# Characterization of farming systems in Africa RISING intervention sites in Malawi, Tanzania, Ghana and Mali

**Carl Timler, Mirja Michalscheck, Charlotte Klapwijk, Nester Mashingaidze, Mary Ollenburger, Gatien Falconnier, Katja Kuivanen, Katrien Descheemaeker, Jeroen Groot**

Produced by Department of Plant Sciences
Wageningen University and Research Centre

Published by International Institute of Tropical Agriculture

14 March 2014
www.africa-rising.net

The Africa Research In Sustainable Intensification for the Next Generation (Africa RISING) program comprises three research-for-development projects supported by the United States Agency for International Development as part of the U.S. government's Feed the Future initiative.

Through action research and development partnerships, Africa RISING will create opportunities for smallholder farm households to move out of hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, particularly for women and children, and conserve or enhance the natural resource base.

The three regional projects are led by the International Institute of Tropical Agriculture (in West Africa and East and Southern Africa) and the International Livestock Research Institute (in the Ethiopian Highlands). The International Food Policy Research Institute leads the program's monitoring, evaluation and impact assessment. http://africa-rising.net/

ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE IFPRI IITA Research to Nourish Africa



This document was made possible with support from the American people delivered through the United States Agency for International Development (USAID) as part of the US Government's Feed the Future Initiative. The contents are the responsibility of the producing organization and do not necessarily reflect the opinion of USAID or the U.S. Government.

# Table of contents

# List of abbreviations

| | |
|---|---|
| Africa RISING | Africa Research in Sustainable Intensification for the Next Generation |
| CBO | Community-Based Organization |
| CLHW | Community Livestock Health Worker |
| CMDT | The Compagnie malienne pour le développement du textile (*CMDT*) |
| EPA | Extension Planning Area (Malawi) |
| GSS | Ghana Statistical Survey |
| HRE | High Resource Endowed (Group of Farmers in Ghana) |
| IER | Institut d'Économie Rurale |
| LRE | Low Resources Endowed (Group of Farmers in Ghana) |
| MRE | Medium Resource Endowed (Group of Farmers in Ghana) |
| RO | Research Objective |
| SI | Sustainable Intensification |
| TLU | Tropical Livestock Unit |

# List of appendices



The appendices can be found as separate files provided as supplements to the report.

# Acknowledgements

This report is a reflection of a year of intensive analysis of farming systems in four countries in West Africa and East and Southern Africa. The assignment was commissioned by the International Institute for Tropical Agriculture (IITA) within the Africa RISING project funded by the Feed The Future initiative of the United States Agency for International Development (USAID). We thank our commissioner Irmgard Hoeschle-Zeledon of IITA, and the support of Jerry Glover and Tracy Powell of USAID. Bernard Vanlauwe, Mateete Bekunda and Asamoah Larbi (IITA) were important in the design and execution of the project.

We were supported by many people during the execution of the project, through help with data collection and analysis, and providing additional data and inspiration in project discussions, during meetings and workshops, through Skype and via e-mail. We thank Sieglinde Snapp and Robert Richardson of Michigan State University (MSU), Beliyou Haile and Carlo Azzarri of the International Food Policy Reseach Institute (IFPRI), Peter Thorne and Ewen LeBorgne of International Livestock Research Institute (ILRI), Tom van Mourik of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Tim Ellis of International Water Management Institute (IWMI) and Pablo Tittonell, Ken Giller, Pradnya Kadam and Linus Franke of Wageningen University and Research Centre (WUR). Special thanks to Hennie Halm (WUR) for conducting chemical analyses.

We especially thank the coordinators and data collectors in the four countries.

The work in Ghana was coordinated by Dr. Asamoah Larbi and Dr. Samuel Adjei-Nsiah with help of Obeng Fosu-Brempong, John Bidzan, Shaibu Mellon and Kwame Kwarteng. We thank the effort of the enumerators Shaibu Azuma, Fuseini Abdulai, Confort Ayiripo, Imoro Abu Kassim, Fatima Iddris, Natar Job Jonah, and Alhassan N. Zakaria in the Northern Region. Enumerators in the Upper West region were Mohammed Abdul-Razak, Gideon Kayang, Danyuo Daniel, Charles Waawula, and Marizouk Abdul-Rashid, and in the Upper East region the data collection was conducted by Joyce Adabugah, Christopher Balua, Andriana Atingnongo, Ruth Aninah, and Elijah Bobby Lugugia.

The work in Malawi was coordinated by Dr Regis Chikowo with the help of Kondwani Khonje, Isaac Jambo, Emmanuel Jambo and Davie Botie. Enumerators that collected the data on-farm were Kondwani Nyengo, Chawezi Theu , Dziwani Kambauwa and Grace Wani.

The work in Tanzania was coordinated by Dr Mateete Bekunda with the help of Festo Ngulu and Swai Elirehema. For the Babati district the enumarators were Ruth Mzava, Peter Sulumo, Odette Ngulu and Edgar Lyakurwa. In the Kongwa and Kiteto district, Elisha Bakuza, Arachus Kategano, Eluid Kongola and Ishmail Ngolinda were involved in the on-farm data collection.

The work in Mali was coordinated by Mary Ollenburger with support of Gilbert Dembele, Karim Mallé and Birama Sissoko. The enumerators involved were Daouda Sanou, Nouhoum Dembélé, Djakaridia Goita, Issouf Boiré, Moussa Samaké and Adama Samaké.

# Executive summary

This report presents the findings of the first phase of farming systems analysis within the Africa RISING (Africa Research in Sustainable Intensification for the Next Generation), a research program of the Feed-the-Future initiative of the USA government. The Department of Plant Sciences of Wageningen University and Research Centre (The Netherlands) performed this analysis in the period April 2013 to March 2014.

The objective of the first phase of farming systems analysis within the Africa RISING project was to characterize farming systems in project intervention areas, to make farm typologies, and to find constraints and entry points for sustainable intensification and innovation at the farm level.

The analysis was performed in intervention areas in Malawi (Dedza and Ntcheu districts), Tanzania (Babati and Kongwa/Kiteto), Ghana (Northern, Upper West and Upper East regions) and Mali (Bougouni and Koutiala areas). It comprised four steps:

1. Rapid characterization of farming systems by a survey.
2. Detailed diagnosis of a representative subset of farms through farmer interviews (Malawi and Tanzania) or a detailed survey (Ghana and Mali).
3. Model-based exploration of trade-offs and synergies within the farms, which results in set of alternative farm configurations that perform different in productive, economic and environmental performance indicators, and
4. Selection of a desirable farm configuration, as identified by the farmer and other relevant stakeholders on the basis of the performance indicators, for fine-tuning and redesigning the case study farm.

The steps 2, 3 and 4 can yield suggestions and entry points for farming systems adjustments. Steps 3 and 4 for were performed for the Malawi, Tanzania and Ghana case study.

A large variation in farm size and endowment was observed in the case study areas in all countries, although the average farm size was smaller in Malawi (1.0±0.7 ha) than in Tanzania (4.3±5.2 ha), Ghana (3.3±8.9 ha) and Mali (9.9±7.1 ha). In all areas the farms were grouped into farm types on the basis of structural and functional farm characteristics that reflect their size (surface area and livestock density), production orientation (subsistence or market) and income sources (on and/or off farm).

In most regions the farmers cultivated 3-4 crops, except in Malawi (Dedza and Ntcheu districts) and the Upper West region of Ghana, where most farmers had 2-3 crops. Maize and a legume (groundnut or pigeon pea, and cowpea to a lesser extent) were the most important crops, whereas in the Kongwa & Kiteto area of Tanzania also sunflower was found as an important

crop. In the Koutiala district in Mali also cotton, sorghum and millet occupied large areas. The crop yields reported by the farmers were extremely variable and often very low.

Livestock numbers per farm differed greatly between the various countries and regions. In Malawi the livestock density was low, with mainly poultry and small ruminants being present in relatively low numbers. On the larger farms in Tanzania, Ghana and Mali more livestock and also cattle was kept, although not always for productive purposes. Generally, livestock management was sub-optimal.

The stated labor inputs per unit of area were variable but tended to decline with farm size. The percentage of female-headed households differed strongly between regions and was as low as 1-2% in the Northern region of Ghana and the Babati district in Tanzania, while in the Upper West and Upper East regions in Ghana on average 40-50% of the households were female-headed. In Malawi 30-40% of the households were female-headed.

The main constraints and critical points that were identified:

- In general, at the household level farm productivity and on-farm income generation and returns to labor are low, in various cases food availability is insufficient during parts of the year.
- Women representation in decision making and ownership is often limited, although large differences between regions exist. Women indicated that the limited availability of food, clean water, options for sanitation and possibilities for education are important constraining factors. Moreover, limitations in opportunities for post-harvest storage and processing of farm products were reported.
- Limited or untimely availability of resources like seeds and fertilizers. Lack of improved crop varieties and animal breeds that are more productive or better adapted (e.g. early maturing and drought-tolerant).
- Crop yields were low. Combined with the small farm areas and seasonality this resulted in food shortages in parts of the year. On the other hand, for cash crops the low productivity led to small volumes of produce for sales and income generation. Moreover, post-harvest storage losses are large in some cases.
- Problems with pest and weed control, in particular Striga is an important issue.
- The management, storage and conservation of crop residues and animal manures were generally poor. As a consequence, the losses of organic matter and nutrients were probably large and availability of these organic resources for

soil improvement was limited, which was reflected in low soil organic matter contents and soil fertility.

- The feeding of livestock was sub-optimal. Larger animals graze crop stubbles and rely on open and common areas for grazing. The management of grazing areas is often inadequate and availability of watering points can be limiting. Diseases are reported to affect animal performance negatively. As a result, the productivity levels of all types of animals kept on the farms (mainly cattle, goats, sheep, chickens and doves) was low.
- The access to training and advice on land preparation, crop cultivation, animal husbandry and farm management is often limited. In particular women indicated that possibilities for education were lacking.
- Farmers often reported to be challenged by climatic conditions. These issues ranged from overall unfavorable conditions for agriculture, to variability and unpredictability, and trends of changes in climate.

The following entry points were identified and analyzed:

- Encourage seed saving and selection, possibly as a joint effort within the community, focusing on collecting the best seeds. This could serve as a backup if no seeds are available in the market before planting, or when prices are high.
- Improved water management, for instance through water harvesting to enhance the availability of clean water for human consumption and irrigation of (vegetable) crops.
- Diversifying cropping, for instance by growing more vegetables, where collected water (see above) could be used. Increase the productivity and integration of legumes in rotations and by intercropping and double-up legume cultivation, which contributes to nitrogen availability. This could contribute to improved nutrition and possibly health, or generate an alternative income source and spread risks of crop failure and price volatility.
- Fencing of fields to allow better livestock and crop residue management. This can be implemented with artificial or natural fences. In the latter case, hedges can include thorny plants as well as leguminous non-thorny plants such as *Gliricidia*, which will then not only provide security for the crops but also can serve as nitrogen rich green manure for soil improvement or a protein rich fodder for animals when trimmed.
- Developing new strategies for pest and weed management, and Striga control.

- Improved management of collected organic resources like manure and crop residues. If alternatives for manure and wood (charcoal) for cooking and heating could be found and burning on the field is stopped, this would enhance the availability of these resources for animal feeding and soil improvement. Moreover, using alternative fuels could contribute to a better health status of household members. Manure can be stored anaerobically by covering with an impermeable sheet to reduce organic matter degradation, to avoid wash-out of nutrients in case of heavy rains, and to avoid exposure to air so that ammonia volatilization is prevented. Crop residues could be harvested in a less mature stage of development and stored (conserved) in an appropriate way to preserve their feeding quality.

- The role of livestock on farms could be strengthened. This could contribute to nutrient cycling, and the production of high-quality and high-value products. However, this development is conditional on various other points of improvement mentioned above and livestock intensification is accompanied with strong trade-offs. Before expanding livestock numbers, the feeding and overall management of currently present livestock should be improved, so that their health status and productivity can be enhanced.

- There is a strong need for education and training, and for the development of institutional arrangements and community-based organizations. These could support the development and implementation of many of the entry points mentioned above. For instance, breeding and exchange of improved crop varieties and livestock types would benefit for cooperative efforts. Improved management of on-farm residues (e.g. fencing) and off-farm communal grazing areas require orchestration and negotiation among community members. Organized and shared storage and processing facilities would allow sharing of investment costs and associated risks. The resulting increased added value in combination with strengthening of community-based organizations and other interest groups could foster the development of opportunities on markets in terms of market access and of better input and product prices.

Various of these entry points were evaluated in the context of the cropping system or farming system to derive potential impacts beyond productivity improvement. In this way, trade-offs were identified, for instance between profitability and household food self-sufficiency, and between nitrogen availability for crop uptake and increased risk of nutrient losses. Moreover, the proposed improvements at field level had differential effects on indicators at the farm and household level, indicating the importance of a system perspective on the evaluation of entry points.

The main limitations and challenges of the research:

- Data were collected in two quick data collection rounds, and depended to a large extent on activities and yields reported by farmers. Since no records of farm management are kept this information relied primarily on recollection, which might be an information source with limited reliability in various cases. Also the conversions needed from farmer-units to standardize units of weight may have caused inaccuracies.

- Not a complete participatory problem solving, design and learning cycle was performed during the first project phase. Feedback and discussion of entry points will be addressed further in the next phases of the project.

We conclude that farmers in all case study areas face considerable constraints to improve their farm performance. Nevertheless, although the suggested entry points should be considered as preliminary, there seem to be possibilities for systems improvements. Potential innovations should be tuned to the development stage and resource endowment of each farm and can be tested with farmers in the upcoming project phase.

# 1. Background and objectives

## 1.1 Rationale

Sustainable intensification aims to increase the productivity of agricultural systems in a sustainable way (Pretty, 2008), by increasing yields or maintaining these while using less resources. Sustainable intensification aims to reduce pressure on ecosystems and ecological processes, to safeguard equitable relations among societal groups (differing in gender and age, etc.), and to support the economic viability of households, enterprises and communities. While technological innovations and tuning of inputs at the level of crops and animals and of farming practices help to optimize a farming systems performance, considerable productivity gaps and pressures on ecosystems, equity and economy can occur due to inefficient configuration and allocation of these components at the farm level. Examples of the inefficiencies observed in smallholder farming systems include insufficient and unbalanced human and animal nutrition, inefficient nutrient cycling and consequent losses, as well as suboptimal labor allocation. At larger scales, interactions of farms with the surrounding region can strongly influence farm performance, for instance through nutrient flows to or from communal areas as well as the dynamics of pests and their natural enemies within agro-ecosystems. Moreover, socio-economic and institutional barriers and constraints that are beyond the control of farm/village level actors affect the options for farm development. Therefore, an integrated approach taking on board the different sub-components of the farming system and their internal and external interactions is needed to identify and test context-specific improvements that can be implemented and tested on-farm to foster experiential learning. These activities should be embedded in the community to enable bottom-up spreading of innovations to achieve impact at larger scales.

In the farming systems analysis, based on farm surveys, characterizations and previous engagements with farmers, model-supported diagnosis and exploration of whole-farm options for sustainable intensification were conducted. A systems-level approach allowed to embed proposed and tested innovations for individual crops, feeds, animals, products and other resources such as manures. In the exploration phase large sets of alternative farm configurations were generated on the basis of the current farm organization and suggested entry points and associated technologies and practices. It is hypothesized that the presentation and discussion of sets of options is beneficial to:

- Show trade-offs and synergies among farm performance indicators, thereby clarifying to farmers the room to maneuver.
- Offer diversity and choice in stakeholder discussions to facilitate adoption processes.

- Avoid lock-in onto undesirable development paths.

This is expected to inform interactive adaptation and learning cycles conducted with farmers and other stakeholders.

## 1.2 Project

Africa RISING (Africa Research in Sustainable Intensification for the Next Generation – www.africa-rising.net) is a research program of the Feed-the-Future initiative of the USA government. The program aims to create opportunities for smallholder farm households to escape hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, particularly for women and children, and conserve or enhance the natural resource base. The program has three regional projects - the International Institute of Tropical Agriculture (IITA) coordinates projects in West Africa (Ghana and Mali) and East/Southern Africa (Malawi and Tanzania).

The first phase of farming systems analysis within the Africa RISING program (conducted from April to December 2013) focused on the characterization of farming systems and the identification of initial entry points for sustainable intensification. To that end, surveys have been conducted in four countries (Tanzania, Malawi, Ghana and Mali). From this first set of farms, representative farms from villages with similar biophysical and demographical conditions were selected for further analysis and exploration of promising options for re-configuration, of improved practices and diversification of farming systems.

## 1.3 Objectives

The objective of the first phase of farming systems analysis within the Africa RISING project was to find constraints and entry points for sustainable intensification and innovation at the farm level. Subsidiary objectives were:

- To characterize the diversity of farming systems in the action sites.

- To diagnose in terms of productivity, environment and economy farm performance.

- To explore trade-offs and synergies among various farm performance indicators.

- To identify potential points of improvement based on farm interviews and model explorations.

# 2. Methodology

## 2.1 Conceptual approach

The farming systems analysis worked around the following framework, with specific activities highlighted in the grey boxed (Figure 2.1). In summary, the process started with a rapid farming system characterization exercise that allowed the development of functional farm typologies. This was followed by a more detailed farming system description, allowing complete farming system diagnosis. This information was then be synthesized and analyzed towards the exploration of system innovations and system redesign.

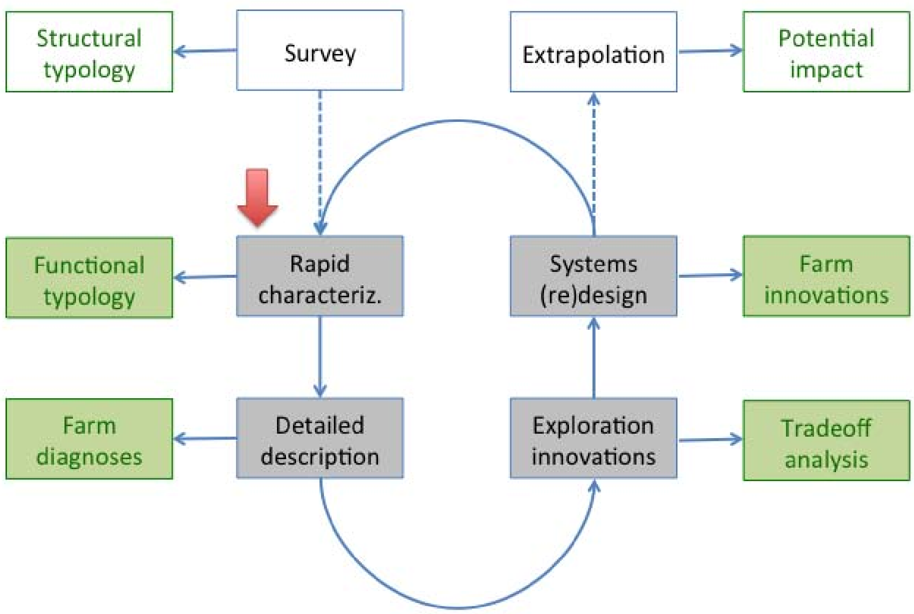



**Figure 2.1.** Components of the farming system analysis and entry point identification strategy. Research phases in the analysis represented by grey boxes, products indicated in green boxes. Starting point of the analysis indicated with the red arrow. Activities in white boxes fall outside the scope of this work.

Smallholder farming systems in Africa are highly diverse in terms of biophysical and socio-economic characteristics. The diversity among systems stems i.a. from differences in soil fertility, farmers' livelihood aspirations and resource endowment (factors for productivity) including land, labor availability as well as cash income. Hence, instead of providing 'blanket' recommendations for smallholder farmers in certain areas, recognizing and responding to the variability in local farm characteristics promises more appropriate, targeted and efficient design recommendations to achieve improvements in agricultural production (Ojiem *et al.*, 2006;

Tittonell *et al.*, 2009). Farm typologies aim at meaningful groupings of farms into subsets, homogenous according to specific criteria (Anderson *et al.*, 2007; Van de Brand, 2011), which can be used for technology targeting. Creating these typologies attempts a meaningful compromise between analyzing every single farm and assuming broad categories such as smallholders in general.

## 2.3 Survey tools

**Tanzania**: For the rapid characterization survey in Tanzania a survey tool was developed, for templates see Annexes 1.1 and 1.2. During April 2013, eight enumerators were trained to complete the survey of 160 households in the Babati and Kongwa & Kiteto districts in Tanzania. This data was presented in MS Excel spreadsheets and was further analyzed to extract data on farm size, household size, crops grown, livestock kept etc. The households were then ranked according to farm size, family size and presence or absence of livestock to enable identification of high, medium and low resource endowment. A total of 17 households were chosen (10 from the Babati and 7 from the Kongwa and Kiteto district) for further detailed characterization. The detailed characterization took the form of a semi-structured interview using a translator (presented in Annex 1.3), and included a visit to the farmers' fields to take a soil sample from their most productive field. The data collected during the rapid and detailed characterization was used in the model FarmDESIGN.

**Malawi**: For the rapid characterization survey in Malawi a survey tool was developed, for templates see Annexes 2.1 and 2.2. During April 2013, four enumerators were trained to complete the survey of 80 households in the Dedza and Ntcheu districts in central Malawi. This data was presented in MS Excel spreadsheets and was further analyzed to extract data on farm size, household size, crops grown, livestock kept etc. The households were then ranked according to farm size, family size and presence or absence of livestock to enable identification of high, medium and low resource endowment. A total of 12 households were chosen (three from each of the four extension planning areas (EPA)) for further detailed characterization. The detailed characterization took the form of a semi-structured interview using a translator (presented in Annex 2.3), and included a visit to the farmers' fields to take a soil sample from their most productive field. The data collected during the rapid and detailed characterization was used in the model FarmDESIGN.

**Ghana**: For the rapid characterization in Ghana the ImpactLITE survey tool was used, assessing farm resources, management strategies, productivity and household economics (the full version of the survey is presented in Annex 3.1). The ImpactLITE survey tool was developed by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). The rapid characterization was conducted in September 2013, encompassing 240 farming households that were previously selected and had already received interventions by AfricaRISING. The data served to develop farm typologies based on resource endowment, production orientation and income sources of the farm household. Based on these typologies, a subset of the farms was chosen to be revisited, in order to conduct a detailed analysis. For this detailed characterization, the data sheet of N2Africa was used (see Annex 3.2), adding details on topics including the access to markets (for sales but also labor markets), market prices, expenditure on farm inputs and on hired labor, information on land tenure, trends in cropping, constraints concerning single crops, preferences in varieties, animals feeds and manure, soil information (through sampling), information on crop management and grain as well as stover yield management. N2Africa is a research for development project working in 13 sub-Saharan African countries aiming to improve benefits from cultivating grain legumes through better yielding varieties and enhanced biological nitrogen fixation.

**Mali**: For Mali, a rapid characterization was conducted using basic farm census data (household size, land holding, area dedicated to major crops) collected by the CMDT (Compagnie Malienne de Developpement des Textiles) and complemented with additional information on livestock and equipment numbers. This allowed an existing typology to be used in Koutiala to classify farms, and a cluster analysis (as pre-typology) to be used in Bougouni. Data comes from 2 villages (Sirakele, Nampossela) in Koutiala and 5 villages (Flola, Madina, Sibirila, Dieba, Yorobougoula) in Bougouni/Yanfolila, totaling 418 households in Koutiala and 328 household in Bougouni. The CMDT data contains a large number of households, comprising nearly all farmers in the concerned villages. For the project specific detailed analysis, the N2Africa survey was adapted to reflect local farm characteristics. The survey tool is presented in Annex 4. This modified version covers most of the aspects required for the FARMSIM model; the remaining information can be obtained from previous studies and concerns aspects such as feed quality, animal breed characteristics and feeding calendars. In three villages (Dieba and Sibirila in Bougouni, Sirakele in Koutiala), three households per farm type were selected for detailed characterization. In total 31 farms were surveyed, crop and soil samples taken from fields of major crops, and fields geo-referenced. Data entry of the detailed farm characterization has not yet been finalized.

