31	0.29	0.34
Surplus/deficit (t yr^{-1})				
Continuous maize no fertiliser	1.32	-0.32	-0.78	-1.23
Maize and 35 kg N ha^{-1}	7.23	1.72	-0.20	-0.82
Maize and pigeonpea (intercrop)	3.93	0.92	-0.39	-0.81
Maize and groundnut (rotation)	0.78	-0.69	-1.05	-1.27
Maize and pigeonpea + 35 kg N ha^{-1}	7.05	2.94	0.80	-0.76
Groundnut	0.18	-0.16	0.05	-0.29
Pigeonpea	0.28	0.54	0.24	-0.04
Maize provision ability (months)[3]				
Continuous maize no fertiliser	24.7	9.0	4.2	1.5
Maize and 35 kg N ha^{-1}	81.4	28.2	10.0	5.0
Maize and pigeonpea (intercrop)	49.7	20.7	8.1	5.1
Maize and groundnut (rotation)	19.5	5.5	1.5	1.1
Maize and pigeonpea + 35 kg N ha^{-1}	79.7	39.7	20.0	5.5

Notes:

1. Actual maize production was based on land under maize;
2. Minimum requirements (kg person^{-1} year^{-1}) are: Maize is 250 (GoM, 1995; Peter and Herera, 1989); Groundnut is 100 (Thangata *et al.*, 2007), pigeonpea varies from 45 to 80 (Simtowe *et al.*, 2009)
3. Maize provision ability (MPA) is the number of months own maize production lasts after harvest (Orr, 1998)

While a poor household is pushed to solve the immediate food crisis, it conflicts with own-farm food production. The low returns from *ganyu* can mean that no surplus is generated for investment in anything but short-term survival, trapping households in a vicious circle of low productivity and low investments (Whiteside, 2000; Pircher, 2010). Competition between the *ganyu* and own-farm cultivation can be critical – a two week delay in preparing the fields can lead to a yield reduction of a quarter, and where *ganyu* is done to obtain or buy seed, late planting often occurs with an associated risk of low yields (Whiteside, 2000;

Pircher, 2010). Table 7.3 further shows the importance of *ganyu* to meet maize deficits. The information implies that even with *ganyu* households who run out of their food stocks earlier (Table 7.3) are not able to meet their food deficits and likely do go hungry.

Table 7.3. *Ganyu* income and maize purchase for different households in 1993/94[1]

Variable	Average MHH	Average FHH	HH with 0.25 ha*	HH with 0.75 ha*
Oct – Feb ganyu earnings (MK)[2]	123	89	347	97
Maize deficits (kg)	98	99	637	306
Cost of replacing deficit (MK)	69	69	446	214
Cash balance (MK)	+54	+20	-99	-117

[1] maize at 0.7 MK kg-1

[2] MK is Malawi Kwacha (Exchange rate: 15MK = 1US$)

* female-headed households in these categories are likely to be even worse off than the average shown in the column

Source: Leach, (1995) in Whiteside, (2000)

For Chisepo, farmers in RG 4 and RG 3 have huge food deficits which come from the inability to replenish soil fertility for adequate yields and operating in the *ganyu* economy exacerbates the situation (Chapter 2; Pircher, 2010). Women-headed households are the worst victims in this circumstance. In addition the HIV/AIDS pandemic adds to the suffering especially for the poor households. HIV/AIDS does not only erode the labour supply potential of a household but it also competes for the scarce income and further keeps the households in absolute poverty (Bryceson, 2006). The additional effect is that HIV/AIDS has the potential to limit the number of better-resourced farmers who offer opportunities for *ganyu* labour and where fewer opportunities for off-farm labour exist, it is sometimes difficult for the very poor to find *ganyu* to find food. Adoption of legume technologies suffers as most of them will need to be planted, weeded and timely incorporated during the peak periods. Farmers clearly pointed out that they rarely will choose to weed or incorporate a legume that has no immediate food value when they have food deficits, and they prefer seeking *ganyu* or work on tobacco. This implies that legumes for poor farmers who sell labour are thus neglected. They cannot plant as a sole crop because it will require additional labour to weed. Those that are intercropped may benefit from the weeding for the main maize crop if it is done at all. Legumes planted in better-resourced farmers' fields often benefit from timely operations and returns are substantial. Incorporation of green manures by poor smallholder farmers is thus not possible due to competing demands for labour.

7.5.4 Competing demands for biomass

Another constraint is the competing uses for the above ground biomass. Farmers burn groundnut haulms to obtain ash for a substitute for soda for cooking leafy vegetables (ICRISAT/MAI, 2000) or burn as a way of clearing the fields, and this contributes to losses of sulphur and nitrogen from crop residues (Douglas *et al*., 1984). Soyabean is harvested by uprooting and processing is done at home, and its biomass is rarely taken back to the main fields and is either burnt or left in the home fields. In addition, soyabean value and utilisation is constrained by unfamiliarity with processing procedures (Blackie *et al*., 1998).

7.5.5 Diseases and pests

One of the biotic constraints for legume adoption is the attack by pests and diseases. Common pests observed in Chisepo were pod sucking bugs (*Nezara viridula*) and pod borers (*Helicoverpa armigera*), and aphids (*Aphis cracci vora*) for cowpea, groundnut and other grain legumes, and diseases were *Furarium udum* Butl for pigeonpea, *Cercospora* leaf spots, *sclerotium rolfsii* and rosette virus for groundnut. The most affected grain legumes were the short duration pigeonpea and determinate cowpea and farmers did not find them suitable. However, long duration pigeonpea was less attacked. Farmers reported that determinate cowpea and short duration pigeonpea were particularly not liked by farmers because of the incidence of aphid for cowpea and beetles for pigeonpea which reduced grain yield.

7.6 Integrated soil fertility management (ISFM) practices

This next section intends to link the potentials for legume production to the integrated soil fertility management. Integrated soil fertility management (ISFM) has been defined as practices that aim at optimum use of available resources such as soil N, crop residues, manure, biological nitrogen fixation and mineral fertilisers to improve the quality of soil and replenish nutrients (Vanlauwe *et al.*, 2010). Research has led to biophysical and socio-economic evaluations of technologies, most of which are proven to be suitable for smallholder use (Vanlauwe *et al*, 2010). With regard to soil fertility management it is generally accepted that productivity potential is optimised with a combined application of organic and chemical fertilisers, within the constraints of social and economic viability and making a maximum use of locally available resources (Vanlauwe and Giller, 2006). Organic N sources positively interact with fertiliser N (Vanlauwe *et al.*, 2002) as a result of better physical conditions of the soil, higher root growth and a supply of other nutrients made possible by the integrated soil fertility management (Olesen *et al.*, 2004) and thus it improves and sustains soil fertility. Improvements in soil fertility will stimulate agricultural productivity growth (Sanchez, 2002). Putting more emphasis on integrated soil fertility management will improve indigenous soil N supply which combined with applied N leads to improved maize yields (Cassman, *et al.*, 2002; Ladha *et al*, 2004; Dobermann *et al.*, 2003).

In Malawi different rates of chemical fertiliser combined with different levels of organic fertiliser resulted in a 50 to 250% production increase per hectare (Kumwenda *et al.*, 1997b; Sakala *et al.*, 2001; Chilimba *et al.*, 2004). While this is an encouraging achievement, several factors constrain smallholder farmers to use organic matter including crop residues. Incorporation of crop residues with low N content leads to immobilisation of N and crop growth is restrained (Vanlauwe and Giller, 2006). Although crop residues are the most available organic resource to farmers, many farmers in central Malawi do not recycle them as their counterparts in Zimbabwe who bring crop residues to the animal *kraals*. In the process more manure is produced for improving soil fertility. Smallholder farmers are constrained by limited resources to do so in Malawi: Small landholdings are restricting the possibilities for keeping livestock. Considering the amount of maize residues produced, the recycling of crop residues including those of legumes such as soyabean haulms would form a better component for ISFM. Although recycling through livestock will be a preserve of the owners of livestock, it remains one of the better options. Conservation agriculture that is supported by FAO, World Bank, DFID and other organisations in Malawi is also a practice that needs more attention. This works on three principles; maximum soil cover, minimum tillage, and maximum water conservation. Residue retention in the field will increase soil cover, conserve moisture and add to soil organic matter content. However, there is need to explore integration of legumes in conservation agriculture as well, and whether it is suitable for all resource groups used in this thesis.

