Towards increased adoption of grain legumes among Malawian farmers - *Exploring opportunities and constraints through detailed farm characterization*

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MSc thesis Plant Production Systems & Sustainable Development

August 2011

Universiteit Utrecht

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Master Thesis Sustainable Development, 45 ECTS
(Track Land Use, Environment and Biodiversity)
Utrecht University & Wageningen Universtity

Date: August 2011

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Contents

1. Summary

Legume technologies are often promoted to increase nutrition, livelihoods and soil fertility of sub-Saharan smallholder farmers. Differences between regions as agro-ecological potential, market access and off-farm income opportunities and differences between farmers in terms of resource endowment and livelihood strategy imply that blanket recommendations for legume technologies are unlikely to be effective. Identification of niches through detailed system characterization, with the use of a farm typology to deal with the enormous diversity in smallholder farms, is an opportunity to improve both recommendations and their targeting. Fine-tuning recommendations to the farm type level will probably improve adoption by farmers and make legume-based development projects more effective. The results of farm characterizations, covering diverse farm types in Mchinji and Salima district in central Malawi, were used to gain insights in the possibilities of legumes to increase nutrition, livelihoods and soil fertility.

Maize was the dominant staple food crop in both regions. Tobacco was a major cash crop in Mchinji, whereas cotton, tobacco and groundnuts were the most common cash crops in Salima. Although the area under legume cultivation was smaller in Mchinji than in Salima, groundnut had high adoption rates in both regions. Soyabean, beans and cowpea had low adoption rates and were allocated only very small areas. Farmers themselves defined the boundaries within which legumes can expand on their farm by food security and income. These were bordered and influenced by highly dynamic socio-economic, agronomic and biophysical factors. Although labour use efficiency of maize was generally higher than that of groundnut, legumes were economically more profitable than maize. Since maize is perceived as the main food security crop, the majority of the farmers indicated that legumes can only be expanded when domestic maize production is sufficient to satisfy household demand. Low resource endowed households were generally less food secure than medium or high resource endowed households and mentioned lack of cash for seeds and lack of land and labour as the major production constraints to expanding legume production. This indicates that targeting low resource endowed farmers who cannot be self-sufficient in maize production with legume technologies is unlikely to be successful. Although legumes did not have the potential to generate as high net benefits as tobacco or cotton, they were less risky in terms of possible negative net benefits and required less establishment costs. Therefore, cultivating legumes can be an option to generate some cash as well as to fortify diets with good quality protein for subsistence oriented farmers who are already self sufficient in maize production. Marketability of legumes other than groundnut was often a major constraint for market oriented farmers to expanding their production. Farmers of all types were less interested in the potential soil fertility benefits of legumes. Current contributions of legumes to soil fertility are likely to vary among farms and fields due to (1) probable variable rates in biological nitrogen fixation and biomass production, notably due to variable soil fertility within farms and the preferential allocation of legumes to less fertile fields and (2) differences in residue management to store nutrients over the dry season.

2. Introduction

2.1 background

In rural Malawi, own maize harvest is equal to household food security and the majority of the smallholder farm land is covered by maize (Smale, 1993). Yet, the prevalence of undernourishment is high[1] (FAO 2010). Over the past 50 years per capita food production has not increased in sub-Saharan Africa (Sanchez, 2002). In many areas soil fertility has declined as a result of continuous cropping with cereals, minimal use of fertilizers and the abandonment of the traditional fallow systems which allowed the soil to recover from several years of cropping (Mafongoya et al., 2006; Snapp et al., 2002a).

According to Mafongoya et al. (2006), the main issue for improving the impoverished agricultural productivity is building up and maintaining soil fertility, despite the low incomes and land and labour constraints faced by the smallholder farmers. Common and effective ways of restoring soil fertility and improving productivity are inorganic fertilizers and manure (Sanginga, 2003; Snapp et al., 2010). However, as in most of sub-Saharan Africa, in Malawi the use of animal manure is restricted because of inadequate availability and limited cattle ownership (Snapp et al., 2002b, Mafongoya et al., 2006). At the same time high costs, inefficient marketing and unreliable returns are likely causes that minimize inorganic fertilizer use (Morris et al., 2007; Sanchez, 2002; Voortman, 2010). Although governments successfully run periodic fertilizer and seed subsidy programs (Snapp et al., 2010), this is not a sustainable solution since the high costs result in reductions in expenditures in other key areas (Morris et al., 2007). Furthermore, after their removal, farmers are not able to afford fertilizer anymore and fall back to low production levels again (De Schutter, 2010).

Nitrogen (N) is thought to be the nutrient that mostly limits tropical agricultural production (Rufino et al., 2006). As an alternative to N inputs from fertilizer or manure, intensification of nitrogen-fixing legumes is often promoted to increase productivity of cereal-based cropping systems in developing countries. They have the potential to increase the N content of the soil and thereby subsequent cereal yields. At the same time sustainability will be improved by diversifying the cereal dominated rotations. Agroforestry systems, green manures and intercrops or rotations with grain legumes are some of the options. However, the first two technologies are unattractive for the majority of the sub-Saharan smallholder farmers, due to the land and labour requirements that do not provide any edible yield (Snapp et al., 2002b; Vanlauwe and Giller, 2006). On the other hand, crop diversification, in the form of rotation or intercropping, with edible grain legumes could be an option.

Besides having the potential to contribute to soil fertility, the protein-rich grains of legumes can prevent malnutrition commonly associated with cereal based diets (Prasanne et al., 2001). Furthermore, legumes can provide market possibilities, thereby providing farmers the opportunity to improve their income and livelihoods (Giller et al., 2011; Kamanga et al.,

[1] In Malawi, 25% - 34% of the total population have a caloric intake below the minimum dietary energy requirement.

2010a), which is needed to truly combat hunger and malnutrition besides an increase in total food production (Bie et al., 2008; De Schutter, 2010).

Aim and relevance

Agricultural productivity needs to be improved where it has been lagging behind to feed the growing world population. At the same time, degradation of ecosystems has to be avoided to not endanger the future ability to maintain adequate production levels. Furthermore, incomes and livelihoods of the poorest need to be improved to effectively reduce hunger and malnutrition. Legume technologies can have a positive effect in terms of soil fertility, nutrition and livelihoods on sub-Saharan smallholder farming systems. However, these farming systems are extremely diverse (Tittonell et al., 2007) and blanket recommendations are unlikely to be effective. This study therefore aims at a first exploration towards identifying 'socio-ecological' niches (Ojiem et al., 2006), or windows of opportunity, for grain legumes in Malawi.

First, a literature review sets the theoretical framework for the research. Then, the research questions and hypothesis for this specific research are presented. The research questions are answered by means of a detailed characterization of the farming systems. Finally, it is discussed how detailed knowledge on the diversity between and within sub-Saharan smallholder farming systems will help with the development of technologies and improves their targeting and chance of adoption.

The N2Africa project

The presented research was conducted within the framework of the N2Africa project. The main objective of this project is to directly link the previously inaccessible atmospheric reserves of nitrogen to the protein and nitrogen needs of poor African farmers, by raising the average grain legume yields for groundnut, cowpea, soybean and common bean and increasing the amounts of atmospheric N fixed by these crops. Important steps in accomplishing these goals are (1) the identification of niches for targeting N fixing legumes (2) testing multi-purpose legumes on their ability to provide food, animal feed and improve soil fertility, (3) promoting the adoption of improved varieties, (4) supporting the development of inoculant production (see theoretical framework) and (5) developing and strengthening capacity for legumes research and technology dissemination. During this process, 225000 households in eight countries across sub-Saharan Africa will be targeted with improved varieties of legumes and inoculant technologies. The presented research contributes to the project by characterizing the highly diverse smallholder farming systems in Malawi and identifying niches for targeting the legume technologies.

2.2 Theoretical framework

Biological nitrogen fixation

Many legume plants (belonging to the family *Fabaceae* or *Leguminosae*) are able to fix atmospheric nitrogen (N_2) in a symbiotic relationship with rhizobia (bacteria) present in the soil. The rhizobia infect the roots of the legumes and form nodules, in which N_2 is fixed by converting it to ammonia (NH_3^-) which is used for plant growth (Mpepereki et al., 2000; Peoples et al., 2009). However, not all legumes nodulate with all rhizobia, and the other way around. Legumes that nodulate with a wide variety of rhizobial strains, or rhizobia that nodulate with a wide diversity of host plants are called promiscuous. A legume which nodulates with a restricted range of rhizobial strains is called specific. The specificness or promiscuity strongly depends on the legume species or variety. For specific legumes, rhizobia, if not naturally present, can be added to the soil in the form of inoculants. Promiscuous legumes that do not require inoculation are cowpea, groundnut, common bean and some varieties of soyabean (Mpepereki et al., 2000)

Although legumes are able to fix N_2, they do not necessarily contribute to improving soil fertility. The proportion of N_2 fixed from the atmosphere and the proportion of N extracted from the soil determines partly whether a legume is a net-contributor or a net-extractor. Besides the influence of differences in legume genotype and rhizobium strain on biological nitrogen fixation (BNF), environmental constraints such as deficiencies in P or K, acidity, drought, flooding and high soil temperature will decrease the amount of N from N_2-fixation (Bohlool et al., 1992; Graham and Vance, 2003; Hungria and Vargas, 2000; Lupwayi et al., 2010). In case there is ample N already available in the soil, either naturally or by targeting it with N fertilizer, the inputs of N from N_2-fixation can also be limited (Peoples et al., 2009). Whereas Mafongoya et al. (2006) review many studies and find that N_2 fixed on southern African smallholder farms is highly variable depending on legume species and research location, Franke et al. (2008) specifically report highly variable rates of N_2-fixations for the same legumes across different environmental circumstances.

The other important factor determining the net N contribution is the N-harvest index. This describes the amount of N removed from the system with crop harvest (Giller and Cadisch, 1995). The N-harvest index will automatically be higher for grain legumes where the protein rich grains are removed than for green manures and legume trees. Among grain legumes, there are still large differences in N-harvest indices. Groundnut and cowpea tend to have low N-harvest indices and are usually net contributors whereas improved varieties of soyabean with higher grain yields can easily be net-extractors due to higher harvest indices for N (Giller and Cadisch, 1995). Dual-purpose varieties of soyabean with a lower grain yield but with more stover, on the other hand, can be net-contributors (Mpepereki et al., 2000). However, residues of grain legumes need to be composted or incorporated in the field immediately after harvest, since just leaving them in the field can cause the accumulated N to disappear almost entirely over the dry season (Franke et al., 2008). If the residues are not returned to the field, grain legumes usually tend to be net-extractors rather than contributors (Giller and Cadisch, 1995; Laberge et al., 2009).

Besides the potential residual fertility benefits, the high quality residues of legumes contribute positively to the soil organic matter (SOM) pool and increase the potential for N mineralization (Peoples et al., 2009; Snapp et al., 1998). Furthermore, rotation with legumes can reduce biotic stresses as weeds and pests and diseases that are enhanced by continuous cropping with cereals (Adjei-Nsiah et al., 2008; Thomas and Kevan, 1993). Advantages associated with intercropping include more efficient use of the growing season, risk avoidance, diversity in products, protecting the soil from erosion and control weeds through shading effects (Roy et al., 2002).

Challenges regarding implementing legume technologies

Many smallholder farmers across sub-Saharan Africa have been growing legumes traditionally, although not on a very large scale. Since the early colonial period, attempts have been made to integrate new legumes in the cropping systems. However, many of these early attempts failed due to poor adaptation of the legume variety to the local conditions, lack of domestic market and unreliable export markets (Shurtleff and Aoyagi, 2007).

In Malawi maize accounts for 66% of the daily calorie intake (Smale, 1993) and approximately 60% of the cultivated land (FAOSTAT, 2011). The nutritional implications of the dominance of maize in the diet and the soil fertility implications of monocropping have been reasons for recent policy concern. Despite the fact that crop diversification has been an explicit goal of agricultural policy in Malawi, the adoption of legume technologies by smallholder farmers has remained limited (Chamango, 2001; Bezner-Kerr et al., 2007). Commonly mentioned agronomic barriers by farmers included the lower yield of legumes compared to cereals, high labour requirements and the use of large amounts of seed (on a weight basis) per land area that increase the establishment costs. Socio-economic barriers included limited and uncertain market access, unstable and highly variable prices for legume products and limited access to improved varieties (Bezner-Kerr et al., 2007). Factors that can improve BNF such as (phosphorus) fertilizer, seeds of improved legume genotypes and inoculants may be too costly or simply not available (Mpepereki et al., 2000; Snapp and Silim, 2002). In the case inoculant is available, it is often of poor quality (Peoples et al., 2009).

Although these challenges have all been identified before, the ability to overcome constraints or to conduct applied research that directly benefits the farmers, has remained low (Peoples et al., 2009). Ojiem et al. (2006) argue that it is often the lack of appropriate methodologies and tools to stimulate adoption and the mode of research employed that causes low adoption rates. Past research did not involve the farmer at an early stage in the evaluation of technologies, leading to 'top-down' recommendations which lacked recognition of farmers' knowledge or a proper understanding of farmers' objectives. Therefore, participatory research methods are now advocated since they are supposed to improve relevance and adoption of technologies (Chamango, 2001; Snapp et al., 2002a). Yet, the high diversity in smallholder farming systems was often not accounted for. Generally, only relatively rich and large-scale farmers have been included in on-farm research because they are best able to invest in risky and longer-term technologies (Snapp et al., 2002a) whereas the majority of the households in sub-Saharan Africa are resource poor and constrained by the availability of land, labour and nutrient sources. Understanding also their unique barriers and possibilities could improve the development of appropriate technologies. In addition, farmers often prefer to allocate crops and nutrients to different plots in spatially heterogeneous farms. Consequently, performance of technologies may even be variable within farms (Tittonell et al., 2009). Ignoring the heterogeneity within farms has also been reason for non-success of technology interventions (Zingore et al., 2007).

Capturing diversity in smallholder farms

Smallholder farming systems in southern Africa are very diverse in terms of biophysical and socio-economic environments (Tittonell et al., 2009). Soil fertility status, labour availability, livestock ownership, cash income, farmer objectives and preferences related to culture are only some among the many factors that contribute to this high diversity (Ojiem et al., 2006). Whereas some of these or other variables present in the system constrain the adoption of particular legume technologies or particular legume species, at the same time they might offer opportunities for other legume technologies or other legume species to be adopted successfully in the same system. Legume technologies thus have to be developed considering farmer specific factors. Therefore, fixed or 'blanket' recommendations for a certain legume technology are not useful (Ojiem et al., 2006). Instead, recognising and understanding the variability among farmers and the underlying drivers behind the farm management indicators is an important step in designing policies regarding improving agricultural production (Andersen et al., 2007; Tittonell et al., 2009). Connecting the biophysical and socio-economic variables and their interactions is then required to see the window of opportunity or 'socio-ecological niche' (see box 1) for a given technology in a given system (Ojiem et al, 2006).

However, assessing a wide range of farm management indicators can be quite complicated (Andersen et al., 2007). Whatmore et al. (1987) state that diversity of agricultural production patterns should be understood as the outcome of both external and internal forces to the farm family. Family farms can then be seen as complex socio-economic structures resulting from the interaction between the family unit and the farm business (Daskalopoulou and Petrou, 2002). A farm typology, defined by Andersen et al. (2007) as "a stratification of farms that is homogeneous according to specific criteria", can then function as a tool to assess the indicators as an integrated set rather than as single indicators. Consequently, to define an ideal farm type, characteristics of both the farm household and the farm production unit are determined (Daskalopoulou and Petrou, 2002). Although typologies are commonly based on wealth or resource endowment indicators, Tittonell et al. (2009) point out that including the dynamics of production orientation and livelihood strategies might improve the typology, depending on the objectives of the analysis.

Box 1 – The socio-ecological niche

Ojiem et al. (2006) developed the concept of the socio-ecological niche. This concept thrives on the same principle as the ecological niche where environmental stresses determine an organisms' habitat and functions in the ecosystem. Its added value lies in the inclusion of an additional variety of socio-economic factors that underline the role of human interest and society. The socio-ecological niche can be adapted and applied in many different contexts. In case of determining a socio-ecological niche for a legume technology in sub-Saharan Africa, there will be four main factors, namely (1) agro-ecological factors, which are the broad scale biophysical conditions such as soil type, precipitation, temperature etc. to which the legumes must be well adapted, (2) socio-cultural factors, such as group values, attitudes and norms, land tenure, labour organization, livelihood strategies, food habits etc, (3) economic factors such as land, financial capital, labour and input and output markets and (4) local ecological factors which are biophysical variables at the farm level such as soil nutrient deficiencies, soil acidity and moisture deficiency. Ojiem et al. (2006, pp 84) subsequently define the socio-ecological niche as 'A smallholder farmer environment fashioned by the interactions between assortments of biophysical and socio-economic factors and processes that facilitate functionality and presents to the smallholder the potential to attain desired production objectives'. In short, the socio-economic niche defines the boundaries for legumes within the existing farming systems. However, one needs to keep in mind that the niche may be dynamic since factors like fluctuating prices or changing policies can alter the boundaries.

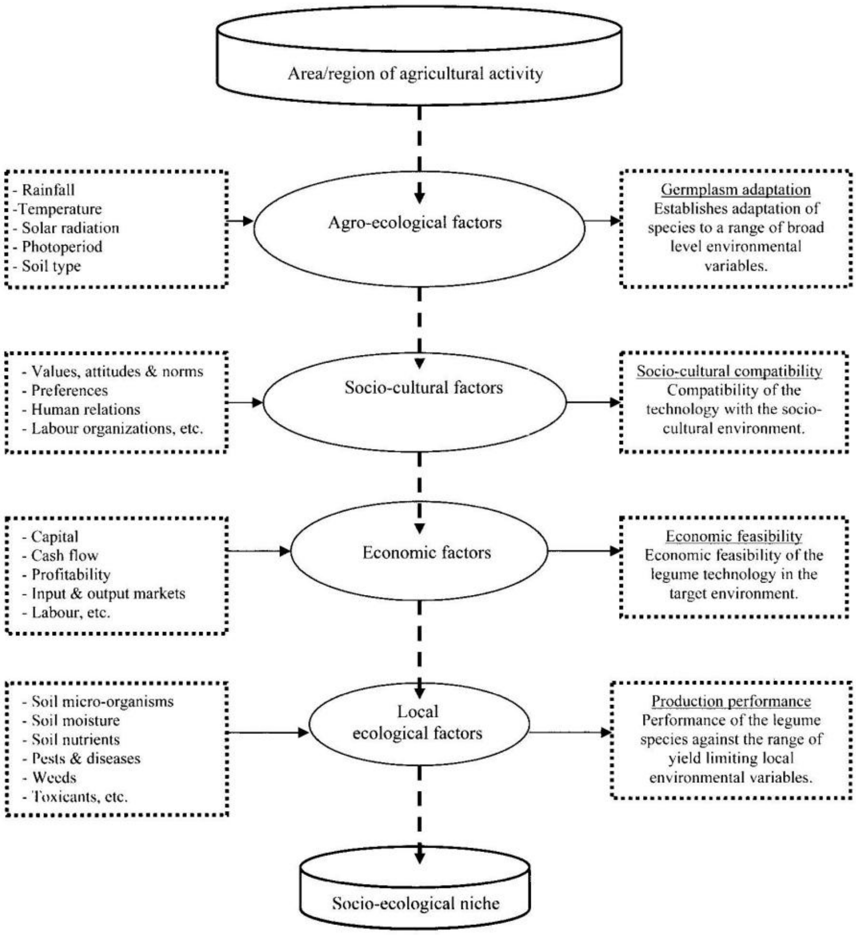

Figure 1. Socio-ecological niche model (Ojiem et al., 2006).

2.3 Research questions

Based on the available body of knowledge four main research questions were developed in correspondence with the objectives of the N2Africa project. The research questions were subdivided in several sub questions for which hypotheses were formulated.

1. In which aspects do smallholder farms in Malawi differ from each other and how can they be stratified into types?
    - It is hypothesised that smallholder farms in Malawi can be distinguished and stratified into types based on resource endowment, livelihood strategies and production orientation.