The findings from the surveys from the various regions in Ghana, Malawi and Tanzania were compared to derive communalities and differences that could support the identification of common constraints and opportunities, allowing exchange of insights among the regions and countries.

## 2.3 Modeling tools

The exploratory models in the NUANCES and COMPASS frameworks are useful tools for describing and explaining the outcomes of the current configuration of a selected farm as well as for exploring alternative farm configurations. Calculations made in the farm and household models describe the productive, economic and environmental performance of farm configurations in terms of indicators related to the livestock feed balance, nutrients flows, organic matter balance, labor balance and operating profit. The tools are flexible and can be extended with additional indicators that are relevant to the project or case study, or are indicated as critical or relevant by the farmers or other stakeholders involved.

Exploration can be supported by multi-objective optimization algorithms, to generate sets of alternative farm configurations that represent part of the window of opportunities or solution space for the case study farm. The alternatives in terms of cropping and livestock activities are then evaluated in terms of tradeoffs and synergies among farm objectives. In the scope of the Africa RISING project particular emphasis is set on the objective of sustainable intensification, with various dimensions to assess a system's performance. The information derived from such modeling exercises will be important in guiding discussions between farmers and other stakeholders towards the selection of a farm set-up that is likely to be adopted by farmers in a target area.

Example tools that are relevant to the farming systems analysis in Africa RISING are:

**Farm DESIGN** is a bio-economic, static modeling tool, assessing structural as well as functional farm characteristics, and is part of the COMPASS framework. Information on labor, climate, soil, crops, livestock, inputs, imports, nutrient cycling and assets are entered into the model. By capturing the links between the different farm components, identifying ranges of possible variables for the single factors, setting constraints as well as desired outcomes, the interplay of farm components can be illustrated and manipulated, in order to explore and evaluate options for the (re-) design of the whole farming system. For more information on the Farm DESIGN model consult Groot *et al.* (2012), or visit https://sites.google.com/site/farmdesignmodel/home.

**FARMSIM** (FArm-scale Resource Management SIMulator) is a dynamic modeling tool, capturing more detail of farming systems in time than the static model, but requiring greater amounts of input as well. It is part of the NUANCES framework. It is able to explore long term changes in farming systems and is based on descriptive models/functions that are derived from experimental research, mechanistic modelling at lower hierarchical levels as well as experts knowledge. Van Wijk *et al.* (2009) described the whole farm model. FARMSIM combines the component models FIELD (soil and crop growth model, Tittonell *et al*., 2007, 2008), LIVSIM (livestock, Rufino *et al.*, 2009) and HEAPSIM (manure, Rufino *et al*., 2007).

## 2.4 Sustainable intensification

Sustainable intensification of farming systems can be defined as changes in their resource use and allocation that increase farm productivity while reducing pressure on local ecosystems and safeguarding social relations. According to Pretty *et al.* (2011) this entails the efficient use of all inputs to produce more outputs while reducing damage to the environment and building a resilient natural capital from which environmental services can be obtained. Sustainable intensification results from the application of technological and socio-economic approaches that may be categorized into genetic, ecological and socio-economic intensification (The Montpellier Panel, 2013). Genetic intensification makes use of improved livestock and/or crop varieties with greater yielding capacity, nutrient use efficiency, nutritional value and / or resilience to pests and diseases than material currently available to farmers. The sustainability of improved crop varieties can be further improved by being incorporated into traditional smallholder practices such as intercropping. This is viewed as ecological intensification because, for instance, intercropping improved maize (*Zea mays* L.) hybrids with legumes such as pigeon pea (*Cajanus cajan* (L.) Millsphaugh) may lead to increased land use efficiency, crop diversity, soil fertility and farm household income if competition between component crops is minimized while beneficial interactions are maximized. The use of crop residues for livestock feed and farmyard manure for ameliorating soil fertility or use of natural enemies to control pests highlight the potential advantages of increased biodiversity at both farm and landscape scales. However, for widespread adoption of an innovation by farmers there is a need to create an enabling environment in the community, region or even at national level. This can be achieved through socio-economic intensification where together with the introduction of innovations that increase productivity, there is improvement in value chain efficiency and innovative institutions are developed at community level or higher scales that ensure collective action for natural resource management or marketing.

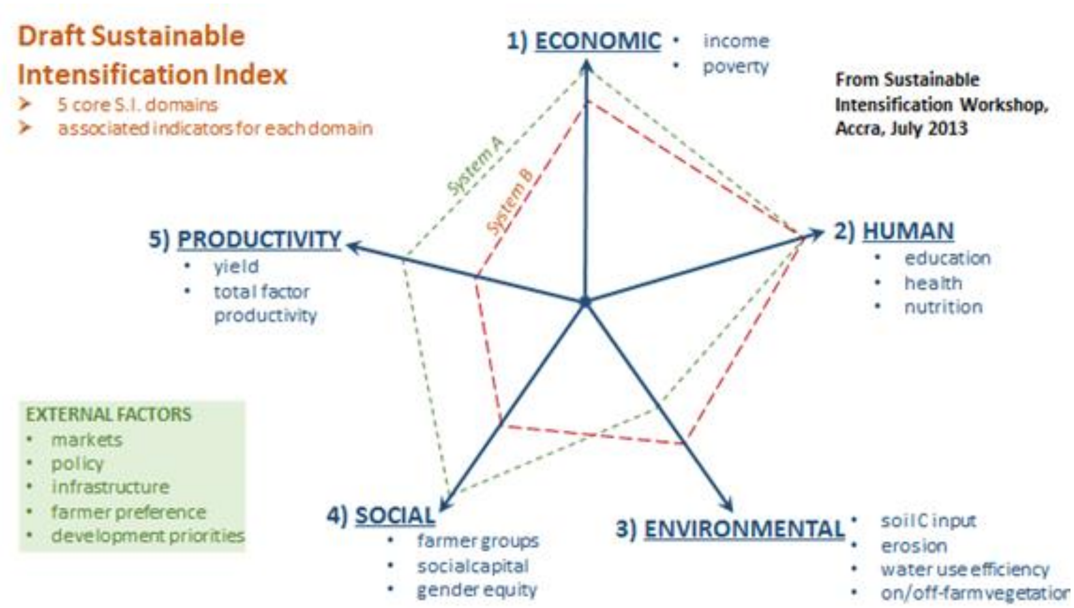



**Figure 2.2.** Example spider diagram illustrating a 5-dimensional indicator system for sustainability assessment.

In the Africa RISING program, a number of innovations have been introduced in targets sites that include improvements to current farmer practices such as intercropping, improved crop varieties and post-harvest storage of produce (Africa RISING, 2013). To ensure the adoption of promoted technologies, there is a need to evaluate the technologies using criteria that resonate with target households. These criteria usually include profitability, availability and affordability of inputs as well as their effect on competition on limited resources such as land, labor and finance. The importance of each criterion varies between different farmer groups depending on wealth endowment and production objectives. Since one of the main objectives of the Africa RISING program is to identify and promote sustainable intensification pathways for farming systems in various target sites, there is a need to clearly define indicators for SI that can be used to evaluate the performance of the different technologies. During various Africa RISING project meetings (SI workshop in Ghana, July 2013; Learning Event in Ethiopia, September 2013) participants were commonly engaged to provide a comprehensive working definition for sustainable intensification, meant as a starting point and foundation for any project activities. The discussions generated a matrix evincing 5 domains, with measurable indicators associated to one of them (Figure 2.2). Possible combinations for win-win's in the different dimensions of sustainability can be explored via trade-off analyses, focusing on associated parameters soil health and biodiversity for environmental sustainability, higher and stable revenues for economic sustainability and nutrition, health and labor opportunities for social sustainability. Ideally there would be thresholds to identify whether or not a farming system is currently sustainable or unsustainable, but for the time being, it serves to compare the systems amongst each other and to judge which is more or less sustainable in which respect.

# 3. Country-specific findings

## 3.1 Tanzania

### *3.1.1 Introduction to the country and the case study regions*

The United Republic of Tanzania is a country in eastern Africa. It borders with Kenya and Uganda in the north, with Rwanda, Burundi, the Democratic Republic of Congo and Zambia in the (south-) west and Malawi and Mozambique in the south. Along its eastern border lies the Indian Ocean. The economy of Tanzania is based heavily on agriculture, employing an estimated 80% of the population. Figure 3.1.1 shows all the districts of Tanzania, with the three case study districts delineated in blue, while Figure 3.1.2 and Figure 3.1.3 show more detailed maps of the two action areas in Tanzania.

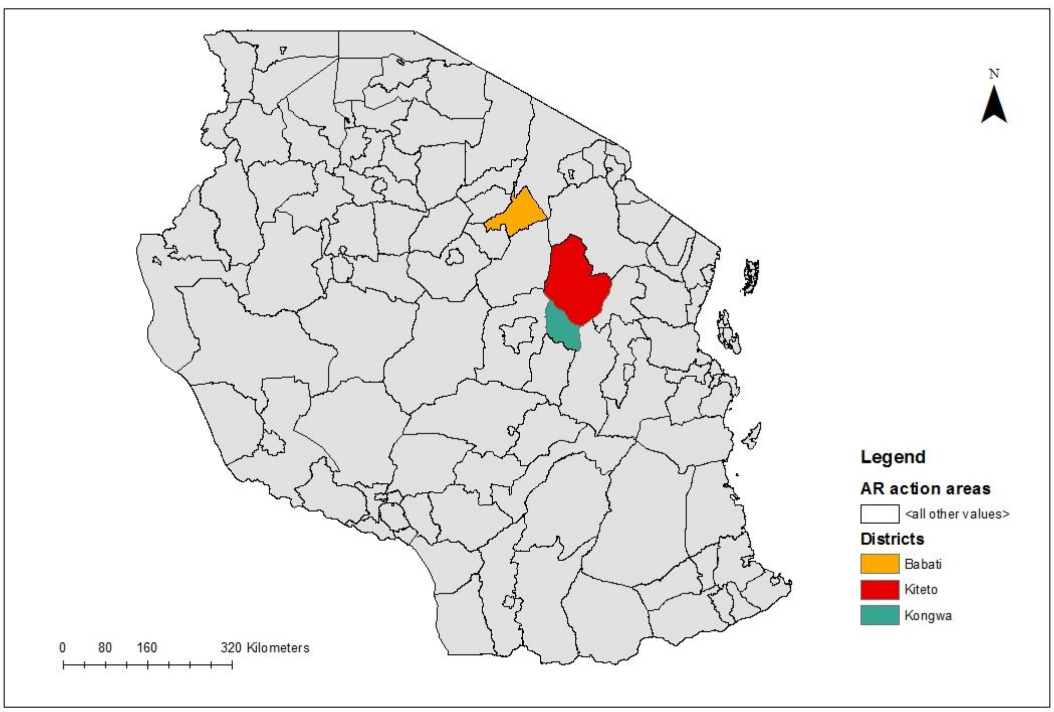



**Figure 3.1.1**. Map of districts in Tanzania. Source: National Bureau of Statistics, 2002.

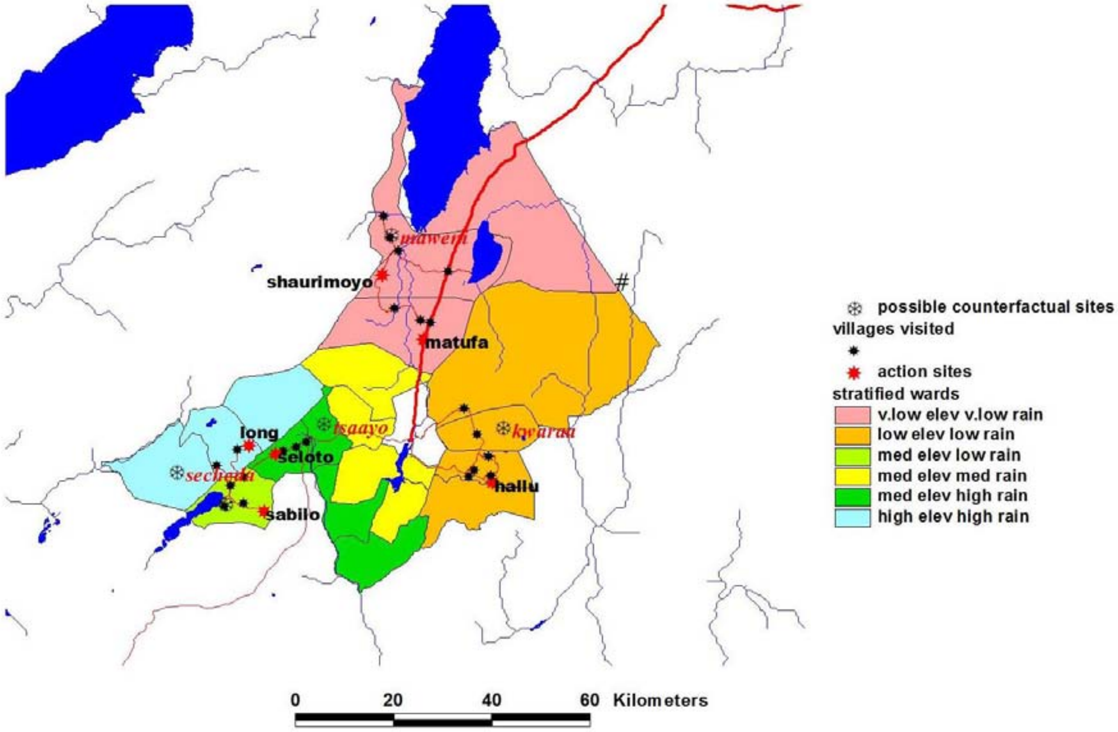



**Figure 3.1.2**. Sub-humid action area – Babati district, Tanzania.

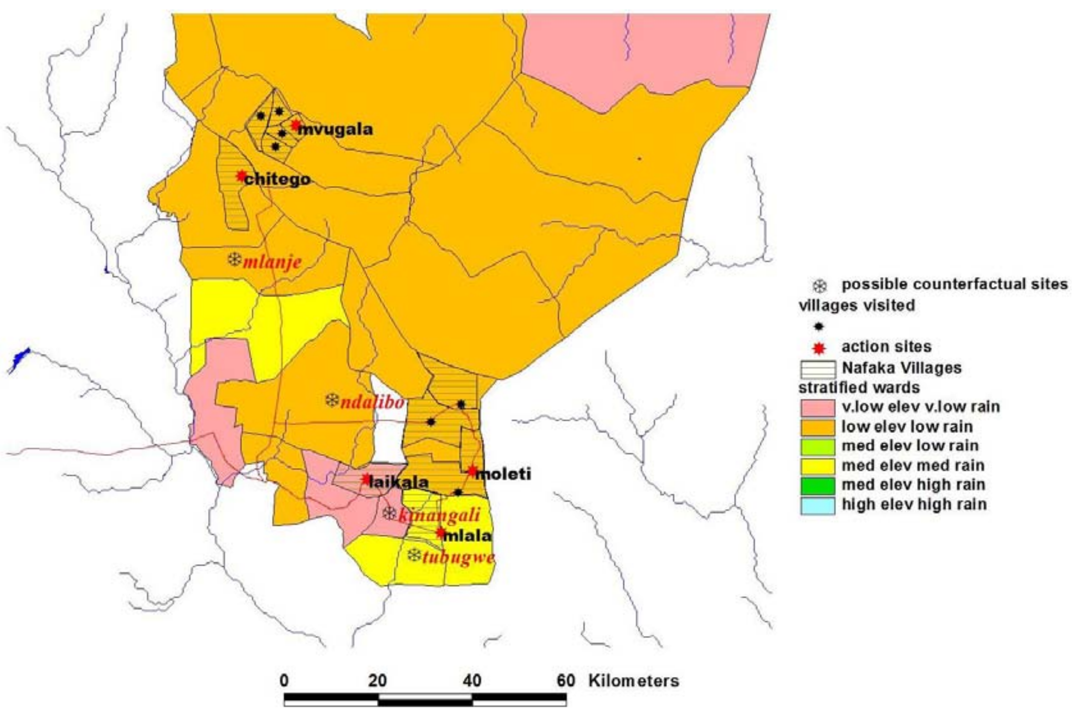



**Figure 3.1.3.** Semi-arid action area – Kongwa & Kiteto districts, Tanzania.

**Table 3.1.1.** Characteristics of the case study region in the Babati district, Tanzania.

| Village | Shaurimoyo | Long | Sabilo | Hallu | Seloto | Matufa |
|---|---|---|---|---|---|---|
| Altitude (m.a.s.l.) | 1018 | 2185 | 1648 | 1233 | 1644 | 1019 |
| Annual rainfall (mm) | 786 | 851 | 763 | 769 | 845 | 788 |
| 2012 Pop. density (/km2) | 86 | 332 | 178 | 123 | 329 | 248 |
| Cropping system | maize-rice | maize-legumes | maize-legumes | maize-legumes | maize-legumes | maize |

**Table 3.1.2.** Characteristics of the case study region in the Kongwa and Kiteto district, Tanzania.

| Village | Laikala | Moleti | Chitego | Mlali | Njoro |
|---|---|---|---|---|---|
| Altitude (m.a.s.l.) | 1176 | 1278 | 1332 | 1322 | 1800 |
| Annual rainfall (mm) | 722 | 776 | 708 | 765 | 935 |
| 2012 Pop. density (/km2) | 97 | 107 | 53 | 283 | n.a. |
| Cropping system | maize-sorghum | maize | maize | maize | maize sunflower |

### *3.1.2 Farm characteristics*

Tables 3.1.3 and 3.1.4 show the main characteristics of the surveyed farms (April and May 2013) in the two case study regions. Among the characteristics were land availability, number of household members, number of cattle, whether a farmer grew a cash crop (for e.g. sunflower) and percentages of produce sold.

These summary tables formed the basis of the selection of farm households for the detailed characterization. With a rich diversity in characteristics of the selected villages, such as climate, elevation, population density and average TLU per household, to choose a representative sample, focused mainly on wealth. Two farmers could be visited per village. The farms were chosen trying to have an equal amount of the three 'types' of farms per district. The numbers of the 17 farm households that were finally revisited during the detailed characterization are marked in bold (Table 3.1.3 and Table 3.1.4).

**Table 3.1.3.** Overview of characteristics of surveyed farms in Babati, Tanzania.

| District | Babati - sub-humid | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Village | Long | | | | | | | Seloto | | | | | | | Sabilo | | | | | | |
| Altitude | 2185 masl | | | | | | | 1644 masl | | | | | | | 1648 masl | | | | | | |
| Rainfall | 851 mm | | | | | | | 845 mm | | | | | | | 763 mm | | | | | | |
| #Hh Area | 635 Hh, 332/km2 | | | | | | | 1144 Hh, 329/km2 | | | | | | | 876 Hh, 178/km2 | | | | | | |
| #TLU Crop sys | 6.85 TLU, maize-legumes | | | | | | | 2.59 TLU, maize-legumes | | | | | | | 5.01 TLU, maize-legumes | | | | | | |
| | 1 | 0.8 | 3 | 4 | 80 | 70 | 3 | 1 | 1.5 | 6 | | | 71 | 4 | 1 | 1.2 | 7 | 2 | 100 | 73 | 3 |
| | 2 | 1.0 | 9 | 7 | | 75 | 4 | 2 | 1.2 | 6 | 7 | | 60 | 4 | 2 | 1.6 | 10 | 5 | 100 | 80 | 3 |
| | 3 | 0.6 | 8 | 11 | | 80 | 4 | 3 | 1.2 | 8 | 5 | | 60 | 4 | 3 | 1.6 | 8 | 4 | 100 | 75 | 3 |
| | 4 | 1.6 | 11 | 4 | | 60 | 4 | 4 | 0.7 | 4 | 7 | 100 | 60 | 3 | 4 | 1.2 | 7 | 2 | | 60 | 4 |
| | 5 | 2.0 | 10 | 5 | | 86 | 4 | 5 | 1.2 | 4 | 2 | | 79 | 4 | 5 | 4.5 | 10 | 13 | | 85 | 4 |
| | 6 | 0.5 | 9 | 4 | | 55 | 4 | 6 | 1.2 | 6 | 9 | | 44 | 4 | 6 | 2.0 | 10 | 7 | | 65 | 4 |
| | 7 | 0.8 | 3 | 2 | | 20 | 4 | 7 | 1.2 | 10 | 12 | | 40 | 4 | 7 | 1.6 | 6 | 6 | | 55 | 4 |
| | 8 | 0.3 | 8 | | | | 1 | 8 | 1.1 | 6 | 3 | | 75 | 4 | 8 | 1.6 | 6 | 6 | | 63 | 4 |
| | 9 | 0.4 | 6 | 3 | | 40 | 4 | 9 | 0.5 | 7 | | | | 1 | 9 | 2.0 | 9 | 18 | | 75 | 4 |
| | 10 | 0.8 | 7 | 18 | | 50 | 4 | 10 | 0.8 | 9 | 2 | | 75 | 4 | 10 | 2.8 | 9 | 12 | | | 1 |
| | 11 | 1.2 | 9 | 3 | | 80 | 4 | 11 | 1.0 | 8 | 10 | | 20 | 4 | 11 | 1.2 | 11 | 11 | 100 | 75 | 3 |
| | 12 | 1.6 | 4 | | | 63 | 4 | 12 | 0.4 | 5 | 10 | | 50 | 4 | 12 | 2.4 | 11 | 14 | 100 | 100 | 3 |
| | 13 | 1.6 | 6 | 7 | | 53 | 4 | 13 | 4.0 | 3 | 1 | | 68 | 4 | 13 | 2.4 | 10 | 12 | 100 | 75 | 3 |
| | 14 | 0.8 | 5 | 7 | | 70 | 4 | 14 | 1.2 | 7 | 3 | | 37 | 4 | 14 | 0.8 | 8 | 9 | | 50 | 4 |
| | 15 | 0.6 | 6 | 3 | | 53 | 4 | 15 | 1.4 | 8 | 11 | | 68 | 4 | 15 | 2.8 | 9 | 10 | | 65 | 4 |
| | 16 | 0.6 | 6 | 2 | | 60 | 4 | 16 | 2.3 | 8 | 12 | | 58 | 4 | 16 | 4.0 | 7 | 4 | 40 | 67 | 3 |
| | | ha | hh | lv | %cc | sub | | | ha | hh | lv | %cc | sub | | | ha | hh | lv | %cc | sub | |
| Averages | | 0.96 | 7 | 6 | 80 | 61 | | | 1.3 | 7 | 7 | 100 | 58 | | | 2.1 | 9 | 8 | 91 | 71 | |