7.7 Fitting the research findings into ISFM and the FISP

Smallholder agriculture often operates under minimal fertiliser regimes, poor soil fertility and often using local crop varieties resulting in low fertiliser responses. Farmers' common practice with little or no external inputs is represented by (a) in Fig. 7.2 with on-farm data from Chisepo: continuous maize with no fertiliser and yields are hardly above 1 t ha^{-1} due to net nutrient mining (de Ridder *et al.*, 2004). Following such performances of farmer practices, the African Green Revolution aims at intensifying agriculture through dissemination of integrated soil fertility management (ISFM) as a framework for boosting crop productivity through reliance upon soil fertility management technologies (Vanlauwe *et al*., 2010).

The ISFM assumes that if complementary restorative technologies are used in such systems, crop productivity will be raised. Focus is on the scarce fertiliser and organic matter which are vital for improving soil fertility for the smallholder fields and thus the need to be promoted. For instance in Malawi, the availability of the fertiliser subsidy programme has offered an opportunity to adopt ISFM, especially where most farmers use the fertiliser without complementary organic matter and timely field operations. For those few farmers with responsive soils, fertilisers alone may raise yields (Vanlauwe *et al*., 2010), but the majority who operate in poor soils, apply fertiliser far too late often in small quantities, whose weed management is poor and often use local varieties that respond poorly to fertiliser, may not be able to maximise the benefits of the fertiliser input subsidy programme. To raise the yields through use of restorative technologies has to be associated with knowledge generation and gain by farmers on aspects of practices that will minimise the constraints limiting crop production. Findings of Chapter 5 set an example of what ISFM can achieve with quality field management and Chapter 3 corroborates with numerous studies on use of legumes and fertilisers to raise crop productivity in smallholder agriculture (Giller *et al*., 2000; Sakala *et al*., 2001; Waddington *et al*., 2004).

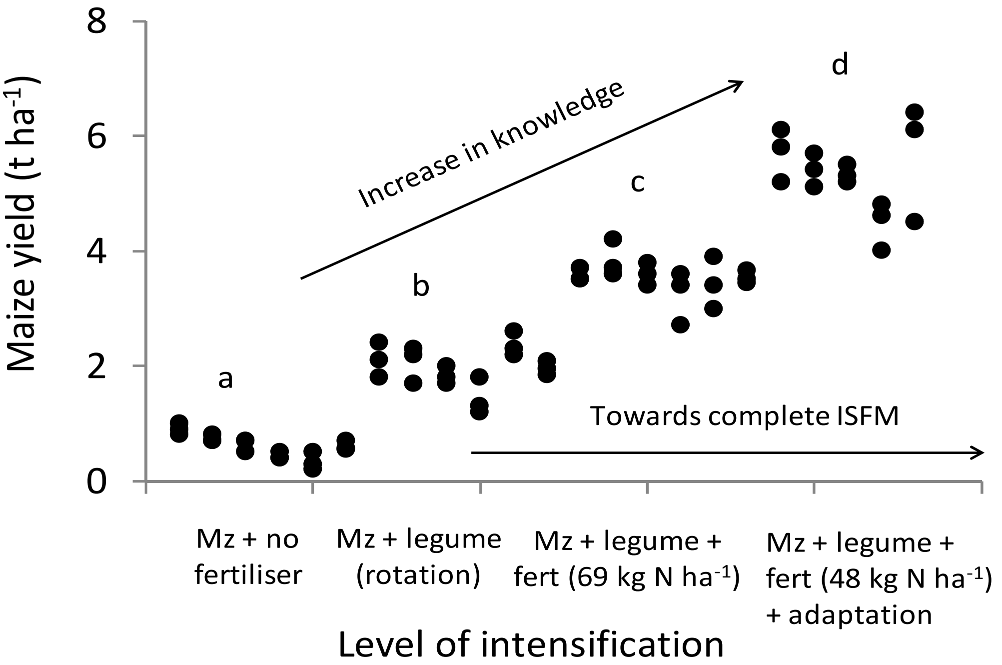

Fig. 7.2. Maize yields at different levels of intensification in smallholder farmers' fields (the 3 left clusters) and on station at Chitedze (the last cluster). Source: Maize yields from a) on-farm, Kamanga, (2001), b) and c) on-farm, Sakala *et al*., (2001), d) on station at Chitedze, (Kumwenda *et al*., 1997b). Based on the framework from Vanlauwe *et al*., (2010).

The most important aspect is to be able to combine legumes or other organic sources and mineral fertiliser within the agronomic principles including judicious use of crop residues, spatial arrangement, use of right varieties and quality and timely farm operations. Adoption of combining mineral and organic fertilisers with agronomic principles allow to raise crop yields to level (b) in Fig.7.2 from on-farm maize yields following legumes in the rotation only (Sakala *et al*., 2001) and this is typical of those farmers who may have adopted some of the legume technologies. Maize yield increments from legume and mineral fertiliser in Chapter 3 corroborates with Fig 7.2 step b and c. The yield increase (from 0.6 to 2 t ha^{-1}) was achieved within the principle of ISFM of inclusion of legumes that contribute to soil organic matter. Yield increments in Chapter 3 were obtained based on the same principle of maize-legume systems and thus were relatively less risky to the farmers.

However, maize yielded much more when incorporated legume biomass N was complemented with half the recommended fertiliser rate of 35 kg N ha^{-1} (Kamanga *et al*., 2010) or at full recommendation of 69 kg N ha^{-1} (Sakala *et al*., 2001). The use of both legumes and mineral fertiliser raised the maize yields further from 2 to 3.5 t ha^{-1} at level (c) in Fig.7.2 indicating the complementarity of both sources of inputs. Steps a to c in Fig. 7.2 are compared further to maize yields under more controlled conditions with yield increasing to 5.3 t ha^{-1} following legumes in the rotation and mineral fertiliser at half the recommended rate (Kumwenda *et al*., 1997b). This still shows that the practices involved in obtaining yields at levels of a to c in Fig 7.2 require that farmers obtain more knowledge to improve their practices to raise maize yields. Several options exist within the ISFM principles, which include exploring options to increase legume biomass yields to increase N return to soil, judicial and innovative use of crop residues, exploring ways of increasing manure production both compost and increasing livestock stocking rates and use of improved germplasm. Use of P to increase legume biomass is advocated (Sanginga *et al*., 2003) and findings of Chapter 4 confirm this potential although the option is not yet practical under smallholder conditions due to the prohibitive costs of P. Farmers who grow tobacco and use considerable P fertiliser are encouraged to follow tobacco with maize-legume intercrops to capitalise on residual P as a means of raising legume biomass that can be returned into the soil to add to soil organic matter. At the moment farmers need to shift and start using research-based concepts especially where land is increasingly becoming scarce. Failure to do so will mean that farmers are missing an opportunity which may remove them from the poverty trap. However, for this to be successful, there is need to promote ISFM within policy interventions which must aim at promoting use of science-based knowledge concepts generated from numerous studies on soil fertility management (Kumwenda *et al*., 1997a; Giller and Wilson, 2001; Vanlauwe and Giller 2006). For example the policy-led fertiliser input subsidy programme in Malawi has proved that production can be increased, and to sustain its impact, promotion of ISFM that focuses on complementary soil fertility restorative technologies would be crucial. There is evidence that small quantities of mineral and relative amounts of organic fertilisers such as manure and legume biomass would increase productivity further (Snapp *et al*., 2002a).

With low adoption of technologies described in Chapter 6 which varied depending on the social context (in this case the farmers' livelihoods levels) in which technologies are introduced, the ISFM through use of legume may remain less achievable if not combined with other policy-based measures. It is observed that increased adoption of technologies is associated with opportunities the technologies offered and food was the primary factor followed by soil fertility. However, lack of established markets for the legumes is the main challenge that reduces maximising benefits for soil fertility improvements through legumes. Establishing and improving markets could increase legume production and in that way indirectly benefit soil fertility in the smallholder agriculture. For those who are food insecure, external assistance for access to inputs like fertiliser and seed supply would be a starting point to encourage and raise production of legumes when markets are available. Thoughtful and well-targeted subsidy or micro-credit programs remain an important component in possible policies to support farmers in breaking out of the poverty trap.