2. What is the current role of legumes in the Malawian farming system?

a. How is land allocated to legumes compared to the other cultivated crops?
    - It is hypothesised that legumes are allocated only very small proportions of the arable land on the least fertile plots far away from the homestead whereas the main staple food crop and the main cash crops are allocated the fertile home fields.

b. How are inputs (labour and nutrients) allocated to legumes compared to the other cultivated crops?
    - It is hypothesised that inputs are mainly allocated to the staple food crop maize and the major cash crops and that legumes receive only little labour inputs and no nutrient inputs.

c. How do legume yields relate to cereal yields?
    - It is hypothesised that legume yields are low compared to cereal yields.

d. What do legumes add to nutrition, household income and possibly soil fertility?
    - It is hypothesised that legumes currently add little to nutrition due to small amounts available. Legumes add little to household income because, besides the above named factors, they are mainly grown for home consumption. Finally, it is hypothesised that legumes add little to soil fertility because residues are usually not returned to the fields and because legumes are grown on poor fields which reduce the potential for effective BNF.

3. What are the possibilities for expanding legume production in Malawi?

a. What are the current farmer-perceived constraints concerning expanding legume production?
    - It is hypothesised that common constraints will include high establishment costs and low availability of inputs, low yielding capacity and low marketability and therefore competition with the main food and cash crops.

b. With what purpose would farmers like to increase legume production?
    - It is hypothesised that the main purpose or production objectives will be food or cash related rather than soil fertility related.

c. Are the biophysical characteristics of the soil suitable for making the expansion of legume production profitable?

- It is hypothesised that legumes are grown on low fertility fields which limit the amount of N_2 fixed from the atmosphere by legumes. If enriching soil fertility is a goal, legumes might not be very effective.

d. How is the availability of inputs?
   - It is hypothesised that inputs for legume cultivation such as seeds and chemicals are not widely available and often against erratic prices.

e. Can legume based farming systems be as profitable (nutrition wise and income wise) as non-legume based farming systems?
   - If legume yields are high enough to generate positive returns to inputs and land, and if their returns are compatible with the other crops, legume based systems can be as profitable as non-legume based farming systems.

4. How does the diversity among Malawian farmers influence the possibilities for expanding legume production?
   - It is hypothesised that differences in resource endowment, source of income and production objectives influence production constraints and objectives.

3. Materials and Methods

3.1 Site description

Figure 2. The research sites in Malawi.

The research was conducted in two different agro-ecological zones in central Malawi: the Mchinji district on the plateau (1000-1200 meters above sea level (masl)) and the Salima district on the lakeshore (500-800 masl) (Figure 2). Data was collected in a radius of 5 km around the village of Kachamba in Mchinji and in a radius of 5 km around the Chitala trading centre in Salima (Table 1).

The dominant ethnic group in central Malawi is the *Chewa,* to which the majority of the population of both locations belongs. Both sites have a similar population density and, due to land scarcity, fallow rotations are hardly used. In terms of biophysical similarities both Mchinji and Salima have a unimodal rainfall pattern with approximately 950 mm rainfall per year between December and April. However, Mchinji is situated more upland than Salima with a corresponding difference in temperature. Also, Salima has a shorter growing season due to a later onset of the rains in December and a higher mean temperature. In both locations local markets are nearby (1 – 8 km). However, urban markets are more difficult to access. Farmers practice a mixed crop-livestock system with maize as the major staple food crop. The other common crops include cotton, groundnuts, cowpea, tobacco and sorghum in Salima and tobacco, groundnuts and soyabean in Mchinji. Land preparation is entirely done by hand-hoe cultivation and usually ridges are made on which the crops are planted. Cattle and goats are the main livestock. During the day they are freely grazing on communal rangelands and on farmers' fields outside the cropping season. At night they are locked in kraals close to the homesteads.

Table 1. Characteristics of the research sites.

Variable	unit	Mchinji 13.75 S 33.04 E	Salima 13.66 S 34.27 E
Biophysical characteristics			
Altitude	masl	1117	578
Annual mean temperature [a]	°C	min 15.4 max 28.2	min 18.1 max 28.6
Total annual rainfall [a]	mm	952	946
Length growing period [b]	days	150-180	120-150
Topography		flat to undulating	flat to undulating
Dominant soil type [b]		latosols	calcimorphic
Socio-economic indicators			
Population density [c]	Inhabitants km^{-2}	100-250	100-250
Common farm size [d]	ha	0.5 – 1.5	0.5 – 1.5
Market access	hours	2-3	3-4
Ethnic group		Chewa	Chewa
Production			
Food crops		maize, groundnuts, soyabean	maize, groundnuts, cowpea
Cash crops		tobacco, groundnuts, soyabean	cotton, tobacco, groundnuts, sorghum

[a] World-Clim database measurements (1950-2000) via Hijmans et al. 2005

[b] Reynolds, 2000

[c] Franke et al., 2011

[d] Snapp et al., 1998

3.2 Initial farm selection & classification

An initial survey was conducted to identify different types of farmers with variation in resource endowment, production orientation and source of income. Basic household data from farmers participating in a soyabean agronomic trial from the International Institute for Tropical Agriculture Malawi (IITA) was already available for approximately 50 farmers in both Mchinji and Salima. Although this might generate a slight bias towards soyabean growing farmers in the total sample, the data was used to save time. The household data for these farmers was complemented with information on production orientation and income. In addition more than 100 mostly randomly chosen farmers were interviewed to supplement the initial sample. However, wealthy farmers were approached actively since they make up only a very small part of the population. The sample therefore does not truly represent national patterns in the statistical sense, but instead aims to include the various socio-economic situations.

In total 153 short structured interviews were conducted in which basic information on (1) household composition and education of household members, (2) land holding, (3) livestock ownership, (4) assets, (5) housing, (6) source of income and (7) production orientation was collected in order to stratify farms into types.

At both research sites there was an informant who knew the area very well and who functioned as a translator during the interviews. Together with the informants the criteria for grouping farmers into different wealth classes were identified. The variables arable land, livestock ownership, assets and quality of housing all functioned as wealth indicators. Based on these four indicators, the farms were divided in three wealth classes: low resource endowment (LRE), medium resource endowment (MRE) and high resource endowment (HRE). The classes were confirmed by the personal opinion of the interpreter and informant at the research site and functioned as the first criterion for the formation of the farm types. The second criterion was source of income, which could be generated on-farm, off-farm or both in different proportions. This resulted in five classes. The third and last criterion was production orientation, where farmers fell into four classes: producing for subsistence only, producing mainly for subsistence and less for the market, producing the same amount for subsistence as for the market and producing truly market oriented. Figure 3 schematically represents the manual construction of the five different farm types from the combination of the three main criteria. This stratification of the sample into farm types subsequently functioned as a tool for sampling the farms for the detailed system characterization.

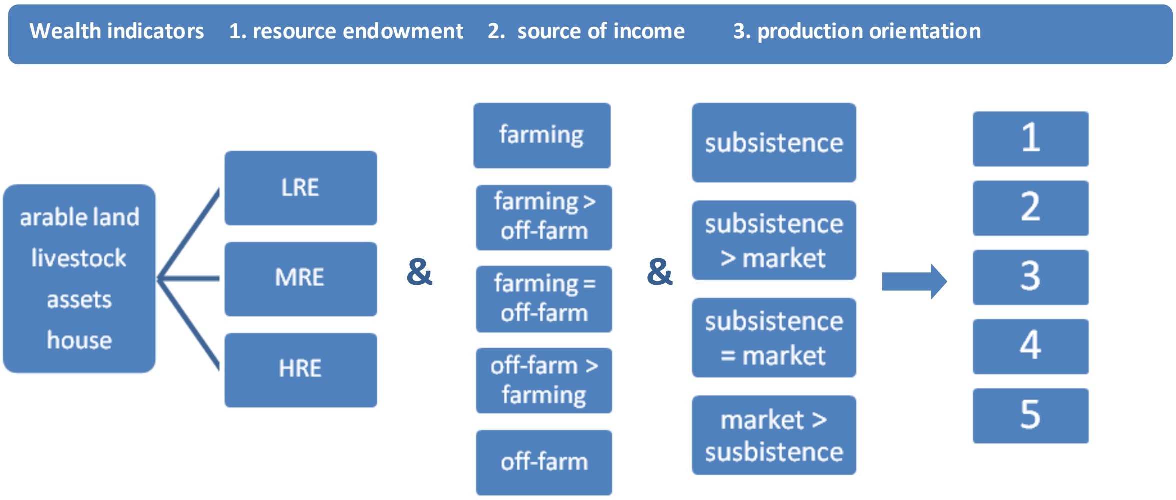

Figure 3. Construction of the farm types based on (1) resource endowment, (2) source of income and (3) production orientation.

3.3 Detailed farm characterization

Farm selection

From the initial sample, 30 farms were selected for detailed system characterization; 14 in Mchinji and 16 in Salima. The farmers were chosen such, that three of them represented each farm type for both sites. However, in the initial sample from Mchinji only two farmers belonged to the 4th type, causing the total number of farmers for this site to be 14. In Salima 16 farmers were chosen, because one farmer initially placed in farm type 1 was moved to another type based on newly acquired information. Therefore, an additional farmer from type 1 was included. Furthermore, per farm type, always one farmer was chosen that participated in a soyabean agronomic trial from IITA[2], either the 2010/2011 growing season

[2] Farmers could participate either in a crop management or nutrient management trial. In both cases they were asked to plant and manage 0.05 ha of their land with the provided seeds and nutrient inputs according to the instructions.

or the previous year's, to be able to view the agronomic research in the context of the wider cropping systems. The other farmers in the type had never participated in this trial. Within these boundaries, the farms were chosen randomly from the initial sample.

Main approaches

Two main approaches were used to assess the biophysical and socio-economic variables related to legume production. Field measurements were done to obtain actual farm sizes and the allocation of land to different crops as well as to obtain soil data. In addition, semi-structured interviews were conducted to obtain information on farm management and the socio-economic variables outlined below. Already in the beginning phase of this research it became clear that women usually have a lower status than men in rural Malawi and that this influenced the responses of women when interviewed in the presence of men. Therefore, women were interviewed separately from men wherever possible. Obtained information was usually cross-checked with another household member present or with the informant. Prior to the interview, permission to start the research was obtained from the farmer. The total characterization took approximately between 4 and 9 hours per farm, depending on the farm size, distance to and between the fields and complexity of the farm. Each farm was visited four times during the growing season of 2010/2011. For every visit, the author was guided by the local informant, who also functioned as an interpreter. However, final yield data were collected by Kondwani Khonje[3] since the author was not present in Malawi during the harvest period.

Semi-structured interviews

In the first part of the interview basic information about the village, household and cropping patterns was acquired. In addition, a schematic map of the farm including all fields and the crop rotation schemes was made together with the farmer.

During the second visit, for each crop a management table, amongst others including inputs and residue management, and an activities calendar, including time spent on each activity for each crop separately, was filled in. Furthermore, the fields were visited and farmers were asked to rate the fertility of the different fields and basic information on slope, drainage and soil type was recorded. Also, the area of each field was measured either by walking around the field with a geographical positioning system (GPS), or by counting 1 meter steps around the field when it was too small for the GPS to estimate the area correctly. The gardens, small plots located in the low lying areas next to a river bed, locally called *dambos*, were excluded from this study because no main crops were produced here and the plot sizes were usually very small compared to the fields.

The third visit started with acquiring information on the livestock, grazing and the collection and production of animal and compost manure. Subsequently, farmers were asked more detailed questions about their incomes and expenditures on farming as well as

[3] As part of an internship from Wageningen UR.

their yield variations for the different crops. Finally, the farmers were asked several questions regarding legume expansion and their own experiences, possibilities, attitudes and constraints.

At the end of the growing season, the farmers were visited a last time to collect the harvest data from the 2010/2011 growing season.

Soil sampling and analyses

Fields were selected for soil sampling based on the representative crop or crop rotation scheme for that field and soil fertility as classified by the farmer. This resulted in one, two, three or four selected fields per farm, depending on the number of fields belonging to a farm and the variety therein. The aim was to cover the variability in soil fertility as much as possible.

Sampling was done in December, at the beginning of the growing season. Within the selected fields for sampling, soil samples (0 – 20 cm) were taken with a soil auger at 10 random points per field. Areas of discontinuity such as termite mounds were avoided. The subsamples were mixed thoroughly and combined into a composite sample of approximately 1 kg per field. The samples were air-dried and sieved through 2 mm and approximately 0.25 kg of each sample was send to the Soil Productivity Research Laboratory (SPRL) in Zimbabwe for soil analyses. There, pH (water), total % N (Kjeldahl digestion), %C (Walkley-Black), available P (Olsen), CEC (extraction with ammonium acetate), K, Ca, and Mg content (atomic absorption spectrophotometry) and texture (Bouyoucos) were determined.

2.4 Data handling and analyses

General remarks

Both quantitative data and categorised open ended questions were entered in Microsoft Excel. For most data presented in tables, the standard errors of mean (SEM) or the range of values (min-max) are given in parenthesis behind the average. In graphs, error bars represent the SEM.

In Salima all soyabean was cultivated within the earlier named trials. Therefore, the management of soyabean in Salima was not accounted for in this research and the yields obtained were only used to demonstrate the difference between yields obtained in trials and yields obtained without the trial context and not included in any further analyses. The farmers who participated in the same trial the previous year did not cultivate soyabean anymore. In Mchinji, all the farmers that for the 2010/2011 cropping season participated in those trials also cultivated their own soyabean. Also here, trial related management and yields were not included in the analyses. However, soyabean trial plots were included in the evaluation of land use patterns, since it had been farmers' own choice whether to participate in the trial or not.

Socio-economic evaluation

Land/labour ratios were determined by dividing the farm size by the amount of family labour available on the farm. Children who worked on the farm outside school hours counted half. Adults with an illness or working part-time on the farm due to illness or any other reason were also included as half.

Total farm income was calculated for each farm individually as the sum of total cropping income, total income from livestock and total income from off-farm activities over the year 2010. Also the relative contributions of crops, livestock and off-farm activities were calculated for each individual farm. The average values per farm type were obtained by aggregating the total yearly incomes as well as the total amounts originating from crops, livestock and off-farm activities from all farms within a type and within a location. Subsequently the average relative contributions of the different income sources as well as the average yearly income were calculated. Expenditures made on farming were not subtracted from cropping income, since the data comprised two different years. However, if farmers had a business, only the profit was included in the yearly income.

Land use patterns

An overview of the arable land use in both locations was made by adding up the total cultivated area of all farms, adding up the total area per crop and calculating the share of the total area allocated to the respective crops in the total cultivated area. Land allocation per farm type was calculated by the same method.

Soil parameters

Except for pH, which was taken from Hungria and Vargas (2000) the critical values of several soil parameters affecting productivity were taken from Snapp (1998) (Table 2). Although they were actually based on maize, they could also be used as critical values for legume production. Only P requirements were higher for legumes (Snapp, 1998). The optimum pH levels for rhizobial growth, and therefore successful symbiosis with the legume host, were between 6.0 and 7.0. Only a few rhizobia grow well with a pH lower than 5.0 (Graham et al., 1994).

Table 2. Critical values of soil parameters for maize production in Malawi (after Hungria and Vargas, 2000; Snapp, 1998).

Parameters	pH	sand	C	P	K	Ca
Critical value	6.0 -7.0 (optimum)	max 85 %	min 0.8 – 1.0 %	min 0.042 cmol/kg	min 0.2 cmol/kg	min 0.2 cmol/kg

Inputs

The amount of labour allocated to each crop was calculated by adding up the hours spent on each activity for each crop separately as given by the farmer. Multiplying these numbers with the corresponding area gave labour in person hours/ha for each crop for each farm. Post-harvest processes (e.g. shelling, drying) were not included because (1) at the time of asking farmers did not know the quantity of their yield and therefore not the time needed for these processes and (2) post-harvest processes are usually done throughout the year, making it almost impossible for farmers to give a good estimation of the amount of time spent.

Nutrient inputs were derived from the respective compositions of the different fertilizer blends used and average values of N and P in kraal manure and compost manure. Although the quality of manure is highly variably depending on source, diet and storage (Mafongoya et al., 2006), animal manure was assumed to have 1.13% N and 0.19% P (Paul et al., 2009). For compost manure, specific data were available for both locations: 0.139% N and 0.016% P for Mchinji and 0.350% N and 0.017% P for Salima (unpublished data, IITA Malawi). Calculations were restricted to N and P since earlier studies proved that K is usually present abundantly in Malawi (Snapp 1998). Quantities of manure were expressed in oxcarts or bags, which were assumed to contain 360 kg or 50 kg respectively. Bags of fertilizer contained 50 kg.

Yields

Yields only included grain yields. Leaves of for example cowpea eaten throughout the season were not included. Farmers reported yields based on actual weights or in local units, such as bags, bales, tins, pails and oxcarts. These were converted into SI units (Table 3). Maize and groundnut yields were usually reported unshelled. Yield of soyabean, bean and cowpea were usually reported threshed and shelled. Unshelled yields were converted to actual grain weights (Table 4). In case farmers obtained yields of the same crops from different fields, they were aggregated per crop to obtain the total yield per farm. However, when soil parameters were linked to yield, the data from the different plots within the same farm were analysed separately.

To compare maize yields in different rotation schemes the average maize yield data were used from plots with a maize-maize sequence, a legume-maize sequence, a tobacco-maize sequence or a cotton-maize sequence.

Table 3. Conversion table for local units to kg.

Local unit	Maize unshelled	Maize shelled	Groundnuts unshelled	Beans/soybean/cowpea threshed	tobacco	cotton
Oxcart	1000 kg					
Bale					100 kg	100 kg
Bag		50 kg	22 kg	50 kg		
Pail/tin		20 kg		16 kg		

Table 4. Conversion factors to calculate actual grain yield from unshelled reported yields.

crop	Conversion factor
Maize	0.36
groundnuts	0.44
Soyabean, beans, cowpea	0.70 [a]

[a] value obtained at Chitedze research station Malawi for 2010/2011 cropping season. Other values were derived from Table 3.

Food security

For the determination of food security, the total grain yields were divided by the number of adults eating in the household. Children (<15 years) were counted as half, children attending boarding schools were excluded and contracted labourers were included for the number of months they worked on the farm and ate in the household. Households were indicated as food secure when domestic food production exceeded the minimum daily energy requirement of 2250 kcal person^{-1} and 48 g protein person^{-1}. The latter was based on the minimum daily protein requirement of 0.8 g/kg body weight (Trumbho et al., 2002) and an average body weight of 60 kg. Nutritional values used of the different crops are given in Table 5.

Table 5. Energetic value and protein content of the commonly cultivated cops.

Crop	Energy (kcal/100 g)	Protein content
maize	342	9% [a]
groundnut	570	26% [b]
soyabean	446	36.5% [a]
cowpea	550	25% [a]
common bean	333	22.5%

[a] IITA
[b] ICRISAT

Economic evaluation

Input costs were separated in hired labour, family labour and purchased inputs such as fertilizer, seed, chemicals etc. Although casual labour was paid by the job rather than per hour, its average value was approximately the same for both locations (1.33$ for 6 hours) and was used to calculate opportunity costs for family labour. Hired labour costs were farm specific, mainly depending on whether labourers worked contracted or casually. Costs of purchased inputs were also farm specific, depending on amount of inputs purchased and whether or not fertilizer was subsidized (6.7$ for both 50 kg of urea and 50 kg of NPK (23:21:0) when subsidized versus approximately 67$ for 100 kg of unsubsidized fertilizer). The values of a farmer's yields only depended on the height of his or her 2010/2011 cropping season yields. Average grain prices of 2010 and 2011 (Table 6) were used to calculate grain values with two price scenarios, since no individual prices were known for 2011 and not every farmer sold his or her product in the previous year. All costs and yields were converted to area bases and all monetary values were converted to US$ at the prevailing exchange rate of 1 US$ = 150 MKw. Net benefits per individual farm were calculated to obtain the minimum and maximum net benefits for each crop, to reflect the variability in net benefits based on yield and investments. Average net benefits of each crop with the two different price scenarios were calculated to average farmer specific costs and grain values. Data from both locations were analysed separately.

Table 6. Grain-prices used to calculate economic net returns to land and inputs.