| District | Babati - sub-humid | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Village | Shaurimoyo | | | | | | | Matufa | | | | | | | Hallu | | | | | | |
| Altitude | 1018 masl | | | | | | | 1019 masl | | | | | | | 1233 masl | | | | | | |
| Rainfall | 786 mm | | | | | | | 788 mm | | | | | | | 769 mm | | | | | | |
| #Hh Area | 698 Hh, 68/km2 | | | | | | | 968 Hh, 248/km2 | | | | | | | 553 Hh, 123/km2 | | | | | | |
| #TLU Crop sys | 7.11 TLU, maize-rice | | | | | | | 4.32 TLU, maize | | | | | | | 2.32 TLU, maize-legumes | | | | | | |
| | 1 | 2.0 | 5 | | | 47 | 4 | 1 | 0.8 | 9 | 6 | | 83 | 4 | 1 | 6.3 | 13 | 30 | 100 | 82 | 3 |
| | 2 | 3.0 | 4 | | | 63 | 4 | 2 | 2.6 | 6 | | | 85 | 4 | 2 | 1.0 | 5 | 3 | 60 | 73 | 3 |
| | 3 | 0.8 | 8 | | | 50 | 4 | 3 | 0.8 | 5 | 3 | | 70 | 4 | 3 | 7.7 | 3 | 31 | 100 | 83 | 3 |
| | 4 | 0.8 | 3 | | | 80 | 4 | 4 | 0.8 | 7 | 1 | | 65 | 4 | 4 | 1.4 | 7 | 9 | 100 | 67 | 3 |
| | 5 | 14.2 | 6 | 31 | | 66 | 4 | 5 | 3.2 | 3 | 1 | | 74 | 4 | 5 | 4.9 | 11 | 14 | 83 | 83 | 3 |
| | 6 | 0.4 | 3 | | | 100 | 4 | 6 | 2.8 | 5 | 8 | | 50 | 4 | 6 | 4.0 | 7 | 2 | 100 | 78 | 3 |
| | 7 | 2.4 | 4 | | | 81 | 4 | 7 | 1.6 | 6 | 3 | | 90 | 4 | 7 | 12.1 | 9 | 20 | 100 | 90 | 3 |
| | 8 | 1.6 | 9 | 8 | | 94 | 4 | 8 | 11.3 | 14 | 20 | 7 | 50 | 3 | 8 | 6.1 | 11 | 12 | 100 | 81 | 3 |
| | 9 | 1.0 | 4 | 7 | | | 1 | 9 | 2.0 | 10 | 32 | | 70 | 4 | 9 | 2.8 | 7 | | | 75 | 4 |
| | 10 | 2.4 | 9 | 12 | | 75 | 4 | 10 | 1.2 | 3 | 10 | | 60 | 4 | 10 | 4.0 | 7 | 15 | 100 | 73 | 3 |
| | 11 | 1.2 | 8 | 15 | | 75 | 4 | 11 | 2.4 | 6 | 10 | | 88 | 4 | 11 | 3.2 | 7 | 20 | 75 | 80 | 3 |
| | 12 | 0.4 | 6 | 19 | | 50 | 4 | 12 | 2.4 | 4 | 9 | | 66 | 4 | 12 | 2.4 | 7 | 10 | 100 | 65 | 3 |
| | 13 | 2.0 | 8 | 2 | | 70 | 4 | 13 | 1.2 | 7 | 23 | | 40 | 4 | 13 | 16.2 | 14 | 14 | 13 | 73 | 3 |
| | 14 | 1.2 | 6 | | | 90 | 4 | 14 | 0.8 | 5 | 5 | | 88 | 4 | 14 | 6.9 | 6 | 47 | 100 | 55 | 3 |
| | 15 | 1.2 | 3 | | | 60 | 4 | 15 | 1.6 | 9 | 10 | 38 | 65 | 3 | 15 | 2.0 | 6 | 2 | | 83 | 4 |
| | 16 | 1.2 | 7 | 4 | | 50 | 4 | 16 | 1.6 | 2 | | | 98 | 4 | 16 | 2.0 | 5 | 6 | | 88 | 4 |
| | | ha | hh | lv | %cc | sub | | | ha | hh | lv | %cc | sub | | | ha | hh | lv | %cc | sub | |
| Averages | | 2.3 | 6 | 12 | | 70 | | | 2.34 | 6 | 10 | 22 | 71 | | | 5.20 | 8 | 16 | 87 | 77 | |

**Legend:**

| | | | |
|---|---|---|---|
| 1 | Farm number | 15 | Sunflower grower and % of land with cash crop |
| | = chosen for detailed characterization | 50 | Sells any product, % sold |
| 1.2 | Farm area | 1 | Orientation 1 - Subsistence only food crops |
| 3 | People in Household (HH) | | 2 - Subsistence with cash crops |
| | no animals recorded | | 3 - Market orientated with cash crops |
| 5 | cattle owner and number of head of cattle | | 4 - Market orientated only food crops |

**Table 3.1.4.** Overview of characteristics of surveyed farms in Kongwa and Kiteto, Tanzania.

| District | Kongwa - semi-arid | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Village | **Chitego** | | | | | | | **Moleti** | | | | | | | **Mlali** | | | | | | |
| Altitude | 1332 masl | | | | | | | 1278 masl | | | | | | | 1322 masl | | | | | | |
| Rainfall | 708 mm | | | | | | | 776 mm | | | | | | | 765 mm | | | | | | |
| #Hh Area | 821 Hh, 53/km2 | | | | | | | 1489 Hh, 107/km2 | | | | | | | 1624 Hh, 283/km2 | | | | | | |
| #TLU Crop sys | 1.14 TLU, maize | | | | | | | 0.42 TLU, maize | | | | | | | 1.54 TLU, maize | | | | | | |
| | 1 | 16.7 | 8 | | | 50 | 4 | 1 | 3.6 | 14 | 2 | 22 | 58 | 3 | 1 | 1.8 | 5 | | 100 | 73 | 3 |
| | 2 | 24.3 | 6 | 6 | | 60 | 4 | 2 | 7.5 | 14 | 20 | | 100 | 4 | 2 | 3.8 | 2 | | 58 | 73 | 3 |
| | 3 | 4.9 | 7 | 4 | | 30 | 4 | 3 | 8.1 | 8 | | 100 | 68 | 3 | 3 | 2.2 | 9 | | 27 | 83 | 3 |
| | 4 | 3.2 | 3 | | 100 | 80 | 3 | 4 | 1.2 | 8 | | 100 | 100 | 3 | 4 | 5.3 | 3 | 7 | 38 | 65 | 3 |
| | 5 | 8.1 | 6 | 2 | 15 | 55 | 3 | 5 | 3.8 | 14 | 9 | 31 | 69 | 4 | 5 | 6.5 | 8 | | 50 | 84 | 3 |
| | 6 | 6.5 | 11 | 2 | | 76 | 4 | **6** | 1.2 | 14 | | 100 | 63 | 3 | 6 | 2.0 | 5 | | 60 | 75 | 3 |
| | 7 | 0.8 | 1 | | 100 | 86 | 3 | 7 | 2.0 | 13 | | 100 | 48 | 3 | 7 | 2.6 | 9 | | 92 | 67 | 3 |
| | 8 | 8.1 | 8 | 17 | 45 | 71 | 3 | 8 | 2.8 | 8 | 6 | | | 1 | 8 | 2.0 | 8 | | 60 | 47 | 3 |
| | 9 | 6.1 | 7 | | | 75 | 4 | 9 | 24.7 | 5 | 68 | | 75 | 4 | 9 | 1.6 | 7 | 6 | 88 | 63 | 3 |
| | 10 | 6.1 | 5 | | 37 | 72 | 3 | **10** | 12.1 | 6 | 15 | | 85 | 4 | 10 | 5.3 | 5 | 20 | 73 | 62 | 3 |
| | 11 | 12.2 | 6 | 10 | 50 | 65 | 3 | 11 | 4.0 | 8 | 5 | | 55 | 4 | 11 | 1.8 | 4 | 2 | 94 | 67 | 3 |
| | 12 | 2.8 | 7 | | | 20 | 4 | 12 | 3.2 | 7 | 7 | | 40 | 4 | 12 | 2.6 | 7 | 8 | 50 | 62 | 3 |
| | **13** | 10.5 | 5 | 16 | 38 | 73 | 3 | 13 | 1.2 | 9 | 2 | 25 | 100 | 3 | 13 | 7.7 | 7 | 52 | 32 | 65 | 3 |
| | 14 | 1.6 | 3 | 16 | 100 | 50 | 3 | 14 | 2.6 | 8 | | 77 | 88 | 3 | 14 | 2.4 | 9 | 1 | 100 | 70 | 3 |
| | 15 | | | | | | 1 | 15 | 2.4 | 10 | 3 | 50 | 63 | 3 | 15 | 1.6 | 9 | | 88 | 100 | 3 |
| | 16 | 2.0 | 6 | | | 50 | 4 | 16 | 6.1 | 8 | 6 | 14 | 60 | 3 | 16 | 6.1 | 7 | 30 | | 50 | 4 |
| | | ha | hh | lv | %cc | sub | | | ha | hh | lv | %cc | sub | | | ha | hh | lv | %cc | sub | |
| Averages | | 7.6 | 6 | 9 | 61 | 61 | | | 5.4 | 10 | 13 | 62 | 71 | | | 3.5 | 7 | 16 | 67 | 69 | |

| District | Kongwa - semi-arid | | | | | | | Kiteto - semi-arid | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Village | **Laikala** | | | | | | | **Njoro** | | | | | | |
| Altitude | 1176 masl | | | | | | | .. | | | | | | |
| Rainfall | 722 mm | | | | | | | .. | | | | | | |
| #Hh Area | 948 Hh, 97/km2 | | | | | | | .. | | | | | | |
| #TLU Crop sys | 0.02 TLU, maize-sorghum | | | | | | | .. | | | | | | |
| | 1 | 2.4 | 3 | | | 55 | 4 | **1** | 4.9 | 7 | | | 75 | 4 |
| | 2 | 3.8 | 8 | | | 25 | 4 | 2 | 8.1 | 2 | | 100 | 88 | 3 |
| | 3 | 6.5 | 9 | | 9 | 49 | 3 | 3 | 40.5 | 5 | | 100 | 92 | 3 |
| | 4 | 15.4 | 10 | | 5 | 75 | 3 | 4 | 6.9 | 5 | | 35 | 87 | 3 |
| | 5 | 9.3 | 4 | 2 | 13 | 59 | 3 | 5 | 7.3 | 5 | | 100 | 82 | 3 |
| | 6 | 6.7 | 12 | | 52 | 59 | 3 | **6** | 12.9 | 5 | | 100 | 92 | 3 |
| | 7 | 2.8 | 6 | 14 | | 20 | 4 | 7 | 2.0 | 6 | | 100 | 58 | 3 |
| | **8** | 15.8 | 14 | 68 | 77 | 40 | 3 | 8 | 8.1 | 10 | | 100 | 70 | 3 |
| | 9 | 24.7 | 5 | 3 | | 75 | 4 | 9 | 8.1 | 6 | | 100 | 87 | 3 |
| | **10** | 6.1 | 9 | 20 | 23 | 40 | 3 | 10 | 8.1 | 4 | | 100 | 83 | 3 |
| | 11 | 4.5 | 8 | | | 18 | 4 | 11 | 12.1 | 9 | | 100 | 70 | 3 |
| | 12 | 4.9 | 9 | | 8 | 65 | 3 | 12 | 8.1 | 5 | | 100 | 67 | 3 |
| | 13 | 4.9 | 6 | | 67 | 76 | 3 | 13 | 7.3 | 7 | | 100 | 57 | 3 |
| | 14 | 3.2 | 7 | 4 | | 25 | 4 | 14 | 8.1 | 7 | | 100 | 96 | 3 |
| | 15 | 2.8 | 4 | | | 50 | 4 | 15 | 1.6 | 5 | | 67 | 88 | 3 |
| | 16 | 4.0 | 7 | 2 | 40 | 60 | 3 | 16 | 8.1 | 6 | | 100 | 70 | 3 |
| | | ha | hh | lv | %cc | sub | | | ha | hh | lv | %cc | sub | |
| Averages | | 7.4 | 8 | 16 | 33 | 49 | | | 9.51 | 6 | | 93 | 79 | |

**Legend:**

| | | | |
|---|---|---|---|
| 1 | Farm number | 15 | Sunflower grower and % of land with cash crop |
| | = chosen for detailed characterization | 50 | Sells any product, % sold |
| 1.2 | Farm area | 1 | Orientation 1 - Subsistence only food crops |
| 3 | People in Household (HH) | | 2 - Subsistence with cash crops |
| | no animals recorded | | 3 - Market orientated with cash crops |
| 5 | cattle owner and number of head of cattle | | 4 - Market orientated only food crops |

Based on the data collected during the rapid and the detailed characterization, separate typologies were developed for Babati and Kongwa & Kiteto districts (Tables 3.1.5 and 3.1.6). The Mclust algorithm (Fraley and Raftery, 2000) was used, applied to the variables listed in Tables 3.1.5 and 3.1.6. The labor availability per ha declined with increasing farm size, whereas the proportion of hired labor increased. The largest numbers of different crops and tropical livestock units (TLU) were on average found on farms of intermediate size. In Babati the input of female labor was highest in small farms (types 1 and 2), whereas in Kongwa and Kiteto the proportion of female labor was on average large in intermediate size farms (type 3).

**Table 3.1.5.** Farm types in the Babati district identified by cluster analysis.

| Variable | Babati 1 | Babati 2 | Babati 3 | Babati 4 | Babati 5 | Babati 6 |
|---|---|---|---|---|---|---|
| Number of farms | 5 | 5 | 12 | 55 | 8 | 12 |
| Field area (ha) | 0.59 | 1.02 | 1.31 | 1.70 | 4.17 | **6.74** |
| Labor density (h/ha) | **3234** | 1815 | 940 | 1131 | 572 | 265 |
| Hired labor ratio | 0.04 | 0.24 | 0.07 | 0.25 | 0.22 | **0.65** |
| Female labor ratio | **0.53** | **0.55** | 0.43 | 0.43 | 0.37 | 0.46 |
| TLU | 6.10 | 4.94 | 4.93 | 3.19 | **12.50** | 7.22 |
| Crop number | 1.80 | 1.62 | 2.00 | 2.38 | 1.62 | **2.83** |
| Orientation | **4.00** | 3.59 | 2.75 | **4.00** | 2.75 | 3.17 |

**Table 3.1.6.** Farm types in the Kongwa and Kiteto (K&K) district identified by cluster analysis.

| Variable | K&K 1 | K&K 2 | K&K 3 | K&K 4 |
|---|---|---|---|---|
| Number of farms | 30 | 34 | 10 | 3 |
| Field area (ha) | 3.36 | 6.51 | 11.30 | **113.27** |
| Labor density (h/ha) | **1250** | 483 | 497 | 43 |
| Hired labor ratio | 0.01 | 0.22 | 0.30 | **0.39** |
| Female labor ratio | 0.44 | 0.45 | **0.52** | 0.38 |
| TLU | 2.69 | 0.68 | **23.79** | 1.19 |
| Crop number | 2.71 | 2.53 | **3.10** | 2.36 |
| Orientation | 3.20 | 3.21 | **3.50** | 2.65 |

### *3.1.3 Land and soils*

The costs of land per hectare were calculated from the reported costs of land in Tanzanian shilling per acre and are presented in Table 3.1.7.

**Table 3.1.7.** Land prices in the case study regions in Tanzania.

| District | Village | TSh / acre | Euro / ha | Comment |
|---|---|---|---|---|
| Babati | Shaurimoyo | 500,000-2,000,000 | 560-2,240 | 500-700,000 in the dry lands, and 1.5-2 million in the wetlands |
| | Long | 3,000,000 | 3,360 | |
| | Seloto | 2,000,000 | 2,240 | Close to town |
| | Sabilo | 1,000,000 | 1,120 | Minimal 800,000 |
| | Hallu | 2,000,000 – 3,000,000 | 2,240-3,360 | Was 500,000 in 2007, still is 100,000 at planes |
| | Matufa | 200,000-500,000 | 220-560 | 1.5-2 million for fertile land, 2.5-3 million for fertile + irrigated |
| Kongwa | Laikala | 100,000 | 110 | |
| | Moleti | 150,000 | 170 | |
| | Chitego | 60,000 | 70 | Was 3500 in '99, people received 5 acre for free to start with |
| Kiteto | Njoro | 100,000 | 110 | 70-80,000 for poor land |

Soils of the 18 farms involved in detailed characterization were analyzed for soil texture, organic matter content and chemical composition (Table 3.1.8). Contents of soil organic matter and of nitrogen, phosphorus and potassium were consistently higher in Babati than in Kongwa/Kiteto.

**Table 3.1.8.** Soil testing results from farms in the Babati, Kongwa and Kiteto districts in Tanzania. Txt = texture, SL = sandy loam, LS = loamy sand, S = sand, SCL = sandy clay loam.

| Farm | OM (%) | Txt | pH-$H_2O$ | P (mg/L) | P total (%) | N (mg/L) | N total (%) | K (mg/L) | K total (%) |
|---|---|---|---|---|---|---|---|---|---|
| Shaurimoyo 3 | 4.07 | SL | 6.25 | 9.50 | 0.1128 | 21.29 | 0.2446 | 66.08 | 0.7925 |
| Shaurimoyo 12 | 7.18 | SL | 6.58 | 10.77 | 0.1283 | 36.24 | 0.4257 | 67.08 | 0.8052 |
| Shaurimoyo 5 | 6.27 | LS | 7.55 | 15.58 | 0.1815 | 34.76 | 0.3969 | 128.25 | 1.5042 |
| Long 2 | 4.77 | LS | 5.65 | 10.84 | 0.1228 | 29.12 | 0.3229 | 41.44 | 0.4706 |
| Sabilo 13 | 2.91 | SL | 5.81 | 15.41 | 0.1810 | 19.32 | 0.2168 | 66.77 | 0.7864 |
| Sabilo 14 | 3.08 | SL | 6.19 | 11.63 | 0.1370 | 20.02 | 0.2266 | 64.35 | 0.7625 |
| Hallu 5 | 3.11 | SL | 6.50 | 8.56 | 0.0984 | 20.09 | 0.2232 | 83.47 | 0.9727 |
| Seloto 2 | 2.85 | LS | 6.56 | 7.88 | 0.0914 | 19.74 | 0.2214 | 26.31 | 0.3054 |
| Seloto 16 | 3.35 | LS | 6.09 | 8.85 | 0.1020 | 19.11 | 0.2121 | 28.95 | 0.3338 |
| Matufa 11a | 2.01 | S | 6.23 | 1.93 | 0.0205 | 10.15 | 0.1059 | 46.20 | 0.5317 |
| Matufa 11b | 4.75 | SCL | 6.41 | 8.58 | 0.0984 | 22.98 | 0.2566 | 77.61 | 0.9020 |
| Laikala 8 | 1.98 | S | 5.83 | 2.00 | 0.0209 | 9.73 | 0.0989 | 22.80 | 0.2539 |
| Laikala 10 | 2.41 | LS | 7.00 | 2.34 | 0.0251 | 14.59 | 0.1562 | 57.86 | 0.6618 |
| Moleti 6 | 1.33 | S | 6.61 | 3.01 | 0.0343 | 4.58 | 0.0425 | 20.52 | 0.2413 |
| Moleti 10 | 0.95 | S | 5.36 | 0.63 | 0.0054 | 3.17 | 0.0249 | 9.22 | 0.1023 |
| Chitego 13 | 1.36 | S | 5.61 | 2.18 | 0.0243 | 2.61 | 0.0188 | 22.52 | 0.2662 |
| Njoro 9 | 1.11 | S | 4.88 | 1.64 | 0.0174 | 3.38 | 0.0274 | 26.40 | 0.3060 |
| Njoro 1 | 1.00 | S | 5.86 | 1.64 | 0.0126 | 5.50 | 0.0536 | 21.59 | 0.2540 |
| Babati | 4.03 | | 6.35 | 9.96 | 0.12 | 22.98 | 0.26 | 63.32 | 0.74 |
| Kongwa/Kiteto | 1.45 | | 5.88 | 1.86 | 0.02 | 6.22 | 0.06 | 25.84 | 0.30 |

### *3.1.4 Crops*

The three most grown crops in Babati were maize, pigeon pea and common bean, with all farmers growing maize. The reported yields have a wide range within both of the regions and the average yields were low. In Tables 3.1.9 and 3.1.10 the number of farmers growing each crop in the different districts are presented.

When comparing the average reported yields of similar crops, there appear to be big differences for the districts in soils as well as water availability. The analysis of the soil samples confirmed a relatively low soil quality in Kongwa and Kiteto district. Farmers in this region also grew more drought-prone crops, such as sorghum and millet, while the cultivation of rice was not found at all. Similar to Babati, all farmers in the Kongwa and the Kiteto districts grew maize.

**Table 3.1.9.** Number of farmers in a sample of 10 farmers in Babati growing each crop, the yield range and the yield average.

| Crop | No of farmers | Yield range (kg/ha) | Yield average (kg/ha) |
|---|---|---|---|
| Maize | 10 | 890 - 4942 | 2446 |
| Rice | 4 | 99 - 3084 | 1713 |
| Sunflower | 3 | 148 - 208 | 176 |
| Pigeon pea | 7 | 43 - 692 | 335 |
| Chickpea | 1 | 272 | 272 |
| Sorghum | 3 | 815 - 927 | 871 |
| Common bean | 6 | 99 - 494 | 334 |
| Groundnut | 1 | 857 | 857 |
| Irish potatoes | 1 | 5931 | 5931 |
| Sweet potatoes | 2 | 6326 - 11861 | 9094 |
| Simsim (Sesame) | 1 | 70 | 70 |
| Okra | 1 | 119 | 119 |
| Lablab | 1 | 415 | 415 |

**Table 3.1.10.** Number of farmers in a sample of 7 farmers in Kongwa and Kiteto growing each crop, the yield range and the yield average.

| Crop | No of farmers | Yield range (kg/ha) | Yield average (kg/ha) |
|---|---|---|---|
| Maize | 7 | 173 - 824 | 373 |
| Sunflower | 7 | 80 - 729 | 324 |
| Pigeon pea | 3 | 58 - 979 | 373 |
| Sorghum | 3 | 71 - 326 | 395 |
| Millet | 3 | 169 | 169 |
| Groundnut | 3 | 173 - 951 | 465 |
| Bambara nut | 2 | 44 - 1112 | 578 |
| Sweet Potatoes | 1 | 692 | 692 |

### *3.1.5 Livestock*

The distribution of number of animals expressed in TLU's per household is expressed as histograms for Babati and Kongwa/Kiteto districts in Figure 3.1.4. In both districts the animals numbers were below 5 TLU. Although the surface area of the farms was smaller in Babati than in Kongwa and Kiteto, the average number of animals per farm was larger in Babati, indicating a considerably higher farm livestock density.

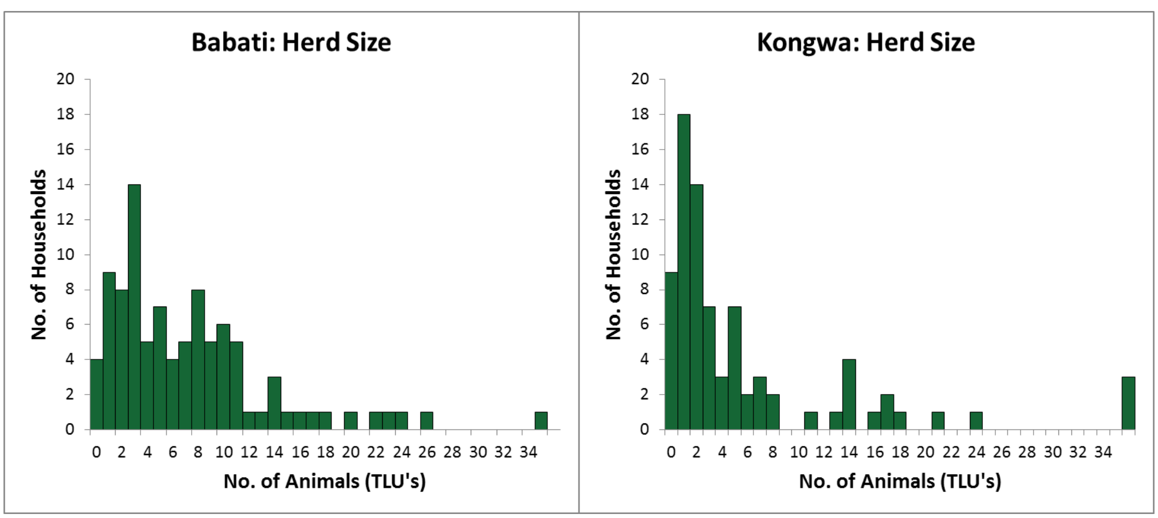



**Figure 3.1.4.** Histograms comparing Animal numbers expressed as TLU's per household for Babati and Kongwa districts in Tanzania.