7.8 Conclusions

This thesis addresses the soil fertility problem in relation to food security. Food insecurity is a major problem in Malawi. The issue of poor people and poor fields is critical and needs to be reflected in a way that we identify a starting point to breaking the poverty circle in subsistence farming. Are the fields to blame for the poverty of the farmers or the poverty itself to blame for the soil fertility decline? The thesis has shown that poverty and poor soil fertility are inextricably interlinked. The thesis through Chapter 2 and this last chapter have pointed out their effects on each other and discuss what could be done to break the poverty circle: "improving soil fertility first". Unless soil fertility is raised, breaking the poverty circle may be problematic in a society that largely relies on subsistence farming.

Soil fertility is a complex activity and is influenced by poverty which is reflected in the ownership of assets and access to resources. It is a function of socioeconomic dynamics within the community. The poor farmers struggle to replenish soil fertility and operate in low productivity cycles. Lack of inputs limits farmers' capacity to make the poor soils productive leading to hiring out their labour and sub-optimal management of their own crops, resulting again in low yields. In this scenario, poverty leads to failure to raise productivity of poor soils, and that results in turn to poor yields and further poverty. Thus in subsistence agriculture, farmers with poor fields operate in a poverty trap. *Ganyu* is their main survival strategy and further keeps them under the poverty cycle. Under the current livelihoods, it is difficult for the poor farmers to jump out of poverty without external assistance to do so. Do legume technologies have a place to break this trap? This thesis has supported the need for legume integration in smallholder agriculture along with increased knowledge to raise soil fertility. Legumes contribute to soil fertility and food security, and legumes alone can improve the current maize dominated cropping systems. However, maize-legume technologies alone cannot solve the problem of food insecurity in a short time. A combination of legumes and mineral fertiliser was proved in this thesis to improve maize-legume cropping systems leading to a conclusion that where possible, legume use should be combined with mineral fertiliser and timely weeding; this may likely lead to sustainability of crop yields. Use of phosphorus to improve legume production showed that legume production in smallholder agriculture is constrained by soil fertility, especially lack of phosphorus. P improved legume grain and biomass yields, although farmers did not see the practice to be of economic importance at that time due to lack of consistent markets of most grain legumes. The thesis further showed that small amounts of fertiliser are profitable. However farmers were not aware of this information. With these findings, farmers were encouraged to spread the fertiliser to a larger area as long as they are assured of investment in extra weeding. In the current fertiliser input subsidy programme, farmers are missing an opportunity to move towards market led growth by not investing in extra weeding of their maize. However, a second weeding coincides with hunger periods and most farmers sell their labour to obtain food. This has been blamed for keeping farmers in a poverty cycle since the time they spend working in other farmers' fields is critical for their own food production. The thesis has further shown that farmers will adopt some legumes that provide food, and that these may have spin-off benefits on soils. It further showed that all types of farmers are interested in adopting legumes, but adoption is disproportionally weak and skewed towards the better-resourced farmers and food grains. Competing demands for labour and lack of tangible benefits including food affect adoption of technologies.

Finally farmer participatory methods stimulate farmer interest, testing and maybe uptake of attractive technologies. The results of this thesis confirm that farmer participation is a necessary condition for identifying agricultural constraints and possible solutions. In this thesis participation of farmers did not only contribute to the generation of quantitative information but also enriched the understanding of the functioning of the actual soil fertility management by farmers. Examples are why farmers often used much manure in fields close to the homesteads than outfields and why primarily on tobacco and not maize in Chisepo. This is driven by the economic benefits attached to the tobacco, and also lack of adequate resources for transporting manure. Another example is why adoption of food grain legumes which was skewed towards women was higher than adoption of non-food grain legumes. It was discussed that food grain legumes are mostly associated with relish which is a concern for women than men, and men only became more involved in growing food grain legumes when their value was more attached to market availability. This pointed out to the importance of including gender aspects in technology development and promotion. The knowledge that researchers acquire from such participatory activities are however to be effectively integrated into the project, the scientific reporting and policy thinking. This thesis made a small step into that direction.

Where farmers can, the thesis recommend that they integrate legumes in the farming systems either as rotation crops (where possible) or as intercrops. That will gradually assist in soil fertility improvement. However, legumes should be viewed as a complementary source of N rather than a substitute for mineral N fertilisers (Giller *et al*., 2000). A combination of fertiliser and organic matter is better than just organic matter alone, and we need to encourage farmers to use these complementary resources together for increased crop yields as well as improved and sustainable soil health. Currently, smallholder farmers need practical knowledge for managing soil fertility through a combined use of organic and inorganic sources of nutrients. There is limited knowledge in Malawi on the complementarities of different soil fertility inputs, and researchers need to understand in detail the synergies between organic and inorganic inputs in order to give good advice for sustainable productivity growth of smallholder agriculture. Malawi needs more information on how smallholder farmers manage soil fertility for a full range of the fields they own. Information on how soil fertility management relates to the heterogeneity of fields, how technologies and policy are targeting different resource-endowed farmers, and how contextual socio-economic conditions affect the attractiveness of technologies merits to be collected. Research on those points requires awareness of the inter-linked character of low soil fertility and poverty.

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Summary

Smallholder farmers in Malawi are faced with several dynamic and interlinked challenges and over 80% of them are poor. Food insecurity (measured by household availability of the dominant staple, maize) is common to most rural households and is directly linked to soil infertility in their fields. Because of widespread poverty, smallholder farmers have very limited resources to sustain soil fertility or to improve its status in their fields. Thus smallholder farmers frequently fail to produce adequate food and generate little income from agriculture; locking them in a poverty trap.

Although technology and management interventions have been developed to improve soil fertility, their integration by smallholder farmers is minimal. The poor uptake of potential technology options has been an issue of debate, with no clear-cut solutions. This thesis focused on evaluating with farmers the contributions of several of the most promising options to soil fertility improvement and associated crop yields in smallholder fields. The options were the integration of various legumes to diversify crop production, break the monoculture of maize and improve soil fertility; use of phosphorus to improve legume productivity, and use of small amounts of nitrogen and phosphorus fertiliser to increase farmers' knowledge on fertiliser use on maize. Risks associated with the legume technologies were assessed, as well as farmer interest in adoption of the legumes. The objective was to contribute to soil fertility improvement through targeting of technologies with farmers. The studies described in this thesis used both qualitative and quantitative methods, which included participatory wealth ranking, focus group discussions, in-depth interviews, semi-structured surveys, resource allocation maps, on-farm experimentation and farmer group evaluations of technologies.

The study was initially part of and then developed from a Risk Management Project led by CIMMYT which introduced ten different legumes to farmers in Chisepo, central Malawi, from 1998 to 2004. These legumes were pigeonpea (ICP 9145) (*Cajanus cajan,* (L.) Millsp.), Magoye soyabean (*Glycine max* (L.) Merrill), groundnut (*Arachis hypogaea* L.), Bambara groundnut (*Vigna subterranea* (L.) Verd), velvet bean (*Mucuna pruriens* (L.) DC), cowpea determinate-habit (*Vigna unguiculata* (L.) Walp.), cowpea indeterminate-habit (*Vigna unguiculata* (L.) Walp.*)*, fish bean (*Tephrosia vogelii* Hook. F.), sunnhemp (*Crotalaria juncea* L.) and grahamiana (*Crotalaria grahamiana* Wight and Arn.*).* All were initially promoted as options that farmers could use for soil fertility improvement.