	Mchinji		Salima	
	Market grain-price 2010 ($/kg)[a]	Market grain-price 2011 ($/kg)[b]	Market grain-price 2010 ($/kg)	Market grain-price 2011 ($/kg)
Maize	0.16	0.12	0.15	0.12
Tobacco	1.58	0.8	2.04	0.8
Groundnuts [c]	0.48	0.29	0.31	0.40
Soyabean	0.25	0.7	na	0.53
Beans	1.33	1		
Cotton			2.00	1.13
cowpea			0.93	0.47

[a] 2010 grain prices were obtained by averaging the prices received by the individual farmers for both locations respectively.

[b] except for tobacco, 2011 grain prices were the farm-gate prices of May-June 2011 as reported by the local informants for both locations respectively. Tobacco prices were auction floor prices.

[c] grain-price for groundnuts was converted to shelled product price

Farmer objectives and constraints

Criteria for production objectives and constraints were individually agreed upon by farmers. Similar answers were categorised. The criteria were generally similar across the locations and have therefore been aggregated during analyses.

Statistical analyses

Statistical analyses were performed in the software package SPSS. To reduce the amount of variables and determining underlying patterns which explain the observed variance, factor analyses were performed on the numerous socio-economic characteristics obtained in the detailed system characterization. This was also used as a validation for methods used to stratify farms into socio-economic types. General correlations between the majority of the obtained socio-economic, biophysical and agrological factors were detected with Spearman's correlation tables. Analyses of variance (ANOVA) were used to detect statistically significant differences between different farm types and maize yields of different rotation schemes.

4. Results

4.1 Farm typology

The stratification of farms based on wealth and production criteria resulted in a typology with five farm types (Table 7), similar to the one developed by Tittonell et al. (2005a). Although the typology was the same for both regions, relative wealth was different for both locations. Overall, the farmers in Mchinji had more assets and owned more livestock than the farmers in Salima. Also, in Mchinji, more farmers lived in a brick house than in Salima, where most of the farmers lived in houses with earth walls. However average farm size was comparable and in both regions the majority of the farms fell in the 2nd or the 3rd type (Table 8). However, this distribution of farmers does not represent national statistical figures, since some of the high resource endowed farmers have been approached actively. This implies that type 4 and type 5 farms are present even less abundant than indicated by these figures.

Table 7. Description of the farm types based on the main criteria considered for their categorization (adjusted from Tittonell et al., 2005a).

farm type	wealth class	production orientation	main source of income
1	LRE	self-subsistence	casual labour
2	LRE	self-subsistence	little farm produce and/or small services
3	MRE	self-subsistence and (low-input) market orientated	little farm produce and/or other small enterprises
4	HRE	market-oriented	cash crops and other farm produce
5	Mainly HRE, some MRE	self-subsistence and market	salary from a job, farm surpluses and sometimes cash crops

Farms of type 1 were LRE small-scale farms where one or more family members worked casually for other farmers to generate additional income and food. Farms of this type hardly owned assets like radio's or bicycles and, except for some chickens and the occasional goat, usually did not own livestock. Furthermore, the household head had received only little formal education. Remarkable is that farms of this type in Mchinji were substantially poorer than in Salima.

Farms of type 2 were in Salima in terms of resource endowment mainly similar to type 1 and in Mchinji less poor than type 1 farms. These farms did not depend on casual labour but had some small temporary businesses (e.g. brewing local beer, trading vegetables or repairing bicycles) and were sometimes able to sell a little farm produce. Also, they owned more livestock (usually chickens and sometimes a goat). The household head had received in general more years of education than the household heads of type 1 farms.

Farms of type 3 were mainly MRE. Income was usually generated through a combination of farm surpluses and small enterprises that generated more income than those found in type 2 (e.g. carpenter or witchdoctor). Houses were usually in a somewhat better state with more often brick walls instead of earth walls and sometimes iron sheets instead of a thatched roof. Also, the total value of assets and livestock was higher.

The HRE farms of type 4 had typically large land holdings, larger livestock (e.g. cows) and a wide range of assets including furniture and sometimes even a car. The houses were larger with iron sheets as roof, brick or cement walls and windows with glass. The farmers of this type usually owned some larger livestock (e.g. cows) and produced for markets. Most of the farms within this type relied on hired labour in cases where the children studied or for the labour intensive activities such as field preparation and harvesting. Some farms also had other enterprises such as renting out houses, but still generated the largest part of their income on-farm. Although all these farms were relatively HRE, there were large differences in actual resource endowment in farms of these types as is reflected by the high standard errors of mean for farm size and value of livestock and assets.

Although on average lower than type 4 farms, the majority of type 5 farms were also HRE. Typically, one of the household members worked outside the farm and earned a fixed monthly salary. These farms sometimes owned some larger livestock too since the animals can be used to accumulate wealth. Household heads from the farms falling in type 4 or 5 had received on average more years of education than the household heads from the farms falling in type 1 – 3.

Table 8. Average values with SEM and descriptions of socio-economic indicators for the different farm types.

	farm type	n	Age HH[a] (years)	Education HH (years)	Family size	Farm size[b] (ha)	Cultivated area (ha)	total value livestock[c] ($)	total value assets[d] ($)	house	source of income	production orientation
Mchinji	1	4	49 (7)	0.50 (0.50)	5.75 (0.48)	0.51 (0.12)	0.51 (0.12)	0 (0)	38 (21)	wall: earth/bricks roof:thatched floor:earth	off-farm	subsistence
	2	20	36 (4)	5.15 (0.95)	4.70 (0.56)	1.30 (0.17)	1.24 (0.18)	130 (54)	89 (19)	wall: bricks/earth roof:thatched floor:earth	mixed	subsistence + low market
	3	38	45 (2)	6.49 (0.53)	5.71 (0.34)	2.56 (0.52)	1.85 (0.18)	679 (317)	160 (16)	wall: bricks/earth roof:thatched/iron sheets floor:earth/cement	mixed	subsistence + low market
	4	2	45 (8)	6.00 (2.00)	9.00 (3.00)	7.00 (3.00)	3.84 (3.80)	22628 (21185)	20407 (20039)	wall:bricks/cement roof:iron sheet floor;cement	on farm>off farm	market
	5	6	58 (5)	8.33 (2.03)	7.17 (1.35)	4.43 (1.27)	3.30 (0.51)	3464 (1722)	1322 (999)	wall:bricks/cement roof:iron sheet/thatched floor:cement/earth	off farm>on farm	subsistence + low market
	average	70	44 (2)	5.91 (0.43)	5.79 (0.27)	2.33 (0.31)	1.95 (0.18)	1306 (648)	764 (572)			
Salima	1	7	44 (7)	2.86 (1.39)	5.14 (1.18)	1.32 (0.33)	1.01 (0.19)	28 (17)	92 (45)	wall: earth/bricks roof:thatched floor:earth	off farm	subsistence
	2	28	40 (3)	6.18 (0.62)	4.54 (0.38)	1.36 (0.17)	1.21 (0.10)	41 (12)	49 (9)	wall: earth/bricks roof:thatched floor:earth	mixed	subsistence + low market
	3	27	43 (3)	5.59 (0.78)	5.70 (0.38)	2.74 (0.38)	1.94 (0.19)	255 (54)	133 (16)	wall: earth/bricks roof:thatched/iron sheet floor:earth	mixed	subsistence + low market
	4	4	49 (5)	9.25 (1.70)	5.00 (1.08)	11.10 (3.32)	6.00 (0.82)	953 (344)	978 (524)	wall:bricks roof:thatched/iron sheet floor:earth/cement	on farm>off farm	market
	5	5	38 (6)	8.40 (2.20)	5.40 (0.75)	1.53 (0.31)	1.53 (0.31)	921 (713)	309 (181)	wall:bricks roof:thatched/iron sheet floor:earth	off farm>on farm	subsistence + low market
	average	73	41 (2)	6.03 (0.44)	5.08 (0.24)	2.37 (0.32)	1.73 (0.15)	223 (58)	152 (36)			

[a] HH = household head.

[b] farm size and cultivated area are farmer estimates.

[c] including poultry, pigs, goats and cattle.

[d] including farming tools, oxcart, wheelbarrow, radio, mobile phone, television, bicycle, car.

4.2 Detailed system characterization

4.2.1 Socio-economic characteristics

Most households targeted for detailed system characterization were male headed, except for a few ones of the 1^{st} and 3^{rd} farm type. The largest households were observed within farm type 4. Often, these included children from multiple wives and/or grandchildren as well as contracted labourers. Age of the household head varied, but the majority of the households with a young household head (20-30 years) fell into the 2^{nd} and 3^{rd} type. Also, these farms had, respective to their total household size, the highest numbers of (young) children in their families.

In Mchinji schooling of the household head generally increased with resource endowment. In a Spearman's correlation table the years of schooling of the household head showed a correlation with farm type and total income (p=0.05). Education of women was also significantly correlated with farm type (p=0.05) and total income (p=0.01). Although not significant, these relations were also observed in Salima. Generally, males had received longer education than females. All children in the category 5 – 15 years received at least some education. A minority of these children did not attend school anymore to be able to work on the farm. The majority, however, was still attending local schools. A small part, restricted to farm type 4 and 5 in Mchinji, attended urban boarding schools. Resource endowment thus seemed to have an important influence on both length and type of schooling.

Table 9. Household composition and education. Average values per farm type from the farms targeted by detailed system characterization.

	farm type	n	gender HH [a]	age HH (years)	schooling HH (years)	Size HH (tot) [b]	Males	Schooling males (years)	Females	Schooling females (years)	Children 5-15 years	Children < 5 years
Mchinji	1	3	male	52	0.67	5.67	1.33	1.33	1.00	0.33	2.67	0.67
	2	3	male	27	5.00	4.33	1.00	5.00	1.00	5.00	1.00	1.33
	3	3	male and female	39	6.33	3.67	1.00	8.33	1.00	4.00	1.33	0.67
	4	2	male	46	6.00	10.50	1.50	6.00	2.00	5.00	5.50	1.50
	5	3	male	48	8.67	9.00	3.67	8.00	2.67	8.00	2.33	0.33
Salima	1	3	male and female	47	5.00	3.67	1.33	3.75	1.33	5.17	1.00	0.33
	2	3	male	43	7.50	5.50	1.00	7.50	1.00	2.00	2.50	1.00
	3	4	male	37	9.00	4.80	1.00	9.00	1.20	8.00	1.80	0.80
	4	2	male	45	10.67	8.00	2.33	11.67	2.67	8.67	2.33	0.67
	5	4	male	41	6.00	5.67	1.33	5.00	2.00	6.50	1.33	1.00

[a] HH = household head

[b] Including all the people who live and eat in the household. Children attending boarding school were therefore excluded from this number and contracted labourers were included for the number of months they worked for and ate in the household.

In Mchinji, type 4 and 5 farms had relatively large land holdings, whereas the majority of the lower resource endowed farms had larger farms in Salima. This was in line with the observations made during the development of the typology. The land/labour ratios depended on available labour and farm size and were therefore variable between farm types and between locations. LRE and MRE farms usually had lower land/labour rations than HRE farms. However, land/labour ratios of especially the market oriented HRE type 4 farms were highly variable, due to high variability in farm and family sizes and depending on whether children were attending urban boarding schools or local schools.

Table 10. Average farm sizes and land/labour ratios with SEM per farm type.

	Mchinji				Salima			
farm type	farm size (ha)		Land/labour ratio (ha/person)		farm size (ha)		Land/labour ratio (ha/person)	
1	0.53	(0.024)	0.19	(0.003)	0.57	(0.271)	0.23	(0.136)
2	0.51	(0.146)	0.23	(0.060)	1.34	(0.135)	0.51	(0.127)
3	1.31	(0.510)	0.52	(0.127)	0.90	(0.138)	0.35	(0.034)
4	6.92	(4.080)	3.46	(2.040)	4.49	(1.490)	1.34	(1.489)
5	2.80	(1.043)	0.61	(0.183)	1.30	(0.310)	0.50	(0.345)

Both LRE and MRE farmers had a low combined yearly income compared to the HRE farmers (Table 11). Type 1 farms earned the largest part off-farm, by working casually for wealthier farms. Farms of type 2 and also the medium resource endowed farms of type 3 had very mixed sources of income, although type 3 farms usually generated more income off-farm through a variety of small businesses and services. Type 4 farms had a high yearly income of which the largest part originated from cropping. Finally, farms of type 5 generated the largest part of their income off-farm with a household member having a contracted job. Farmers of type 5 in Mchinji often had higher waged jobs like extension worker or teacher than in Salima, where people worked as guard or tailor. The remaining household members worked on the farm and usually generated some extra cash by selling crops. Although farms of type 5 still had a relatively high yearly income, in the majority of the cases it was considerably lower than for the type 4 farms. Livestock generally only contributed very little to the yearly incomes of the Malawian smallholder farmers.

Table 11. Average yearly income in $ and its proportional distribution between crops, livestock and off-farm sources per farm type over 2010.

	Mchinji				Salima			
farm type	average total income	crops	livestock	off-farm	average total income	crops	livestock	off-farm
1	173	4%	0%	96%	287	20%	8%	72%
2	404	64%	22%	15%	328	32%	0%	68%
3	492	21%	2%	76%	359	25%	1%	74%
4	14643	74%	0%	26%	16000	97%	1%	2%
5	2493	42%	9%	49%	1478	5%	2%	92%

Although some LRE farmers of type 1 earned a reasonable part of their (very small) cropping income with groundnuts and maizre, in Mchinji 93% of the total cropping income was generated by tobacco. In Salima, groundnuts generally accounted for the largest contributions to total cropping income. Tobacco and cotton had a much lower share. If farmers cultivated soyabean, cowpea or beans, these occasionally contributed much to the total income from cropping in a household.

Table 12. Average cropping income and its proportional distribution between the different crops per farm type over 2010.

	Mchinji						Salima						
farm type	Cropping income ($)	maize	tob [a]	gnuts	soyabean	beans	Cropping income ($)	maize	tob	gnuts	cotton	sorg	cowpea
1	6	46%		54%			56	0%		61%			39%
2	257	5%	79%	2%	14%		133	6%	13%	29%	51%		
3	106	5%	82%	13%			82	25%		75%			
4	10880	2%	98%	0%	0%		10436	3%	23%	54%	1%	2%	17%
5	1042	24%	61%	8%	1%	6%	45	17%		83%			

[a] tob=tobacco, gnuts=groundnuts, sorg=sorghum

Although the samples farms showed differences in resource endowment, distribution of cropping income and off-farm income opportunities, factor analyses revealed that the variability between the farms in both locations could be largely explained by three components. These components explained 84% of the variance among the Mchinji farms and 70% of the variance among the Salima farms. The component that explained most of the variance in both Mchinji and Salima contained the variables farm size, income, land/labour ratios, off-farm income and production orientation and in Mchinji also value of assets (Table 36 in Appendix II). The second component in Mchinji and the third component in Salima expressed the contribution of educational variables to the total variance. The third component in Mchinji and the second component in Salima had a different composition for both areas.

Based on these outcomes, it can be concluded that wealth indicators as farm size, value of assets and income explain most of the socio-economic variety. Factors as household composition, education, production orientation and source of income explain the remaining majority of the variance. The criteria used for development of the typology were therefore mainly effective in capturing the enormous variety. However, in Salima value of assets alone did not explain the variety in resource endowment. This underlines that resource endowment should be based on several indicators, as was done during the construction of the typology. Preferentially, income should also be included as a wealth indicator. However, total yearly income is rather difficult to estimate during a rapid survey whereas arable land and assets are easier to indicate. Whereas education also explained a large part of the observed variety, it was not included in the formation of the typology. Yet, education was correlated to resource endowment and was thus indirectly also accounted for in the typology.

4.2.2 The cropping system

Production patterns

In both locations, maize was the dominant crop (Table 13). In Mchinji tobacco came at a second place in terms of both adoption by farmers and allocated area, followed by groundnuts, soyabean and lastly beans. In Salima, the second most popular crop was groundnuts, followed by cotton, cowpea, tobacco and finally soyabean and sorghum. Also farmers always ranked maize as the most important crop on their farm. If tobacco was grown, it came second, followed by groundnuts. Cotton, soyabean, beans and cowpea always came last.

Although the average cultivated area was larger in Mchinji, the cropping system in Salima was more diverse. Here, relatively less area was allocated to maize and more to groundnuts. In addition, whereas in Mchinji tobacco was the single real cash crop, in Salima there was a higher diversity in cash crops, namely cotton, tobacco, sorghum and groundnuts. However, the proportion of the cultivated area allocated to non-edible cash crops was equal at both locations.

Table 13. Overview arable land use Mchinji and Salima. Minimum and maximum values are given in parentheses.

	Mchinji (n=14)		Salima (n=16)	
crop	% farmers growing	Proportion of cultivated area (%)	% farmers growing	Proportion of cultivated area (%)
maize	100	69 (39 - 100)	100	46 (12 - 100)
tobacco	71	17 (0 - 55)	19	12 (0 - 43)
groundnuts	57	10 (0 - 28)	75	24 (0 - 59)
Soyabean [a]	36	3 (0 - 44)	19	1 (0 - 4)
cotton	0	0	38	13 (0 - 39)
sorghum	0	0	6	2 (0 - 25)
cowpea	0	0	31	3 (0 - 19)
beans	7	1 (0 - 4)	0	0

[a] All the soyabean cultivating farmers in Salima participated in a trial. In Mchinji farmers cultivated soyabean without participating in a trial or cultivated more than only the area for the trial.

Maize was grown across all farm types and the majority of the farmers allocated it the largest proportion of their cultivated area (Figure 4). Although farmers of the 1st, 2nd and 3rd type occasionally sold a small amount of maize within the village, only the larger-scale farmers of type 4 and sometimes 5 considered maize to be a cash crop besides being the main food security crop. The cash crops tobacco, cotton and sorghum were mostly grown by the market oriented farmers of type 4, who allocated these crops relatively large areas. Only small areas of cash crops were grown by the farmers of the other types.

Groundnuts were grown across all farm types, especially in Salima. In some cases, groundnuts were considered as a cash crop only, but most farmers cultivated groundnuts for both home consumption and income. Generally, groundnuts were eaten as snack, as ‘relish’ (the side dish next to the maize porridge), or ground to flour to mix with maize flour for the morning porridge. Soyabean, cowpea and beans were cultivated very little compared to the other crops and fullfilled roles in both home consumption and generating cash. Beans and cowpea were eaten as relish and soyabean was also ground to flour.

Both in Salima and Mchinji, type 1 farms showed the least crop diversity (Figure 4). Some of these farmers did not cultivate any other crop besides maize. Relative diversification however, did not necessarily increase with cultivated area. Despite large land holdings, type 4 farms in Mchinji for example showed approximately the same relative distribution of land to crops as the type 1 farms in that regions. In Salima almost all farm types showed more crop diversity than their equivalents in Mchinji. However, for both locations cowpea, soyabean and beans still comprised only a very small part of the area, even in farms showing a relatively high degree of crop diversity. Although in both regions the farms that allocaced their whole farmland to maize were small-scale and LRE farms, general cropping patterns were considered more dependent on region than on farm type.