### *3.1.6 People and livelihoods*

The data on household size, farm size and farm size per household member are expressed as histograms for Babati and Kongwa/Kiteto districts in Figure 3.1.5. The household size was the same for both districts (an average of 7 persons per household), but due to the larger farm surface area in Kongwa and Kiteto, the cropping area available per person was larger.

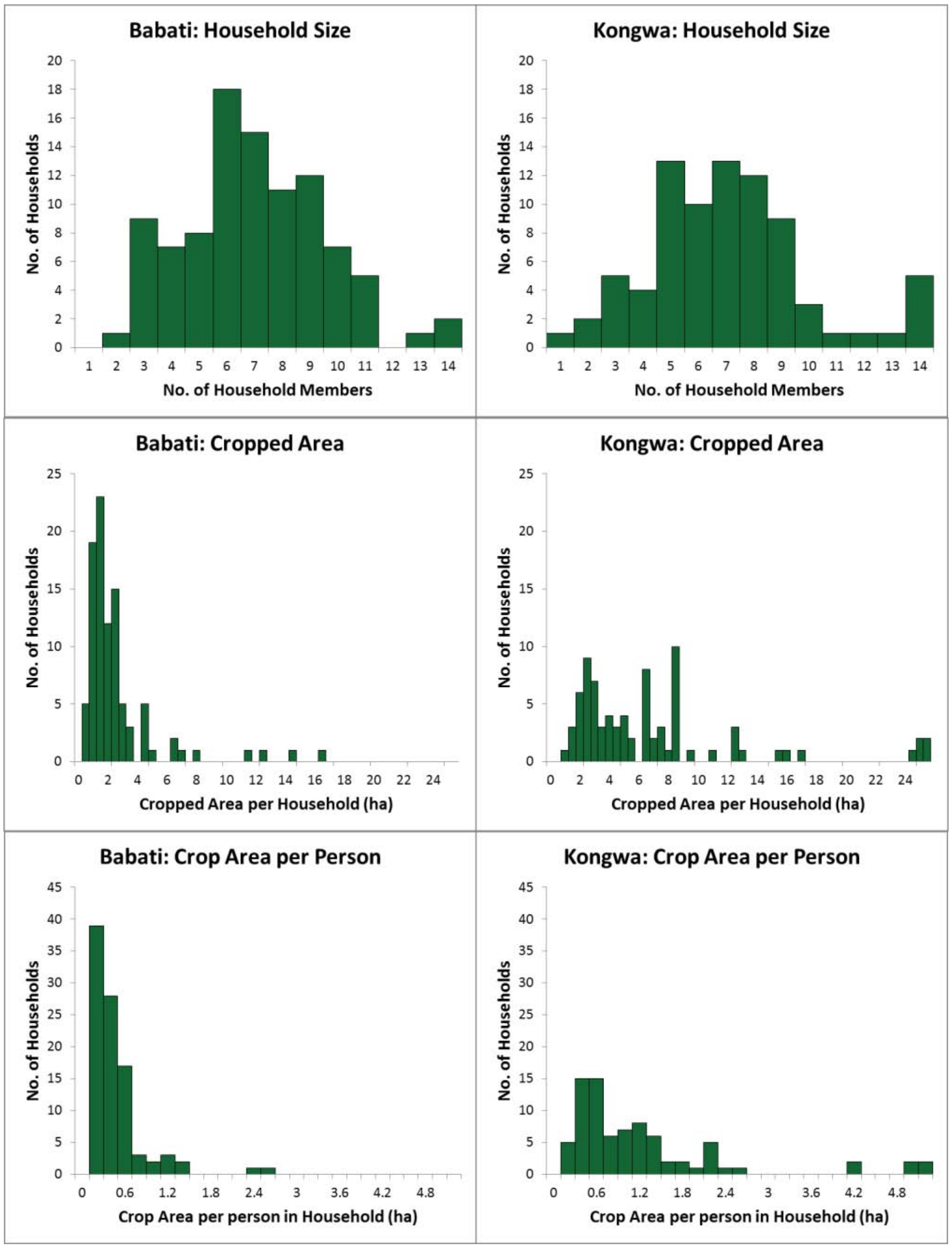



**Figure 3.1.5.** Histograms comparing household and farm size and crop area per household member for the Babati and Kongwa & Kiteto districts in Tanzania.

### *3.1.7 Farmers' dreams and objectives*

During the detailed analysis of the farming systems in September the farmers were asked for their dreams, objectives and main concerns. An overview is provided in Tables 3.1.11 and 3.1.12.

**Table 3.1.11.** Answers to qualitative questions provided by ten farmers in the Babati district during the detailed characterization interviews in September 2013.

| Farmer | Objectives | Challenges | Dreams |
|---|---|---|---|
| *Shaurimoyo 3* | He first lived somewhere else, on leased land, now rents in Shaurimoyo. Not planning to settle, because of land-pressure. He likes farming, makes him feel secure. Would like to raise capital through farming to invest in off-farm business. His children have mixed perceptions on farming. | Land shortage.<br>Low awareness of improved agronomical practices.<br>Poor road network.<br>Unstable markets.<br>Pests and diseases. | Education; higher quality for his children and for him on agronomy practices (improved technologies and marketing)<br>Raise capital and invest in non-farm enterprises. |
| *Shaurimoyo 12* | Farming for cash; he quit cotton production in Magugu, because of poor payments so he recently moved to Shaurimoyo to produce rice. He likes farming; with more money he would buy more land. | Market instability; see objective. Poor infrastructure. Old irrigation canals.<br>Pests and diseases: (*kideri)* – New Castle disease and tick-borne diseases for cattle. | Intensify and expand his farming activities, for both crops and livestock.<br>Education; both basic and on entrepreneurship. |
| *Shaurimoyo 5* | Improved livelihood with farming as source of income. So far the couple has been investing farm income in buying new land and building new houses. Her sons used farm income to invest in other business in urban areas. | Poultry diseases.<br>Rice-stunting diseases.<br>Poor markets for farm products. | Access to stable markets, build modern houses and install solar power. |
| *Long 2* | Farming for better living standards. | Limited access to improved seed and stable markets. | Increase income through better farming methods.<br>Enhance capacity in competitive markets.<br>Knowledge on improved practices for production of sweet potatoes.<br>*'Wishes to practice mono-cropping for higher production'* |

| Farmer | Objectives | Challenges | Dreams |
|---|---|---|---|
| *Sabilo 13* | Improve his standard of living through farming. He likes farming and is interested only in agriculture. | Drought; rains coming less frequent.<br>Diseases and pests.<br>Fake seeds.<br>Poor quality of livestock feed. | Reach higher yields for increased income.<br>Reliable market and education; increased knowledge on good farming practices. |
| *Sabilo 14* | Crop-livestock farmer also running a small non-agricultural enterprise in the village. | Drought.<br>Unstable markets.<br>Pests and diseases. | Engage in enterprises with higher returns to investment, as dairy cows and trading of livestock. |
| *Hallu 5* | Keen in and committed to farming – it is the right thing for him to do. His oldest son has just graduated and is now a teacher. Other children are still in school, it is too early to say something about their aspirations. | Unstable market prices. Pigeonpea price has dropped from 150k to 100k per bag. | Markets should be more attractive (pigeon pea for example used to sell for 150k a bag) and products like chemical fertilizer should become less expensive. *Would like to learn key findings from all the surveys executed in the village.* |
| *Seloto 2* | | Crop and livestock diseases. | Uplift standard of living of his family through farming. |
| *Seloto 16* | | Low capital for investing in agriculture.<br>Pests and diseases. | Policy changes on inputs and marketing. |
| *Matufa 11* | Realize higher yields for higher income to support his family and meet education obligations. His main interest is in farming, not so sure about his children. | Might reduce nr. of cows, since it is difficult to feed them. Market system should change; better and more stable prices. Subsidy system for fertilizers and seeds should be improved; come late and lots of bureaucracy. | |

**Table 3.1.12.** Answers to qualitative questions provided by seven farmers in Kongwa and Kiteto districts during the detailed characterization interviews in September 2013.

| Farmer | Objectives | Challenges | Dreams |
|---|---|---|---|
| *Laikala 8* | He admires agriculture. He wants his children to read and to study. | One big problem; climate change. Weather has changed much over the past 10-15yrs; the rain season starts later and the dry spell is longer and longer. | Education! He really needs education on agricultural practices, the scientific part of it. At the moment none |
| *Laikala 10* | She prefers farming, but her wish for her children is that they go all the way to secondary school and not come back to the farm. | | Quick and early maturing crop varieties.<br>Also, she would love to keep dairy cattle. |
| *Moleti 6* | He likes farming, very much. The son who's around likes to keep livestock. Grandma hopes her grandchildren will keep on studying, to secondary school and further. Of the 2 grandchildren we asked, 1 wanted to become a farmer, the other a pastor. | | He would like to see his grandchildren progress; he wishes them to not come back for farming, but to become a doctor, teacher, Member of Parliament, or researcher. He himself was brought up poor, but now he knows that educations is very valuable. |
| *Moleti 10* | He would like to be a businessman, but lacks the investment money. If he would have the money, he would mechanize his farming operations. His children have to be educated; he doesn't want them to come back for farming, but to rescue him. | Lack of machinery. | He wishes to give up on agriculture. |
| *Chitego 13* | He likes farming, because it gives him a good income. He cannot make predictions for his children, because they're still young, but he would like them to become doctors. | | To own a tractor, for full mechanization of his farm. |
| *Njoro 9* | Even if he wouldn't want to farm, it is the only thing he has, there's no other way to survive. He always liked school, went even while his father didn't agree – could have been a big man by now. His son likes healthcare, and livestock. '*One would be in trouble without farming*.' | The main problem are unstable and too low prices, they are flexible in a negative way. | Education. A bigger house. And to keep 5 dairy cows; they would provide nutritious milk to the children, while surplus could be sold in the shop. |

| Farmer | Objectives | Challenges | Dreams |
|---|---|---|---|
| *Njoro 1* | Yes, also because it is (more or less) the only thing he has. His sons need to go to school; they need to become teachers. | Lack of improved seeds; he recycles planting material. First time he bought from a fellow farmer, now recycling. | He would like to see his children go to school. |

### *3.1.8 Constraints and critical points*

Following the analysis of the detailed characterization, the constraints to sustainable intensification for farmers can be summarized as:

- Low productivity. Especially in Kongwa and Kiteto, the soils are relatively poor (sandy or sand), and the overall yields are quite low. Low yields and crop failures result in a lower income and indirect income losses, because farmers need to buy maize for prices that have tripled since they sold their produce.
- Climate - many farmers in the two semi-arid districts reported changing rainfall patterns, with a longer dry spells and less frequent rains.
- Pests and diseases. All farmers faced multiple pests or diseases for their crops and/or livestock, affecting growth rates and final yields.
- Poor animal nutrition. Almost all livestock appeared to be fed sub-optimally, in both fodder quality and fodder quantity. This leads to a lower animal productivity, affecting growth, production and reproductions rates.
- Poor manure storage and poor crop residue management. Manure is often stored open, in a pile, resulting in losses in quality as well as nutrient leaching into the soil. Crop residues were almost always removed from the land and fed to cattle, decreasing amounts of organic matter available to add the soil.

### *3.1.9 Entry points and suggestions*

**<u>Education</u>**

The entry-point of education holds the potential to change farmers' lives in many ways, as knowledge helps to make better-informed decisions. In their answers to the qualitative questions, many farmers also expressed their wish to 'be educated', which is a good opportunity. Through means of for example focus group discussions or Innovation (or Research 4 Development) Platforms, farmers would be able to exchange knowledge and ideas, and interact with other stakeholders in the agricultural sector. The range of possible topics is wide; from manure storage, livestock feeding, specific pests in crops or diseases in livestock, to processing of agricultural products, or even family planning.

**Pest and disease management**

As pests and diseases reduce growth rates, or even cause death, of plants and animals, they decrease overall yields and production. Therefore to improve the management of the most encountered pests and diseases would help to improve overall productivity of farms. Trainings to help farmers identify pests and diseases and to increase the knowledge on how to fight back would help to reduce the harm done by pests and diseases.

**Cash crops**

An attractive market seems to be one of the main drivers of adoption for smallholder farmers, since families need cash as well as food, to be able to pay for example school fees, clothes and medication. The right cash crop at the right time and place can help farmers to make a living, to earn the cash they need and maybe even escape from poverty. Processing of agricultural products might be another opportunity for farmers to earn additional income, depending on the crop/product, this could be done individually, or collectively, providing the opportunity to share investment costs, etc.

**Agricultural diversification**

Diversification of agricultural activities would help to spread the risk that households take and would also improve dietary diversification. When smallholder farmers keep multiple types of livestock and grows a wide variety of crops, the chance to have insufficient food to eat, as a result of crop failure, will be much lower compared to a situation in which a farmer grows only one crop.

**Improved livestock feed**

The nutrition of the different types of livestock could be improved, both in quantity and quality. Farmers could for example establish contours on which grasses or bushes can be grown, specifically to provide fodder, the contours would have the additional benefit of erosion control. There are also several leguminous bushes and trees that would improve the quality of feed. In addition if farmers were to harvest their residues that they would use for animal feed earlier in the season, and if necessary store them well, the quality of the feeds would be improved. The residues that would be left on the field should be incorporated earlier as well. This would also ensure that their quality would be higher and would make them less accessible to wandering grazers.

In the model FarmDESIGN we can create scenarios that demonstrate the effects of applying such management techniques. To represent increased feed quality, for the crop residues fed to animals, we increased the protein and nitrogen content by 25% and energy values by 10%; Scenario 1. In Scenario 2 we allocate the improved (feed) quality residues with equal distribution to the soil and to animal feed. In Table 3.1.13 a summary of the changes in selected indicators resulting from implementing these scenarios as compared to the current situation on this farm is presented.

**Table 3.1.13.** Percentage increases and decreases for selected indicators in the FarmDESIGN model using improved feed values and two different destination uses of crop residues for the farm 'Sabilo 14', Babati, Tanzania.

| Indicator | Current Situation | Scenario 1 Improved feed value Residues fed to animals | Scenario 2 Improved feed value Equal residues to soil and animals |
|---|---|---|---|
| Organic matter added (kg/ha/yr) | 907 | -0.33% | 7.83% |
| Manure produced (kg DM) | 6236 | -1.01% | -1.73% |
| N in Import crop prods (kg/ha/yr) | 143 | 0.00% | 5.59% |
| Crop Nitrogen Uptake (kg/ha/yr) | 11 | 36.36% | 36.36% |
| Nitrogen in Green manures (kg/ha/yr) | 0 | none | improved |
| Nitrogen fed to animals (kg/ha/yr) | 148 | 2.03% | 2.70% |
| Nitrogen in Manure (kg/ha/yr) | 140 | 2.14% | 2.86% |
| Nitrogen in Manure to soil (kg/ha/yr) | 118 | 1.69% | 2.54% |
| Nitrogen in Soil losses (kg/ha/yr) | 115 | -0.87% | 6.09% |
| Nitrogen Volatilization (kg/ha/yr) | 14 | 7.14% | 7.14% |
| Total Nitrogen losses (kg/ha/yr) | 129 | 0.00% | 6.98% |

When feed values improve the animals need to eat less of the better quality feed, thus the amount of manure produced is less, and thus the amount of organic matter added to the soil is lower. However when the residues are equally allocated to the soil and to the animal feed, then the organic matter added increases as this compensates for the lower organic matter additions from manure. There is more nitrogen fed to animals as the crop residues have a higher protein and nitrogen content. Consequently there is also more nitrogen in their manure. When no residues are added to the soil in Scenario 1, then there are less losses to the soil and total nitrogen losses remain the same. Nitrogen volatilization increases with increased nitrogen in the farm cycle. There is no change to labor as this was assumed to remain the same, and there is no change to profit as only on farm cycles are changed and no external products are added or removed.

**Improved manure storage**

Better management and storage of manure would result in better quality manure. Currently manures are stored exposed to the elements where aerobic degradation is the dominant process. Storing manures in a hole lined and covered with an impermeable sheet, changes the degradation process to anaerobic , preventing nutrients from leaching out and slowing down degradation rates. The addition of crop residues and/or other plant material to manures would increase the organic matter content of the soil, once the manure is returned to the fields. Low soil fertility and degradation of soils are a major problem in Sub Saharan Africa and ways to restore the soils should therefore receive much attention.

We performed a model-based analysis to investigate the effects of improving the manure storage. If it assumed that the manure is stored air tightly under an impermeable sheet, the fraction of manure degradation that takes place under aerobic conditions can be reduced from 70% to 5%, and thus anaerobic fermentation increases from 30% to 95%. Moreover, the exposure of manure to air is less, so that ammonia volatilization is reduced. These changes increase the nitrogen available in the manure applied to the soil/crop. As the model does not yet have a yield increase response to increased available nitrogen in the soil from the manure, two further scenarios were added with a 10% and a 15% yield increase. Table 3.1.14 shows a summary of the changes in selected indicators resulting from implementing these scenarios as compared to the current situation on this farm.

**Table 3.1.14.** Percentage increases and decreases for selected indicators using improved manure storage and yield increases on the farm 'Sabilo 14', Babati, Tanzania.

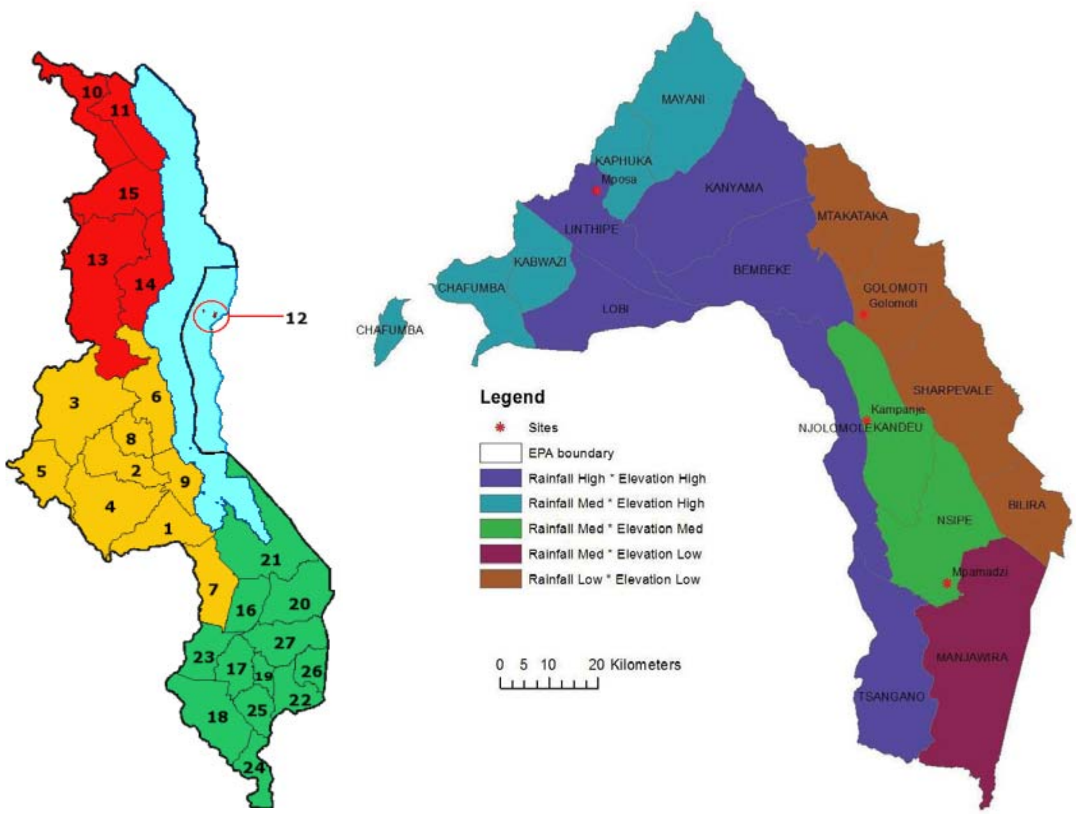
| Indicator | Current Situation | Scenario 1 Improved storage with No yield increase | Scenario 2 Improved storage with 10% yield increase | Scenario 3 Improved storage with 15% yield increase |
|---|---|---|---|---|
| Organic Matter added (kg/ha/yr) | 907 | 15.99% | 15.88% | 16.21% |
| Manure production (kg DM) | 6 236 | 45.01% | 44.47% | 45.45% |
| Crop Nitrogen Uptake (kg/ha/yr) | 11 | 0.00% | 63.64% | 90.91% |
| Nitrogen in manure (kg/ha/yr) | 118 | 4.24% | 2.54% | 3.39% |
| Total Nitrogen losses (kg/ha/yr) | 129 | 0.00% | -6.98% | -8.53% |
| Operating profit (Tsh/yr) | 6 840 407 | 0.00% | 2.02% | 3.02% |

The manure production greatly increases with better storage, and with less degradation more manure is available to add more organic matter to the soil. The improved amount of nitrogen in the manure means that there is more nitrogen available for the crops to take up. The additional yield increases require more nitrogen and there are lower losses of nitrogen when the yields are higher. With higher yields there is a greater quantity of produce to sell which results in higher gross margins for crops and hence higher operating profits.

# 3.2 Malawi

### *3.2.1 Introduction to the country and the case study regions*

Malawi is a landlocked country in southeastern Africa. It borders with Tanzania in the north and east, Zambia in the west and Mozambique in the east and south. Along its eastern border is Lake Malawi. Agricultural lands make up roughly 47% of the total land area (FAO, 2013). The main crops are maize, potatoes and cassava, and to a lesser extent legumes such as groundnuts, beans, pigeon peas (FAOSTAT, 2011). Smallholder farmers also grow cash crops such as tobacco and cotton. These farmers contribute about 80% of Malawi's food requirements (Damaphiletsa *et al*., 2007).




a. b.

**Figure 3.2.1.** a. Map of Malawi districts. Yellow: central Malawi with 1: Dedza, 7: Ntcheu. b. Rainfall and elevation distribution over Dedza and Ntcheu districts.

Two districts were examined in central Malawi, Dedza and Ntcheu. These can be seen in Figure 3.2.1 and Figure 3.2.2. Within each district there were two Extension Planning Areas (EPA's) and within each EPA there were two villages. The structure is indicated in Table 3.2.1. Each EPA was considered as a single region with similar climatic conditions.