Using wealth ranking to characterise farm households, 136 farmers from Chisepo were categorised into four resource-groups which were used in several studies described in the thesis. The resource groups helped to understand farmers' soil fertility management and assist in targeting maize-legume technologies. A livelihood analysis using the five types of capital: human, physical, natural, social and financial, was done to identify social heterogeneity and people at risk in order to assess whether the variations had effects on soil fertility management behaviour by farmers. The four resource classes developed were the better-resourced – Resource Group (RG) 1 (5% of farmers), medium–resourced – RG 2 (10%), poor-resourced – RG 3 (47%) and the less well-resourced (RG 4) farmers (38%). In general all farmers were poor, but the wealth ranking revealed that most of the farmers were extremely poor (RGs 3 and 4). The livelihood analysis revealed that farmers' soil fertility management behaviour was rational. They operate in a diverse environment. Soil fertility management is a complex activity which is influenced by poverty which in turn is measured by ownership of assets and access to resources. Per capita land and labour availability showed significant differences ($P < 0.05$) among resource groups. The few members of RG 1 had 7.7 ha more land than RG 4 who had an average landholding of 1.4 ha. RG 2 had 6.9 ha while those in RG 3 had 3.5 ha of land. Only farmers in RG 1 and RG 2 owned cattle (3.1 units in RG 1). Other livestock (goats, pigs and

chicken) were also more common in RG 1 and RG 2 than RG 3 and RG 4. RG 1 and RG 2 diversified their income sources, with the largest share of 60% coming from agriculture, 40% from non-farm income for RG 1 and 58% and 42% for RG 2. Agriculture was less important for the poorest farmers. 56% of income for RG 3 and 78% for RG 4 was from non-farm sources. RG 1 engaged in remunerative microenterprises such as grocery shops while RG 3 and RG 4 engaged in microenterprises with less returns (including brewing local gin *kachasu*) which added little to their annual income. *Ganyu* labour was the main non-farm asset of farmers in RG 4. With these resources, farmers from RG 1 purchased on average eleven 50 kg bags of fertiliser and those from RG 2 bought six bags. This was in combination with 5 t and 2.3 t manure respectively. RG 3 only purchased one bag of fertiliser while RG 4 had purchased none. Small amounts of manure were used by RG 3 and RG 4. This means that the vast majority of farmers in Chisepo use almost no fertility inputs. With their investments in soil fertility, RG 1 and RG 2 obtained relatively high maize yields (about 4 t ha^{-1}) and tobacco yields while farmers from RG 3 and RG had poor maize yields. In addition, farmers from RG 1 and RG 2 hired-in labour to perform their farm operations in a timely manner. Most of this labour was provided by members of RG 3 and 4 households. The poor crop yields obtained by RG 3 and 4 meant large food deficits. Often they used *ganyu* labour offered to better-resourced farmers to reduce the food deficits, while neglecting their own food production.

Using an on-farm mother baby approach over four years, farmers evaluated maize (cv. MH18) in rotation with pigeonpea, cv. ICP 9145, intercropped with groundnut, cv. CG 7, (Mz/Pp+Gn); maize intercropped with tephrosia (Mz+Tv); maize intercropped with pigeonpea (Mz+Pp); and maize in rotation with mucuna (Mz/Mp). These technologies were compared with sole crop maize without fertiliser (Mz−Ft) and sole maize plus 35 kg N ha^{-1} (Mz+Ft). Economic and risk assessments were done on technologies. Results showed that cumulative maize grain yields over the four years were greater in RG 1 and 2 than in RGs 3 and 4. In all the groups, Mz+Ft significantly ($P < 0.001$) outperformed all the other treatments with the highest cumulative maize grain yield of over 14 t ha^{-1} in RG 1. The response of maize to fertiliser showed a similar trend in both mother and baby plots, although baby plots (15.2 t ha^{-1} for RG 1 and 5 t ha^{-1} for RG 4) had slightly higher cumulative maize grain yields than mother plots (14.5 t ha^{-1} for RG 1 and 4.6 t ha^{-1} for RG 4). Mz+Pp and Mz+Tv gave greater cumulative yields than Mz/Pp+Gn and Mz/Mp. Legumes improved maize grain yields by between 0.2 and 4 t ha^{-1} over Mz-Ft. Grain legume grain yields were often poor. Groundnut and pigeonpea yielded poorly in all treatments in all years and the largest yield of groundnut was 1.2 t ha^{-1} of grain in the mother plots of the RG 1 farmers in the first year and 1.4 t ha^{-1} in the first year from RG 1 in baby plots. The largest yield of pigeonpea (1.5 t ha^{-1} grain) in mother plots was found with RG 2 in the fourth year and 1.8 t ha^{-1} in baby plots of RG 1 farmers in the first year. Mucuna gave the largest grain yield of 6 t ha^{-1} followed by tephrosia (3 t ha^{-1}), pigeonpea (1.8) and groundnut (1.4). Biomass was largest for mucuna and lowest with pigeonpea. N contributions from above ground biomass ranged from 12 to 223 kg ha^{-1} and averaged around 100 kg N ha^{-1}. This was a large contribution of N to the soil, although not all of it would be available for a following crop to use. Risk assessment at $P = 0.05$ and 0.25 showed that Mz+Pp ($P = 0.075$), Mz+Ft ($P = 0.1$) Mz+Tv ($P = 0.12$) and Mz+ Pp ($P = 0.16$) were less risky to RG 1 and RG 2 but all were risky to RG 3 and RG 4 with legumes alone. Applying 35 kg N ha^{-1} to the legumes resulted in Mz+Ft, Mz+Pp, Mz+Tv, Mz/Pp+Gn and Mz/Mp being least risky to RG 1 and RG2, while all except Mz−Ft became less risky at varying probabilities to RG 3. Mz+Ft, Mz+Pp and Mz/Mp became less risky at $P = 0.25$ to RG 4. Mz+Pp was less risky to all farmers. Economic analysis showed that RG 1 had the highest returns to labour, US\$0.8 day^{-1} with Mz-Ft and US\$1.1 day^{-1} with Mz+Pp. These increased to 1.9 and 1.7 respectively with 35 kg N ha^{-1}. Mz+Pp intercrop had consistent positive returns across the RGs. RG 4 had negative returns to labour for all legumes except Mz+Pp. Thus Mz+Pp was the overall least risky technology, suitable for all RGs.

Application of phosphorus fertiliser (0, 20 kg P ha^{-1}) to legumes significantly ($P < 0.05$) increased grain and biomass yields for mucuna, groundnut, soyabean, Bambara groundnut and cowpea by 1.0, 0.8, 0.5, 1.0 and 0.3 t ha^{-1} respectively over unfertilised plots. Biomass and biomass N were highest in mucuna (6 t ha^{-1} and 190 kg N ha^{-1}) on plots with P, compared with 4.5 t ha^{-1} and 115 kg N ha^{-1} in plots without P. Pigeonpea gave the lowest dry matter yields in both plots with and without P. Many legumes performed better in middle fields ($P = 0.05$) than home fields, although cowpea and fertilised groundnut had better yields in the home fields than middle fields. Pigeonpea showed no response to P in the home fields but both pigeonpea and cowpea had the strongest response to applied P fertiliser in the middle fields. Financial returns were larger in middle fields than home fields, and larger for legumes with P than legumes without. Mucuna had the largest highest returns to labour (US$11 man-day^{-1}) and pigeonpea gave negative returns to labour (US$-1 man-day^{-1}). Pigeonpea and cowpea were not profitable when P fertiliser was applied to them as their benefit-to-cost ratios were below 1. Farmers were happy with the performance of soyabean and groundnut and many were not satisfied with pigeonpea and Bambara nut. Pigeonpea seed had germination problems in the experiments and that reduced its yielding potential. From this experiment, farmers learnt that legume yields could improve with P fertiliser and that frequent weeding of legumes was important. Despite the positive responses of legumes to P, many of the poorer farmers said that they were not ready to use fertiliser to grow legumes, because at the time they could not source sufficient fertiliser even for maize and tobacco due to its high price.