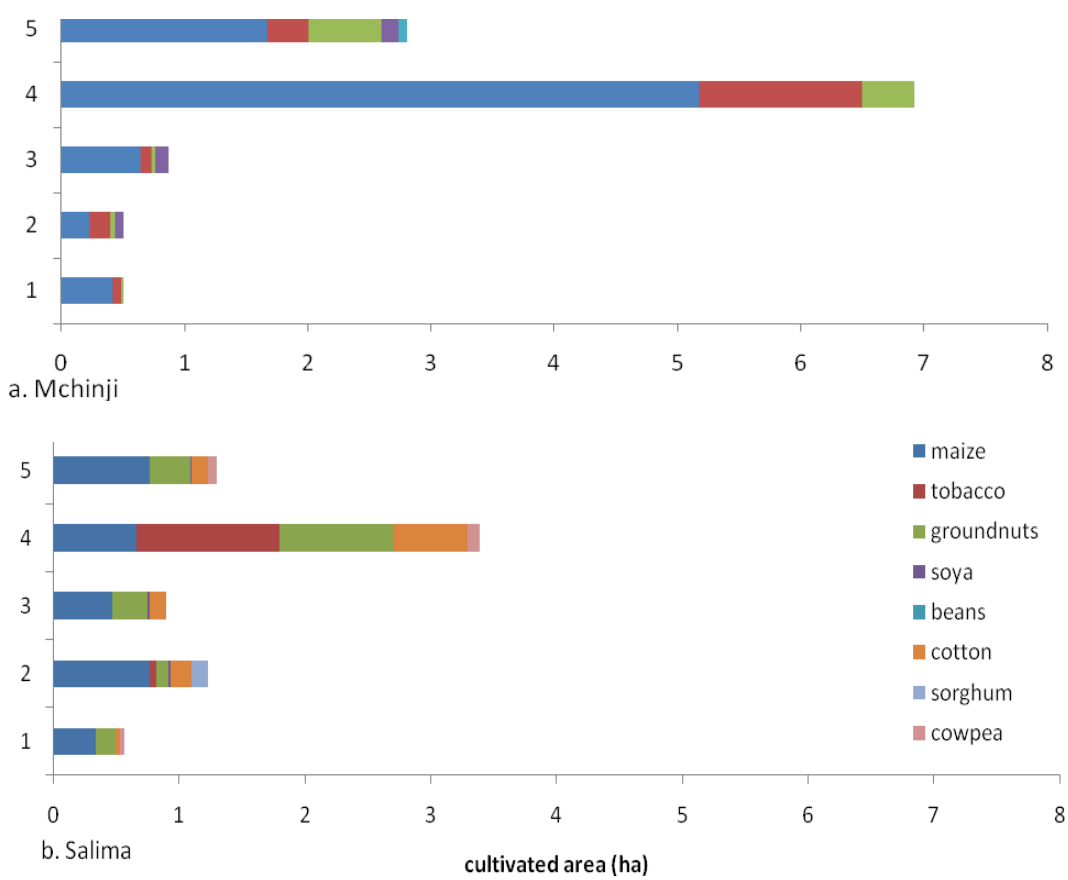

Figure 4. Average land allocation to the different crops per farm type for (a) Mchinji and (b) Salima.

Field descriptions and layout

In both locations, soils were predominantly sandy (Table 15) and the majority of the farmers indicated that infiltration rates were high on their fields. Only a few farmers mentioned erosion due to high run-off rates as a problem. Average pH was lower in Mchinji than in Salima, but was in none of the locations considered below any critical values for maize or legume production. Available P was highly variable among fields with average values below the critical value of 0.042 cmol/kg at both locations. However, there were fields that had P concentrations above the critical value. Compared to available P, total N varied only little among fields. In Mchinji the average value of K was just below the critical level of 0.2 cmol/kg. In Salima the average value was much higher. However, in both locations the variability of K was very high, implying that in both regions there were fields with values far below the critical value as well as with values multiple times higher the critical value.

Average Ca values were highest in Salima, but for both locations well above the critical value (0.2 cmol/kg). In Salima even the lowest value measured exceeded the critical value. In Mchinji, the lowest value was just below the critical value. The lower K, Ca and Mg values for Mchinji corresponded with the lower CEC for this region. In Salima, average CEC was more than two times higher.

From all the soil parameters, only available P in Mchinji correlated with assets and number of livestock in a Spearman's correlation table (p=0.05). Accordingly, available P was statistically significant lower in type 1 and 3 farms than in type 2, 4 and 5 farms (ANOVA). No further relevant correlations between soil parameters and socio-economic indicators were found.

Land holding patterns varied from farms equipped with a single field adjacent to the homestead to farms having their fields all scattered and far away (0.5 – 3.5 km). Farmers could also have one or more relatively close (0 – 0.5 km) field combined with one or more fields far away. In case farms owned only one field, it was usually subdivided in several plots on which the different crops were cultivated. Except for tobacco, which was usually grown closest to the homestead, farmers did not preferentially allocate fields to different crops based on distance from the homestead. The hypothesised gradient in soil fertility as a function of distance from the homestead was not observed either. Some farmers even considered the field with the largest distance from the homestead as their most fertile one.

Although most crops were part of a crop rotation scheme, farmers generally classified their 2010/2011 maize and tobacco fields on average as slightly more fertile than the groundnut, cotton and cowpea fields. Comparing average soil parameters for different fields showed that tobacco was in both locations cultivated on the fields containing the highest organic C concentrations (Table 15). Legumes were generally cultivated on less fertile fields with lower concentrations of organic C, K, Ca and Mg. In Salima legume fields were notably lower in P than the other fields.

Table 14. Distribution of plots with different rotation schemes of current maize fields (numbers represent % of the total number of fields).

	continuous maize	legume rotation	other rotation [a]
Mchinji	33%	17%	50%
Salima	22%	43%	13%

[a] Other rotation usually meant tobacco in Mchinji, and cotton, tobacco or sweet potatoes in Salima.

Table 15. Average values of soil parameters per location and per field with the respective crop types. SEM in parentheses.

Mchinji	n [a]	rating [b]		distance [c] (km)		pH		C (%)		N (%)		P (cmol/kg)		CEC (cmol/kg)		Ca (cmol/kg)		Mg (cmol/kg)		K (cmol/kg)		sand (%)		clay (%)		silt (%)	
all fields	39	2	(0.06)	0.9	(0.11)	6	(0.07)	0.69	(0.032)	0.099	(0.004)	0.023	(0.004)	4.8	(0.4)	0.87	(0.09)	0.44	(0.03)	0.18	(0.04)	77	(1.2)	14	(0.9)	9	(0.5)
fallow	1	3		0.6		5.9		0.248		0.082		0.005		4		0.20		0.25		0.10		92		4		4	
maize	24	1.9	(0.08)	0.9	(0.14)	5.9	(0.09)	0.694	(0.036)	0.098	(0.004)	0.025	(0.006)	4.9	(0.5)	0.88	(0.11)	0.44	(0.04)	0.20	(0.06)	77	(1.4)	14	(1.1)	9	(0.6)
gnuts	5	2.1	(0.23)	1.5	(0.32)	6	(0.24)	0.608	(0.117)	0.088	(0.014)	0.023	(0.010)	4.8	(1.4)	0.66	(0.22)	0.35	(0.07)	0.12	(0.02)	78	(5.0)	11	(3.3)	10	(2.5)
tobbaco	6	1.9	(0.14)	0.7	(0.22)	6	(0.09)	0.822	(0.061)	0.108	(0.010)	0.021	(0.009)	4	(0.7)	0.99	(0.13)	0.51	(0.05)	0.15	(0.03)	71	(1.8)	20	(1.3)	10	(1.2)
soyabean	3	1.8	(0.2)	1	(0.56)	6.1	(0.23)	0.682	(0.181)	0.106	(0.028)	0.013	(0.003)	6	(2.0)	1.17	(0.61)	0.52	(0.19)	0.28	(0.12)	78	(4.6)	15	(3.5)	7	(1.3)
Salima																											
all fields	41	1.9	(0.08)	0.8	(0.1)	6.9	(0.07)	0.665	(0.025)	0.11	(0.004)	0.027	(0.004)	12.2	(0.8)	3.69	(0.35)	1.75	(0.11)	0.46	(0.04)	72	(1.2)	18	(1.1)	10	(0.5)
fallow	1	3		0.5		6.8		0.9		0.103		0.051		8		2.81		1.30		0.59		78		12		10	
maize	19	1.8	(0.13)	0.9	(0.14)	7	(0.12)	0.655	(0.033)	0.111	(0.007)	0.030	(0.006)	13.5	(1.3)	4.19	(0.66)	1.79	(0.19)	0.57	(0.06)	72	(1.6)	18	(1.4)	10	(0.8)
gnuts	10	2.1	(0.14)	0.8	(0.2)	6.6	(0.12)	0.674	(0.030)	0.108	(0.004)	0.014	(0.001)	12.2	(1.4)	2.68	(0.39)	1.59	(0.23)	0.44	(0.06)	70	(2.1)	22	(2.0)	8	(0.9)
tobbaco	2	1.4	(0.24)	0.3	(0.16)	7.1	(0.35)	0.805	(0.201)	0.143	(0.040)	0.040	(0.020)	6	(4.0)	2.93	(0.57)	2.00	(0.35)	0.37	(0.01)	75	(3.0)	13	(1.0)	12	(4.0)
soyabean	1	0.3	(1.01)	0.8	(1.67)	7.6	(1.01)	0.384		0.074		0.004		12		4.89		2.47		0.13		58		32		10	
cotton	5	2.1	(0.28)	0.8	(0.28)	7.1	(0.14)	0.531	(0.059)	0.104	(0.011)	0.032	(0.014)	11.6	(2.2)	4.02	(0.72)	1.65	(0.07)	0.34	(0.09)	76	(4.2)	14	(2.9)	9	(1.4)
cowpea	2	2.3	(0.48)	0.7	(0.43)	6.6	(0.42)	0.77	(0.024)	0.103	(0.002)	0.029	(0.018)	10	(2.0)	4.78	(1.19)	1.67	(0.14)	0.10	(0.07)	78	(6.0)	12	(6.0)	10	(0.0)

[a] n does not apply to distance and rating, since also non-soil sampled fields could be used. [b] farmers rated their fields as 1: fertile, 2: medium, 3: poor. [c] distance from the homestead.

Table 16. Average of soil parameters per location and per field with the respective maize rotation. SEM in parentheses.

Mchinji	n	pH		C (%)		N (%)		P (cmol/kg)		CEC(cmol/kg)		Ca (cmol/kg)		Mg (cmol/kg)		K (cmol/kg)		sand (%)		clay (%)		silt (%)	
maize-maize	10	5.82	(0.08)	0.635	(0.064)	0.092	(0.007)	0.021	(0.009)	4.8	(1.04)	0.74	(0.17)	0.43	(0.05)	0.13	(0.03)	78	(2.47)	13	(1.91)	9	(1.00)
legume-maize	8	6.13	(0.19)	0.719	(0.059)	0.104	(0.008)	0.020	(0.007)	5	(0.65)	0.92	(0.19)	0.45	(0.08)	0.30	(0.16)	78	(2.24)	13	(1.56)	9	(1.25)
tobacco-maize	6	5.86	(0.24)	0.759	(0.050)	0.1	(0.008)	0.039	(0.017)	4.33	(0.80)	1.05	(0.26)	0.44	(0.06)	0.18	(0.04)	75	(2.46)	17	(2.51)	9	(0.99)
Salima																							
maize-maize	7	7.31	(0.19)	0.633	(0.055)	0.11	(0.008)	0.045	(0.012)	14.86	(2.26)	3.70	(0.66)	1.67	(0.16)	0.77	(0.09)	78	(2.35)	13	(1.99)	9	(1.44)
legume-maize	10	6.94	(0.14)	0.719	(0.045)	0.105	(0.005)	0.015	(0.002)	13.2	(1.69)	3.71	(1.09)	1.61	(0.22)	0.42	(0.07)	67	(1.64)	22	(1.29)	10	(1.07)
tobacco-maize	2	6.8	(0.45)	0.525	(0.191)	0.161	(0.053)	0.061	(0.035)	13	(5.00)	5.00	(1.81)	2.73	(1.23)	0.52	(0.31)	72	(2.00)	14	(0.00)	14	(2.00)

Typical crop rotations in Mchinji were tobacco-maize and groundnut-maize. If soyabean was grown, it was grown in rotation with maize rather than tobacco. The majority of the fields allocated to maize were preceded by tobacco (Table 14). A smaller part was cropped continuously with maize and the smallest part was grown in rotation with legumes, which in the 2010/2011 growing season only comprised 14% of the total area (Table 13). In Salima the most typical rotation was cotton-(maize-) groundnut-maize. Soyabean and cowpea were usually grown in rotation with maize and tobacco was grown in rotation with all crops. Here, the majority of the maize fields were cultivated in rotation with legumes, which comprised 28% of the total cultivated area in the 2010/2011 growing season (Table 13). In approximately one-fifth of the plots, maize was grown continuously, preferably on those fields close to a stream.

Average values of fields representing different rotation schemes gave more insight in the variability of soil parameters of the 2010/2011 maize fields. At both locations, available P was highest in the maize fields preceded by tobacco and lowest in the maize fields preceded by legumes (Table 16). Whereas legume-maize fields had not been targeted with nutrients in the legume year, tobacco-maize had usually been targeted with high amounts of nutrients in the tobacco year. This probably explains the differences in P status. Except for the higher N status of the tobacco-maize fields in Salima, average total N was rather equal.

Crop yields

Generally, maize gave the greatest yields on a hectare basis (Figure 5). Tobacco, cotton, groundnuts, soyabean and beans all gave a lower yield per hectare. However, the differences in average yield between maize, tobacco, groundnuts and soyabean were not very high in Salima for the 2010/2011 cropping season. Yields of all crops varied between location and among individual farmers. Maize was on average higher yielding in Mchinji than in Salima, whereas in Salima groundnuts were higher yielding than in Mchinji.

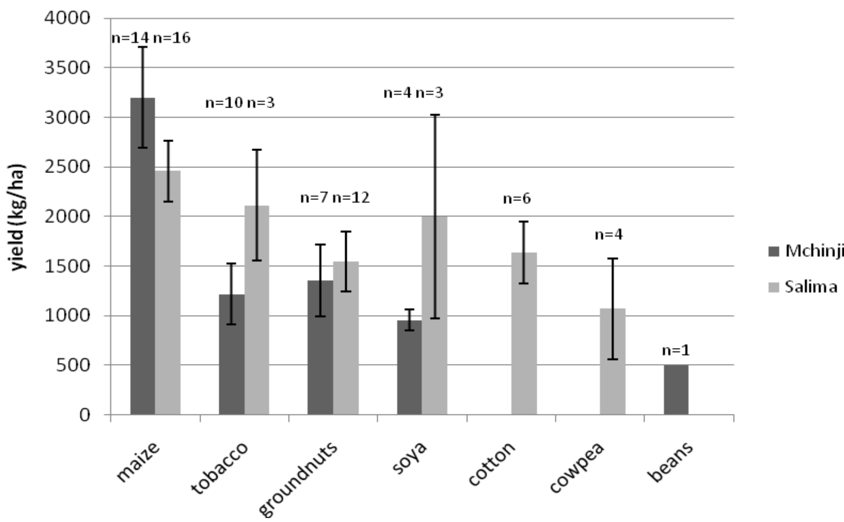

Figure 5. Average yields per location of the 2010/2011 cropping season.

Although for both locations type 1 farms obtained the lowest maize yields, for Mchinji no clear further pattern could be observed (Table 17). For Salima, however, maize yields of both type 1 and type 2 farms were significantly lower than those obtained by type 4 farmers (ANOVA). Also type 5 farmers obtained relatively high maize yields in Salima.

Yields of tobacco were also variable, with the highest yields obtained by type 5 farmers in Mchinji. Although type 2 farms in Salima seemed to have the highest groundnut yields, no clear further distinctions between farm types could be found. In the few cases where cowpea was grown, grain yield was highly variable ranging from 463 kg/ha to 2083 kg/ha. The trial related soyabean yields obtained by farmers in Salima were very high compared with the non-trial related yields in Mchinji and are not included in any further analyses. For all crops, yields were also variable within farms, with different plots generating different yields on an area basis, due to differential management and differences in inherent soil fertility. The presented values however, are based on aggregate yields per crop per farm.

Among years yields also varied strongly. Based on average values of farmer yield estimates about the period 2006 – 2010, there was about a factor 2 difference between the lowest yield and the highest yield of each crop obtained in that period (Table 33 in Appendix I). Compared with those estimations, the 2010/2011 season seemed to be a very good year. However, these values were farmer estimates of both yield and area on which the particular crop was grown and therefore unlikely to be true representatives. Yet, they do give a sense of the yield variations between years and help viewing the 2010/2011 yields in a wider context.

Table 17. Average yields of the 2010/2011 cropping season per farm type, in kg/ha. Minimum and maximum yields obtained by farmers within a type are presented in parentheses.

Mchinji	farm type	maize		tobacco		groundnuts		soyabean [a]	
	1	1903	(1125 - 2917)	350		1875			
	2	4981	(2400 - 7143)	644	(500 - 833)			450	
	3	2538	(1125 - 3790)	1165	(455 - 1875)	3050		375	
	4	3981	(2229 - 5733)	711	(588 - 833)	635	(182 - 1089)		
	5	3253	(1915 - 5482)	2667	(2000 - 3333)	880	(666 - 1286)	805	(643 - 968)
Salima		maize		tobacco		groundnuts		cotton	
	1	1430	(720 - 1983)			1137	(489 - 1786)	1389	
	2	1580	(1230 - 1957)	2013		4459	(3035-5882)	1042	
	3	2099	(1350 - 2903)			868	(540 - 1075)	1818	
	4	4375	(3750 - 5000)	2163	(1200 - 3125)	1583	(570 - 2596)	2759	
	5	3284	(1936 - 4125)			1351	(933 - 1936)	1154	

[a] For Mchinji, soyabean yields obtained in agronomic trials were excluded.

Farmers appeared to have different perceptions of good and bad yields within the 2010/2011 cropping season when rating their yield with low, average or high. Looking at the whole region, the ratings individual farmers gave to their yields did not correspond to actual yield. This suggests that individual farmers had different perceptions regarding estimates of yield. In case farmers perceived their yield as average or low, inadequate fertilizer and erratic rains were the most commonly mentioned factors constraining maize yields. Also mentioned were poor soils, poor weeding, poor germination, low yielding varieties, late planting and monocropping. Factors that limited a high tobacco yield were diseases, erratic rains, poor soils, poor germination and in Salima also lack of fertilizer. For groundnuts, the main limiting factor was perceived to be poor germination, pests and diseases, erratic rains and late planting. Limiting factors for obtaining higher cotton yields were perceived to be poor germination, lack of fertilizer and monkeys destroying the fields. Finally, lack of pesticides was thought to limit cowpea yield.

Soil parameters and yield

Although not significant, the scatter plot for Mchinji showed a positive relation between total N and maize and groundnut yield. This relation was less clear for Salima. However, Spearman correlation analysis for both areas together showed a strong positive correlation between total N and groundnut yield (p=0.01). In Mchinji, also tobacco yields were significantly correlated with total N (p=0.05) and clay content (p=0.01). Groundnuts on the other hand correlated negatively with clay content in Salima (p=0.05). Clear relations between available P and crop yield could not be derived from these results.

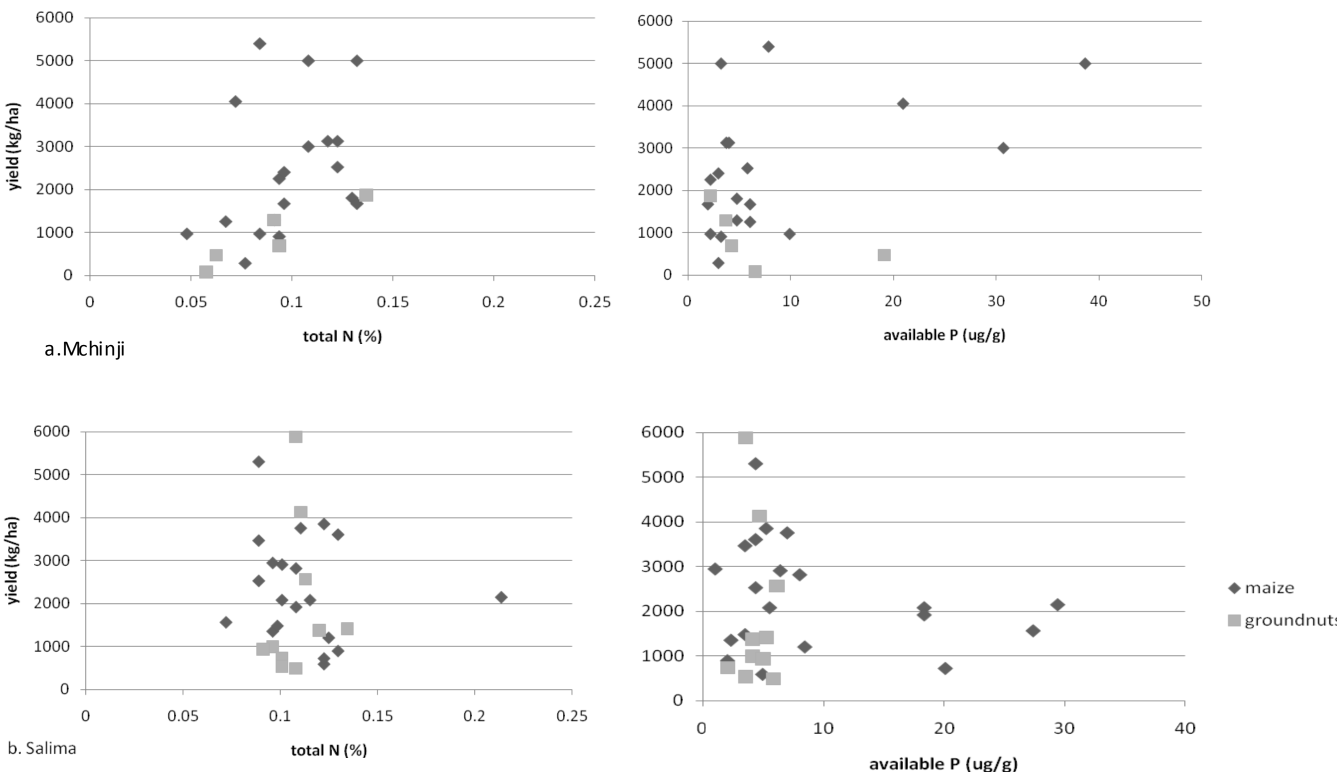

Figure 6. Yield response of maize and groundnut to total N and available P for a) Mchinji and b) Salima. 3 maize yields in Mchinji exceeding 9000 kg ha^{-1} from small plots were excluded, since estimates from these small plots were unlikely to be true representatives of yield of the relevant plot.