**Table 3.2.1.** Case study regions and villages in central Malawi.

| District | Dedza | | Ntcheu | |
|---|---|---|---|---|
| EPA | Linthipe | Golomoti | Nsipe | Kandeu |
| Altitude (m) | 1250m | 550m | 800m | 800m |
| Climate | Cool | Hot semi-arid | Intermediate | Intermediate |
| Rainfall (mm/y) | 800 - 1500 | 800 - 1000 | 730 - 950 | 700 - 800 |
| Villages | Mbidzi, Chibwana | Msamala, Kalumo | Amosi, Ziliongwe | Dauka, Gonthi |

### *3.2.2 Farm characteristics*

After the rapid characterization in April and May 2013, the farms were assessed for their surface area, number of household members, presence of animals and/or cattle, whether they grew cash crops like tobacco or cotton and whether or not they were subsistence farmers (did not sell any produce) (Table 3.2.2). From this table the farmers were divided into four orientations. Orientation 1: A subsistence farmer who only grows food crops. Orientation 2: A subsistence farmer who grows food crops and non-food crops and who only sells his non-food crops such as cotton or tobacco. Orientation 3: A farmer who is market orientated who grows and sells food and non-food crops. Orientation 4: A farmer who is market orientated who grows and sells only food crops.

It was assumed that farms that had a large area and had cattle were the most well-endowed farms, whereas farms that were small and had no cattle were least well endowed. In this manner, three farms per EPA were pragmatically chosen for the detailed analysis; one well-endowed farmer, one poorly endowed farmer and a farmer that was averagely endowed.

**Table 3.2.2.** Summary of Malawi farmers used for identification of farmer selection.

District: Dedza

EPA: Linthipe — Altitude: 1250 m — Climate: Cool

EPA: Golomoti — Altitude: 550 m — Climate: Hot semi-arid

Village name: Mbidzi — Ave Farm area: 0.9 ha — Ave HH size: 4.7

| | | | | | | |
|---|---|---|---|---|---|---|
| 8 | 0.2 | 4 | | | | 4 |
| 6 | 0.4 | 4 | | | | 4 |
| 2 | 0.6 | 4 | | | | 4 |
| 3 | 0.6 | 8 | | | | 4 |
| 4 | 0.6 | 3 | | | | 4 |
| 7 | 0.8 | 5 | | | S | 1 |
| 9 | 1.0 | 4 | | | | 4 |
| 10 | 1.0 | 6 | | | S | 1 |
| 5 | 1.4 | 2 | | | | 4 |
| 1 | 2.0 | 7 | | 15 | | 3 |

Village name: Chibwana — Ave Farm area: 0.7 ha — Ave HH size: 4.0

| | | | | | | |
|---|---|---|---|---|---|---|
| 6 | 0.2 | 6 | | | | 4 |
| 8 | 0.3 | 2 | | | | 4 |
| 3 | 0.4 | 4 | | | | 4 |
| 7 | 0.4 | 5 | | | | 4 |
| 5 | 0.4 | 3 | | | S | 1 |
| 2 | 0.6 | 4 | | | | 4 |
| 10 | 0.6 | 6 | | | | 4 |
| 4 | 1.0 | 4 | | | | 4 |
| 1 | 1.0 | 3 | | | | 4 |
| 9 | 2.2 | 3 | | 1 | | 3 |

Village name: Msamala — Ave Farm area: 1.3 ha — Ave HH size: 5.0

| | | | | | | |
|---|---|---|---|---|---|---|
| 9 | 0.2 | 5 | | | | 4 |
| 5 | 0.6 | 7 | | | S | 1 |
| 1 | 0.8 | 7 | | | | 4 |
| 8 | 0.8 | 3 | | | S | 1 |
| 2 | 0.8 | 6 | | | | 4 |
| 7 | 1.0 | 5 | | 40 | SC | 2 |
| 3 | 1.6 | 4 | | 25 | | 3 |
| 4 | 1.6 | 5 | | 38 | SC | 2 |
| 6 | 1.8 | 4 | | 33 | SC | 2 |
| 10 | 3.6 | 4 | | 33 | SC | 2 |

Village name: Kalumo — Ave Farm area: 1.1 ha — Ave HH size: 5.0

| | | | | | | |
|---|---|---|---|---|---|---|
| 9 | 0.4 | 8 | | | S | 1 |
| 7 | 0.4 | 3 | | | S | 1 |
| 6 | 0.6 | 8 | | | S | 1 |
| 3 | 0.7 | 3 | | 43 | | 3 |
| 4 | 0.8 | 5 | | 25 | SC | 2 |
| 2 | 1.0 | 6 | | 40 | | 3 |
| 10 | 1.0 | 4 | | | | 4 |
| 8 | 1.2 | 3 | | 67 | SC | 2 |
| 1 | 1.6 | 6 | 1 | 25 | SC | 2 |
| 5 | 3.0 | 4 | 4 | 33 | | 3 |

District: Ntcheu

EPA: Kandeu — Altitude: 700 m — Climate: intermediate

EPA: Nsipe — Altitude: 700 m — Climate: intermediate

Village name: Dauka — Ave Farm area: 1.3 ha — Ave HH size: 5.1

| | | | | | | |
|---|---|---|---|---|---|---|
| 3 | 0.6 | 5 | | | S | 1 |
| 1 | 0.6 | 4 | | | | 4 |
| 5 | 0.6 | 3 | | | | 4 |
| 10 | 0.8 | 5 | | | | 4 |
| 4 | 1.2 | 8 | | | | 4 |
| 7 | 1.2 | 3 | | | | 4 |
| 2 | 1.6 | 6 | | 25 | SC | 2 |
| 6 | 1.8 | 5 | 8 | 11 | | 3 |
| 8 | 2.0 | 7 | 8 | | | 4 |
| 9 | 2.7 | 5 | | | | 4 |

Village name: Gonthi — Ave Farm area: 1.0 ha — Ave HH size: 5.3

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | 0.4 | 4 | | | S | 1 |
| 7 | 0.5 | 5 | | | S | 1 |
| 1 | 0.6 | 3 | | | S | 1 |
| 9 | 0.6 | 6 | 7 | | | 4 |
| 6 | 0.8 | 6 | | | | 4 |
| 8 | 1.0 | 8 | 1 | | S | 1 |
| 10 | 1.0 | 4 | | | | 4 |
| 2 | 1.2 | 7 | | | S | 1 |
| 3 | 1.2 | 4 | 14 | | | 4 |
| 4 | 2.4 | 6 | | | | 4 |

Village name: Amosi — Ave Farm area: 1.0 ha — Ave HH size: 5.2

| | | | | | | |
|---|---|---|---|---|---|---|
| 9 | 0.4 | 4 | | | S | 1 |
| 1 | 0.6 | 5 | | | S | 1 |
| 8 | 0.6 | 4 | | | S | 1 |
| 7 | 0.6 | 6 | | | | 4 |
| 2 | 0.8 | 5 | | 50 | | 3 |
| 10 | 0.8 | 5 | | | | 4 |
| 3 | 0.9 | 5 | | | | 4 |
| 4 | 1.4 | 7 | | | | 4 |
| 6 | 1.4 | 4 | | 29 | SC | 2 |
| 5 | 2.0 | 7 | 6 | | S | 1 |

Village name: Ziliongwe — Ave Farm area: 1.0 ha — Ave HH size: 3.5

| | | | | | | |
|---|---|---|---|---|---|---|
| 6 | 0.2 | 2 | | | | 4 |
| 9 | 0.3 | 3 | | | S | 1 |
| 4 | 0.6 | 5 | | | | 4 |
| 2 | 0.6 | 6 | | | S | 1 |
| 8 | 0.8 | 2 | | | | 4 |
| 7 | 0.9 | 4 | | | | 4 |
| 3 | 1.0 | 2 | | | | 4 |
| 1 | 1.2 | 4 | | | S | 1 |
| 5 | 1.2 | 5 | 3 | | | 4 |
| 10 | 3.2 | 2 | | | | 4 |

**Legend:**

- 1 Farm number
- = chosen for detailed characterization
- 1.2 Farm area
- 3 People in Household (HH)
- no animals recorded
- 5 cattle owner and number of head of cattle
- 15 Non food crop grower and % of land with non food crop
- S Subsistence farmer does not sell any crops
- SC Subsistence farmer only sells non food crop
- 1 Orientation 1 - Subsistence only food crops
  - 2 - Subsistence with non food crops
  - 3 - Market orientated with non food crops
  - 4 - Market orientated only food crops

A typology of the farms in Malawi was established by cluster analysis (Table 3.2.3). The Mclust algorithm (Fraley and Raftery, 2000) was used, applied to the variables listed in Tables 3.1.5 and 3.1.6. The analyses were conducted separately for Dedza and Ntcheu districts. Within Dedza three types were found and in Ntcheu only two. One of the groups for Dedza (Dedza 0) contained only two outliers that were characterized by low farm area, a large proportion of hired labor, a low proportion of female labor and cultivation of only two crops.

For groups Dedza 1 and Ntcheu 1, the proportion of hired labor was low (<0.10), whereas the input of female labor was high (≥ 0.60; Table 3.2.3). The total livestock numbers were low, with on average 0.17 TLU (tropical livestock units).

The groups of larger farms Dedza 2 and Netcheu 2 had more labor available, both from the family and hired, but the labor input by women was considerably lower than for the types with smaller farms. Average livestock numbers were larger for Dedza 2 and Ntcheu 2.

Comparing the types of Dedza and Ntcheu (Dedza 1 vs. Ntcheu 1 and Dedza 2 vs. Ntcheu 2), on average the types of Dedza had smaller farms, lower proportions of hired and female labor and lower crop diversity, but more total labor input and larger livestock numbers.

**Table 3.2.3.** Farm types in the Dedza and Ntcheu districts identified by cluster analysis.

| Variable | Dedza 0 | Dedza 1 | Ntcheu 1 | Dedza 2 | Ntcheu 2 |
|---|---|---|---|---|---|
| Number of farms | 2 | 24 | 25 | 15 | 14 |
| Field area (ha) | 0.30 | 0.70 | 1.02 | 1.10 | **1.57** |
| Labor density (h/ha) | **14302** | 2307 | 2029 | 5158 | 2476 |
| Hired labor ratio | **0.47** | 0.03 | 0.08 | 0.16 | 0.32 |
| Female labor ratio | 0.22 | 0.60 | **0.64** | 0.35 | 0.43 |
| TLU | 0.16 | 0.17 | 0.16 | **2.15** | 0.90 |
| Crop number | 2.00 | 2.48 | 2.63 | 2.61 | **2.67** |
| Orientation | **4.00** | 3.17 | 2.72 | 3.13 | 2.29 |

### *3.2.3 Land and soil*

The land costs per hectare in Malawi were estimated to be 30 000 Malawian Kwatcha which translates to approximately US$ 89 in September 2013 (Jambo pers. comm., 2013). This figure was used as a blanket figure for all farms in the two districts, however there would certainly be variation according to the fertility of the land in question and who the buyer is.

Soils of the 13 farms involved in detailed characterization were analyzed for soil texture, organic matter content and chemical composition (Table 3.2.4). The variation in soil organic matter was considerable (from 1.36 to 5.44 %). The pH was low, on average 5.6. The soil organic matter percentage was strongly correlated to the contents of nitrogen (88.7%), phosphorus (77.2%) and potassium (84.2%), after correction for the outlier Mbidzi 1, which combined high soil organic matter with low nutrient content.

**Table 3.2.4.** Soil testing results from farms in Dedza and Ntcheu districts in Malawi. Txt = texture, SL = sandy loam, LS = loamy sand, S = sand, SCL = sandy clay loam.

| Farm | OM (%) | Txt | pH-$H_2O$ | P (mg/L) | P total (%) | N (mg/L) | N total (%) | K (mg/L) | K total (%) |
|---|---|---|---|---|---|---|---|---|---|
| Mbidzi 1 | 5.44 | SCL | 4.92 | 1.98 | 0.02 | 13.07 | 0.15 | 7.079 | 0.079 |
| Mbidzi 7 | 3.5 | LS | 5.13 | 13.17 | 0.15 | 10.21 | 0.11 | 44.602 | 0.521 |
| Chibwana 6 | 2.54 | S | 5.28 | 9.78 | 0.12 | 9.97 | 0.11 | 25.574 | 0.309 |
| Msamala 2 | 3.24 | S | 5.77 | 15.81 | 0.18 | 10.05 | 0.10 | 30.521 | 0.347 |
| Msamala 10 | 1.8 | S | 4.96 | 4.70 | 0.05 | 6.94 | 0.07 | 17.893 | 0.209 |
| Kalumo 9 | 2.54 | LS | 5.86 | 14.39 | 0.17 | 9.39 | 0.10 | 35.876 | 0.428 |
| Amosi 5 | 1.36 | S | 5.27 | 2.79 | 0.03 | 5.80 | 0.06 | 17.548 | 0.199 |
| Amosi 9 | 2.41 | S | 6.79 | 9.05 | 0.10 | 9.64 | 0.10 | 27.373 | 0.312 |
| Zililongwe 3 | 1.99 | S | 5.78 | 4.27 | 0.05 | 8.41 | 0.09 | 17.114 | 0.193 |
| Dauka 6 | 1.92 | S | 5.47 | 4.34 | 0.05 | 7.68 | 0.08 | 19.642 | 0.224 |
| Dauka 3 | 2.25 | S | 5.67 | 8.23 | 0.09 | 7.43 | 0.07 | 17.931 | 0.200 |
| Gonthi 10 | 1.72 | S | 5.92 | 6.41 | 0.07 | 9.07 | 0.09 | 21.542 | 0.244 |
| Average | 2.56 | | 5.57 | 7.91 | 0.09 | 8.97 | 0.09 | 23.56 | 0.27 |

### *3.2.4 Crops*

Yields varied quite largely within each district. In Tables 3.2.5 and 3.2.6 the number of farmers found growing each crop in all 12 farms in the two districts is presented. The ranges in reported yields were large and the average yields indicated by farmers were low.

**Table 3.2.5.** Number of farmers in a sample of 6 farmers in Dedza growing each crop, the yield range and the yield average.

| Crop | No of farmers | Yield range (kg/ha) | Yield average (kg/ha) |
|---|---|---|---|
| Maize | 6 | 375 - 4000 | 1723 |
| Bean | 3 | 200 - 500 | 344 |
| Groundnut | 3 | 75[a] - 750 | 442 |
| Cowpea | 2 | 125 | 125 |
| Soybean | 1 | 1333 | 1333 |
| Sweet potato | 1 | 2817 | 2817 |
| Tobacco | 1 | 667 | 667 |
| Cotton | 1 | 583 | 583 |

[a]. 75 kg/ha was an outlier – crop failure, 600 kg/ha is more realistic average yield

**Table 3.2.6.** Number of farmers in a sample of 6 farmers in Ntcheu growing each crop, the yield range and the yield average.

| Crop | No of farmers | Yield range (kg/ha) | Yield average (kg/ha) |
|---|---|---|---|
| Maize | 6 | 531 - 3063 | 1178 |
| Groundnut | 4 | 14 – 200[b] | 125 |
| Bean | 2 | 40 – 42[b] | 41[b] |
| Cowpea | 2 | 47 - 80 | 63 |
| Pumpkin | 2 | 983 - 1250 | 1117 |
| Tobacco | 1 | 2025 | 2025 |

[b.] Beans and groundnuts do not perform as well in the hotter lower altitudes, as they do in Dedza district

In Dedza district all farmers grew maize (Table 3.2.5). Beans were mostly grown in the cooler climate of Linthipe and cotton was only found in the hotter climate of Golomoti. There was quite a large range in the yields reported, in some cases due to crop failures; in other cases it was unclear as to the reason for the relatively low yield. Similarly to Dedza district, all farmers in

Ntcheu district grow maize (Table 3.2.6). Beans and groundnuts have lower yields in Ntcheu district when compared to Dedza. This is most likely due to the warmer climate.

During the detailed characterization interviews, when questioning on the costs of cultivation, only the costs of purchasing seeds was mentioned as a cultivation cost. Where the farmer saved his seed, his cultivation costs were recorded as zero. No farmers used any mechanization such as tractors to till their fields. All work is done by hand, by themselves or in the case of high resource endowed farmers, by hired laborers. No farmers (except 'Dauka 6') used hybrid seeds, most farmers try to save seeds, but often the seeds are eaten as the requirement for food (or direct cash) increases in the months before replanting. Within our small sample of farmers, groundnut seeds were still bought locally as these seeds either store less well than maize, or could be readily sold to satisfy temporary cash flow problems. Farmers mentioned that often the cost of seeds and locating a good source is a problem.

**Table 3.2.7.** Number of farmers in a sample of 6 farmers in Dedza growing each crop (combination), and the range and average labor requirement.

| Crop (combination) | No of farmers | Labor range (h/ha) | Labor average (h/ha) |
|---|---|---|---|
| Maize Bean | 3 | 627 - 12060 | 4454 |
| Maize Cowpea | 2 | 1044 - 2555 | 1800 |
| Maize | 2 | 1075 - 1120 | 1098 |
| Groundnut | 3 | 23a - 10150 | 3600 |
| Soybean | 1 | 627 | 627 |
| Sweet Potato | 1 | 627 | 627 |
| Tobacco | 1 | 627 | 627 |
| Cotton | 1 | 793 | 793 |

Labor required per hectare for the various crops and crop combinations is presented in Tables 3.2.7 and 3.2.8. Again, as with the yield data, there are some quite large variations in the range in how much labor is actually used for different crops. Both within and between districts the variation in range is great. With farmers who have small fields it is possible that the labor per hectare is overestimated. During the detailed characterization interviews these figures were difficult to recheck with the initial rapid characterization survey, as the initial monthly sheets were not available and the time period (the last 12 months before April 2013) would be confusing for the farmers. Thus, the figures that were collected during the initial characterization were used in the model.

**Table 3.2.8.** Number of farmers in a sample of 6 farmers in Ntcheu growing each crop (combination), and the range and average labor requirement.

| Crop (combination) | No of farmers | Labor range (h/ha) | Labor average (h/ha) |
|---|---|---|---|
| Maize Bean | 1 | 400 | 400 |
| Maize Cowpea | 2 | 469 - 1620 | 1044 |
| Maize Groundnut | 1 | 1222 | 1222 |
| Maize Pumpkin | 2 | 2630 - 2720[c] | 2675 |
| Groundnut | 2 | 998 - 2639 | 1818 |
| Tobacco | 1 | 7075 | 7075 |

[c.] The high labour requirement that was found in our small sample could be due to the extra labour with harvesting bulky pumpkins. One farmer had not even managed to get all her pumpkins off her fields.

### *3.2.5 Livestock*

Table 3.2.9 presents a summary of the livestock data collected in terms of different livestock types encountered during the detailed characterization, and the average numbers of each livestock type collected for each district. Labor requirements for the livestock was recorded during the rapid characterization, and in some cases confirmed during the detailed characterization. For larger livestock like cattle and goats the labor requirements were well recorded, however for smaller livestock such as chickens and ducks labor requirement was minimal and in many cases recorded as zero.

**Table 3.2.9.** Number of farmers in Dedza (n = 6) and in Ntcheu (n = 6) that keep each livestock type and the average number of each livestock type kept.

| Livestock type | Dedza | | Ntcheu | |
|---|---|---|---|---|
| | No. of farmers | Livestock no. | No. of farmers | Livestock no. |
| Cows | 0 | 0 | 2 | 4 |
| Bulls | 0 | 0 | 2 | 3 |
| Goats | 2 | 3 | 4 | 4.5 |

| Livestock type | Dedza | | Ntcheu | |
|---|---|---|---|---|
| | No. of farmers | Livestock no. | No. of farmers | Livestock no. |
| Pigs | 1 | 1 | 2 | 3 |
| Chickens | 2 | 32.5 | 6 | 4 |
| Ducks | 1 | 1 | 0 | 0 |
| Doves | 0 | 0 | 1 | 28 |

Larger livestock such as cattle are not common in Malawi, only 2 of the 12 farmers kept cattle. Smaller livestock such as goats, pigs and poultry are far more common. The number of animals expressed in TLU's per household was expressed as histograms for Dedza and Ntcheu in Figure 3.2.2.

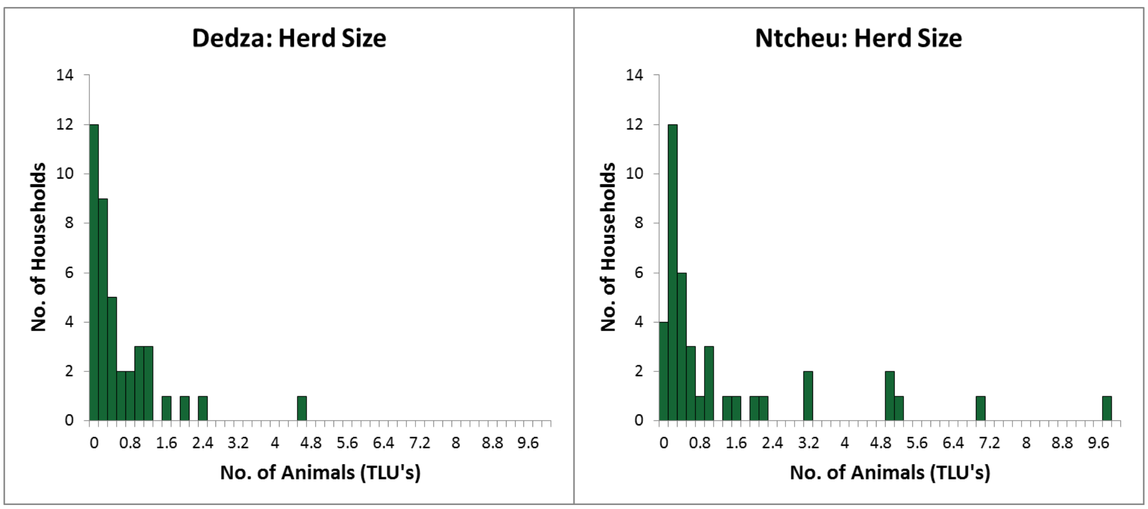



**Figure 3.2.2.** Histograms comparing animal numbers expressed as TLU's per household for Dedza and Ntcheu districts in Central Malawi.

### *3.2.6 People and livelihoods*

In Table 3.2.9 the average household (HH) size for the different villages in each district are presented. Both districts have the same average household size and a very similar average farm size. The data comparing household size, farm size and farm size per household member are presented as histograms for Dedza and Ntcheu in Figure 3.2.3.

**Table 3.2.10.** Average household size and farm size (hectares) in Dedza and Ntcheu (n=80).

| District | Village | Household size | Farm size (ha) |
|---|---|---|---|
| Dedza | Mbidzi | 4.7 | 0.90 |
| | Chibwana | 4 | 0.74 |
| | Kalumo | 5 | 1.08 |
| | Msamala | 5 | 1.30 |
| | Average | 4.7 | 1.00 |
| Ntcheu | Amosi | 5.2 | 0.95 |
| | Zililongwe | 3.5 | 1.00 |
| | Gonthi | 5.3 | 0.98 |
| | Dauka | 5.1 | 1.26 |
| | Average | 4.7 | 1.04 |

In terms of the qualitative questions asked during the detailed characterization interviews, many of the same answers were given for novel technologies as well as the same reasons for why these technologies are not being implemented, as was given during the surveys in April/May. However, in some cases, it was possible to get further discussion going to find out more substantial information. Some farmers, especially the more resource endowed farmers, provided very useful information with regards to animal production. Tables 3.2.11 and 3.2.12 contain a summary of the answers to questions on dreams and desires and challenges, information about off farm incomes as well as further information for each farmer in each district.