Experiments were conducted with eight farmers on the use of small amounts of NP fertiliser (0, 15, and 30 kg N ha^{-1} and 0, 20 kg P ha^{-1}) in two weeding regimes for maize., Maize grain and stover yields increased with application of N by 0.4 t ha^{-1} from 0.9 t ha^{-1} to 1.3 t ha^{-1} while harvest index was unchanged at 44%. Weeding showed significant ($P < 0.001$) differences for maize grain and stover yield and cob length at $P<0.01$, while harvest index did not change. Maize yields increased by 0.4 t ha^{-1} when weeded twice compared with weeding once (0.9 t ha^{-1}), stover yields were 2.3 and 1.6 t ha^{-1} respectively, and cob lengths were 16.8 and 14.2 respectively. Mean N in grain in plots weeded twice was 17.1 kg ha^{-1} of grain N and 9.8 for plots weeded once while stover N values were 10.1 and 5.6 kg N ha^{-1}. Applying N at 15 kg N ha^{-1} increased maize yields from 0.7 to 1.7 t ha^{-1}, but there were no significant differences in yield at 30 kg N ha^{-1} due to the effects of a dry spell mid-season. All fertiliser use efficiency indices for N showed significant differences due to weeding; agronomic efficiency of applied nitrogen (N) (AE_N at $P < 0.001$, recovery efficiency of N (RE_N) and partial factor productivity of N (PFP_N) at $P<0.01$). Physiological efficiency of N (PE_N) was unchanged The average PE_N of 40.7and PFP_N of 78.8 in plots weeded twice were within the ranges of 40–60 kg grain kg^{-1} N and 40–80 kg grain kg^{-1} N applied respectively. AE_N and RE_N values of 38.7 and 0.9 respectively were above the common range of 10-30 kg grain kg^{-1} N applied and 0.3-0.5 or 0.5–0.8 kg N kg^{-1}. Mean indices from plots weeded just once were all within the ranges stated above but lower than indices from plots weeded twice; suggesting the unsustainability of the use of fertiliser without means to raise its efficiency through better management or combination with organic resources. Financial returns to labour were higher at 15 kg N ha^{-1} (US$0.53 day^{-1}) than at 30 kg N ha^{-1} (US$0.33 day^{-1}). Gross margin increased from US$4.00 with one weeding to US$35.00 with extra weeding and the benefit to cost ratios were 1.6 and 1.4 respectively. This was due to small differences in yields between the two rates. Weeding twice gave higher returns to labour (US$0.35 day^{-1}) than weeding once (US$0.11 day^{-1}). The breakeven price of maize based on AE_N at 15 and 30 kg N ha^{-1} were US$5.33 and US$2.67 kg^{-1} grain kg^{-1} N in plots weeded twice and mean breakeven prices were lower to US$3.33 and US$1.67 in plots weeded once indicating that weeding twice was more profitable. Calculation of the financial returns used open market prices because in this year the free fertiliser distribution did not adequately leach the farmers in the study area and most farmers who used fertiliser in this year bought it from markets. Farmers became aware that small amounts of fertiliser have high payoffs as long as extra weeding is done especially in the dry years. Farmers were thus encouraged to spread the fertiliser over a large area of maize as long as they are able to invest in extra weeding. Farmers said that second weeding was difficult because it coincides with hunger periods when their priority is to look for *ganyu* to respond to the food deficits. It is also the peak period for other crops such as tobacco which require more labour for processing.

Using a survey, focus group discussions and the analytical hierarchy process (AHP), adoption of the ten legumes introduced to farmers was assessed among 136 farmers in 2004 and a wider group of 84 farmers in 2007. The survey showed that 35% of the farmers had adopted at least one legume in 2004 when the project phased out. The AHP showed that food security was the primary reason farmers adopt legumes, with improvement of soil fertility secondary. Use of legumes to control weeds was a less important factor for adopting legumes. Farmers from RG 1 and RG 2 however showed a stronger preference for soil fertility. The AHP predicted that farmers from RG 1 and 2 would more adopt soyabean, mucuna and groundnut in that order and cowpea and sunnhemp were predicted the least to be adopted by farmers from RG 1 and 2. It predicted that groundnut, soyabean, mucuna were to be highly adopted by farmers from RG 3 and 4, and tephrosia and sunnhemp were least to be adopted. The follow up survey and discussions in 2007 showed that the adoption rate decreased to 22%. Unlike what the AHP predicted, farmers in RG 1 and 2 adopted soyabean, groundnut, pigeonpea, Bambara groundnut mucuna and tephrosia, while farmers from RG 3 and RG 4 adopted groundnut, soyabean, Bambara groundnut, pigeonpea cowpea, and mucuna was least adopted. Sunnhemp and grahamiana were not adopted at all. Thus the AHP was able to predict adoption of grain legumes but over-predicted green manure uptake. In practice in Chisepo, soyabean and groundnut are planted more as an intercrops than a sole crops Lack of consistent markets, lack of seed, and shortages of land and labour were cited for weak adoption.

In conclusion, soil fertility management by smallholder farmers is influenced by ownership of assets. The majority poorest farmers fail to invest adequately in improving soil fertility. In the absence of adequate resources to improve soil fertility, integration of legumes in smallholder agriculture remains a viable option for the poor-resourced farmers to use to gradually improve crop yields and break the poverty cycle. The legumes should be used together with mineral fertilisers where possible, to give larger yields. In absence of mineral fertiliser, use of legumes with other organic sources such as compost would be important. For better-resourced farmers, legumes will complement their use of mineral fertilisers and sustainably improve maize yields further. The least-resourced farmers should focus on continuously growing legumes in their main fields at appropriate plant densities to increase the N contributions, and where possible they should apply their fertiliser where legumes are grown in association with maize. Pigeonpea and soyabean are two grain legumes that least-resourced farmers found especially attractive to grow with maize. For all farmers there is need to focus on providing practical knowledge to assist them on how best to integrate organic and inorganic sources of fertiliser. This is important because it will improve farmers' current practices of growing legumes and management of their biomass to add more N to the soils. These uses of legumes in farming systems would be important to the economy in that small increases in yields at a farm level contribute substantially to national food security.

The participatory methods used in the study helped farmers better understand some of the soil fertility concepts and options, including the legumes. The results of this thesis confirm that farmer participation is a necessary condition for identifying agricultural constraints and possible solutions. In this thesis participation of farmers did not only contribute to the generation of quantitative information but also enriched the understanding of the functioning of the actual soil fertility management by farmers. There is need to focus on how to assist farmers with practical knowledge to help them best combine organic and mineral fertiliser resources for improving soil fertility, and to develop and promote new dual-purpose legume options that feed humans and the soil.

Samenvatting

Kleine boeren in Malawi worden geconfronteerd met verschillende dynamische en gerelateerde uitdagingen, en meer dan 80% van hen is arm. Voedselonzekerheid (gemeten als de beschikbaarheid van mais, het hoofdvoedsel, op het niveau van het huishouden) is normaal voor de meeste rurale huishoudens en is direct gerelateerd aan de onvruchtbaarheid van hun velden. Door de wijdverbreide armoede hebben boeren weinig beschikking over hulpmiddelen om hun bodemvruchtbaarheid in stand the houden of te verbeteren. Kleine boeren falen dus ook vaak in hun poging om voldoende voedsel te produceren en ze genereren weinig inkomen: ze zitten gevangen in een armoede val.

Alhoewel technologie- en beheer-interventies ontwikkeld zijn om bodemvruchtbaarheid te verbeteren zijn hun integratie daarvan in het systeem van kleine boeren minimaal. De zwakke toepassing van potentiele technologieën is een punt van discussie geweest, zonder duidelijke uitkomsten. Dit proefschrift concentreert zich op het evalueren, samen met boeren, van de bijdrages van verschillende van de meest belovende opties om bodemvruchtbaarheid en gerelateerde gewasopbrengsten in velden van kleine boeren te verbeteren. De opties waren het integreren van verschillende leguminosen om de gewasdiversiteit te verbeteren, de monocultuur van mais te doorbreken, de bodemvruchtbaarheid te verhogen, het gebruik van fosfaat om de productiviteit van leguminosen te verbeteren, en het gebruik van kleine hoeveelheden stikstof- en fosfaatbemesting om de kennis van boeren over kunstmestgebruik in mais te vergroten.

De aan leguminosen technologieën gerelateerde risico's werden geëvalueerd, evenals de belangstelling van boeren voor de adoptie van de leguminosen. Het doel was om bij te dragen aan verbetering van bodemvruchtbaarheid door 'targeting' van technologieën met boeren. De studies die zijn beschreven in deze thesis maken gebruik van zowel kwalitatieve als kwantitatieve methoden, inclusief participatory wealth ranking, focus group discussies, diepte interviews, semi-gestructureerde enquetes, resource allocation mapping, on-farm experimenten en groeps evaluatie van technologieën door boeren.

De study was aanvankelijk deel van en daarna ontwikkeld vanuit een Risk Management Project geleid bij CIMMYT dat tien verschillende leguminosen introduceerde bij de boeren in Chisepo, centraal Malawi, van 1998 tot 2004. Deze leguminosen waren pigeonpea (ICP 9145) (*Cajanus cajan,* (L.) Millsp.), Magoye soya (*Glycine max* (L.) Merrill), aardnoot (*Arachis hypogaea* L.), Bambara noot (*Vigna subterranea* (L.) Verd), mucuna (*Mucuna pruriens* (L.) DC), cowpea met een 'determinate' groeigedrag (*Vigna unguiculata* (L.) Walp.), cowpea met een 'indeterminate' groeigedrag (*Vigna unguiculata* (L.) Walp*.)*, tephrosia (fish bean, *Tephrosia vogelii* Hook. F.), crotalaria (*Crotalaria juncea* L.) en grahamiana (*Crotalaria grahamiana* Wight and Arn*.).* Allen werden aanvankelijk gepromoot als opties die boeren konden gebruiken om de bodemvruchtbaarheid te verbeteren.