Maize yield and rotation

Although not statistically significant (ANOVA), rotation schemes seemed to have an effect on maize yield. Continuous cultivation of maize or cotton usually led to lower yields than rotation with legumes or tobacco (Figure 7). Rotation with tobacco usually generated the highest maize yields. However, tobacco was usually targeted with high nutrient inputs increasing the benefits of residual fertility (especially P) for maize on those fields (Table 16). In Salima, where less tobacco was grown and fewer nutrients were allocated to tobacco compared to Mchinji, the difference between legume rotation and tobacco rotation was much smaller. Here, also the difference between continuous maize and maize in rotation with legumes was very small and comparable to fields preceded by cotton. However, cotton growing farmers preferred to rotate maize, cotton and legumes on the same fields.

The fields on which maize was grown continuously had a higher P and N content in Salima than in Mchinji. Also, it was in Salima that farmers indicated to prefer to grow maize year after year on their most fertile fields close to the stream. This probably contributed to the fact that continuous maize yields were higher in Salima than in Mchinji and that the difference in maize yields between continuous maize and rotation with legumes was less obvious.

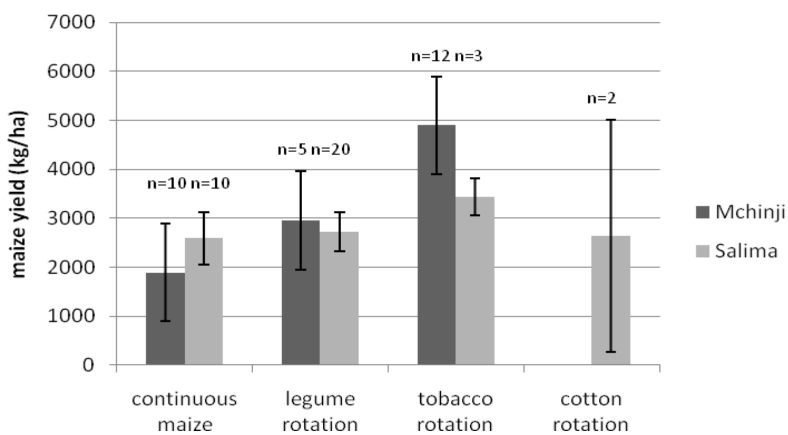

Figure 7. Maize yields of different rotation schemes.

Inputs

Labour

Tobacco was by far the most labour intensive crop grown by Malawian farmers (Figure 8). High labour requirements were probably caused by: (1) the cultivation of seedlings in a nursery during the dry season, necessitating daily watering, (2) the high application rates of manure and (3) the long and laborious harvesting period (Table 18). Labour inputs for tobacco were higher in Salima due to higher average temperatures that necessitated watering two times a day during the nursery period, whereas once a day was the common practice in Mchinji. In addition, the tobacco fields in Salima were smaller than those in Mchinji while the work done during the nursery period is not proportional with field size.

Groundnuts were the second most labour intensive crop. Approximately half of the labour inputs to groundnuts were spent on the harvest, where groundnuts need to be dug from the ground. The total amount of labour spent on groundnuts correlated (Spearman, p=0.01) with the number of adult males and females in the household in Mchinji and with the number of males in the household in Salima. Because this was not the case with tobacco and maize, this correlation might indicate that tobacco and maize are prioritized in terms of labour. Only in case there is sufficient family labour in the form of a higher number of adult males and females in the household more labour is spent on groundnuts.

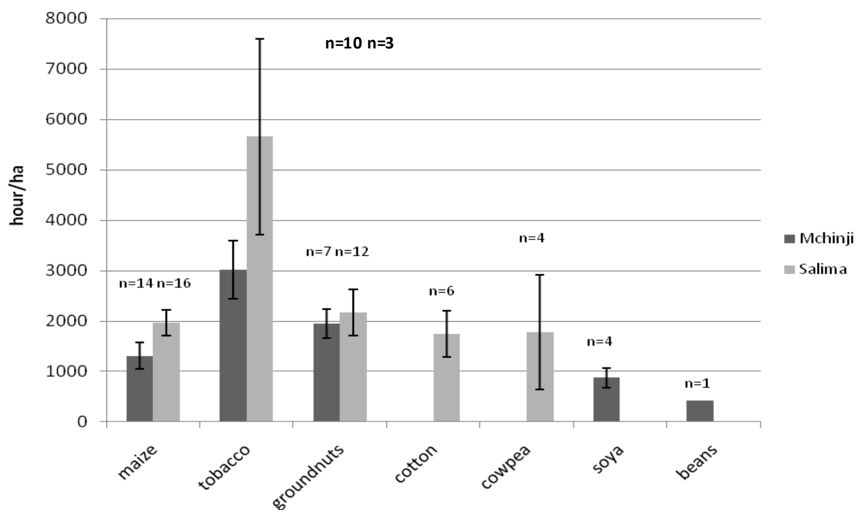

Figure 8. Average labour per crop (hours ha^{-1}).

In Mchinji the amount of labour spent on maize and tobacco correlated with the amount of livestock on the farm (Spearman, p=0.05). Livestock produce manure and the distribution of manure on the fields is a labour intensive activity. Even though farmers did not apply manure in groundnut fields and sometimes weeded those fields only once, maize required a little less labour than groundnuts according to current farmer practices. This is probably due to the lower labour inputs for harvesting maize. Even though cotton harvest was also relatively laborious, its total labour inputs remained rather low.

Of all crops, farmers spent the least amounts of labour on soyabean and beans. Labour allocated to cowpea was variable. However, approximately half of the farmers weeded those crops only once, after which they said the next activity would be 'just wait for harvest'. Maize, and in Mchinji also tobacco, was not only prioritized over the other crops in terms of management, but also in terms of planting date.

Although in general the labour inputs were higher in Salima than in Mchinji, both locations showed the same trend. The generally higher labour inputs in Salima can be partly expained by the smaller field sizes and therefore smaller efficiency. However, all labour numbers were farmer estimates, and farmers might over- or underestimate the time needed for each activity. Yet, all farms showed the same trend, both in relative amounts of labour allocated to each crop and in the relative amount of time spent on each activity.

Table 18. Distribution of labour per crop, in % of total labour hours for the respective crop. Spraying of cotton is not included because it took only a very small amount of time. SEMs are presented in parentheses.

	crop	n	Nursery	field preparation	Manure application [a]	planting	Fertilizer application	Weeding [b]	harvest
Mchinji	Maize	14		27 (4.14)	17 (4.55)	3 (0.48)	6 (1.59)	34 (3.57)	28 (4.56)
	tobacco	10	20 (6.64)	7 (1.25)	3 (1.04)	5 (0.94)	3 (0.53)	14 (2.38)	49 (7.49)
	groundnuts	7		22 (4.37)		5 (1.89)		21 (5.52)	52 (8.76)
Salima	maize	16		33 (3.48)	3 (2.11)	5 (1.18)	4 (1.56)	27 (2.54)	30 (3.99)
	groundnuts	12		29 (3.73)		3 (0.61)		17 (2.75)	50 (5.73)
	cotton	6		25 (2.61)		2 (0.49)		21 (4.17)	50 (6.33)

[a] Manure was not applied by all farmers.

[b] Weeding was usually done twice (the second weeding was generally referred to as 'banking' or 'making ridges bigger'), except for groundnuts, where farmers sometimes weeded once.

Despite their high land/labour ratios, type 4 farms spent the highest amounts of labour per hectare on their farms (Table 19). In Mchinji, the majority of the labour was allocated to tobacco by farmers of this type. In Salima they allocated much labour to both maize and groundnuts. Since some type 5 farms in Mchinji also regularly used hired labour, they were also able to allocate relatively high amounts of labour to their fields. The fact that type 1 farms in Mchinji allocated the least labour per hectare to their farm might indicate that they indeed became labour constraint by casually working on other farms. However, in Salima type 3 farms spent the least amount of labour per hectare on their farms, and they were usually not working on other farms.

Table 19. Average labour per farm type per crop and as total labour spent on the farm, in hour ha $^{-1}$.

	farm type	maize		tobacco		groundnuts		soyabean		total farm	
Mchinji	1	777	(58)	1735		2300				910	(142)
	2	1123	(373)	2024	(639)	1000		1188		1388	(390)
	3	1335	(405)	2824	(664)	1050		513		1509	(357)
	4	979	(46)	6128	(148)	1520	(393)			2030	(1)
	5	2225	(1066)	2231	(199)	2408	(490)	899	(293)	1760	(374)
		maize		tobacco		groundnuts		cotton		total farm	
Salima	1	1737	(621)			3164	(675)	1301		1876	(701)
	2	2510	(120)	9513		2079	(259)	1275		2489	(507)
	3	1300	(175)			1103	(236)	2419	(1371)	1326	(205)
	4	3453	(897)	3736	(416)	4437	(1808)	2343		3060	(105)
	5	1652	(560)			1103	(296)	715		1432	(324)

Except for tobacco in Mchinji, no correlations were found between land/labour ratios and labour spent on the respective crops. Land/labour ratios may be complemented with hired labour, or the other way around; farmers leave their own land and work on other farms. Therefore, land/labour ratios are no proper indicator on how much labour farmers are able to allocate to their fields.

Generally, labour use efficiency (LUE) was higher for maize than for groundnut. However, relative differences between LUE for those two crops differed per site. Farmers of all types in Mchinji generally had higher a LUE for maize than farmers in Salima, whereas the LUE of groundnuts was generally higher in Salima than in Mchinji (Table 20).

LUE also differed per farm type. Although type 4 farms in Mchinji had relatively low maize yields on an area basis, they still had a relatively high LUE. In Salima, LRE farmers clearly had lower labour use efficiencies for maize than MRE and HRE farmers. Non-edible cash crops were not included and labour use efficiencies for the other food crops were not measured since there were too little observations. Furthermore, no significant correlation was found between labour inputs and yield of any of the crops.

Table 20. Average labour use efficiencies of maize and groundnuts per farm type, in kg product hour^{-1}. SEM of the total average value is presented in parentheses.

	Mchinji		Salima	
farm type	maize	groundnuts	maize	groundnuts
1	2.47	0.82	0.98	0.33
2	5.33	na	0.62	1.61
3	2.48	2.90	1.85	0.92
4	4.16	0.37	1.28	0.24
5	2.47	0.37	2.51	1.46
average	3.33 (0.61)	0.70 (0.36)	1.55 (0.26)	0.96 (0.22)

Nutrients

In Mchinji tobacco received on average three times more nutrients than maize, both from inorganic and organic sources (Table 21). In Salima, overall less animal and compost manure was used and it was usually allocated to maize. In this region, the total amount of nutrients allocated to maize and tobacco was more or less equal. The other crops were grown without any nutrient inputs. The majority of the farmers indicated that it would be a waste to target legumes with nutrients, because they learned that legumes 'can make their own fertilizer or manure'. Only farmers who participated in the soyabean agronomic trials said that soyabean might benefit from additional nutritional inputs. All farmers agreed that groundnuts do not need these nutrient inputs because 'then they won't grow well'. However, as all legumes were grown in rotation with maize or tobacco, they were likely to benefit from residual effects of nutrient applications in previous crops.

In Salima, nutrient allocation was clearly highest by the HRE production orientated farms. Although farmers of this type in Mchinji allocated relatively high amounts of nutrients to tobacco, they allocated maize with the lowest rates of nutrients compared to the other farm types in this region. Likely causes might be the larger acreage on which to distribute the fertilizer compared the farms of other types within the same region. In addition, type 4 farms in Mchinji had larger areas cultivated with fertilizer demanding maize and tobacco than farmers of the same type in Salima, who had smaller land holdings and cultivated more legumes. Probably contributing to the observed in nutrient inputs is the governmental subsidy program which aims to target poor farmers with 100 kg of subsidized fertilizer (available for 6.7$ instead of approximately 67$). LRE farmers with small holdings but who do receive subsidized fertilizer might therefore have higher application rates than wealthier farms with larger land holdins. However, not all farmers received subsidized fertilizer and some farmers in Salima did not apply any nutrients in their fields at all.

Table 21. N and P allocation to maize and tobacco per farm type, in kg ha^{-1}. The used fertilizers were NPK (32:21:0) urea, calcium ammonium nitrate (CAN) and compound D (8N: 18P: 15K: 6S: 0.5Zn: 0.1Bo) Organic inputs include both animal manure and compost, of which the largest part was comprised of animal manure.

		maize				tobacco			
		fertilizer		*organic inputs*		*fertilizer*		*organic inputs*	
	farm type	N	P	N	P	N	P	N	P
Mchinji	1	65.49	3.18	4.76	0.77	57.50	22.93		
	2	136.90	8.01			153.82	7.64	10.43	1.19
	3	94.38	13.45			275.28	22.70	40.66	4.65
	4	48.90	6.50			113.23	13.57	60.77	9.63
	5	109.07	13.86	1.56	0.18	220.83	26.75	158.81	26.37
	average	99.10	9.15	3.16	0.48	173.77	17.19	71.52	11.29
Salima	1	83.16	14.83						
	2	33.82	3.38	9.00	1.51	37.83	15.08		
	3	82.70	9.96	0.82	0.14				
	4	183.68	15.92	2.63	0.13	137.36	26.47	8.14	1.37
	5	66.83	8.48	66.69	11.21				
	average	82.22	9.69	29.17	4.84	104.18	22.67	8.14	1.37

Despite the high variability in inorganic nutrient inputs, in Mchinji organic inputs to tobacco were clearly correlated with farm type (Spearman, p=0.01). Although both type 4 and type 5 farms often owned cattle, the type 5 farms applied higher rates of animal manure, because they had smaller fields on which to distribute the manure. Farms of the other types applied either very low amounts of animal manure or nothing at all. In Mchinji, compost manure was more widely used across all farm types. In Salima hardly anyone made and used compost manure.

Within farm variability in nutrient allocation was also observed, more in Salima than in Mchinji. Some farmers applied more nutrients in certain fields than in other fields with the same crop. Reasons for this variability were differences in farmer perceived inherent fertility of the fields (if farmers had a high fertility field, they did not target it with nutrients), the variety of maize and the amount of fertilizer available. If the available fertilizer was not sufficient for all maize fields, its distribution was either rather randomly or, in case farmers grew both hybrid and local maize, preferentially allocated to the hybrid variety. However, usually farmers started applying fertilizer on the first planted field and stopped when they run out of fertilizer.

Nutrient input and yield

Although farmers often mentioned lack of fertilizer as a limiting factor for obtaining higher maize yields, no statistically significant correlations were found between nutrient inputs and maize yield. Yet, the scatter plots do show some relation between maize yields and nutrient inputs up to 100 kg N ha^{-1} and 15 kg P ha^{-1} (Figure 9). Although tobacco yields were clearly higher with higher nutrient inputs in Mchinji, only inorganic nutrient inputs were significantly correlated with yield (Spearman, $p=0.05$). However, inherent or residual fertility, losses of N from fertilizer or manure through heavy rainfall, pest and disease or any other factor influencing crop yield could have influenced the response of crops to nutrient inputs.

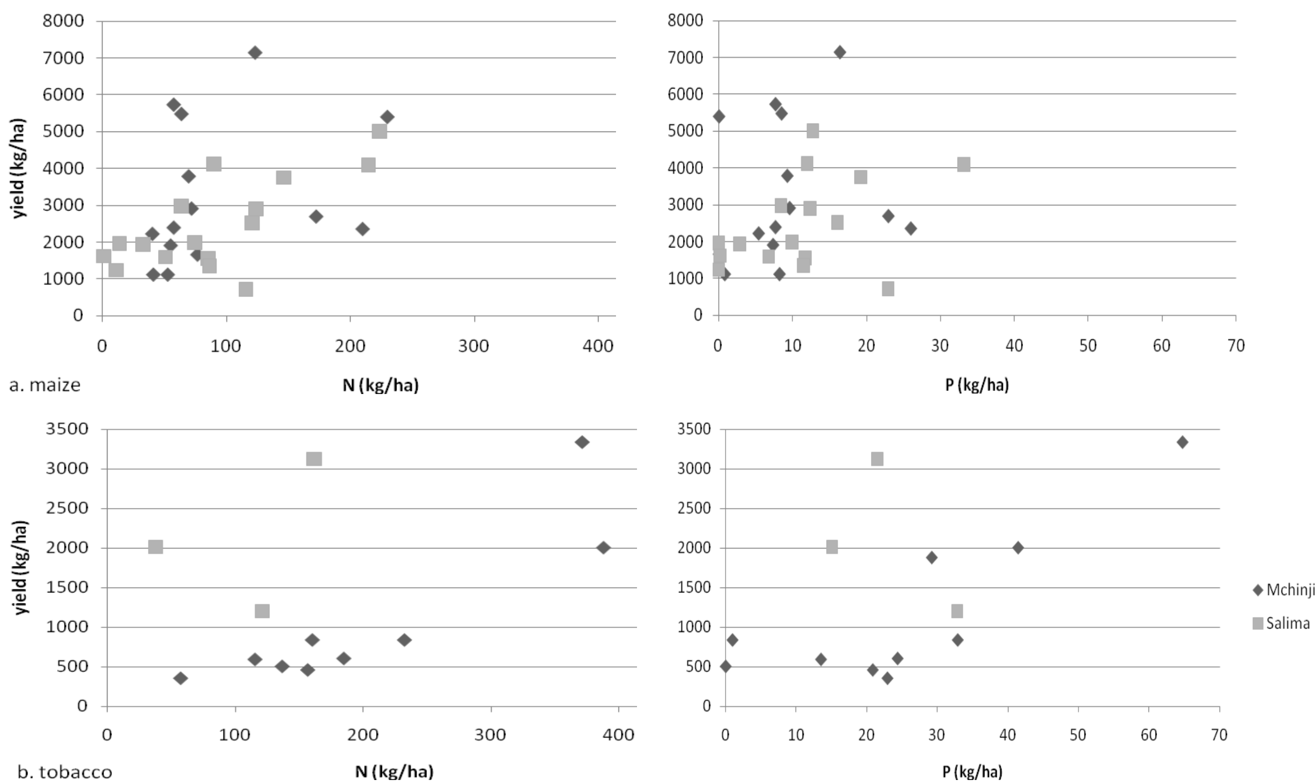

Figure 9. Crop yield responses to N and P inputs, for (a) maize and (b) tobacco.

Residue management

Residue management depended on location and crop (Table 22). Resides of the non-food crops tobacco and cotton were usually burned or left in the field. Maize was more often burned in Salima than in Mchinji. Approximately one third of the farmers composted maize residues. In Salima, only one third of the farmers composted or incorporated groundnut residues and the majority left them in the field. In

Mchinji, two third of the farmers composted or incorporated groundnut residues. Soyabean residues were always composted in Mchinji. However, residues of beans were burned. The majority of the farmers in Salima also burned their cowpea residues and did not compost soyabean residues.

Whereas some farmers who did not incorporate or compost their legume residues said not to know the benefits of these techniques, others regarded the returns to labour to low. Surprisingly, some farmers said not to know the added value of incorporating or composting groundnut or cowpea residues whereas they did recognize the added value of soyabean residues, reflected by 100% composting rate of soyabean in Mchinji. Farmers might have learned this during the (former) participation in the soyabean trials, but did not learn that residues of other legumes are also valuable. Yet, in Salima all the soyabean growing farmers participated in the same trial and only a minority composted the residues. However, in Salima, some farmers mentioned not to know how to make compost. Composting rates were generally higher indeed for Mchinji.