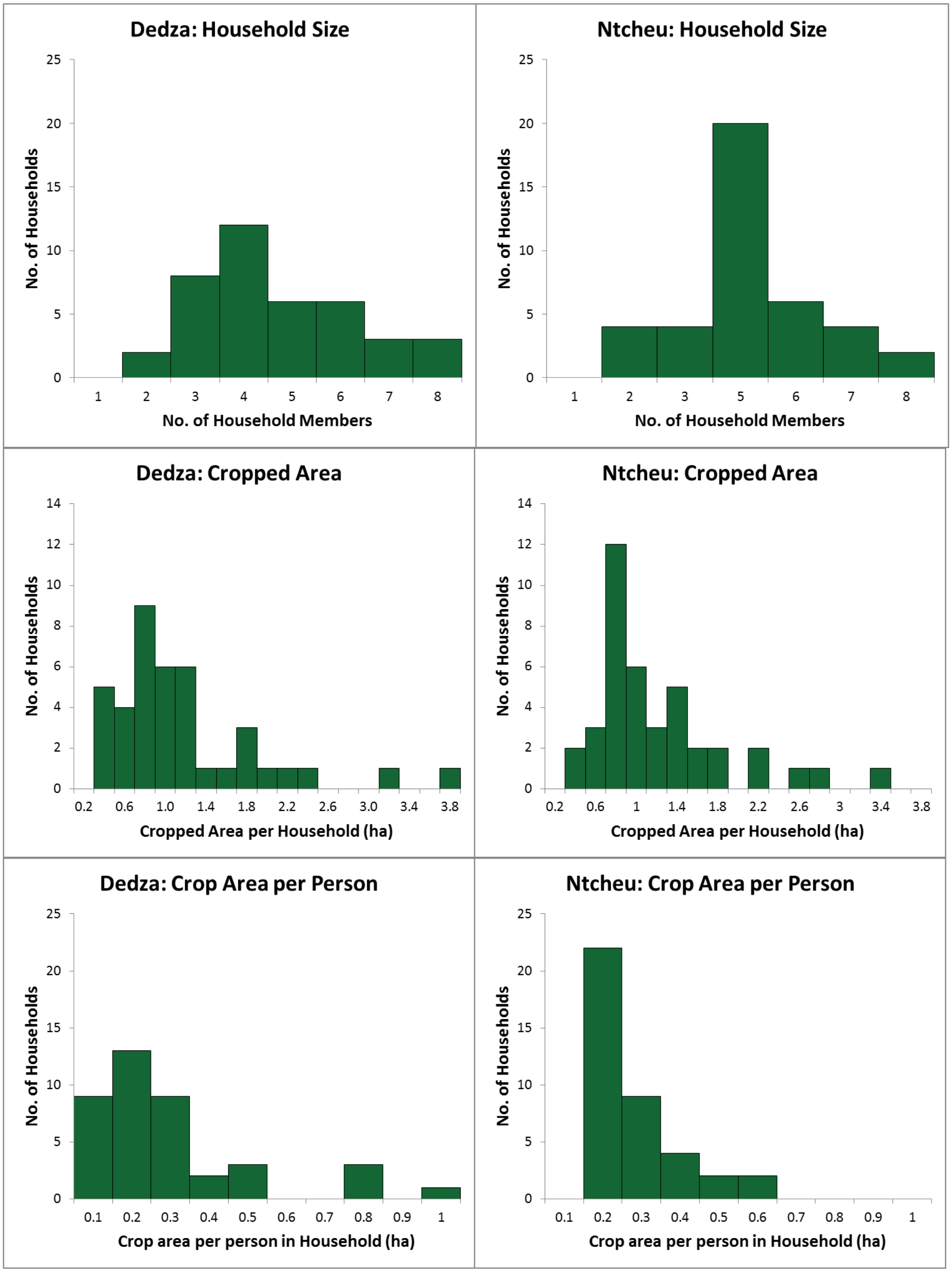



**Figure 3.2.3.** Histograms comparing Household and farm size and crop area per household member for Dedza and Ntcheu districts in Central Malawi.

**Table 3.2.11.** Answers to qualitative questions and additional information provided by six farmers in Dedza district during the detailed characterization interviews in September 2013.

| Household | Comments |
|---|---|
| Mbidzi 1 | He desires to bring back fertility to his fields by manuring and composting He desires to plant crops that improve fertility but problems such as goats eating pigeon peas discourage him from growing them. He already grows groundnuts and practices composting. His only pig died since we were there last, but he would really love to have more pigs. Pigs produce many offspring and provide much meat |
| Mbidzi 7 | She and her daughter work off farm about 8 days (64 hours x 2 = 128 hours) to be paid 27kg (10 800 kw) of groundnut seeds. No fertilizer on groundnuts, but 23:21:0+4S and Urea and Manure used on maize and bean field. Normally harvests 3.5 oxcarts maize 3150/ha, but due to wind damage only 1.5 oxcarts this year. She would desire to buy an oxcart worth 345 000 kw, a bicycle and rebuild her house. She would like to grow tobacco but feels her soils are too infertile, in addition she feels she has too little land She would love to buy large livestock, goats/pigs/cattle but does not have the extra cash. She would especially love pigs because pigs are fecund, produce much meat and much manure. |
| Chibwana 6 | Goats produce 2 offspring per year, offspring are sold when 1 year old at 10 kg for 10 000 kw. She does not work off-farm to gain any income. She really would like to have a 'hybrid' cow to get manure and milk, She would keep it in a stable and cut fodder for it. She also wants to use 'Hybrid' maize and believes her yields will double. She watches the Mother - Baby trials and plans to try these techniques. |
| Msamala 2 | She lives quite a long way away from her field, about 2 hours walk Sometimes she sells firewood as an off-farm income, but this is not a regular income source. Her biggest challenge is to get seeds and fertilizers She grows traditional varieties but would like to try 'hybrids'. New crops that she would like to try: groundnuts, pigeon peas and soybeans. Purchasing seeds is expensive. She is caring for her son's AIDS infected girlfriend and baby. He is working in the city and does not support much. The costs for bottle feeding and caring for a sick daughter-in-law are a strain on her resources. She would like to keep goats to get manure and sell the baby goats, but purchasing goats is very expensive. |
| Msamala 10 | Cotton seed is provided free by purchaser of the cotton. The shop described in initial survey has since been closed. The husband collects grass for fencing to sell |

| Household | Comments |
| --- | --- |
| | at 800 kw/bundle. The homestead is surrounded by a new grass fence! The farmer would love to have livestock like goats and or poultry for the products they produce. Soy, Groundnuts and "hybrid" maize are all crops that she would like to try. A limited cash flow prevents the family from trying new crops or starting livestock/poultry enterprise. Their biggest challenge is occasional flooding in the fields and loss of harvest, and the fact that their harvest is always meagre |
| Kalumo 9 | When questioned about off farm income it seemed that he was earning some small income from '*Dimbas*' - small fields that are next to the rivers where tomatoes and vegetables are grown. He wants to grow a variety of crops but cannot afford the seed and the fertilizer for the recommended rates. He gave example that a bag of groundnut seed costs 5 000 kw His main challenge is that he cannot provide for the basic needs of his household (6 children), as he has limited land. He desires to have livestock which he could sell if he needed urgent cash, and which would provide more food and manure. His fields are very close to his house, but they are very small, only 1 acre (0.4ha) together. In my opinion his fields are probably quite fertile, but tests will tell... |

**Table 3.2.12.** Answers to qualitative questions and additional information provided by six farmers in Ntcheu district during the detailed characterization interviews in September 2013.

| Household | Comments |
| --- | --- |
| Amosi 5 | She keeps her best seed to plant the next year, however groundnut seed she buys each year at a cost of 5000 kw. Cattle roam around during the dry period, but after harvest they are left in the fields and towards the end of the dry period when stubbles have been eaten/trampled, they search off farm for forage. During the rainy season they are off farm in grass. Husband works at water supply and gets 19 000 Kw/month. Would love to grow cassava and soybeans to get extra cash, but cattle are often destroying cassava crops. Would love to have dairy cattle and she would also keep them indoors and cut feed for them. Want to buy an oxcart (90 000 kw) to transport things easier. Biggest challenge is water, wants irrigation to be able to grow a second crop. (husband's influence from his job!). |

| Household | Comments |
| --- | --- |
| Amosi 9 | She is a divorced lady and has to do all the work, thus is sometimes too tired to work all the land -hence the fallow land and mulched pumpkins. She earns some off farm income buying and reselling tomatoes, she makes about 500 Kw/week, 26 000 kw/year. She desires to be food sufficient, wants to grow legume crops that do not require fertilizer and bring more money. She would like to grow rabbits which multiply quickly and provide meat. She reports that pigs grow to 22 kg in about 2 years and can be sold for 17 000kw. Goats sell for 12 000 kw. But she has not sold livestock this year. Her biggest challenge to get the labor done and run her household by herself, she struggles, but she is determined. |
| Zilongwe 3 | This is a very old couple, the old man excused himself that he might not be remembering all details 100% accurately. Groundnut yield was low at 1 bag, it is usually 2.5 bags. They sell young goats for 5 000kw per goat, chickens sell for 1 500 each (1 000 kw/kg). They used to raise pigs, but they died of disease, He desires to have them again. He used to get 5 piglets per year (10 born per year).<br>Pigs would be fed with maize bran, a pail of bran (80 kw) is enough for 2 pigs per month. Adult pigs are 20 - 36 kg and take 3 - 4 years to grow and can be sold for 40 000 kw. He lacks money to buy pigs, but has much experience. He also desires to become food sufficient. |
| Dauka 6 | She milks cows which give 1 litre of milk per day for a 7 month lactation. Milk production could be 2 litres, but some milk is left for the calf. She sold one cow in the past year, she received 80 000 kw for this adult cow. They feed pigs maize bran. 50kg/pig/month (250kw). Their pigs are fully grown within 1 year and are sold for 24 000 kw. Each sow produces 10 piglets/year (80% survive). Goats sell for 10 000 kw. They would like to have layer chickens to produce more eggs, but cannot source these chickens. Cattle are mostly fed crop residues and when grazing, are along the river. Farmer's field is far away from house and much needs to be transported by oxcart. Biggest challenge to secure enough capital for inputs. She desires to be a modern farmer who uses fertilizer, hybrid seeds and good breeds of animals. I asked about manures and she feel that although it is good, it is the old way, and fertilizers are the new way forward. |
| Dauka 3 | This farmer is very resource poor, he would like to grow groundnuts but seed is too expensive for him. He would like to raise goats as they can bring in cash, especially in times when he needs money like at planting time. He is trying to build up a chicken flock by leaving the eggs. He really desires to have cattle as he believes he will have achieved something then with his life. He works on other people's farms and by doing this he earns about 50 000 kw per year |

| Household | Comments |
|---|---|
| Gonthi 10 | They would like to grow hybrid soybeans to raise some income, however the high seed cost makes this currently unattainable. Would like to raise goats, but cannot afford to purchase goats. Their biggest challenge is to get enough fertilizer for all crops; they feel they don't have enough. Also owning livestock would give them manures. The husband works for 6 months off farm in Lilongwe on the tobacco auction floor where he earns 23 000 kw/month They dream of having a corrugated iron roof on their house, of having enough money to buy hybrid (soy) seeds and pigeon pea seed. Finding these seeds at affordable prices is a challenge in their area. Their field is relatively close to water, but is thus also prone to flooding. Soil surface showed signs of flooding (cracked sediment). |

### *3.2.7 Constraints and critical points*

The constraints to sustainable intensification for farmers can be summarized as:

- High reliance on subsidized mineral fertilizers and other expensive inputs such as hybrid seeds, which are unsustainable in the longer term and make the farmers less autonomous.
- Lack of natural composts and manures and poor crop residue management. This leads to lower levels of organic matter in the soils which impacts soil fertility and nutrient and water holding capacity.
- Low grain yields result in lower margins for crop production and hence lower overall farm profitability, as well as less grain availability for home consumption, less food security and less or no seed stock for future growing seasons.
- Poor animal husbandry. In particular small livestock such as chickens are sub-optimally fed. High incidence of poor hygiene in pig production. This leads to less productivity, lower gross margins for animal production and overall lower farm profitability.

### *3.2.8 Entry points and suggestions*

**Fencing of crop fields**

A common problem facing farmers is the fact that animals and in some cases people eating/taking produce or residues from their fields. Fencing, either subsidized man-made, barbed wire and posts or otherwise naturally thorny plants massively propagated and grown in nurseries, could be implemented. Hedges can include thorny plants as well as leguminous non-thorny plants such as *Gliricidia*, which will then not only provide security for the crops but also can serve as nitrogen rich green manure for soil improvement or a protein rich fodder for animals when trimmed. *Gliricidia* forms good dense hedges when regularly trimmed. Nurseries can be constructed where such plants are multiplied by seed or by cuttings on a large scale, but farmers should also be taught propagation methods to further propagate their own hedges. Biodiverse hedges in turn, attract natural predators of pests and diseases and provide microclimates that enhance further biodiversity.

Using a whole farm model, the system-level effects of including a leguminous hedge can be investigated. Living fences are added as an additional crop, taking up an area of 0.02 ha for every hectare planted to each existing crop. *Gliricidia sepum* has a potential fresh yield (of leaves) of 40 Mg/ha, which translates to 800 kg/ha of fresh weight if 0.02 ha are grown. Plant composition and other secondary data was taken from the online database Feedipedia.

Three scenarios were explored: 1. All leaves are harvested and incorporated into the soil, 2. All leaves are harvested and fed to animals and 3. All leaves are equally allocated to soil and animal feed. Table 3.2.13 shows a summary of the changes in selected indicators resulting from implementing the scenario as compared to the current situation on this farm.

**Table 3.2.13.** Percentage increases and decreases for selected indicators when living fences are added as a crop to the farm Dauka 6, Ntcheu, Malawi.

| | Current Situation | Scenario 1 Leaves to soil | Scenario 2 Leaves to animals | Scenario 3 Leaves to soil & animals |
|---|---|---|---|---|
| Organic matter added (kg/ha/yr) | 1 074 | 2.23% | 0.09% | 1.2% |
| Nitrogen in green manures (kg/ha/yr) | 31 | 19.4% | -3.2% | 9.7% |
| Nitrogen in animal feed (kg/ha/yr) | 110 | 0.0% | 6.4% | 3.6% |
| Manure nitrogen add to soil (kg/ha/yr) | 80 | 0.0% | 6.3% | 2.5% |

When the leaf trimmings are only added to the soil, this results in the greatest improvements to the amount of organic matter added and increases the total amount of nitrogen present in soil amendments. Only feeding leaves to animals results in the greatest increase in nitrogen supplied to animals, and as a result the manures from these animals supply the greatest amount of nitrogen to the soil when they are applied as fertilizer. There is a 28.6% increase in nitrogen fixation over all scenarios and a minimal increase of 0.1% in operating profit. The labor required decreases by about 2% for all scenarios due to the decreased amount of land cropped, however this is likely to be offset by labor required for cutting leaves.

**Improving quality and quantity of manures**

Currently almost all farmers store manure either in open heaps in the yard or in unlined holes in the ground. Sealing manures from the elements, using holes in the ground that are lined and covered with an impermeable sheet to prevent excessive leaching of nitrogen into the ground would be a technique to retain the quality of the manure and reduce the negative impacts to the environment caused by excessive mineral leaching. When manures are sealed more anaerobic fermentation takes place resulting in slower degradation rates which in turn improve the quality of the manure. Moreover, exposure to the heap surface to air is avoided, reduce ammonia volatilization. Extension programs should stimulate better manure management and compost making. Compost making and manure storage techniques could be demonstrated in central locations in villages.

We investigated the effects of improving the manure storage in a model-based analysis. The fraction of fermentation that takes place under aerobic conditions was reduced from 70% to 5%, thus anaerobic fermentation increased from 30% to 95%. This change increases the nitrogen available in the manure. As the model does not yet have a yield increase response to increased available nitrogen in the soil from the manure, two further scenarios were added with a 10% and 15% yield increase. Table 3.2.14 shows a summary of the changes in selected indicators resulting from implementing these scenarios as compared to the current situation on this farm.

**Table 3.2.14**. Percentage increases and decreases for selected indicators using improved manure storage and yield increases on the farm Dauka 6, Ntcheu, Malawi.

| Indicators | Current Situation | Scenario 2 Improved manure storage with 10% Yield increase | Scenario 3 Improved manure storage with 15% Yield increase |
|---|---|---|---|
| Organic matter added (kg/ha/yr) | 1 074 | 11.1% | 11.9% |
| Manure production (kg/yr) | 3 625 | 45.3% | 45.4% |
| Crop nitrogen Uptake (kg/ha/yr) | 68 | 8.8% | 11.8% |
| Nitrogen in manure (kg/ha/yr) | 96 | 2.5% | 2.5% |
| Total nitrogen losses(kg/ha/yr) | 141 | -1.4% | -2.1% |
| Operating profit (MWK/yr) | 356 580 | 4.6% | 6.9% |
| Labor (hours/yr) | 2 986 | 0.0% | 0.0% |

Degradation rates are much lower under anaerobic conditions and hence the final amount of manure produced when it is sealed when stored is increased by 45% as compared to storing it in aerobic conditions. As there is a greater quantity of manure available, more can be added to the soil. Higher crop yields not only translate into more profit, but also more residues available for animal feed which results in further (slight) increases in manure production as well as more residues available for incorporation in the soil and hence more organic matter added.

**Improved crop residue management**

Mulching is already being practiced to some extent, however often crop residues are burnt or are eaten by straying cattle and this organic matter is lost from the field. Crop residues are also fed to animals at a stage in the development when their feed value is low. If crop residues are harvested at an earlier stage of their development, and possibly stored in a way that conserves their nutritional value, the overall feed value of these residues can be improved.

The effect of improved feed values can be investigated using a whole farm model. We have created two scenarios. Scenario 1, the feed values of the currently fed residues are increased by raising the energy value by 10% and protein and nitrogen values for maize and groundnut residues by 25%. Scenario 2, the reliance of the farm on purchased external feeds is reduced and the farm relies more on the improved feed and maize residues which are currently left on the field. Examining and rebalancing the feed balance it was possible to reduce the reliance on purchased maize bran by 29% in scenario 1 and 58% in Scenario 2. Table 3.2.15 shows a summary of the changes resulting from implementing these two scenarios as compared to the current situation on the farm.

**Table 3.2.15.** Percentage increases and decreases in the whole farm model for selected indicators using improved feed values, use of maize residues for feed and reduced purchases of maize bran on the farm Dauka 6, Ntcheu, Malawi.

| Indicators | Current Situation | Scenario 1 Improved Feed Values | Scenario 2 Improved feed values, maize residue fed to animals, reduced ext. maize bran |
|---|---|---|---|
| Organic matter added (kg/ha/yr) | 1 074 | -0.1% | -6.4% |
| Maize bran purchased (kg DM) | 2 400 | -29.2% | -58.3% |
| Total nitrogen losses (kg/ha/yr) | 141 | -4.3% | -8.5% |
| Operating profit (MWK/yr) | 356 580 | 0.9% | 2.0% |

In scenario 1 the slight reduction in the OM balance and the reduced losses of nitrogen from the system are a result of lower amounts of (improved) feed being fed to animals causing less manure to be available and hence less organic matter and nitrogen to be added to the soil. In scenario 2 the trade-off for feeding maize residues to animals instead of adding it to the soil becomes apparent with the further reduction in the amount of organic matter added. A further benefit from this trade-off, apart from the increased autonomy of the farmer, is further reductions in losses of nitrogen from the system. The improved profit in both scenarios is due to the improved margins from animal production resulting from lower feed costs as less maize bran is required. Labor was kept constant in both scenarios thus there is no change.

**Doubled-Up legumes**

Combining legume crops with each other has been shown in the previous research in Malawi to be a beneficial technique to improve soil quality and yields (Njira *et al*., 2012a, 2012b). Within the AfricaRISING project doubled up legumes were shown to be successful in Mother and Baby trials in Dedza and Ntcheu.

The effects of using doubled-up legume technologies at the framing systems can be demonstrated using a whole farm model. The existing crop of groundnuts was changed into a doubled up crop of groundnuts and pigeon peas. Rates of nitrogen fixation as well as pigeon pea yields were taken from the work done by Njira *et al*. (2012a, 2012b). Prices for pigeon peas were used from other farms surveyed during the detailed characterization. The current groundnut yields on the farm were extremely low (0.188 Mg/ha) due to a poor cropping year. An average groundnut yield found during the detailed characterization of 0.45 Mg/ha was rather used to provide a more realistic current situation. The labor requirement for this particular crop combination was assumed to increase by 20% as compared with the sole crop of groundnuts. Cultivation costs were assumed to remain the same assuming that the farmer saves pigeon pea seeds as she does for groundnuts. Table 3.2.16 shows a summary of the changes from implementing this scenario as compared to the current situation on the farm.

**Table 3.2.16**. Percentage increases and decreases for selected indicators in the whole farm model using Doubled Up Legume techniques on the farm Dauka 6, Ntcheu, Malawi.

| | Current Situation | Adding a Doubled Up legume crop of Groundnuts and Pigeon peas |
|---|---|---|
| Organic matter added (kg/ha/yr) | 1 074 | 8.5% |
| Crop nitrogen Uptake (kg/ha/yr) | 77 | 0.0% |
| Nitrogen fixation (kg/ha/yr) | 7 | 428.6% |
| Total nitrogen losses (kg/ha/yr) | 135 | 13.3% |
| Operating profit (MWK/yr) | 391 351 | 29.7% |
| Labor (hours/yr) | 2 986 | 5.7% |

The increase in the amount of organic matter added is a result of there being increased amounts of crop residues from the additional pigeon peas as well as the increased groundnut residue yields linked to the projected increased groundnut grain yield. The increased nitrogen fixation not only results in more nitrogen availability, but also translates into greater nitrogen losses from the soil. The extra groundnut yield and the additional yield of pigeon peas boost operating profit by almost 30%.

**Encourage seed saving**

The inclusion of more composts and manures that improve the soil quality would result in improved yields. This would ensure that there would be surplus seeds available for replanting. Apart from fertilizer and labor, seed costs are a large expense for planting. Saving seed from the best seeds from the previous harvest, is a useful technique to improve the farmer's own local variety that is suited to their own soil and climatic conditions. Local markets should be stimulated whereby farmers are able to make seed available for each other, either for cash or for trading goods or services. This is already in place to some extent, but it should be further stimulated. Saving costs will improve the profitability of the crops, as well as the suitability to the local conditions. Hybrid seeds that cannot be harvested for seed saving should be seen as a quick win, but not as a long lasting solution that is sustainable.

**Livestock intensification**

Although livestock intensification is an entry point that would most likely result in benefits that reduce the constraints mentioned in Section 3.2.7 above, it is potentially difficult to achieve. Even though many farmers desire to own livestock, the high costs of investment in starting up such enterprises and the lack of experience in, and information about animal husbandry makes this prohibitive. If livestock programs are introduced to provide livestock at subsidized rates for resource poor farmers, this should be paired with proper extension given in monthly or bi-weekly meetings. An example of such a program could be as follows: Communal land is made available to allow the construction of a suitable area to house pigs (or other small livestock). It could be similar to the Mother/Baby trial idea, whereby farmers copy what they have seen in the Mother trial in a baby trial on their own lands. The initial costs for receiving livestock could be a type of credit system, whereby you repay the debt by passing on further young livestock to new farmers. The extension can be provided on location at the communal housing, attention should be paid to good health care for these animals. Malawi suffers from swine fever, which is spread by poor hygiene in pig husbandry. Farmers participating in this livestock scheme share the labor required to manage these animals. As animal feeding has been identified as a constraint, suitable feeds should be sourced for these animals and networks of stakeholders can be developed linking the village with for instance veterinary or feed suppliers. This is an especially useful system for smaller livestock like pigs or chickens, which have many offspring per year.