Met het gebruik van wealth ranking om boerenhuishoudens te karakteriseren werden 136 boeren in Chisepo gecategoriseerd in vier resource-groepen welke vervolgens werden gebruikt in verschillende studies welke in dit proefschrift staan beschreven. De resource-groepen hielpen om het beheer van bodemvruchtbaarheid door boeren te begrijpen en om de mais-leguminosen technologieën te 'targeten'. Er werd een 'livelihood' analyse gedaan die gebruik maakte van vijf types kapitaal (menselijk, fysiek, natuurlijk, sociaal en financieel) om de sociale heterogeniteit en mensen die risico liepen te identificeren, om vervolgens vast te stellen of de variaties effect hadden op het beheer van bodemvruchtbaarheid door boeren. De vier resource-klassen die ontwikkeld werden waren de better-resourced – Resource Groep (RG) 1 (5% van de boeren), de medium–resourced – RG 2 (10%), de poor-resourced – RG 3 (47%) en de less well-resourced (RG 4) (38% van de boeren). In het algemeen waren alle boeren arm, maar de wealth ranking wees uit dat de meeste boeren buitengewoon arm waren (RGs 3 en 4). De 'livelihood' analyse wees uit dat boerenbeheer van bodemvruchtbaarheid rationeel was. Ze opereren in een diverse omgeving. Beheer van bodemvruchtbaarheid is een complexe activiteit die beïnvloed is door armoede welke op zijn beurt beïnvloed wordt door bezit van 'assets' en toegang tot 'resources'. De per capita beschikbaarheid van land en arbeid was significant verschillend tussen de groepen ($P < 0.05$). De weinige leden van RG 1 hadden 7.7 ha meer land dan RG 4 die een gemiddelde bedrijfsgrootte hadden van 1.4 ha. RG 2 had 6.9 ha terwijl zij in RG 3 3.5 ha land hadden. Alleen boeren in RG 1 en RG 2 hadden vee (3.1 eenheden in RG 1). Andere soorten vee (geiten, varkens en kippen) waren ook meer algemeen in RG 1 en RG 2 dan in RG 3 en RG 4. RG 1 en RG 2 diversifieerden hun bronnen van inkomsten, met het grootste deel van 60% komende van landbouw, en 40% van niet-landbouw activiteiten voor RG 1, en 58% en 42% voor RG 2. Landbouw was minder belangrijk voor de armste boeren: 56% van het inkomen voor RG 3 en 78% voor RG 4 was van niet-landbouw activiteiten. RG 1 waren betrokken bij lonende micro-ondernemingen zoals groentewinkels terwijl RG 3 en RG 4 betrokken waren in minder winstgevende micro-ondernemingen (inclusief het brouwen van de locale gin *kachasu*) die weinig aan hun jaarlijkse inkomsten toevoegde. *Ganyu* arbeid was de belangrijkste niet-landbouw 'asset' van boeren in RG 4. Met deze 'resources' kochten farmers van RG 1 gemiddeld 50 kg zakken kunstmest en die van RG 2 kochten zes zakken. Dit was in kombinatie met respectievelijk 5 ton en 2.3 ton mest. De RG 3 kochten slechts een zak kunstmest terwijl RG 4 geen enkele kocht. RG3 en RG 4 gebruikten kleine hoeveelheden organische mest. Dit betekent dat de grote meerderheid van boeren in Chisepo bijna geen inputs voor bodemvruchtbaarheid gebruiken. Met hun investering in bodemvruchtbaarheid verkregen RG 1 en RG 2 relatief hoge mais opbrengsten (rond de 4 t per ha) en tabaksopbrengsten, terwijl boeren van RG 3 en RG schrale mais opbrengsten hadden. Daarbij komt dat boeren van RG 1 en RG 2 arbeid inhuurden om hun landbouw activiteiten volgens tijdsplanning uit te voeren. Het meeste van deze arbeid werd geleverd door leden van de RG 3 en 4 huishoudens. De schrale gewasopbrengsten die door de RG 3 en 4 verkregen werden betekenden grote voedsel tekorten. Vaak gebruikten zij het aanbieden van *ganyu* labour aan de better-resourced RG1 om hun voedseltekorten te verminderen, terwijl ze hun eigen voedselproductie veronachtzaamden.

Met het gebruik van de on-farm 'mother baby approach' evalueerden boeren gedurende vier jaar mais (cv. MH18) in rotatie met pigeonpea, cv. ICP 9145, in tussenbouw met aardnoot, cv. CG 7, (Mz/Pp+Gn); mais in tussenbouw met tephrosia (Mz+Tv); mais in tussenbouw met pigeonpea (Mz+Pp); en mais in rotatie met mucuna (Mz/Mp). Deze technologieën werden vergeleken met een enkel mais gewas zonder kunstmest (Mz−Ft) en enkel mais plus 35 kg N ha^{-1} (Mz+Ft). Er werden economische en risicobeoordelingen van de technologieën gedaan. De resultaten gaven aan dat cumulatieve mais-graanopbrengsten over de laatste vier jaar hoger waren in RG 1 en 2 dan in RG 3 en 4. In alle groepen overtrof Mz+Ft significant ($P < 0.001$) alle andere behandelingen met de hoogste cumulatieve mais-graanopbrengst van meer dan 14 t ha^{-1} in RG 1. De respons van mais op kunstmest toonde een vergelijkbare trend in zowel mother as baby plots, alhoewel baby plots (15.2 t ha^{-1} voor RG 1 en 5 t ha^{-1} voor RG 4) een licht hogere cumulatieve mais-graanoogst hadden dan mother plots (14.5 t ha^{-1} voor RG 1 en 4.6 t ha^{-1} voor RG 4). Mz+Pp en Mz+Tv gaven grotere cumulatieve opbrengsten dan Mz/Pp+Gn en Mz/Mp. Leguminosen verbeterden de mais-graanopbrengst met 0.2 tot 4 t ha^{-1} in vergelijking met Mz-Ft. Opbrengsten van leguminosen die om hun graan worden geteeld waren vaak laag. Aardnoot en pigeonpea gaven lage opbrengsten in alle behandelingen in alle jaren en de hoogste aardnotenopbrengst was 1.2 t ha^{-1} graan in de mother plots van de RG 1 boeren in het eerste jaar en 1.4 t ha^{-1} in het eerste jaar van de RG 1 in baby plots. The hoogste opbrengst van pigeonpea (1.5 t ha^{-1} graan) in mother plots werd gevonden met RG 2 in het vierde jaar en

1.8 t ha^{-1} in baby plots van RG 1 boeren in het eerste jaar. Mucuna gaf de hoogste graanopbrengst van 6 t ha^{-1}, gevolgd door tephrosia (3 t ha^{-1}), pigeonpea (1.8) en aardnoot (1.4). Biomassa was het grootst met mucuna en het kleinst met pigeonpea. N bijdrages van bovengrondse biomassa varieerde van 12 tot 223 kg ha^{-1} en was gemiddeld rond 100 kg N ha^{-1}. Dit was een grote bijdrage van N aan de bodem, alhoewel niet alles daarvan beschikbaar zou zijn voor gebruik in het volgende gewas. Risicobeoordeling op het niveau van $P = 0.05$ en 0.25 toonde aan dat Mz+Pp ($P = 0.075$), Mz+Ft ($P = 0.1$), Mz+Tv ($P = 0.12$) en Mz+ Pp ($P = 0.16$) minder risicovol waren voor RG 1 en RG 2 maar ze waren allemaal risicovol voor RG 3 en RG 4 met enkel leguminosen. Toedienen van 35 kg N ha^{-1} aan leguminosen maakte Mz+Ft, Mz+Pp, Mz+Tv, Mz/Pp+Gn en Mz/Mp het minst risicovol voor RG 1 en RG2, terwijl allen behalve Mz−Ft minder risicovol waren op het niveau van verschillende waarschijnlijkheden voor RG 3. Mz+Ft, Mz+Pp en Mz/Mp werden minder risicovol op het niveau van $P = 0.25$ voor RG 4. Mz+Pp was minder risicovol voor alle boeren. Economische analyse gaf aan dat RG 1 de hoogste winst gaf op arbeid, US\$0.80 dag^{-1} met Mz-Ft en US\$1.10 day^{-1} voor Mz+Pp. Deze namen toe tot respectivelijk 1.9 en 1.7 met 35 kg N ha^{-1}. Mz+Pp tussenbouw gaf consistent positieve resultaten voor alle RGs. RG 4 had negatieve resultaten voor arbeid, voor alle leguminosen behalve Mz+Pp. Dus was Mz+Pp over alle behandelingen de minst risicovolle technologie, geschikt voor alle RGs.