Table 22. Residue management per crop and per location.

	maize		tobacco		groundnuts		soyabean		beans	cotton	cowpea
	Salima	Mchinji	Salima	Mchinji	Salima	Mchinji	Salima	Mchinji	Mchinji	Salima	Salima
n [a]	23	22	4	13	17	16	4	5	1	7	4
animal feed	4%					6%					
composted	26%	41%	25%	8%	12%	38%	25%	100%		14%	
burned	61%	36%	75%	8%	6%	19%			100%	71%	75%
left in the field [b]	9%	23%		62%	53%	6%	75%			29%	25%
Incorporated [c]				23%	29%	31%					

[a] n was larger for some crops than the number farmers cultivating that crop, since some farmers had multiple management strategies.

[b] residues left in the field indicate at grazing by animals, burning or incorporation prior to the next growing season or burning by someone else

[c] most farmers did not yet incorporate the residues by the time of asking, right after harvest, but were still intending to do so

4.2.3 Food security and nutrition

Energetic returns to land depended on the energetic value and yield of a particular crop. In Mchinji, maize gave by far the highest energetic returns to land (Table 23). Beans had a quite low energetic value and were at the same time low yielding, resulting in the lowest energetic returns. In Salima energetic returns of maize were much lower than in Mchinji due to a lower average yield of this crop. Although here the differences between the respective crops were minimal, the energetic returns of groundnuts were slightly higher than for maize.

Table 23. Average energetic returns to land per crop.

	Mchinji				Salima			
	maize	groundnuts	soyabean	beans	maize	groundnuts	soyabean	cowpea
Energetic returns to land (kcal ha^{-1})	11234219	7194459	3080024	1237500	8402952	8806500	8920000	7584500

Based on the 2011 grain yields for every respective farm and the resulting daily amount of energy available per person, seven households in the total sample were food insecure (

Table 24). The majority belonged to farm type 1 and 2. For almost all farms, the majority of the available energy originated from maize and generally only the households that were indicated food insecure produced less than between 200 kg maize per person, which is thought to be the minimum yearly requirement for a household to be self-sufficient in maize (Snapp et al., 2002b).

For many households, the greater part of the protein available originated consequently from maize rather than legumes. This implies that most household do not meet the minimum of daily requirement of 48 g good quality protein person^{-1-} day^{-1}, since maize protein lacks essential amino acids (Prasanna et al., 2001) and available protein from legumes was below the minimum daily requirement for a large number of households. In addition, the preferred processing of maize includes pounding and milling, which substantially reduces the protein content (Smale, 1993).

However, also with processing of legumes, the protein content can decrease. In addition, post-harvest losses can decrease the actual amount of food available for the household and many households sell part of their legume and/or maize harvest. Therefore, more households than first appears from the total protein numbers are unlikely to meet their daily protein requirements originating from their own farm. On the other hand, households earning cash from off-farm sources or selling other crops, still have the possibility to buy legume grain or other high-quality food for consumption.

Table 24. Available grain from food crops per person per year and the daily available energy and protein per person for each household. Reductions caused by post-harvest losses and selling products are not included.

	Mchinji						Salima					
farm type	Maize (kg/y)	gnuts (kg/y)	soyabean or beans (kg/y)	energy (kcal/d)	total protein (g/d)	legume protein (g/d)	Maize (kg/y)	gnuts (kg/y)	soyabean or cowpea (kg/y)	energy (kcal/d)	total protein (g/d)	legume protein (g/d)
1	400	34		4283	578	24	115	50	13	2047*	73	44
1	125	19		1464*	89	13	240	39		2860	87	28
1	120	4		1194*	117	3	72			675*	18*	0
2	216			2024*	53	0	405	100		4482	171	71
2	667			6247	413	0	420			3935	104	0
2	180		23	1962*	123	23	201	198	47	5917	237	188
3	360			3373	116	0	373			3498	92	0
3	216		64	2806	319	64	216	70	14	3299	118	65
3	940	122		10713	164	87	309	163		5443	193	116
3							180	41		2328	74	29
4	2293	18		21766	44	13	441	113		5897	189	81
4	2726	62		26511	33	44	144	42		1998*	65	30
5	1163	137	33	13409	67	126	463			4337	114	0
5	400	24		4130	195	17	880	105	26	10825	309	92
5	579	43	22	6363	716	52	391	64	15	4898	153	56
5							520	243	25	9400	326	198

*Indicates food insecure farms, based on the minimum daily requirement of 2250 kcal/person.

3.2.4 Economic and market evaluation

Seed and grain markets

Approximately half the farmers used maize seeds saved from the previous harvest. The other half either purchased certified hybrid seed or received it through the governmental subsidy program. Prices of maize seed were highly variable, but on average slightly lower than those of groundnut (

Table **25**). However, for the latter, the majority of farmers used saved seeds. Only a small part bought certified seeds. In both cases the common groundnut variety was CG7. Soyabean and cowpea seeds were in the majority of the cases saved or obtained by participating in a trial. Certified improved varieties of soyabean, beans and cowpea were not widely available and the local varieties available were relatively expensive. Tobacco seeds were usually saved and sometimes bought from certified sources. Cotton seeds were either bought or obtained on loan from a cotton company. Some farmers also received free tobacco or groundnut seeds from friends or relatives.

Table 25. Average seed-price and grain-price per kg for 2010 and the averages of the lowest and highest grain-prices for the period 2005-2009. SEM presented in parentheses.

	crop	Seed-price 2010		Grain-price 2010		lowest price (2005-2009)		highest price (2005-2009)	
Mchinji	maize	0.87	(0.603)	0.16	(0.011)	0.10	(0.011)	0.24	(0.021
	tobacco	na		1.58	(0.320)	0.68	(0.107)	4.14	(1.423)
	groundnuts [a]	0.58	(0.250)	0.48	(0.155)	0.35	(0.062)	0.64	(0.102)
	soyabean	1.33		0.25	(0.050)	0.20	(0.077)	0.55	(0.017)
	beans	1.33		1.33		na		na	
Salima	maize	1.32	(0.467)	0.15	(0.013)	0.13	(0.020)	0.24	(0.067)
	tobacco	na		2.04	(0.458)	1.30	(0.500)	2.55	(0.050)
	groundnuts	0.47		0.31	(0.018)	0.20	(0.023)	0.35	(0.028)
	soyabean	na		na		na		na	
	cotton	0.58	(0.089)	2.00	(0.133)	0.24	(0.054)	0.52	(0.056)
	sorghum	na		0.33		0.33		0.47	
	cowpea	na		0.93	(0.400)	0.67	(0.333)	1.33	

[a] groundnuts are generally sold unshelled and grain prices are for the unshelled product.

Maize was usually sold at the farm gate or at the local market and generated stable and comparable market prices at both locations, irrespective of market outlet. However, over the years grain-prices varied with more than a factor two (

Table 25). Although tobacco clearly generated the highest prices per kg in 2010, the individually obtained prices varied highly. 70% of the farmers directly sold their product on the auction floors in Lilongwe and the remaining 30% chose to sell it to traders or on the local market, from where it was eventually sold on the same auction floors. Especially farmers who cultivated only a small area of tobacco chose for this last option. The highest prices were always obtained by type 4 farms who sold it directly on the auction floors. Cotton was usually sold to vendors in the village or sometimes immediately to the cotton company who also provides seeds and chemicals to some farmers. Cotton prices had been extremely low for approximately a decade, but rose in 2010 (The Nation, 32-02-2011).

In Salima, received grain prices for groundnuts in 2010 were rather stable with a well-established market. At some larger-scale farms traders came at the farm gate to buy the product. Small-scale farmers sold their groundnuts on the local market or within the village. Slightly lower prices were usually generated when farmers sold their product on the farm gate to individuals. The average grain price for groundnuts was approximately two times higher than for maize. In Mchinji the average 2010 grain-price for groundnuts was higher, but also more variable.

If soyabean, cowpea and beans were sold, it was always on the local market or at the farm gate to individuals. Although variably between years, beans and cowpea usually generated relatively high market-prices, but soyabean did not every year. However, these findings are based on a few observations only since not many farmers cultivated these crops and often they were used for home consumption only.

A partial budgeting analysis with both 2010 and 2011 market grain-prices showed the net benefits per crop (Table 26). Average net benefits of maize were generally low or negative. Although grain-prices for groundnuts varied over the two years, in both locations net benefits were positive with both price scenarios for the two consecutive years. With the good market prices of 2010 tobacco had the ability to generate the highest benefits. However, due to a large reduction in market price, average benefits became negative the following year. In addition, for the 2011 analysis only the auction floor prices have been used because the majority of the farmers sold it there. One still has to keep in mind that those farmers who sold their product to traders received only half of that price, which will result in even lower monetary net benefits.

Table 26. Economic net-benefits per crop. Values in parenthesis present the lowest and highest net benefits generated by individual farmers.

	crop	costs ($/ha)				grain value ($/ha)	net benefits ($/ha)	grain value ($/ha)	net benefits ($/ha)
		purchased inputs	*hired labour*	*family labour*	*total costs*		*2010 prices*	*2011 prices*	
Mchinji	maize	125	27	264	416	526	**109** (-924 – 706)	394	**-22** (-1018 – 490)
	tobacco	263	181	490	933	1796	**863** (-928 – 4202)	1437	**504** (-1114 – 3149)
	groundnuts	9	52	327	387	1377	**990** (-256 – 1231)	455	**404** (-129 – 1810)
	soyabean	8	47	147	202	173	**-29** (-158 – 1810)	215	**125** (44 – 557)
	beans	67	0	93	160	499	**339**	375	**215**

Salima	maize	152	27	410	589	369	**-220** (-658 – 197)	295	-**294** (-771 – 90)
	tobacco	459	144	1114	1717	4310	**2593** (655 – 5141)	1690	**-27** (-833 – 1266)
	groundnuts	24	30	451	505	1082	**576** (-329 – 3598)	1406	**901** (-209 – 4833)
	cotton	61	0	297	358	1094	**736** (353 – 1153)	1844	**1487** (833 – 2422)
	cowpea	31	0	144	175	1282	**1108** (287 – 1873)	648	**473** (-7 – 914)

Cotton generated relatively high economic returns with both price scenarios. However, market prices for cotton were high in both 2010 and 2011, relative to preceding years (

Table **25**). Soyabean in Mchinji generated only slightly positive or even negative net benefits, depending on the market price. Beans and cowpea always gave positive net returns, although the latter also fluctuated with more than a factor 2 due to variable market-prices.

The minimum and maximum obtained net-benefits per crop indicate that net benefits vary highly for individual farmers, since different farmers obtained different yields (Table 17) and had different inputs costs (Table 27) within the same price scenario. Even with the high 2010 market prices for tobacco some farmers had negative returns to inputs due to low yields. Although also some farmers obtained negative monetary net benefits from legumes, they were not as low as for tobacco or maize.

Expenditures on inputs

Expenditures on crops were separated into hired labour costs, family labour costs and purchased inputs such as fertilizer, seeds, chemicals etc. Farms of the 1st, 2nd type did not spend any money on hired labour at all and farms of the 3rd type occasionally a little amount (Table 27). For these farm types, the largest part of the total costs for a crop was comprised by the opportunity costs of family labour. Farms of the 4th and 5th type always complemented their family labour with hired labour for maize, tobacco and groundnuts and in one case also cowpea in Salima. Hired labour was never used to cultivate soyabean, beans or cotton. In addition, these farms usually had high costs from purchased inputs for maize and tobacco and low or zero costs from purchased inputs for groundnuts, soyabean and cowpea.

T**able 27**. Expenditures on farming with its relative distribution of purchased inputs, hired labour and family opportunity labour costs per farm type and per crop.

	crop	farm type					crop	farm type				
expenditures	*Mchinji*	1	2	3	4	5	*Salima*	1	2	3	4	5
purchased inputs [a]	*maize*	13	89	30	121	371	*maize*	41	59	137	468	149
hired labour [b]		0	0	20	63	63		0	0	0	146	34
family labour [c]		173	250	277	154	431		386	558	289	621	333
Total ($ ha^{-1})		185	339	326	339	865		427	617	426	1235	516
purchased inputs	*tobacco*	17	112	111	540	486	*tobacco*		11		647	

hired labour		0	0	117	649	137			0		216	
family labour		173	250	277	154	431			2114		614	
Total ($ ha^{-1})		189	362	504	1343	1054			2125		1477	
purchased inputs	*groundnuts*	0		0	0	23	*groundnuts*	0	0	0	77	19
hired labour		0		0	111	63		0	0	0	140	26
family labour		511		233	226	472		703	462	245	846	219
Total ($ ha^{-1})		511		233	338	558		703	462	245	1063	265
purchased inputs	*soyabean*		7	23		0	*cotton*	37	61	21	175	22
hired labour			0	0		95		0	0	0	0	0
family labour			264	114		105		289	283	538	521	159
Total ($ ha^{-1})			271	137		200		326	344	559	696	181

[a] purchased inputs include seeds, fertilizer, chemicals and materials for drying tobacco and were farmer specific depending on the amount of inputs bought and whether or not fertilizer and/or seeds were subsidized.
[b] prices for hired labour were farmer specific. If payments were in food or livestock, the equivalent of these products was expressed in dollars.
[c] based on US$ 1.33 person^{-1} day^{-1}

3.2.5 Farmers' objectives and constraints

Almost all farmers mentioned and prioritized either cash or food as the main production objective for cultivating legumes (Table 28). Some farmers liked to increase legume production not only for the availability of food itself, but also for the added nutritious value legumes have. If farmers still mentioned rotational effects or soil fertility, it was less important than cash or food. Low input demand was also mentioned and 2 of the 30 farmers thought that was the main benefit.

Although all farmers associated benefits with cultivating more legumes, there were many factors constraining them from doing so, or the benefits were not compatible with those of other crops. The most often heard constraint was the lack of financial capital to buy seeds. In the second place came the lack of land, followed by the availability of labour and lack of market to sell the product. Finally, some farmers mentioned the availability of seeds and chemicals and the proneness to diseases of certain legumes. In case farmers still had fallow land to cultivate, they mentioned lack of labour and cash as constraining factors.

Table 28. Farmers' production objectives and constraints regarding legume expansion, as a percent of response for both Mchinji and Salima. 'Soil fertility' also refers to the answer 'N-fixation' and 'nutrition' is included in 'food'.

Production objective	% of responses (n=30)	constraint	% of responses (n=30)
Income	93	cash for seeds	43
food	83	land	40

soil fertility	40	labour	27
low input demands	17	market	23
rotational effects	13	availability of seeds	10
payment for casual labour	3	diseases	3
		availability of chemicals	3

No clear patterned emerged from grouping the arguments to expand legume production per farm type (Table 29). Almost all farmers put cash and food forward as the most important reasons. Only farms of type 3 seemed to show relatively more interest in the potential of legumes to increase soil fertility than the other types. However, also here, cash and food were usually still prioritized. Although HRE market oriented farmers mentioned the same objectives food and cash as the LRE subsistence oriented farmers, the implications of cash are different for both farm types looking at the total cropping income of these respective farms. HRE market oriented farmers will need larger markets than LRE subsistence farmers who occasionally sell small amounts within the village.

Looking at the constraints per farm type, a certain pattern emerged. For all low to medium resource endowed farmers with small land holdings (type 1, 2 and 3) the availability of cash, land and labour were the main constraints. For the 4th farm type, (lack of) market potential was the most important constraint, followed by availability of labour. For the 5th farm type, constraints were very diverse.

Table 29. Production objectives and the main constraints per farm type. Number in ( ) indicates the number of times that objective or constraint was mentioned. In case reasons were mentioned with the same frequency, the reason which was prioritized by the largest number of farmers was put first.

farm type	Production objectives	main constraints
1	food/cash (6) low input demand/soil fertility (2)	cash (5), land (2), labour (1)
2	cash (6) food (5) rotational effects (2)low input demands/soil fertility (1)	cash (4), land/labour (2)
3	cash (6) food (5) soil fertility (4)	land/cash (4)
4	cash/food (3) soil fertility (2)	market (4) labour (3)
5	cash (6) food (5) soil fertility (2) rotational effects (2)	land/market (4), labour/availability of seeds (3), cash (2), availability of chemicals/diseases (1)

5. Discussion

This research explored the possibilities for expanding legume production on the highly diverse Malawian smallholder farms with means of detailed system characterizations. A typology based on socio-economic indicators obtained from a larger initial sample was developed to assure that socio-economic variability was covered in the detailed system characterizations of a smaller sample. In addition, the typology functioned as a tool to deal with the enormous diversity among smallholder farms in exploring windows of opportunity for legume intensification.

Based on the detailed system characterization, analyses at a crop level were performed to test both economic and energetic profitability of legumes in relation to other non-legume crops and to gain more insight in the potential of legumes to ameliorate soil fertility, income and nutrition. In addition, the data gave insights in financial and labour investments required to grow legume crops and non-legume alternatives and farmers' preferences for different crops. Analyses at a farm level were performed to validate the stratification method and to detect individual or farm type related differences in windows of opportunity for legume intensification.

The farm typology

Ojiem et al.'s (2006) socio-ecological model (Figure 1) showed that windows of opportunity for legume technologies are determined by different factors. The choice for a typology based on only socio-economic factors rather than production patterns or local biophysical factors such as soil fertility parameters had several reasons. First, the theory that differences in structure (endowment) and functioning (livelihood strategy) between farms have implications for designing technologies and improving their adoption is widespread and well elaborated by amongst others Andersen et al. (2007) and Tittonell et al. (2009). Cropping patterns are in turn supposed to depend on wealth indicators (Kamanga et al., 2010b). Second, the value of a certain indicator depends mainly on being easy to measure, understand and communicate (Tittonell, 2007). Socio-economic variables are relatively easy to measure during a rapid survey, whereas measuring factors as soil parameters is very laborious and costly. Furthermore, the latter are likely to vary within farms (Tittonell al., 2005b, Zingore et al., 2007). Although the typology was based on solely socio-economic factors, all agronomic, biophysical and institutional factors dealt with in the detailed characterization were considered in relation to the socio-economic typology.

As hypothesised, based on the work by Tittonell et al. (2005a), diversity in resource endowment, source of income and production orientation allowed for manual stratification of farm households in two distinct regions in central Malawi. This resulted in five farm types: (1) LRE (poor) farms that rely on working causally for wealthier farmers, (2) LRE subsistence farms that rely on a variety of low waged small services and some farm produce, (3) MRE farmers that rely on a variety of small businesses and services and some farm produce, (4) HRE market oriented farmers that derive the largest part of their income from cropping and (5) mostly HRE farms where a household member earns a monthly off-farm salary. However, variability within farm types could not be avoided. As noted by Tittonell et al. (2009), characteristics of each farm pertain mainly to the 'core concept'. Especially type 2 and 3 farms showed high variability in distribution of on-farm and off-farm income. Within HRE types, farmers showed high variability in arable land, assets and livestock ownership, since some farmers were much wealthier than other 'relatively wealthy' farmers. Furthermore, the majority of the farms often had more than one source of income. Also Tittonell et al. (2009) stated that farmers often pursue various livelihood strategies at the same time, sometimes only for brief periods of time.

In addition, the context in which different rural households operate is dynamic. Due to regional differences in agro-ecological potential, market opportunities, population density, rural-urban connections and off-farm opportunities, livelihood strategies, farm structure and relative wealth change from site to site (Tittonell, 2007). For example, a family that can be considered poor in a certain area may be considered rich somewhere else. Even among the two locations in Malawi, regional differences were observed in relative wealth and off-farm opportunities. However, the variance within the locations was explained by the same underlying patterns or 'core concepts': resource endowment indicators (e.g. value of assets, income), source of income, production orientation and education of the household members. Education was not used as indicator to stratify farms into socio-economic types. However, it was strongly correlated to resource endowment. Although Malawian smallholder farms operate in a different regional context than the western Kenyan smallholder farms for which the original typology was developed by Tittonell et al. (2005a), also in Malawi resource endowment, source of income and production orientation proved to be valid to use as indicators for a socio-economic typology.