In conclusion, a stronger focus on agro-ecological methods of cultivation and animal husbandry appear to be promising entry points that could provide large benefits in terms of productivity to these communities. However, it is important to present these entry points along with supportive extension. The entry points outlined above are self-replicating, thus after initial years of support and subsidy, farmers should become more autonomous, self-sufficient, and less reliant on subsidies from the state, however, support, in terms of extension work from the Department of Agriculture, should always be present.

## 3.3 Ghana

### *3.3.1 Introduction to the country and case study areas*

The agricultural sector of Ghana is dominated by subsistence farming, with farm sizes averaging 1.2 ha (3 acres), producing about 80 % of the total agricultural output of the country (Mahama, 2012; FAO, 2013). In 2009, only 0.44 % of cultivable land (of which approximately half is under cultivation) was under irrigation, demonstrating a heavy dependence on rain-fed farming (Ahwoi, 2010). As for 2013, the national agricultural production met domestic demands for roots and tubers, but only 85 % of the demand for maize and 30 % of the demand for rice (FAO, 2013).

The Africa RISING case study area in Ghana embraces the administrative Northern, the Upper East and the Upper West regions. The country is divided into six agro-ecological zones (see Figure 3.3.1), distinguished by natural vegetation, climate and soil characteristics, but most of northern Ghana is covered by the Guinea Savannah Zone. Parts of north-east Ghana however are classified as Sudano-Sahelian Savannah and the southernmost parts of the Northern Region evince the typical features of the so called Transition Zone (Germer and Sauernborn, 2008). The Northern Savannah is a grassland agro-ecosystem with scattered shrubs and trees, unimodal rainfall distribution and an average annual rainfall of 1,000 mm (World Bank, 2010). Mean monthly temperature varies from 36°C in March to 27°C in August. Northern Ghana is dominated by Luvisols (Woods, 2013), which typically evince a mixed mineralogy, high nutrient content and good drainage (Bridges, 1997). Percent organic matter and nitrogen are particularly low in the savannah and transition zones (FAO, 2005).

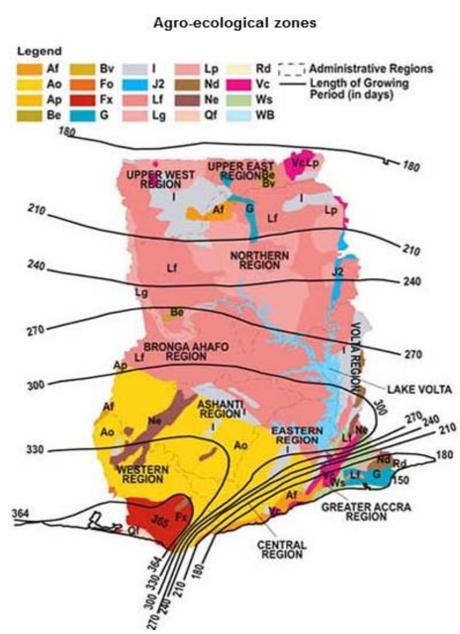




**Figure 3.3.1.** Agro-ecological zones in Ghana. Source: Germer and Sauernborn, 2008

**Figure 3.3.2.** Growing periods in Ghana. Source: DSMW-FAO-UNESCO

Africa RISING has 25 action sites (Intervention Communities) in northern Ghana: 5 in the Upper East and 10 each in the Northern Region and Upper West. Four, representative communities were selected from the Upper West (because the communities were smaller) while three representative communities each were selected from the Upper East and Northern Region (communities were of medium and larger size). The rapid characterization served to establish farm typologies based on a survey of the sampled households to achieve a more precise diagnosis of constraints and opportunities per farm type and targeted interventions. In Ghana these surveys embraced 240 farming households, with 80 households per administrative region, randomly selected within the intervention communities. The names and sample size of each community are listed in Table 3.3.1, while their location is illustrated in Figure 3.3.3.

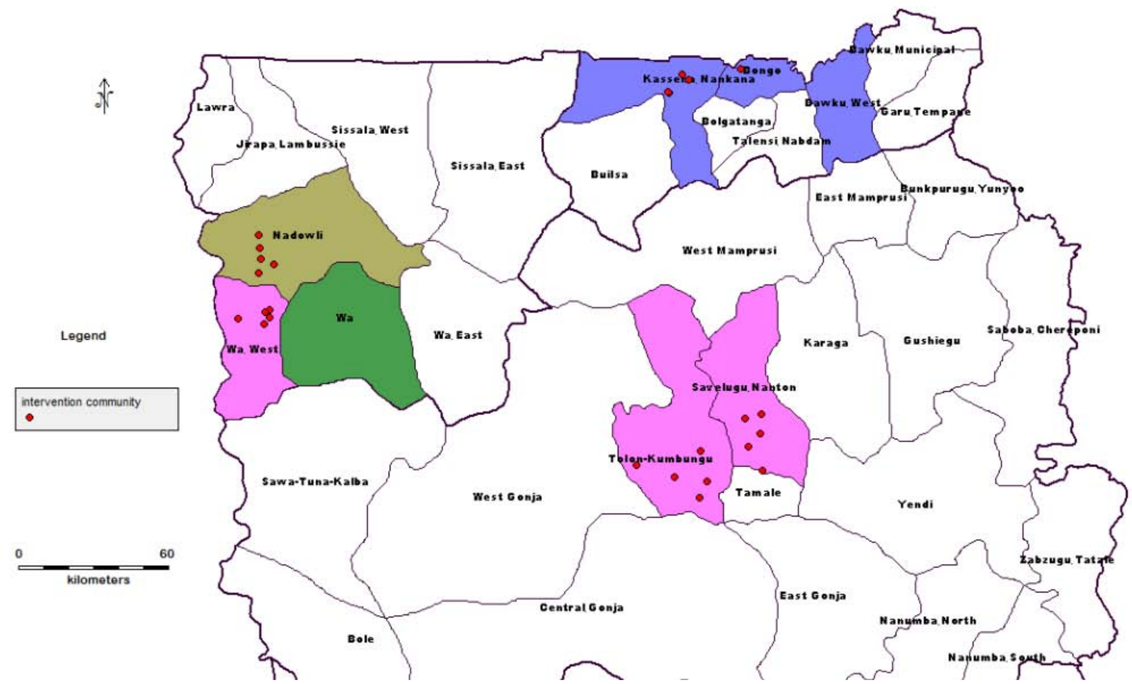



**Figure 3.3.3.** Map illustrating the intervention communities within the Africa RISING project in northern Ghana. Source: Adjei-Nsiah (2013).

**Table 3.3.1.** Name, size and sample size associated to the different Africa RISING intervention communities in Ghana.

| Region | Community size | Sample size (No. of Households) |
|---|---|---|
| *Northern Region* | | |
| 1.Tingoli | Large | 30 |
| 2.Kpallung | Medium | 30 |
| 3.Botingli | Small | 20 |
| *Upper West* | | |
| *A. Wa West* | | |
| Passe | Small | 10 |
| Nyagli | Small | 5 |
| Guo | Large | 15 |
| *B. Nadawli* | | |
| Natodori | Large | 20 |
| Goli | Medium | 10 |
| Gyilli | Small | 20 |
| *Upper East* | | |
| 1.Gia | Large | 30 |
| 2.Nyangua | Medium | 20 |
| 3.Sanboligo | Large | 30 |

### *3.3.3 Farm typology*

Based on the results of these surveys farming households were clustered into 4-5 'types' per region according to their resource endowment (or: wealth class), their production orientation and their income source. According to their wealth, farmers were assigned to the Low Resource Endowed (LRE), the Medium Resource Endowed (MRE) and the High Resource Endowed (HRE)

Group. At all the sites, informants were identified who assisted with the criteria for grouping farmers into the different wealth classes. Criteria included farm size, livestock ownership, ownership of television, ownership of motor bikes, housing type, household size, Number of educated children and ownership of other businesses besides farming. Grouped according to their production orientation farmers could be classified as 'Subsistence producers', 'Producing more for home consumption than for the market', 'Producing equally for home consumption as for the market' and 'Producing more for the market than for home consumption'. The third criterion was the income source, hence farmers were grouped into 'On-farm income only', 'On-farm more than off-farm', 'On-farm same as off-farm' or 'Off farm more than on-farm'. Figure 3.3.4 shows a schematic representation of the construction of the different farm types based on resource endowment, production orientation and income sources.

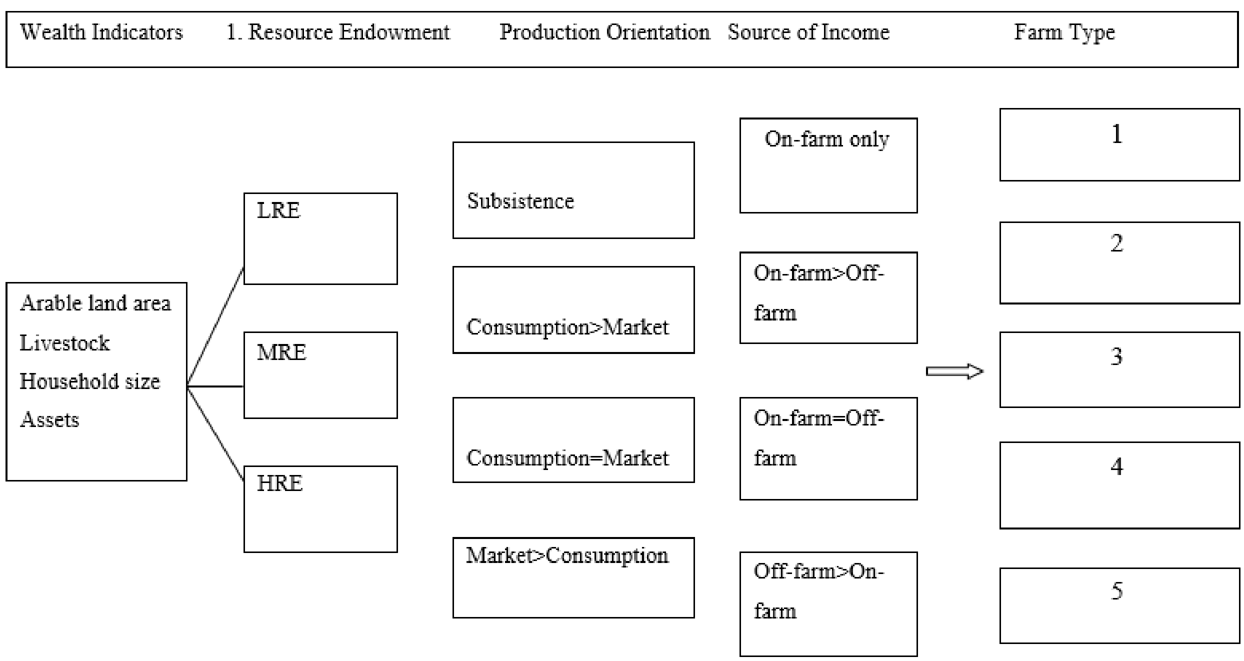



**Figure 3.3.4.** Schematic representation of farm types in Ghana.

The tables below illustrate the farm typologies for the three AR-case study regions in Ghana. The farm types are arranged in ascending order.

**Table 3.3.2.** Farm typology for Northern Region (NR), Upper West region (UW) and Upper East region (UE) of Ghana.

| Region and farm type | Resource endowment group | Production orientation group | Income source group | Age of Household head (years) | Mean Household size | Mean size of arable land-holding (ha) | Mean TLU | % of households in the region |
|---|---|---|---|---|---|---|---|---|
| NR1 | Medium Resourced Endowed | Subsistence | All income is from the farm especially from livestock sales. Have no off-farm income | 46 | 11 | 4.05 | 4.13 | 11.25 |
| NR2 | Medium Resourced Endowed | Consumption more than market | Have more on-farm income than off-farm. Off-farm income sources include casual labor, remittances and small businesses | 48 | 17 | 3.91 | 3.35 | 47.50 |
| NR3 | Low Resource endowed Group | Consumption more than market | Have more on-farm income than off-farm income. Off-farm income sources include casual labor, remittances and small businesses | 48 | 11 | 2.71 | 0.89 | 21.25 |
| NR4 | High Resource endowed Group | Consumption more than market although about 20% sell more than what is consumed | Have more on-farm income than off-farm income . Off-farm include casual labor, remittances and small businesses | 50 | 24 | 9.15 | 20.67 | 20.00 |

| Region and farm type | Resource endowment group | Production orientation group | Income source group | Age of Household head (years) | Mean Household size | Mean size of arable land-holding (ha) | Mean TLU | % of households in the region |
|---|---|---|---|---|---|---|---|---|
| UW1 | Medium Resource Endowed Group | Subsistence | On-farm more than off-farm especially from livestock sales. Off-farm income include remittances, small business, casual labor | 45 | 10 | 3.62 | 2.12 | 16.25 |
| UW2 | Medium Resource Endowed Group | Home consumption > market | About 80% derive most of their income from the farm but have other off-farm income from small businesses while few of them also engage in casual labor or have salary work. About 20% of them have no off-farm income source | 39 | 10 | 3.03 | 1.93 | 47.5 |
| UW3 | Medium Resource Endowed Group | 40% engaged in subsistence while 60% consume more than what is sold | Obtain more income from off-farm than from on-farm. Off-farm income is mainly from small businesses and remittances | 36 | 10 | 2.90 | 2.13 | 15 |

| Region and farm type | Resource endowment group | Production orientation group | Income source group | Age of Household head (years) | Mean Household size | Mean size of arable land-holding (ha) | Mean TLU | % of households in the region |
|---|---|---|---|---|---|---|---|---|
| UW4 | Low Resource Endowed Group | 50% engaged in subsistence production while 50% produced for both the market and for home consumption but consumed more than what was sold | 50% obtain more income from on-farm than from off-farm while 50% either obtain as much income from on-farm as from off-farm or obtain more from off-farm than from on-farm | 42 | 7 | 1.62 | 0.29 | 12.5 |
| UW5 | High Resource Endowed Group | 50% engaged in subsistence while 50% consume more than what is sold | 70% obtain more income from on-farm than off-farm while about 30 obtain more from off-farm than from on-farm | 46 | 13 | 4.97 | 12.78 | 8.75 |

| Region and farm type | Resource endowment group | Production orientation group | Income source group | Age of Household head (years) | Mean Household size | Mean size of arable land-holding (ha) | Mean TLU | % of households in the region |
|---|---|---|---|---|---|---|---|---|
| UE1 | Medium Resource Endowed Group | Subsistence | Derive all their income from the farm especially from livestock sales. They have no off-farm income. | 57 | 10 | 2.54 | 3.13 | 13.75 |
| UE2 | Medium Resource Endowed Group | Home consumption > market | Derive more income from on-farm than from off-farm. Off-farm income is mainly from small businesses | 49 | 12 | 1.97 | 3.45 | 45.00 |
| UE3 | Medium Resource Endowed Group | Subsistence or home consumption> market | Derive more income from off-farm than from on-farm sources. Off-farm income mainly from small businesses and or from casual labor | 48 | 7 | 1.63 | 2.78 | 16.25 |
| UE4 | Low Resource Endowed Group | Home consumption > market | Derive more income from off-farm than from on-farm. Own small businesses and or sells labor or engage in fishing | 44 | 7 | 0.91 | 0.45 | 13.75 |

| Region and farm type | Resource endowment group | Production orientation group | Income source group | Age of Household head (years) | Mean Household size | Mean size of arable land-holding (ha) | Mean TLU | % of households in the region |
|---|---|---|---|---|---|---|---|---|
| UE5 | High Resource endowed group | Subsistence or consumption more than market | About 40% depends on on-farm income alone, about 33% derive more income from off-farm than on farm while about 22% derive more income from on-farm than from off-farm | 53 | 19 | 2.22 | 9.38 | 11.25 |

*3.3.4 Land*

**Table 3.3.5.** Average size of land holdings in hectare per region, and relative to household size.

| Area | Northern | Upper West | Upper East | Total |
|---|---|---|---|---|
| Average arable land size | 5.24 | 3.05 | 2.079 | 3.46 |
| Land / household size | 0.33 | 0.32 | 0.125 | 0.31 |

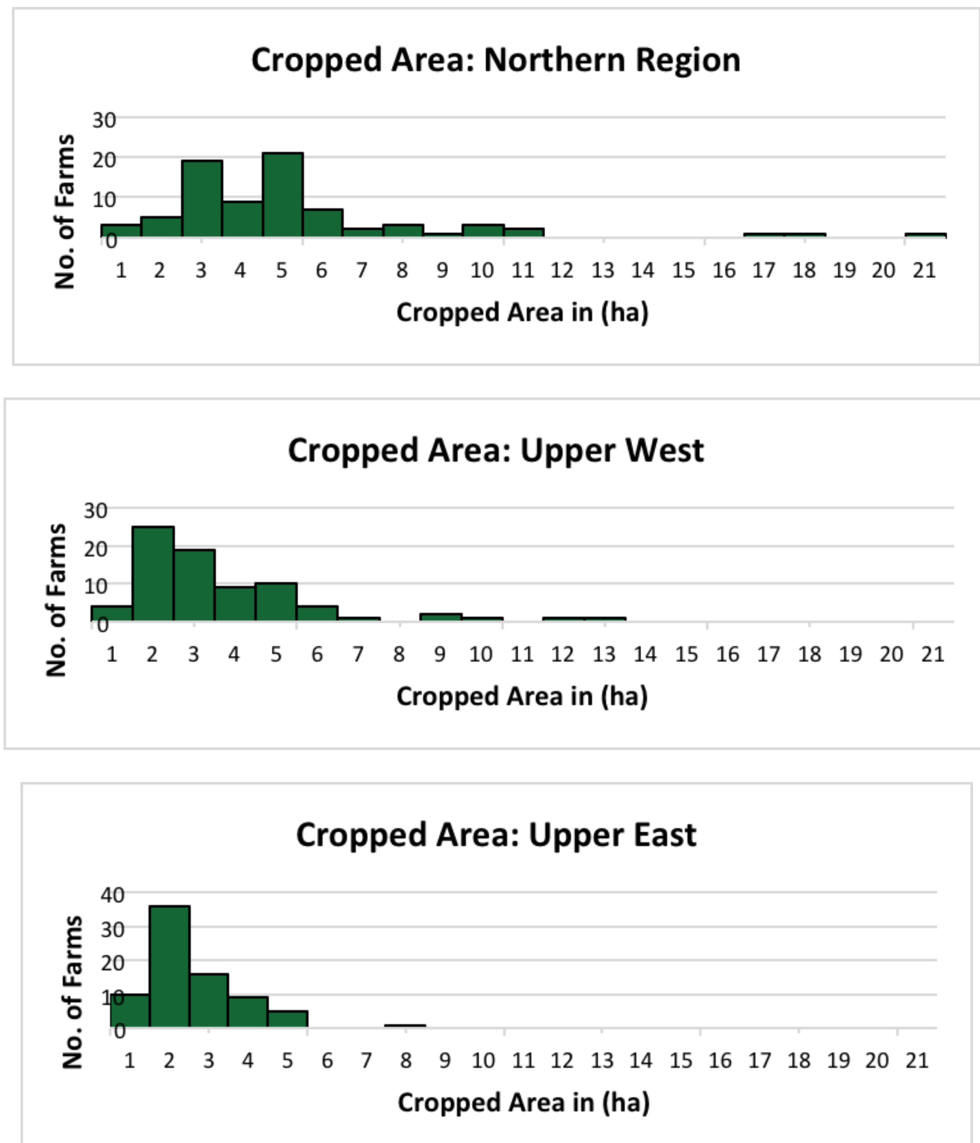



**Figure 3.3.5.** Histograms of cropped areas in the Northern Region, the Upper West and Upper East of Ghana.

The histograms in Figure 3.3.5 illustrate the farm sizes within the Northern Region, the Upper West and the Upper East. One case from the Northern Region (#28), with an indicated land area of 50 ha was omitted to allow a better display of the distribution. The histograms in Figure 3.3.6 illustrate the farm size per person in the three different regions

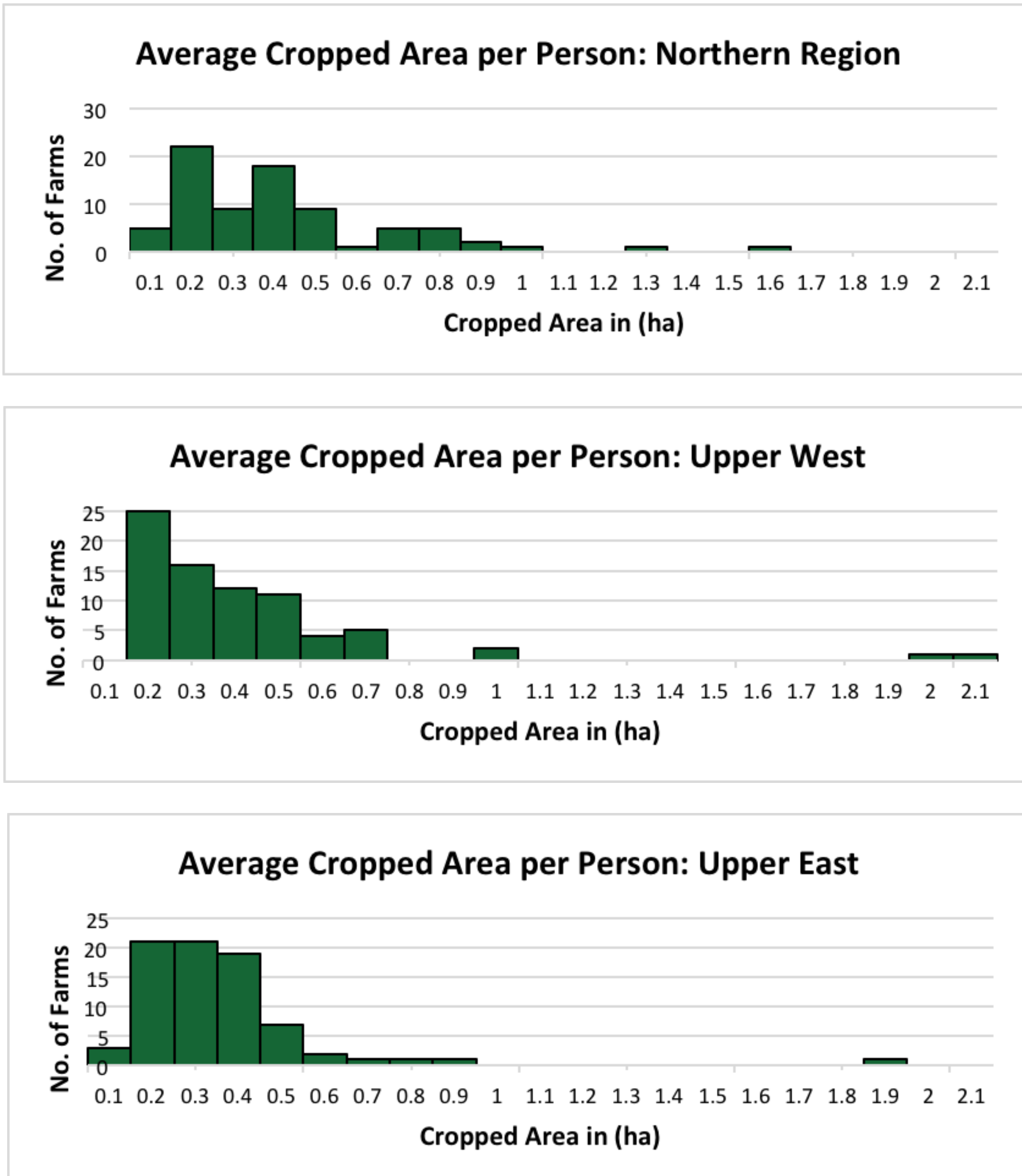



**Figure 3.3.6.** Histograms of cropped areas/person in the Northern Region, the Upper West and Upper East of Ghana.

The actual land ownership per family member is however dependent on age and gender.