Toedienen van of fosfaatbemesting (0, 20 kg P ha^{-1}) aan leguminosen gaf een significant ($P < 0.05$) hogere graan en biomassa opbrengst voor aardnoot, soya, bambaranoot en cowpea van respectievelijk 1.0, 0.8, 0.5, 1.0 en 0.3 t ha^{-1} over de niet-bemeste plots. Biomassa en N in de biomassa waren het hoogst in mucuna (6 t ha^{-1} en 190 kg N ha^{-1}) in de plots met P, vergeleken met 4.5 t ha^{-1} en 115 kg N ha^{-1} in plots zonder P. Pigeonpea gaf de laagste droge stof opbrengst in zowel plots met en zonder P. Veel leguminosen presteerden beter in ‘middle fields’ ($P = 0.05$) dan in ‘home fields’, alhoewel cowpea en bemeste aardnoot beter opbrengsten hadden in de ‘home fields’ dan in de ‘middle fields’. Pigeonpea toonde geen respons op P in de ‘home fields’ maar zowel pigeonpea als cowpea hadden de sterkste respons op toegediende P bemesting in de ‘middle fields’. Financiële rendementen waren groter voor de ‘middle fields’ dan voor de ‘home fields’, en groter voor leguminosen met P dan voor leguminosen zonder. Mucuna had het hoogste rendement op arbeid (US\$11 man-dag^{-1}) en pigeonpea gaf negatieve rendementen op arbeid (US\$-1 man-dag^{-1}). Pigeonpea en cowpea waren niet winstgevend wanneer P bemesting toegediend was aangezien hun profijt-kosten verhoudingen minder dan 1 waren. Boeren waren blij met de prestatie van soya en aardnoot, en velen ware niet tevreden met pigeonpea en Bambaranoot. Zaad van pigeonpea had in de experimenten problemen met de kieming en dit verlaagde hun potentiele opbrengst. Boeren leerden van dit experiment dat opbrengsten van leguminosen konden verbeteren met P bemesting en dat frequent wieden belangrijk was. Ondanks de positieve respons van de leguminosen op P zeiden vele boeren dat ze niet klaar waren om kunstmest toe te passen omdat ze op dat moment niet voldoende kunstmest konden verkrijgen, zelfs niet voor mais en tabak, om de hoge prijs.

Er werden experimenten uitgevoerd samen met acht boeren over het gebruik van kleine hoeveelheden NP bemesting (0, 15, en 30 kg N ha^{-1} en 0, 20 kg P ha^{-1}) in twee regimes van wieden van onkruiden in mais. Mais-graan en -stro opbrengsten namen toe met de toediening van N met 0.4 t ha^{-1} van 0.9 t ha^{-1} tot 1.3 t ha^{-1} terwijl de oogst index van 44% onveranderd bleef. Wieden gaf een significant ($P < 0.001$) verschil voor mais-graan en -stro opbrengst en lengte van de kolf op het niveau van $P<0.01$, terwijl de oogst index niet veranderde. Mais opbrengst nam toe met 0.4 t ha^{-1} wanneer het tweemaal werd gewied in vergelijking met eenmaal wieden (0.9 t ha^{-1}), stro-opbrengsten waren respectievelijk 2.3 en 1.6 t ha^{-1}, en lengte van kolven waren respectievelijk 16.8 en 14.2. Gemiddeld N in het graan in plots die tweemaal werden gewied was 17.1 kg ha^{-1} N en 9.8 voor plots die eenmaal werden gewied, terwijl N waardes voor het stro 10.1 en 5.6 kg N ha^{-1} waren. Toedienen van N in de dosering van 15 kg N ha^{-1} verhoogde de mais opbrengst van 0.7 tot

1.7 t ha^{-1}, maar er waren geen significante verschillen in opbrengst op het niveau van 30 kg N ha^{-1} als gevolg van de effecten van droge periodes in het midden van het seizoen. Alle indices van N-gebruiksefficiëntie van kunstmest toonden significante verschillen als gevolg van wieden; agronomische efficiëntie van toegediende stikstof (N) (AE_N op het niveau van $P < 0.001$, recovery efficiency van N (RE_N) en partial factor productivity van N (PFP_N) op het niveau van $P<0.01$). Physiological efficiency van N (PE_N) was onveranderd. De gemiddelde PE_N van 40.7 en PFP_N van 78.8 in de plots die tweemaal waren gewied, varieerden respectievelijk van 40–60 kg graan en 40-80 kg graan per toegediende kg N . AE_N en RE_N waarden van respectievelijk 38.7 en 0.9 waren boven de algemene warden van 10-30 kg graan per toegediende kg N en 0.3-0.5 of 0.5–0.8 kg N kg^{-1}. Gemiddelde indices van plots die slechts eenmaal waren gewied waren allemaal binnen de aangegeven variatie van waarden maar lager dan de indices van plots die tweemaal waren gewied; suggererend dat het gebruik van kunstmest niet duurzaam is zonder middelen om de efficiency daarvan te vergroten door beter beheer of door combinatie met organische bemesting. Financiële rendementen op arbeid waren hoger op het niveau van 15 kg N ha^{-1} (US\$0.53 dag^{-1}) dan op dat van 30 kg N ha^{-1} (US\$0.33 dag^{-1}). De bruto marge nam toe van US\$4.00 met een enkele keer wieden tot US\$35.00 met een extra keer wieden en de profijt-kosten verhoudingen waren respectievelijk 1.6 en 1.4. Dit was een gevolg dan kleine verschillen in opbrengsten tussen de twee doseringen. Twee keer wieden gaf hogere rendementen op arbeid (US\$0.35 dag^{-1}) dan een enkele keer wieden (US\$0.11 dag^{-1}). De prijs van mais waarbij profijt en kosten gelijk waren, gebaseerd op een AE_N van 15 en 30 kg N ha^{-1} waren US\$5.33 en US\$2.67 kg^{-1} graan kg^{-1} N in de plots die tweemaal waren gewied en de gemiddelde prijzen waarbij profijten en kosten gelijk waren, waren lager tot US\$3.33 en US\$1.67 in plots die een enkele maal gewied waren, wat aangeeft dat tweemaal wieden winstgevender was. Bij de berekening van de financiële rendementen werd gebruik gemaakt van de open markt prijzen omdat in dit jaar de vrije verdeling van kunstmest niet in voldoende mate de boeren in het studiegebied had bereikt en de meeste boeren die kunstmest gebruikten in dit jaar, kochten het op de markt. Het werd boeren duidelijk dat kleine hoeveelheden kunstmest hoge beloningen gaven zo lang er een extra keer gewied werd, speciaal in drogere jaren. Boeren werden hierdoor dus aangemoedigd om de kunstmest over grotere oppervlaktes te verspreiden zolang zij in staat waren een extra keer te wieden. Boeren zeiden dat een tweede keer wieden moeilijk was omdat het samenviel met de 'hunger periods' waarin hun prioriteit ligt bij het zoeken naar *ganyu* als een respons op hun voedseltekorten. Het is ook een piek periode voor andere gewassen zoals tabak, dat meer arbeid nodig heeft voor de verwerking.

Met gebruik van een enquête, focus group discussies een het analytical hierarchy process (AHP), werd de adoptie door boeren van tien leguminosen bepaald onder 136 boeren in 2004 en een bredere groep van 84 boeren in 2007. De enquête liet zien dat 35% van de boeren ten minste één leguminoos hadden geadopteerd in 2004 toen het project eindigde. De AHP liet zien dat voedselzekerheid de hoofdreden was waarom boeren leguminosen adopteerden, met verbetering van de bodemvruchtbaarheid als een ondergeschikte reden. Gebruik van leguminosen om onkruid te beheersen was een minder belangrijke reden om leguminosen de adopteren. Boeren van RG 1 en RG 2 gaven een sterkere voorkeur aan voor bodemvruchtbaarheid. De AHP voorspelde dat boeren van RG 1 en 2 meer soya, mucuna en aardnoot zouden adopteren – in die volgorde –, en cowpea en crotalaria zouden het minst geadopteerd worden door boeren van RG 1 en 2. Het voorspelde dat aardnoot, soya, mucuna hoge adoptie zouden ondervinden bij boeren van RG 3 en 4, en tephrosia en crotalaria het minst. De vervolg-enquête en discussies in 2007 toonden aan dat het adoptie percentage daalde tot 22%. Verschillend van wat de AHP voorspelde, adopteerden boeren in RG 1 en 2 soya, aardnoot, pigeonpea, Bambara noot en tephrosia, terwijl boeren van RG 3 en RG 4 aardnoot, soya Bambara noot, pigeonpea cowpea adopteerden, en mucuna was het minst geadopteerd. Crotalaria en grahamiana werden in hun geheel niet geadopteerd. Dus was AHP in staat de adoptie van leguminosen die geteeld worden om hun graanopbrengst te voorspellen, maar het overschatte de opname van groenbemesting. In de praktijk van Chisepo worden soya en aardnoot meer als tussengewas geteeld dan als enkel gewas. Gebrek aan een consistente markt, het ontbreken van zaad, en het gebrek aan arbeid werden genoemd als reden voor de gebrekkige adoption.