Cropping patterns

Although in both regions maize was the main staple food crop and rated as most important crop by all farmers, the remaining of the cropping system was different in both locations. In Mchinji tobacco was the main cash crop and groundnuts, soyabean and beans were mainly cultivated for home consumption and small-scale sales. In Salima groundnut was the major cash crop, in combination with tobacco and cotton. Cowpea and soyabean were cultivated generally for home consumption. In Mchinji, with only 14% of the total cultivated area allocated to legumes, the cropping systems were generally less diverse than in Salima, where 28% of the area was allocated to legumes. Groundnut was the most commonly cultivated legume and in Salima grown among farmers of all types. Soyabean, cowpea and bean had low adoption rates and were usually not grown by the LRE and MRE farmers with restricted land. In both locations, type 1 farms generally showed the least diversity in crops and sometimes only cultivated maize. Although the type 4 and 5 farms with larger land holdings still cultivated relatively large areas with maize, there was more room for other crops as tobacco, cotton or legumes. Tefera et al. (2007, unpublished data) found that in Malawi the average land holding of soyabean growing farmers is 2.76 ha and that these farms usually owned goats and poultry. This indicates that also outside the studied sample areas, at least soyabean is indeed not widely grown by LRE farmers.

Likely causes for more legume cultivation (notably groundnut) in Salima might be the fact that the climate is less favourable for tobacco, which is preferred as a cash crop in Mchinji. Whereas the climate in Salima is favourable for cotton, prices have been very low for a long time. Therefore, more farmers cultivate groundnut as alternative cash crop. Cropping patterns are thus likely to vary among regions as well as among farm types.

Windows of opportunity for any new technology that change the current cropping pattern have to be viewed within the boundaries of the smallholder system. In this study farmers of all types defined the primary boundaries by food security and income, since they all mentioned these as the primary factors intensification of legumes should be able to provide. Although valued by many farmers, the longer term goal of improving soil fertility was not prioritized. This concurred with the findings of Snapp et al. (2002b) who concluded that 'the capacity of crops to be competitive is key' (pp. 171). The ability of legumes to provide adequate food and income is therefore discussed within the region and farm specific agronomical, biophysical, socio-economical and cultural contexts.

Competitiveness of legumes – food

Maize was highest yielding in kg ha^{-1} at both locations, and gave the highest energetic returns to land of all crops in Mchinji. However, in Salima energetic returns to land were higher for groundnuts due to its high nutritious value and relatively high yields. Legume yields other than groundnut and trial-related soyabean were generally low and consequently generated lower energetic returns than maize or groundnuts. Although the majority of the households were food secure in terms of daily required energy based on 2010/2011 domestic production, fewer farms, especially in Mchinji, met their daily requirements good quality protein[4]. Whereas food insecurity mainly concurred with falling into farm type 1 or 2, inadequate good quality protein production did not depend on farm type. In Mchinji more farmers were food insecure than in Salima, probably due to the smaller farm sizes of the LRE farmers in Mchinji and the cultivation of tobacco as cash crop rather than groundnuts.

Even though legumes can improve the nutritious status of many households, and notably groundnuts had relatively high energetic returns to land, lack of cash, land and labour were the most commonly mentioned constraints to expanding legume production by the LRE and MRE farmers of type 1, 2 and 3. This concurred with other reports that lack of seed or cash to buy seed, lack of labour, low yields and to a lesser extent also land shortage are the main factors constraining legume expansion (Bezner-Kerr et al., 2007; Snapp et al., 2002b). Although lack of cash is a relatively easy constraint to overcome since legume seed can easily be multiplied, the majority of the farmers with restricted land thought that it was not possible to reduce the area under maize cultivation without endangering food security. Only maize is regarded as a food security crop (Smale, 1993) and farmers strongly prefer to avoid the need to purchase part of their maize on the market (Snapp et al., 2002b). For farmers with larger land holdings, the expansion of legumes could thus positively benefit to the nutritious status of households, especially in Mchinji.

Although most households also met the minimum amount to be self sufficient in maize with the 2010/2011 yields, its ability to generate adequate food security is dynamic. Maize yields obtained by individual farmers within the same year varied with more than a factor seven. Although differences in yield among farmers are often associated with differences in resource endowment (Kamanga et al., 2010; Zingore et al., 2008), this was only observed for Salima and not for Mchinji. However, the underlying reason that soil fertility status, used inputs and management depend on resource endowment were not all observed in this study either. Besides the fact that most soil fertility parameters were not significantly correlated to farm type or resource endowment, the governmental fertilizer subsidy program probably reduces the effects of being able to buy yield increasing nutrient inputs or not. However, the first might also be a result from the latter since nutrient inputs can also be reflected by measured soil parameters. Furthermore, in Mchinji HRE market oriented farms clearly prioritized tobacco over maize in terms of labour and nutrient allocation, which probably negatively affected their maize yields. In this study, resource endowment did not influence legume yield at all, since no observation was observed between legume yields and farmers of diverse type and legumes did not receive nutrient inputs and were never prioritized by farmers of any type.

Lowest and highest yield obtained by the same farmer between the years 2005-2010 could differ with more than a factor two. National figures from 2000-2009 (FAOSTAT, 2011) even showed that average maize yields varied with more than a factor three in this period of time. It appeared that the 2010/2011 maize yields were generally high, approaching, and in Mchinji even exceeding, the country's maximum average maize yield obtained between 2000 and 2009. Alene et al. (2008) found that 45% of Malawian households are food insecure based on 2200 kcal/day, whereas other estimates lie between

[4] Although the exact balanced diet between cereal protein and legume protein was not considered, their relative distribution gives an indication on quality of nutrition.

25% and 34 % (FAO, 2010). Food insecurity of the sampled farms was below these numbers (23%) and can be attributed to the generally high yields of food crops and/or to the fact that HRE farmers were on purpose disproportionally abundant in the used sample.

Especially in Mchinji, expanding legume production could improve self-sufficiency in high quality protein. However, legumes in general have to compete with the cultural status of maize as the only proper food security crop and food security has to be viewed in the wider context of variable yields; between regions and years, but also between farmers who are in different positions to produce adequate amounts of food based on available land, soil fertility status and availability of inputs. Also removal of fertilizer subsidies can decrease maize yields, especially for LRE farmers.

Competitiveness of legumes – income

Groundnut was already grown as a major cash crop in Salima. Although in Mchinji some LRE farmers of type 1 earned a reasonable part of their (very small) cropping income with groundnuts, tobacco provided the largest part of the cropping income for the vast majority of the farmers from the other types.

Besides attained yields, economic feasibility depended on highly variable market prices and input costs. Generally, product prices fluctuated per region and per year. In addition, individual farmers often received different prices for their product, depending on where and when[5] a farmer sold his or her product. Input costs also varied among farmers, depending on the allocated amounts of family and hired labour, the amount of inputs purchased and whether these were subsidised or not.

Despite lower yields, economic net benefits per hectare from any legume were generally higher than the often negative net benefits from maize due to higher market grain-prices and lower inputs costs of legumes. This was in line with other authors who found that inclusion of legumes in maize based cropping systems substantially increased the economic benefits (Adjei-Nsiah et al. 2008; Franke et al., 2010; Snapp et al., 2002b). Of the legumes, groundnut generated the highest net benefits. Soyabean, depending on market price, generated either rather positive or slightly negative net benefits. Cowpea and beans generated relatively high benefits but only few observations were made.

The economic competitiveness of legumes relative to tobacco and cotton mainly depended on the yearly fluctuating prices of these export crops. Although groundnuts were not always as profitable as tobacco or cotton, they were less risky in the sense that their average market prices varied not more than with a factor two over the period 2005 – 2011, whereas those of tobacco and cotton varied with more than a factor five. Furthermore, the variation in legume yield and input costs among individual farmers within the same year did not risk as strong negative economic net benefits for legumes as it did with tobacco, even when tobacco prices were high.

Competitiveness of a crop in the farming system also depends on its investment costs. Not all farmers are able to make the same investments. Therefore, a crop that might be able to generate high

[5] Although not measured in this study, it is likely that market prices for agricultural produce also fluctuate within years (Ojiem, 2007).

net benefits, but requires large initial investments, might not be feasible for all farmers. Input costs for legumes were generally low and existed for the largest part of opportunity costs for family labour, since legumes were never targeted with fertilizer and most farmers relied on saved seeds. Total labour inputs were a little higher for groundnuts than for maize or cotton, but much lower than for tobacco. Labour inputs to soyabean and beans were very low. However, these crops were usually weeded only once whereas maize and tobacco and in the majority of the cases also groundnuts were weeded twice. Labour use efficiencies in terms of kg product per labour hour were approximately two (Salima) and four (Mchinji) times higher for maize than for groundnut.

Although labour estimates were highly variable among farmers, all farms showed the same trend in relative amounts of labour allocated to each crop. Furthermore, both the average total amounts of labour allocated to maize and the relative amounts of time spent on each activity were within the ranges found by Takane (2008) for several locations in Malawi. The variability in household labour estimates in this study might be explained by (1) the ability of a farmer to correctly estimate the amount of labour (2) the possibility that labour efficiency increases with field size and (3) the actual availability of labour. Since land/labour ratios were generally not correlated to actual labour spent to the different crops, the actual availability of labour is thought to be mainly influenced by the ability to hire labour, and whether or not farmers work outside their farm. Although Takane (2008) found that Malawian farmers working casually on other farms did generally not spend less labour on their own farms than farmers who did not, in this study the type 1 farmers from Mchinji generally did spend less labour on their own farm. However, this was not per se the case for Salima. Yet, Takane (2008) does argue that farmers who also work on other farms might become unable to timely plant and weed on their farm. Besides the fact that market oriented type 4 farms spent allocated more labour to their fields, they also spent more money on an area basis on purchased inputs.

In short, although not grown as major cash crops in Mchinji, legumes were found to be less risky than tobacco or cotton, which have the capability to generate strong negative net benefits without any edible yield. Furthermore legumes required less initial investments in the form of labour and purchased inputs. Yet, economic feasibility is highly dynamic, since with both used price scenarios, differences between the minimum and maximum obtained net benefits per farmer were high for each crop and prices are subject to large fluctuations. Although labour efficiency of maize was generally higher than that of groundnut, groundnut still generated higher net benefits than maize. Yet, small-scale farmers are too risk averse to replace part of their maize production by legumes. Although legumes are generally more profitable, when maize harvests are low, prices rise and the benefits of legumes will not be adequate to purchase sufficient maize.

Constraints against expanding legumes as cash crop

Although legumes were generally profitable as cash crop and had relatively low risks, many farmers, especially in Mchinji, did not grow legumes as major cash crop. HRE market oriented farmers always mentioned market potential as a major constraint against expanding legumes on their farm. Although also small-scale LRE and MRE farmers mentioned income as a production objective, they did not mention marketability as a constraint. These farmers produced only small quantities of legume grains and marketing of legumes that are popular food (relish) crops on a village or local scale was thus far never mentioned as problem. However, large-scale market oriented farmers having to sell a large amount of legumes might have to focus on urban or export markets. Although groundnuts were well marketable on a larger scale, market oriented farmers mentioned that marketing of soyabean, beans and cowpea was problematic or not profitable.

Although some farmers additionally mentioned low availability and high prices of legume seeds as constraining factors, the hypothesis that inputs for legume cultivation such as seeds and chemicals are often not available and against erratic prices could not be confirmed for all legumes. Certified varieties of groundnut seeds (usually CG7) were often saved by the farmer and besides that also widely available on the local markets and within the village. For beans, cowpea and soyabean, however, on the local market only seeds of local (unknown) varieties were available for relatively high prices and not always in time for planting. Because the above mentioned legumes were not widely grown, the 'network' was not as extensive as for groundnuts. Also, farmers complained about the non-availability and/or high prices of chemicals needed to spray cowpea. Availability of inputs to cultivate legumes other than groundnut is currently thus a valid constraint for legume expansion.

Many subsidy and donor or relief programs distribute free seed. Alene et al. (2008) found that for the 2007/2008 cropping season 83% of adopters of improved varieties of soyabean in Malawi received seed from NGOs. Tripp and Rohrbach (2001) argue that reliance on free seed distribution is a major constraint to seed system development. The possibility that the government or any organisation will suddenly initiate a free seed distribution program reduces interest in the development of local seed distribution channels. In this current study, many farmers relied on subsidized maize seed and seeds of legumes other than groundnut were often obtained by participation in trials. Although the non-availability of certain seeds was constraining some farmers from expanding legumes on their farm, too little or too inconsistent demand does not stimulate the seed market to produce and sale small packs of legume seeds. Initial market development proving the level and consistency of seed demand is a requirement for the also risk averse seed traders to stock up on certain crops or varieties (Tripp and Rohrbach 2001). Projects might fulfil this initial role through promotion and distribution of different varieties. However, if a critical mass is reached, projects should retreat so that also the seed market has a chance to develop and that adoption of future improved varieties does not require project aid. Although legume seeds can easily be recycled this is not thought to hampered seed-market development. In both research sites in Malawi groundnut 'seed networks' were well-established. Still, groundnut seed was widely available on all local markets and farmers regularly bought new seeds.

However, institutional constraints against legumes as cash crops alone cannot explain the preference of farmers for cash crops as tobacco over legumes. Marketing of the rather profitable and low risk legume groundnut was for example not considered a problem. Yet, in Mchinji farmers did generally not grow groundnut as a cash crop. Some larger-scale farmers instead even cultivated very large areas of generally non-economically profitable maize, of which they mentioned to sell substantial amounts every year. In Salima, farmers did cultivate groundnuts as a cash crop, but with the rising cotton prices of the last two years, some farmers mentioned that the cultivation of cotton was expanding again on their farm and the cultivation of groundnuts was decreasing. Cultural constraints against cultivating legumes as cash crops were never directly mentioned by farmers. However, informal communication with farmers generally pointed at the status associated with different crops. Although women also worked in the tobacco fields, the nursery was purely men's terrain. Tobacco was thus a men's crop, influencing his status. Despite the low economic benefits, to be able to grow large quantities of maize rather than legumes also positively influences a man's status. Successful promotion and targeting of legumes as cash crops thus needs further research on the cultural status of the different crops.

Legume contributions to soil fertility

Although field measurements to assess the contribution of legumes to soil fertility went beyond the scope of this research, some indications on this role of legumes can be given. First, especially in Mchinji, the small area under legume cultivation probably limited the contribution of legumes to soil fertility at a farm level. Second, especially in Salima, many farmers did not incorporate or compost legume residues immediately after harvest. Instead they were burned or just left in the field to be incorporated or burned only prior to the next growing season after being grazed upon by freely roaming livestock. Nutrient cycling by livestock can be an effective way of preserving nutrients over the dry season (Franke et al., 2008). However, legume farmers without livestock do not benefit from their nitrogen rich residues if they are carried away to other farms by livestock. Zingore et al. (2007) support the theory that this is one of the underlying mechanisms that is able to cause soil fertility gradients between farms with different livestock numbers and thus different resource endowment. Given the length of the dry season in Malawi and the presence of freely grazing ruminants, the majority of the N in residues remaining on the soil surface after harvest is likely to be lost from the field at the start of the next growing season (Franke et al., 2008). Of the farmers who did not incorporate or compost legume residues, a part indicated not to know the added value of recycling legume residues and a part considered the returns to labour too low.

Third, among the measured factors that might constrain legume biomass production and effective BNF, especially plant available P and exchangeable K were found to be highly variable. High variability of available P was also confirmed by amongst others Snapp (1998) and was attributed to the enormous spatial heterogeneity in topography of Malawi. In this study, available P also seemed to relate with resource endowment and livestock numbers. K levels found in this study were highly variable and lower than found by Snapp (1998), who indicated that 99% of the soils contained more than three times the level critical for maize. This indicates that regional and local variations in soil parameters are high. Tittonell (2007) even underlined that differences in soil fertility within a single farm may be as wide as between agro-ecological zones, strongly influencing performance of different technologies.

In the current study no evidence was found for the hypothesised soil fertility gradients and associated differential management of fields as a function of distance from the homestead. Such gradients might indeed be reduced or absent in densely populated areas with low ruminant densities (Tittonell et al., 2005b), as was the case in the studied areas. Yet, farmers preferred to allocate maize and tobacco to the more fertile fields. Legumes were more frequently cultivated on the less fertile fields which might have deficiencies that constrain productivity and effective BNF. Although the small contribution of legumes to soil fertility is generally ascribed to low biomass production, Ojiem et al. (2007) also observed 44% less N_2 fixation in low fertility fields compared to high fertility fields in Kenya.

Nevertheless, farmers always mentioned the positive effects of legumes on subsequent maize yields. Although highest maize yields were reported on fields preceded by tobacco, maize yields were higher indeed after legumes than after (often fertilized) maize. It went beyond the scope of this research to assess whether the increase in maize yields after legumes was caused by a net N contribution of legumes to the soil, or caused by other rotational effects such as breaking pest and disease cycles. Lupwayi et al. (2011) also remark that even when legumes do fix not enough N_2 to positively contribute to the net N-budget of the soil, they can still 'spare' or 'conserve' N. Furthermore, groundnut - the most widely grown legume in Mchinji and Salima - has a low N harvest index and accumulates much N in the leaves (Giller and Cadisch, 1995). Therefore, the potential N contribution of groundnut to subsequent crops is relatively large. However, this is only the case if large N losses from the residues during the dry season can be avoided. The high maize yields obtained after tobacco were probably due to residual fertility benefits of the high amounts of nutrients from both organic and inorganic sources allocated to tobacco.

Legume intensification for soil fertility improvements must also be evaluated in relation to other inputs. With the current subsidy program inorganic nutrient inputs were generally high compared to surrounding countries. The reduced need to seek alternative soil fertility methods might cause the low interest farmers showed in soil fertility options of legumes. Also, especially in Salima, farmers hardly made and used compost manure, but indicated to start doing that when the subsidies would be removed. Then, they might become more interested in the potential of legumes to contribute to soil fertility. However, since farmers perceive maize to be the only proper food security crop, it is well possible that with removal of fertilizer subsidies and subsequently lower maize yields, LRE farmers will expand the area under maize cultivation and probably decrease the area under the least valued crops: legumes.

Yet, in both areas but especially in Salima, soil fertility could benefit from better residue management aimed to carry carbon, N and other nutrients over the dry season. This also assures that nutrients in residues remain within the same farm rather than moving from LRE to HRE farms.

Windows of opportunities

The windows of opportunity that emerge from the above discussed boundaries are different for different types of farmers. Generally, all farmers with enough land to be self sufficient in maize production can start cultivating legumes or expand the area under legume production without endangering 'maize-security'. Especially for the farmers of the 1st, 2nd and 3rd in Mchinji who sometimes grow small areas of tobacco, replacement of tobacco by legumes can be a more sustainable and less risky alternative cash crop. Farmers who grow larger amounts of maize than necessary can also expand legume cultivation, to increase maize yields with rotational effects as well as to improve nutrition and increase income, since legumes are likely to generate more cash than a surplus of maize. Because groundnuts have under the current management the highest yields, these will be the most suitable legume, both for fortifying maize based diets and for providing market possibilities. Since labour efficiencies for groundnuts were lower than in Salima, improvements could also be made on this terrain.

In Salima many farmers of these same types already cultivated relatively much groundnut and it is unlikely that they will still expand their area. Because groundnut is already widely grown, and farmers are already acquainted with the crop, options for yield improvement or different varieties are more likely to be adopted than whole different species of legumes. However, it is unlikely that an increase in yield will result from nutrient inputs, since farmers of these types usually were cash constraint. On the other hand, improvement of management might be a strategy to increase yields. Yet, the increase in yield has to be substantial to make the changes in management sustainable, since it is likely that maize will still be prioritized in terms of planting and weeding. However, this strategy will unlikely to be effective for type 1 farmers, who casually work on other farms and might therefore become unable to timely manage their own crops. In addition, if farms cannot meet their maize requirements, it is unlikely that they will expand the area under legumes or adopt new species or varieties.

Also farmers of type 4 could still benefit from increased on-farm production in legumes to improve nutrition, especially in Mchinji. However, the availability of seed and the absence of a market for the produce, or the competition with non-edible cash crops as tobacco and cotton are likely factors that currently constrain these farmers from expanding the area of legumes other than groundnut beyond home consumption. Promotion of groundnut as cash crop is not necessary in Salima, but might be useful in Mchinji, where type 4 farmers mainly grow tobacco and the role of groundnut as profitable and low risk cash crop is often neglected. However, techniques or new varieties that result in higher yields have a change for adoption. Besides groundnuts, soyabean also has the potential to become a large-scale cash crop. Whereas national production of groundnut exceeds domestic use, 8437 tonnes of soyabean are imported yearly (FAOSTAT, 2011). This seems paradoxically, but marketability of groundnuts for larger-scale farmers is generally not a problem since (1) the combination of relatively large areas under cultivation and the relatively high yields result in high enough amounts for a farmer to deal with transaction costs to link the product to the urban or export market and (2) seeds are well available. Soyabean on the other hand has no well established seed market, low yields, and farmers only allocate it small areas. The small amounts produced are not compatible with the imported foreign soyabean. These three factors are interrelated, since low yields do not stimulate a farmer to cultivate large areas, and low seed demand by farmers hampers development of the seed market. Opportunities for soyabean to become a marketable product and increase national self-sufficiency in this product thus have to be sought in all three fields. Increased yields with improved varieties and better management can be a valuable first step.

Although type 5 farms generally differed in their cropping patterns and production orientation, also for these farms in Mchinji area under legumes could be expanded, with a reduction in maize and tobacco. In both areas different legume species could be promoted to diversify the self-sufficiency in legumes for home consumption and increases in yield can probably be obtained.

Improved residue management may be a relatively easy way to increase nitrogen contributions of legumes to subsequent crops for farms of all types. Although relatively high labour requirements are associated with adequate residue management, improved management of at least long duration legumes should be attainable for all farmers, since it is done after the cropping season and no more labour is required for weeding or harvesting. In addition, legumes could be planted on more fertile fields to gain more from BNF and prevent the still fertile continuous maize fields from being depleted too.

The role of projects

Besides the easy opportunity of a project to assist cash constrained type 1, 2 and 3 farms with a starter package of seeds which can subsequently be recycled, the role of the project really should be to educate farmers and initiate both seed and market development by reaching a critical mass of farmers. Education of farmers can (1) have positive effects on soil fertility through better residue management, (2) improve farmers' knowledge on varieties and which one fits best for their purpose (3) improve farmers' management and thereby yields and (4) get rid of the perception of farmers that legumes do not require any fertilizer since they can make their own. If legumes other than common food crops are promoted, or if the local market becomes satisfied, the role of the project should also be to assist these small scale farmers in marketing their product (Giller et al., 2011). Small-scale farmers are not able to market their relatively small amounts of produce directly on urban or export markets due to e.g. high transport costs or indirectly via traders for whom only large enough quantities are economically valuable.

Increasing the market potential of a crop is of major interest for the type 4 farms. The first objective of a project in increasing marketability of a product should be to assists farms in attaining higher yields, so that farmers become interested in the crop and increase its area under cultivation. Simultaneously, seed and grain markets need to develop. If for example soyabean can be produced in large quantities to make it competitive with the otherwise imported product, farmers can sustainably cultivate more soyabean and at the same time benefit from options to improve soil fertility. However, this development has to be accompanied with development of input markets. Since soyabean often benefits from inoculation and P fertilizer, these products will have to be available on the market when project help stops.

Yet, many projects and on-farm trials have not substantially increased farmers' adoption of legume technologies (Snapp et al., 2002b). Although this is commonly attributed to the also in this study mentioned constraints, the rather unsustainable 'ad hoc' strategy of many projects might also play part in this. As came forth from this current study, the soyabean farmers who participated previously in a crop or nutrient management trial fell back to their own production patterns as soon as their participation ended[6]. The agricultural transformation in Western Europe a century ago on the other hand, was mainly initiated by the establishment of numerous local small-scale research stations where farmers could see and experience the longer term effects of certain crops and technologies, in combination with farmer cooperatives and development of infrastructure for input and output markets.

Although in Malawi relatively large governmental research stations were present, its local smallholder-scale equivalents were largely lacking. As can be concluded from the above, the context in which dynamic smallholder farmers operate is highly dynamic. At least regional variation can be

[6] Although the trial was not a project aimed at aid and development, the comparison is thought to be valid here.

captured in those research stations. Furthermore, these stations can function as a gathering place for the large existing body of knowledge, which has usually not systematically been brought into practice. Snapp et al. (2002b) for example concluded than a maize rotation with intercropped groundnut/pigeonpea was the most profitable option from a range of intercropping and rotation possibilities. Information like this can well be tested, practiced and disseminated by local research stations. Although it is commonly acknowledged that legumes have the potential to contribute much to soil fertility, nutrition and livelihoods, risk-adverse farmers may besides the valid declared production constraints be stuck in 'old behaviour patterns' (Kollmuss and Agyeman, 2002). The roll of disrupting this pattern might be also be fulfilled by these farm-scale research stations and media such as radio. The latter proved to be a valuable strategy for the improved adoption of hybrid maize in Malawi (Smale, 1993). Also, as discussed above, infrastructure for seed and grain market was mainly lacking. Giller et al. (2011) clearly illustrate that a strong technology can only be sustainable when it is embedded in a strong institutional environment.

Cooperation with local extension workers and agronomists to establish long-term locally run research stations and the development of farmer corporations might be a more sustainable option for projects than approaching many individual farmers on a short term. In addition, infrastructure for seed and grain market need to be developed.

Concluding remarks

Although grain legumes will probably not always positively contribute to soil fertility on all fields, they offer high quality protein that many households would otherwise lack. In addition, legumes seemed to be a less risky cash crop option than tobacco or cotton. Yet, expanding legume production on smallholder farms is only likely to be effective when food security is maintained and the relevant legume is compatible as cash crop. For the subsistence oriented type 1, 2 and 3 farms, legumes have the potential to be adopted or expand when the household is self-sufficient in maize. An easy to measure socio-economic indicator to be included in a rapid survey to determine 'target' farms for legume projects could thus be the ratio between available land and number of people eating in the households combined with the prevailing maize yields. As a rule of thumb 200 kg maize production per year can be used as a minimum. Although cropping patterns differed per region, in both regions there are possibilities to improve yields of grain legumes. Marketing and availability of inputs were merely constraints mentioned for expanding legumes other than groundnut by the HRE market oriented type 4 farmers. A project should thus not focus on the distribution of seeds as such, since this will disrupt the desired seed market development currently mentioned as a major constraint by many farmers, but only to disseminate different legumes and increase farmers' knowledge on varieties, how to increase yields and thereby creating initial potential for seed market development. Preferentially, the impact of a project has to be long term and sustainable, by for example establishing long term local farm-scale research stations in cooperation with local extension workers and agronomists.

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Appendix I – detailed tables per farm

I.I GPS coordinates of the homesteads

Table 30. GPS coordinates of the homesteads of the farms targeted by detailed system characterization.

Mchinji			Salima		
farm ID	coordinates homestead		farm id	coordinates homestead	
1	S 13,74453	E 033,03860	1	S 13,66539	E 034,27876
2	S 13,74562	E 033,03992	2	S 13,66539	E 034,27876
3	S 13,71632	E 033,05110	3	S 13,63181	E 034,30308
4	S 13,71652	E 033,04910	4	S13,64294	E034,29461
5	S 13,70885	E 033,00689	5	S13,65281	E034,28435
6	S 13,71576	E 033,00900	6	S 13,69693	E 034,22465
7	S 13,70612	E 033,01496	7	S13,68779	E034,24757

8	S 13,70702	E 033,03024	8	S 13,68610	E 034,24850
9	S 13,70996	E 033,05959	9	S 13,68627	E 034,24868
10	S 13,70919	E 033,08837	10	S 13,68651	E 034,24873
11	S 13,73542	E 033,04661	11	S 13,66967	E 034,25776
12	S 13,75941	E 033,06334	12	S 13,66571	E 034,26008
13	S 13,76121	E 033,04378	13	S 13,66571	E 034,26030
14	S 13,76185	E 033,04343	14	S 13,66049	E 034,27781
			15	S13,65989	E034,27860
			16	S13,63353	E034,29850

I.II – Yearly income from cropping, livestock and off-farm sources per farm

Table 31. Yearly income in $ and its proportional distribution between crops, livestock and off-farm per farm over 2010

Mchinji						Salima					
farm type	farm id	total income	crops	livestock	off-farm	farm type	farm id	total income	crops	livestock	off-farm
1	6	189	5%	0%	95%	1	9	313	42%	0%	58%
1	10	143	7%	0%	93%	1	10	427	9%	17%	75%
1	11	187	0%	0%	100%	1	16	120	0%	0%	100%
2	4	337	100%	0%	0%	2	1	383	9%	0%	91%
2	9	670	49%	39%	11%	2	4	552	42%	0%	58%
2	12	205	51%	0%	49%	2	5	47	96%	4%	0%
3	2	947	0%	0%	100%	3	3	502	4%	0%	96%
3	3	233	57%	0%	43%	3	7	485	34%	0%	66%
3	8	297	62%	11%	27%	3	8	239	40%	0%	60%

3						3	13	211	38%	5%	57%
4	1	1560	94%	0%	6%	4	6	19533	98%	1%	1%
4	14	27727	73%	0%	27%	4	11	12467	96%	0%	4%
5	5	2259	47%	0%	53%	5	2	991	17%	6%	76%
5	7	3720	48%	0%	52%	5	12	2740	1%	1%	99%
5	13	1499	18%	44%	38%	5	14	1273	7%	5%	88%
5						5	15	908	3%	0%	97%

I.III – Cropping patterns per farm

Table 32. Cropping patterns per farm

	Mchinji							Salima								
farm type	farm id	total ha	maize	tob [a]	gnuts	soyabean	beans	farm id	total ha	maize	tob	gnuts	soyabean	cotton	sorg	cowpea
			proportion of cultivated area							proportion of cultivated area						
1	6	0.56	100%	0%	0%	0%	0%	9	0.56	41%	0%	20%	0%	19%	0%	19%
1	10	0.54	56%	37%	7%	0%	0%	10	1.04	65%	0%	35%	0%	0%	0%	0%
1	11	0.48	100%	0%	0%	0%	0%	16	0.1	100%	0%	0%	0%	0%	0%	0%
2	4	0.22	45%	55%	0%	0%	0%	1	0.90	92%	0%	8%	0%	0%	0%	0%
2	9	0.6	47%	33%	20%	0%	0%	4	1.61	28%	0%	14%	3%	30%	25%	0%
2	12	0.7	43%	29%	0%	29%	0%	5	1.18	87%	13%	0%	0%	0%	0%	0%
3	2	1.12	100%	0%	0%	0%	0%	3	0.79	87%	0%	0%	0%	13%	0%	0%

3	3	0.52	39%	17%	0%	44%	0%	7	1.28	34%	0%	28%	4%	34%	0%	0%
3	8	0.88	70%	18%	11%	0%	0%	8	0.90	41%	0%	59%	0%	0%	0%	0%
3								13	0.63	64%	0%	36%	0%	0%	0%	0%
4	1	2.84	63%	21%	15%	0%	0%	6	3.78	25%	26%	43%	0%	0%	0%	5%
4	14	11	78%	19%	4%	0%	0%	11	3.00	12%	43%	7%	0%	39%	0%	0%
5	5	4.86	66%	0%	28%	3%	4%	2	2.00	47%	0%	22%	3%	26%	0%	3%
5	7	1.5	63%	27%	11%	0%	0%	12	0.54	100%	0%	0%	0%	0%	0%	0%
5	13	2.04	43%	29%	14%	14%	0%	14	1.54	63%	0%	26%	0%	0%	0%	11%
5								15	1.12	56%	0%	40%	0%	0%	0%	4%

[a] tob=tobacco, gnuts=groundnuts, sorg=sorghum

I.IV – 2010/2011 yields and maximum yield variation per farm.

Table 33. Reported yields for a. Mchinji and b. Salima per farm, in kg ha^{-1}. Lowest and highest yield refer to the lowest and highest yields respectively obtained by the individual farmers in the period 2006-2010. For lowest and highest yields, both yields and the area on which the crop that year was cultivated are farmer estimates.

a.Mchinji	farm id	maize			tobacco			groundnuts			soyabean			beans		
farm type		2011	lowest	highest	2011	lowest	highest	2011	lowest	highest	2011	lowest	highest	2011	lowest	highest
1	6	2917	750	1500												
1	10	1667	248	998	350			1875	330	495						
1	11	1125	1125	1500												
2	4	5400	1500	3750	833	500	1000									
2	9	7143	2175	4275	600	250	1500		308	919						
2	12	2400	1500	2250	500	250	500				450	625	1125			
3	2	1125	1500	2625												
3	3	2700	750	1875	455						702	125	250			
3	8	3790	750	1875	1875	625	625	3050	660	1760		175	650			
4	1	5733	1350	2400	833	1000	2250	182	303							
4	14	2229	1920	3600	588	2000	4100	1089	275	900						
5	5	2363	2250	8250				666	450	1125	968	500	500	500	375	375
5	7	1915	750	1200	2000	750	1500	688	220	1320						
5	13	5482	1500	3000	3333	1000	1600	1286	550	1320	643	625	1500			

b. Salima	farm id	maize			tobacco			groundnuts			soyabean[a]	cotton			sorghum			cowpea		
farm type		2011	lowest	highest	2011	lowest	highest	2011	lowest	highest	2011	kg/ha	lowest	highest	2011	lowest	highest	2011	lowest	highest
1	9	1983	1875	3250				1786	1173	1760		1389	750	1000				463	750	200
1	10	1588	750	1125				489	440	1540										
1	16	720	500	1500																
2	1	1957	750	1748				2588	147	367										
2	4	1230	998	2498	2013	250	1000		440	2420										
2	5	1553	375	3000				3860	330	825	615	1042	500	1000						
3	3	1618	1500	1733									500	1000						
3	7	2523	1748	2498				989	1210	2310	1385	1818	1000	1125						
3	8	2903	750	3000				1075	990	1650										
3	13	1350	1200	2400				540	1320	1650										
4	6	3750	7188	9375	1200	2875	3650	570	1998	2750					na	2688	4063		250	50
4	11	5000	1500	2813	3125	1000	1500	2596	1650	2338		2759	750	2000						
5	2	2978	1500	2498																
5	12	4125	5625	6248				1183	917	1650								656		
5	14	4097	750	3000				933	330	1650								2083		
5	15	1936	750	1875				1936	587	1540	4000	1154	250	875						

[a] only obtained in agronomic trials.

I.V – labour inputs per farm

Table 34. Labour inputs (both family and hired) per farm and per crop, in hours ha^{-1}

	Mchinji						**Salima**						
Farm type	farm id	maize	tob	gnuts	soyabean	beans	farm id	maize	tob	gnut	cotton	sorg	cowpea
1	6	817					9	2517		3839	1301		648
1	10	663	1735	2300			10	2182		2489			
1	11	850					16	510					
2	4	560	833				1	2728		2338			
2	9	1829	3020	1000			4	2489		1820	1275	770	
2	12	980	2220		1188		5	2313	9512.5				
3	2	2143					3	1588			3790		
3	3	875	2011		513		7	1449		691	1048		
3	8	987	3638	1050			8	793		1108			
3							13	1370		1509			
4	1	933	5980	1127			6	2555	3320	2629		553	5180
4	14	1025	6276	1913			11	4350	4153	9845	2343		
5	5	1948		2545	540		2	567		741	715		
5	7	533	1988	1500		420	12	1706					
5	13	4195	2475	3179	1258		14	1154		1690			1000
5							15	3179		879			293

I.VI – N and P inputs per farm

Table 35. N and P inputs to maize and tobacco per farm.

	Mchinji	maize				tobacco				**Salima**	maize				tobacco			
		inorganic		organic		inorganic		organic			inorganic		organic		inorganic		organic	
farm type	id	N	P	N	P	N	P	N	P	id	N	P	N	P	N	P	N	P
1	6	71.88	9.55							9	74.35	9.88						
1	10	76.67	0.00			57.50	22.93			10	50.74	6.74						
1	11	47.92	0.00	4.76	0.77					16	115.58	22.93						
2	4	230.00	0.00			152.08	0.00	16.68	1.91	1	13.89	0.00						
2	9	123.21	16.38			172.50	22.93	12.51	1.43	4	11.23	0.00			37.83	15.08		
2	12	57.50	7.64			136.88	0.00			5	76.33	10.14	9.00	1.51				
3	2	41.07	8.19							3	0.00	0.00	0.82	0.14				
3	3	172.50	22.93			156.82	20.84			7	120.91	16.07						
3	8	69.56	9.24			393.75	24.56	40.66	4.65	8	123.66	12.33						
3										13	86.25	11.46						
4	1	57.50	7.64			143.75	19.10	88.65	13.79	6	143.75	19.10	2.63	0.13	113.00	31.44	8.14	1.37
4	14	40.30	5.36			82.72	8.03	32.89	5.48	11	223.61	12.74			161.72	21.49		
5	5	208.44	25.79	1.56	0.18					2	63.42	8.43						
5	7	55.05	7.32			273.75	22.93	114.21	18.53	12	89.84	11.94						
5	13	63.71	8.47			167.92	30.57	203.40	34.20	14	83.47	11.09	131.23	22.06				
5										15	30.59	2.44	2.16	0.36				

Appendix II – Factor analyses of socio-economic indicators.

Table 36. factor analyses of socio-economic variables. For both locations the maximum number of components was fixed at three.

Mchinji

Rotated Component Matrix[a]

	Component		
	1	2	3
land/labour ratio	.989		
cropping income ($)	.981		
total income ($)	.981		
livestock ($)	.968		
off-farm income ($)	.966		
assets ($)	.954		
farm size (ha)	.948		
land/person (ha)	.946		
children 5-15	.862		
grain/person (kg)	.807		
household size	.739		
production orientation	.655		
males		.865	
education HH		.853	
education males (years)		.842	
females		.748	
livestock income ($)		.676	
education females (years)		.573	
age HH (years)			.847
source of income			.754
children < 5			-.753

Salima

Rotated Component Matrix[a]

	Component		
	1	2	3
farm size (ha)	.947		
cropping income ($)	.877		
total income ($)	.875		
land/labour ratio	.868		
livestock income ($)	.862		
males	.762		
land/person (ha)	.757		
production orientation	.568		
children < 5	-.521		
household size		.957	
females		.943	
livestock ($)		.835	
children 5-15		.777	
grain/person (kg)			
education HH (years)			.924
education males (years)			.909
age HH (years)	.530		-.633
education females (years)			.619
assets ($)			
off-farm income ($)			

Extraction method: Principal Component Analysis.
Rotation method: Varimax with Kaiser Normalization.
[a] Rotation converged in 7 iterations.

Mchinji

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	11.149	53.091	53.091	11.149	53.091	53.091	10.410	49.572	49.572
2	3.644	17.354	70.444	3.644	17.354	70.444	4.369	20.803	70.374
3	2.763	13.156	83.600	2.763	13.156	83.600	2.777	13.226	83.600
4	1.035	4.930	88.530						
5	.844	4.017	92.547						
6	.614	2.925	95.472						
7	.321	1.526	96.998						
8	.270	1.285	98.283						
9	.179	.851	99.134						
10	.116	.554	99.688						
11	.037	.178	99.865						
12	.015	.072	99.938						
13	.013	.062	100.000						
14	.000	.000	100.000						
15	.000	.000	100.000						
16	.000	.000	100.000						
17	.000	.000	100.000						
18	.000	.000	100.000						
19	.000	.000	100.000						
20	.000	.000	100.000						
21	.000	.000	100.000						

Salima

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.927	34.634	34.634	6.927	34.634	34.634	6.288	31.438	31.438
2	4.033	20.167	54.801	4.033	20.167	54.801	4.157	20.786	52.223
3	3.020	15.101	69.902	3.020	15.101	69.902	3.536	17.679	69.902
4	1.771	8.857	78.759						
5	1.222	6.109	84.868						
6	1.062	5.312	90.180						
7	.822	4.111	94.291						
8	.618	3.089	97.380						
9	.226	1.130	98.510						
10	.127	.637	99.147						
11	.079	.395	99.542						
12	.055	.273	99.815						
13	.026	.128	99.943						
14	.011	.057	100.000						
15	.000	.000	100.000						
16	.000	.000	100.000						
17	.000	.000	100.000						
18	.000	.000	100.000						
19	.000	.000	100.000						
20	.000	.000	100.000						