Als conclusie, beheer van bodemvruchtbaarheid door kleine boeren is beïnvloed door eigendom van 'assets'. De meerderheid van de armste boeren mislukt in het adequaat investeren in verbetering van bodemvruchtbaarheid. Zonder adequate resources om bodemvruchtbaarheid te verbeteren blijft het integreren van leguminosen in kleine-boerenlandbouw een levensvatbare optie voor de boeren met weinig bezittingen om langzaamaan hun opbrengsten te vergroten en de armoede spiraal te doorbreken. De leguminosen zouden gebruikt moeten worden met kunstmest wanneer mogelijk, om hogere opbrengsten te produceren. Als kunstmest niet aanwezig is, dan is het gebruik van leguminosen met andere organische bemesting belangrijk. Voor de boeren met meer bezittingen zijn leguminosen complementair aan hun gebruik van kunstmest en zullen de maisopbrengsten verder duurzaam verbeteren. De boeren met de minste bezittingen zouden zich moeten richten op een ononderbroken planten van leguminosen in hun belangrijkste velden met geschikte plantdichtheden om de N bijdrage te vergroten, en waar mogelijk zouden zij moeten bemesten daar waar leguminosen geplant zijn in combinatie met mais. Pigeonpea en soya zijn twee leguminosen die om hun graanopbrengst worden geteeld en die de armste boeren speciaal aantrekkelijk vonden om met mais te planten. Voor alle boeren is er een noodzaak om te focussen op het geven van praktische kennis om hen te assisteren in de manier waarop zij het best het gebruik van organische en anorganische bemesting zouden kunnen combineren. Dit is belangrijk omdat het de huidige praktijken van boeren zal verbeteren om leguminosen te telen en biomassa te beheren om N aan de bodems toe te voegen. Het gebruik van de leguminosen in de boerensystemen zou belangrijk voor de economie, omdat kleine verhogingen van opbrengst op het niveau van het boeren substantieel bijdragen aan de nationale voedselzekerheid.

De participatieve methoden die gebruikt zijn in deze studie hebben de boeren geholpen om beter begrip te krijgen van een paar concepten van bodemvruchtbaarheid en opties, inclusief de leguminosen. De resultaten van deze thesis bevestigen dat boeren-participatie een noodzakelijke conditie is om landbouwkundige beperkingen en mogelijke oplossingen te identificeren. In deze thesis heeft participatie van boeren niet alleen bijgedragen aan het genereren van kwantitatieve informatie maar heeft ook het begrip verrijkt over het functioneren van actueel beheer van bodemvruchtbaarheid bij boeren. Het is nodig om te focussen op hoe boeren kunnen worden ondersteund met praktische kennis om hen te helpen hoe zij het best organische en anorganische soorten van bemesting kunnen combineren om de bodemvruchtbaarheid te vergroten, en om twee doelen dienende leguminosen opties te ontwikkelen die mens en bodem voeden.

Biography

Bernard Chizengo Gomezgani Kamanga was born at Chitembeya Nkhata Village in Mzimba District, northern Malawi. After primary education at Vibangalala Full Primary School and later at Mzimba L.E.A. Primary School, he enrolled for secondary education in 1984 at St. John Bosco Secondary School, Champhira in the same district. In 1988, he embarked his higher education at Bunda College of Agriculture, a constituent College of the University of Malawi. He successfully obtained a Diploma in Agriculture in 1991 and a Bachelor of Science Degree in Agriculture in 1993, both with credit. From 1993 to 1996 he worked as a secondary school teacher at Likhubula Private Secondary School in Blantyre and at Arts, Science and Technology Private Institute (ASTEPI) in Luchenza, Thyolo. In February 1996, he was given an opportunity to pursue a Master of Science programme at the same university under the Rockefeller Foundation Food Security Programme. The MSc study focussed on socio-economic impacts of integrating legumes in smallholder fields in Songani catchment area in Zomba, southern Malawi. He successfully finished and obtained the Master of Science Degree in 1998.

In the same year he secured employment with the International Centre for the Improvement of Maize and Wheat (CIMMYT) as a research associate under the Risk Management Project covering Malawi and Zimbabwe. He worked for CIMMYT until 2004. In 2003 while working for CIMMYT, he enrolled for a sandwich PhD programme with the Technology and Agrarian Development (TAD) Chairgroup at Wageningen University. The financial support came from the Rockefeller Foundation, coordinated by the Participatory Approaches and Up-scaling (PAU) project. He worked with DanChurchAid as a food security and global funding officer for almost 4 years from 2007 when he was supposed to have been finishing his studies, until early 2011. However, during this period he resisted the pressures to abandon the PhD and worked harder when time was found.

His PhD study “Poor people and poor fields? Integrating legumes for smallholder soil fertility management in Chisepo, central Malawi” with a focus on maize-based cropping systems was thus a product of collaborative supervision by the Plant Production Systems and the Technology and Agrarian Development Chairgroups. He is reachable at bcgkamanga@gmail.com

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3. Book chapters

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Completed Training and supervision Plan

Name Bernhard Chizengo Gomezgani Kamanga
PhD candidate, Wageningen School of Social Sciences (WASS)
Completed Training and Supervision Plan

Description	Department/Institute	Month/Year	Credits
I. Orientation			
CERES Introductory Courses	CERES	March – April, 2003	5.5
Ceres presentation tutorials	Ceres, De Hoorneboeg, Hilversum	May, 2003	5
PhD research proposal development	Wageningen University	September 2002-June 2003	6
Writing grant proposal for IFS	TAD, WUR	October 2007	2
II. Scientific and Professional			
PAU/TAO Cornell Workshop, Participatory Approaches and Up-scaling	PAU Programme, WUR, WICC, Wageningen	22-26, August 2002	1
Facilitating change in up-scaling of participatory approaches	PAU Programme, WUR, Boxmeer	10-18 October, 2002	3
Sharing experiences on PhD research on participatory approaches and up-scaling	PAU programme, WUR,Malindi, Kenya	13-18 June, 2004	2
Learning in PAU: Support to analysis and PhD thesis write-up	PAU Programme, WUR, Jinja, Uganda	24-28 January 2006	2
CIMMYT workshops and seminars	Zimbabwe and Malawi	2003 - 04	1
Legume and maize seed technology and development: An economic perspective. Policy Network Group, Bunda College	Lilongwe Hotel, Malawi	24-27 July, 2004	1
III. Seminar Presentations			
TAD Seminars	TAO, Social Sciences, WUR	September 2002-June, 2003	1
Advanced Research Seminars	PPS, Plant Sciences, WUR	March – June 2011	1
Workshop on proposal development	European Aid, Harare, Zimbabwe	17-21 August, 2009	1
IV. Academic skills			
Mobilising Scientific networking	WGS, WUR	August, 2007	1
Introduction to the Sociology of Knowledge and Rural development	MSc course RDS 20804	RDS Group	
Management of Change: Inter-Human Processes and Communication	MSc course CIS 31306	May, 2003	
Technology, Social Choice, and Development	MSc course TAD 30304	March-April 2003	
Introduction to Agro-ecological technology Studies	MSc course TAD 20304	Sept. –October, 2003	
Technography, Researching Technology and Development	MSc course TAD 30804	2003	
			32.5

Colophon:

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Cover design

The cover was designed by the author with assistance from Dr. Conny Almekinders. The pictures on both covers were taken by the author. The pictures depict the poor farmer, Mr. Kamangira (late) with his “hoe” technology and the part of the field of a better-resourced farmer.