Concerning soil fertility, no own samples have been taken by Africa RISING so far, hence average values from the Soil Research Institute in Kumasi as published by the UN FAO (2005) are presented here.

**Table 3.3.6.** Average soil fertility status of the Northern Region, the Upper West and Upper East regions of Ghana. Source: Soil Research Institute (SRI) CSIR - Kumasi.

| Region | Soil pH | Organic Matter | Total Nitrogen | Available P | Available Ca |
|---|---|---|---|---|---|
| | | (%) | (%) | (mg/kg soil) | (mg/kg soil) |
| Northern Region | 4.5 - 6.7 | 0.6 - 2.0 | 0.02 - 0.05 | 2.5 - 10.0 | 45 - 90 |
| Upper West | 6.0 - 6.8 | 0.5 - 1.3 | 0.01 - 0.07 | 2.0 - 7.4 | 52 - 152 |
| Upper East | 5.1 - 6.8 | 1.1 - 2.5 | 0.06 - 0.14 | 1.8 - 14.8 | 44 - 152 |

### *3.3.5 Crops*

Maize and groundnut are the major crops in all three case study regions according to the rapid characterization. Rice and yam are the third and fourth most common crops in the Northern region, while cowpea and millet are grown in the Upper West and millet and rice in the Upper East.

Ellis-Jones *et al.* (2012) reported that a major trend across the three regions is increasing maize and decreasing sorghum and millet production with generally static legume production, apart from soybean, which is increasing in some areas. This is due to its low production cost and ready market providing an important income source, particularly for women. However, lack of soybean utilization knowledge and processing skills are limiting production in other areas.

To provide examples for intercrops for the major crops in each region according to the rapid characterization:

In the Northern Region, maize is sometimes intercropped with millet (2/100 plots), groundnut (1/100), sorghum (1/100) and cowpea (1/100); while groundnuts are intercropped with millet (2/43) and maize (1/43).

In the Upper West maize is intercropped with rice (2/72 plots), cowpea (1/72) and soybean (1/72), while groundnut was found to be intercropped with millet (1/38).

In the Upper East, groundnuts are intercropped with cowpea (6/64), millet (2/64), bambara (2/64) and beans (1/64) while maize is intercropped with millet (2/62), cowpea (2/62) and sorghum (1/62). Owing to scarcity of land in the region, the Upper East is noted for its different combinations of intercropping systems. The combination of groundnut and cowpea seems to function particularly well (9.4 % of plots) and could be investigated during later studies and field visits.

### *3.3.6 Livestock*

Pye-Smith (2013b) as well as Naminse (2011) reported that people in northern Ghana use livestock as a form of security: If crops fail, sheep or goats are sold to buffer the income gap. Due to their smaller size and lower value, chicken meat might occasionally be consumed by the household itself, but apart from that it is mainly their eggs as well as the milk and cheese of ruminants that contribute to household nutrition (Mahama, 2012). Table 3.3.7 presents the average livestock ownership per region in tropical livestock units (TLU) as well as in absolute numbers per animal type. Figure 3.3.7 shows the shares of livestock types in the three regions.

**Table 3.3.7.** Average livestock ownership per region in TLU and numbers per farm.

| Livestock units | Northern | Upper West | Upper East | Total |
|---|---|---|---|---|
| TLU | 4.1 | 2.6 | 3.3 | 3.3 |
| Cattle | 3.5 | 1.6 | 2.5 | 2.5 |
| Sheep | 7.4 | 4.4 | 3.6 | 5.1 |
| Goats | 6.6 | 7.1 | 5.0 | 6.2 |
| Poultry | 29.8 | 17.1 | 12.3 | 19.7 |
| Pigs | - | 1.1 | 1.1 | 1.1 |
| Donkeys | - | - | 0.65 | 0.65 |

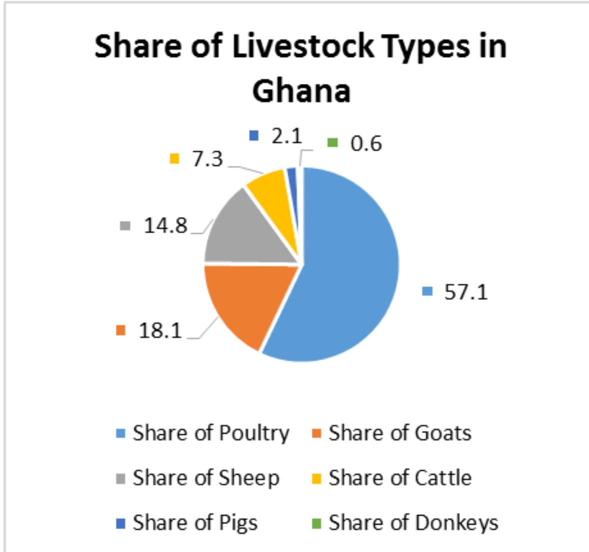



**Figure 3.3.7.** Average share of livestock types among the three regions.

The histograms in Figure 3.3.8 illustrate the herd size associated with each household sampled, grouped according to their region.

Concerning the gender ownership of livestock, cattle almost exclusively belong to men (also described by Naminse, 2011), while the highest female ownership rate is in pigs (64% in the Upper West and 13% in the Upper East) and poultry (9.2% for local fowl and 9.5% for guinea fowl in the Upper West).

The maximal female share in livestock ownership is 5% for women in the Upper West for goats and 3.8% for sheep. In the Northern Region 5% of women and men owned sheep and goats together.

What is particularly interesting is that in the Upper East, despite their relatively low average numbers of animals per household, there is a significantly higher number of households owning cattle (almost more than double than in the North and West respectively), goats (the number is 12.5% higher than in the Northern Region) and guinea fowl (the number is twice as high as in the Upper West). The Northern Region has a significantly higher variance in TLU units, which is another demonstration of heterogeneity of households in the Northern Region.

Households in the Upper East and Upper West are more homogenous in terms of overall livestock ownership (TLU's) than the Northern Region.

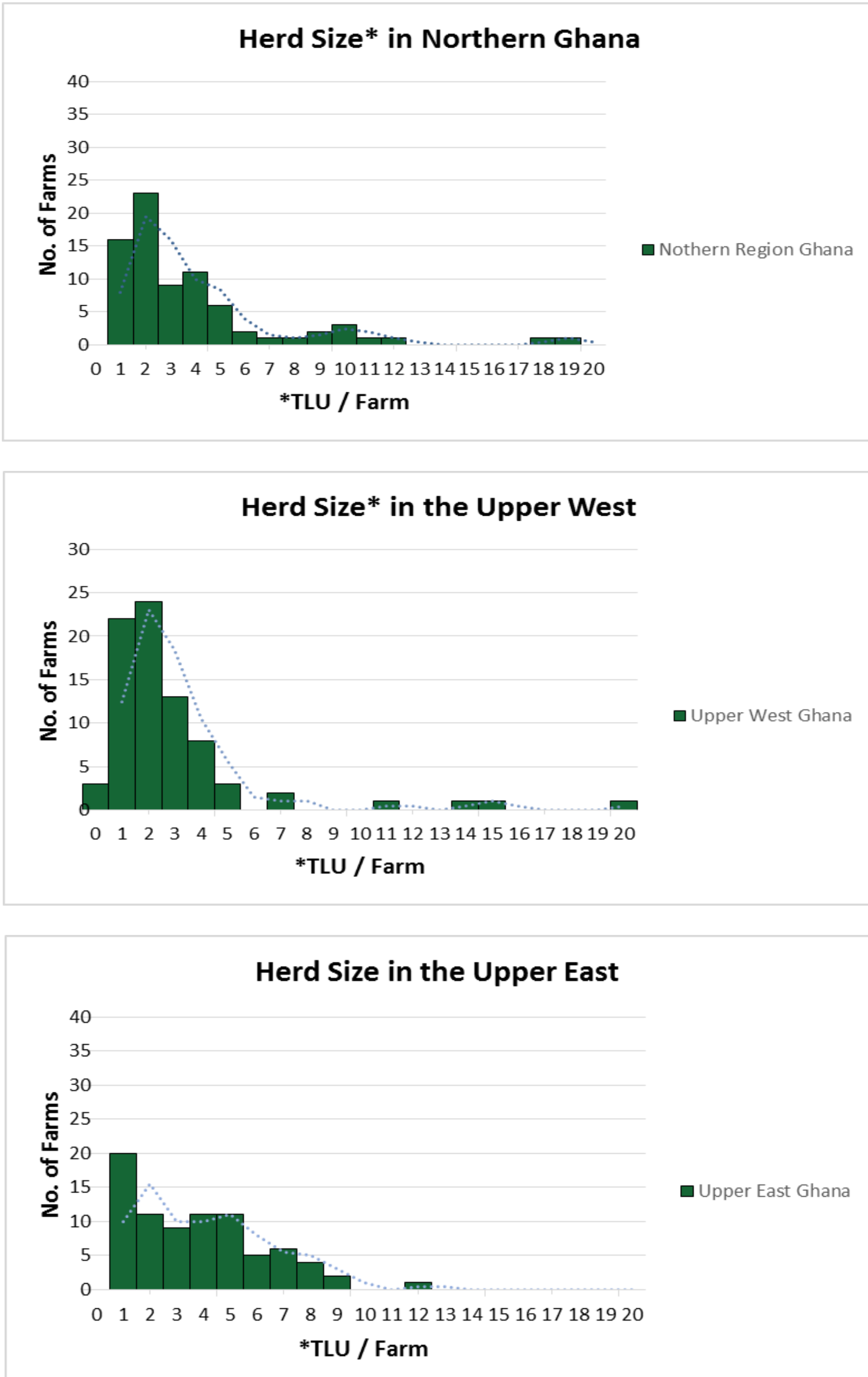



**Figure 3.3.8.** Histograms of Tropical Livestock Units (TLU) per household in the Northern Region, the Upper West and Upper East of Ghana.

Ellis-Jones *et al.* (2012) reported that diseases and pests are major constraints to livestock production in the case study areas, but that small ruminants and poultry production in particular are increasing in those areas where disease is not a major problem.

### 3.3.7 People and livelihoods

The average household size in the Northern Region was determined as 15.7, with values ranging from 4 - 45. In the Upper West the average household size is 9.6 with values ranging from 4 - 20 and in the Upper East the average size was 8.3 with numbers ranging from 3 - 19. The histograms in Figure 3.3.9 display the household sizes within the sample, grouped according to their case study region.

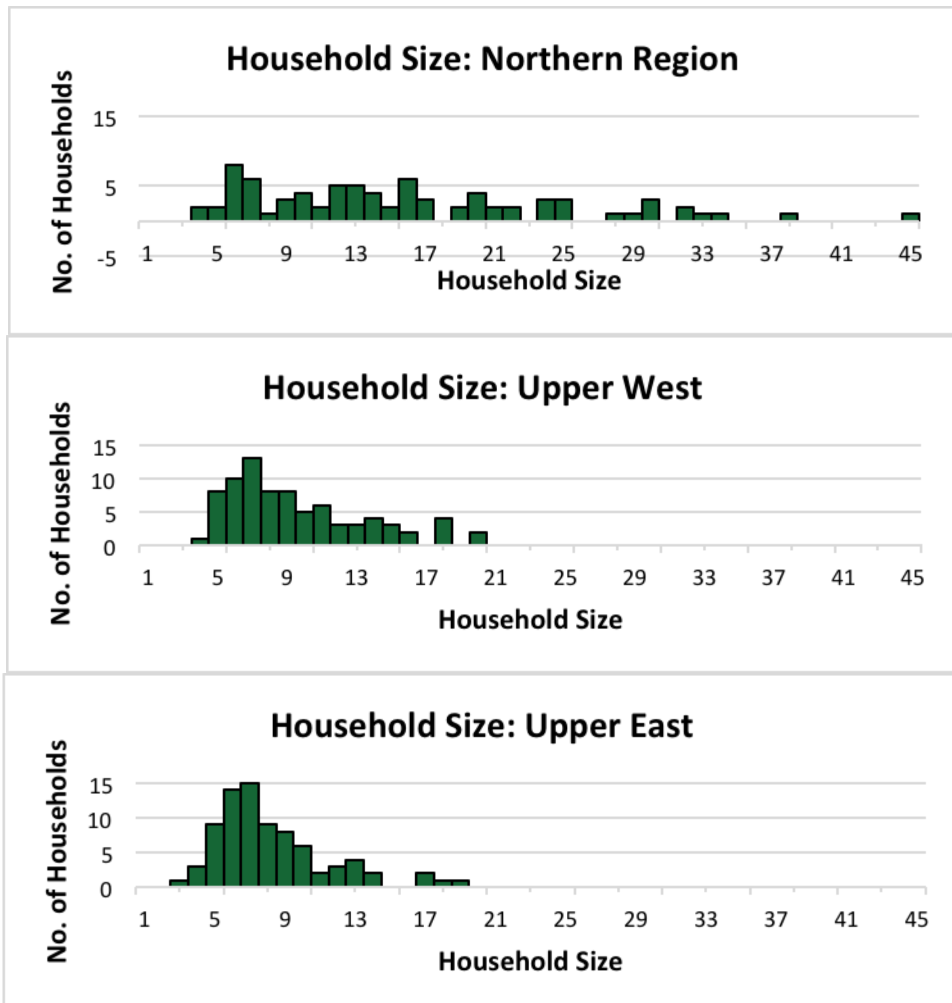



**Figure 3.3.9.** Histograms of household sizes in the Northern Region, the Upper West and Upper East.

Concerning the age distribution, the figures below (3.3.10.) indicate the average share of the indicated age categories within the interviewed families.

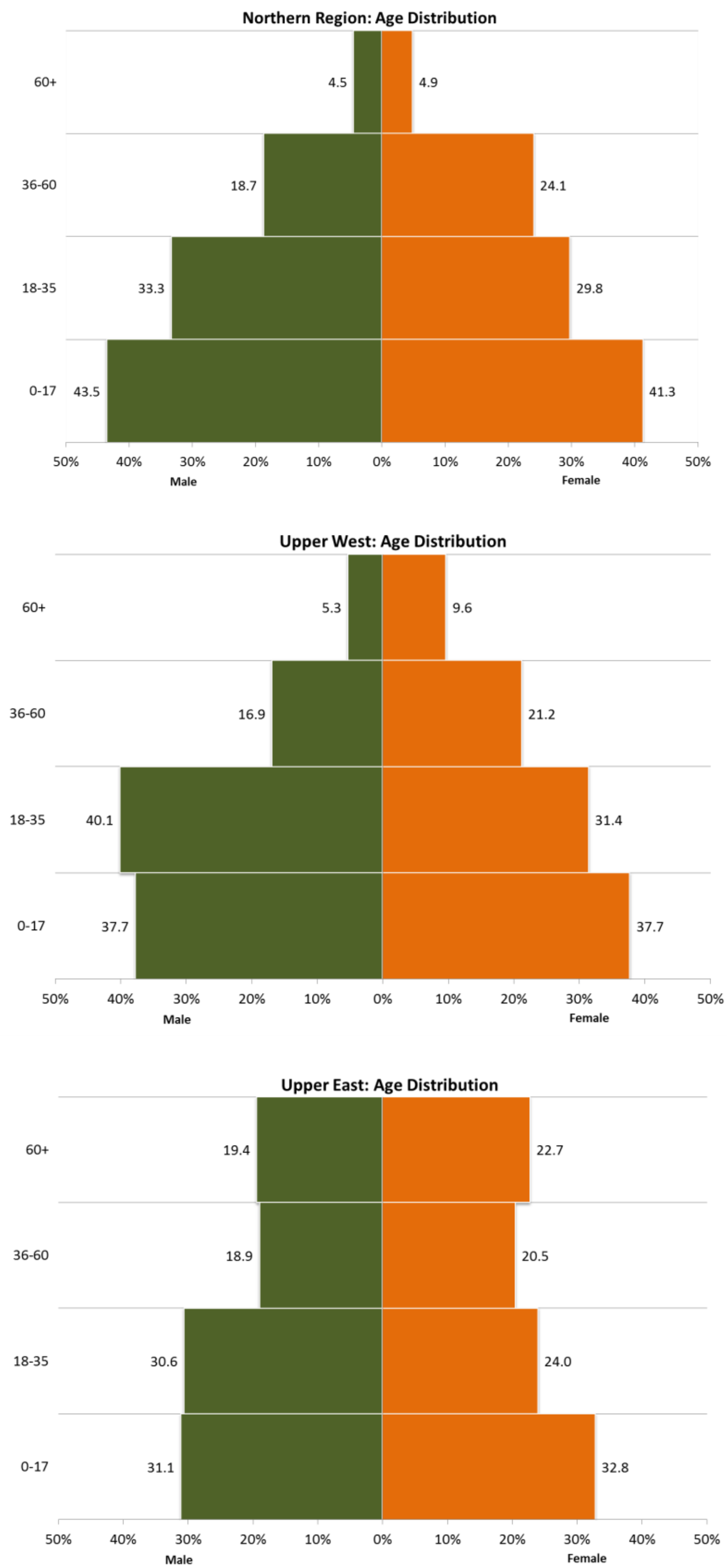



**Figure 3.3.10.** Age distribution in the three regions in Ghana.

Table 3.3.8 demonstrates the number of female headed households (of a sample of 80 households each) in the three different regions.

**Table 3.3.8.** Number of female-headed households (n = 80 in each area)

| Area | Northern Region | Upper West | Upper East |
|---|---|---|---|
| Number of female headed households | 4 | 10 | 3 |

Among the HH's in the North, 64 indicated to have had no schooling at all, 8 received informal education, 4 completed primary school, 2 junior-high school and 1 farmer senior high school.

Concerning food security: Pye-Smith (2013b) reported that in the Africa RISING target population 97% of the interviewed households experienced significant 'food-insecure' periods during the year. He further reported that staple foods lasted 7 months, with the Upper East being most affected by the 'food gap'. Furthermore, 27% of the children in the Upper East were underweight as compared to 13.9% for Ghana as a whole. In the Upper West, 13.9% of the children suffered from wasting as compared to 8.5%, the national average.

The histogram in Figure 3.3.11 below illustrates the months during which the households interviewed in the rapid characterization indicated to be food insecure (struggling to find sufficient food to feed everyone in the household).

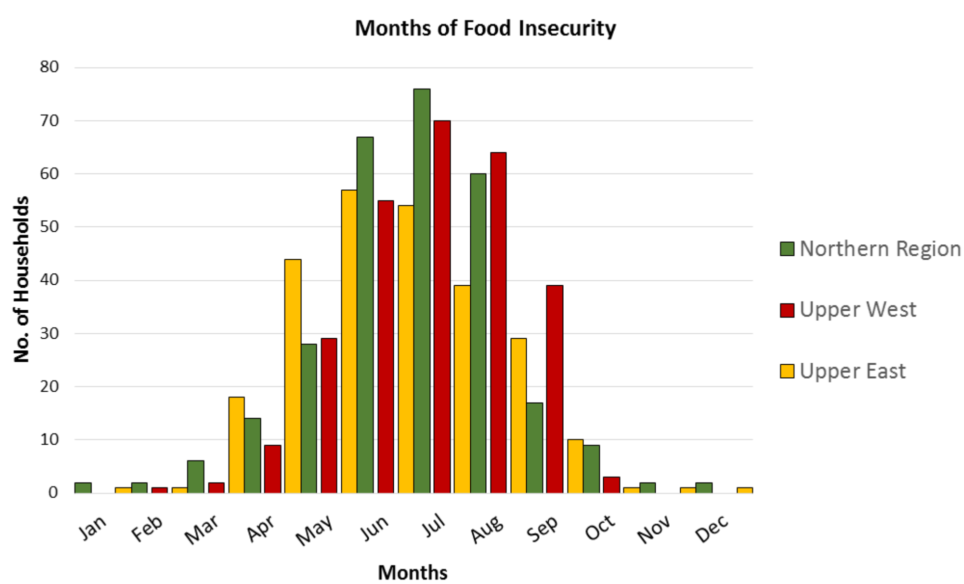



**Figure 3.3.11.** Months of food insecurity in the case study areas.

The chart reveals that peaks in food insecurity are in May, June and July for the Upper East, the Northern Region and the Upper West respectively. The time that the food shortage occurs is associated with the time of crop harvest, depletion of household food-stocks and fluctuating food prices.

A 2012 USAID-report displayed that in northern Ghana, maize is sown in May and harvested in October to November. After harvest the household stocks are filled and market prices are lowest in January and February. The stocks go down (through consumption and post-harvest losses) while the price rises to a peak in May to August, matching the period of food insecurity as indicated by the households in the rapid characterization. Figure 3.3.12 illustrates the maize harvesting seasons and monthly prices.

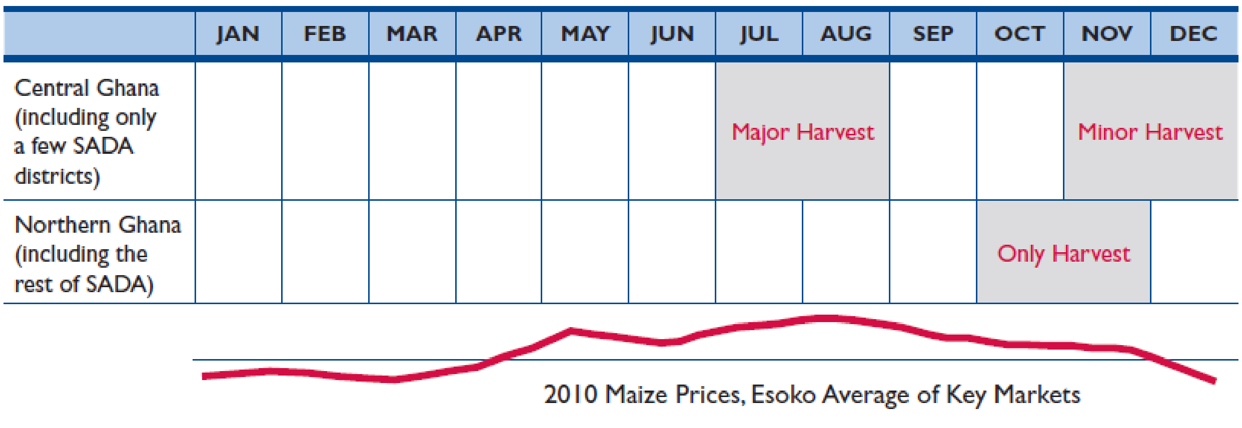



**Figure 3.3.12.** Maize harvesting seasons in Ghana and 2010 monthly maize prices. Source: USAID, 2012.

The availability of rice (November to December harvest) and groundnuts (August to October harvest, needing some storage before consumption and sales) to households is similar to the one of maize, reinforcing the described dynamics in local food security. The government has already reacted: In 2009 the National Food Buffer Stock Company (NAFCO) was set up by the Ghanaian Ministry of Food and Agriculture to purchase, store and market grains (rice, maize and soybeans) to facilitate food security in Ghana (USAID, 2012).

Concerning the main sources of income, farmers in all intervention sites indicated that revenues from cropping (43 - 59%) and livestock (24 - 30%) made up the highest proportion of their income. In the Upper West and Upper East, trading (15% of the income) was more common than in the Northern Region, where remittances were somewhat higher instead. The pie chart in Figure 3.3.13 illustrates the average share of the different income sources for households within the three regions.

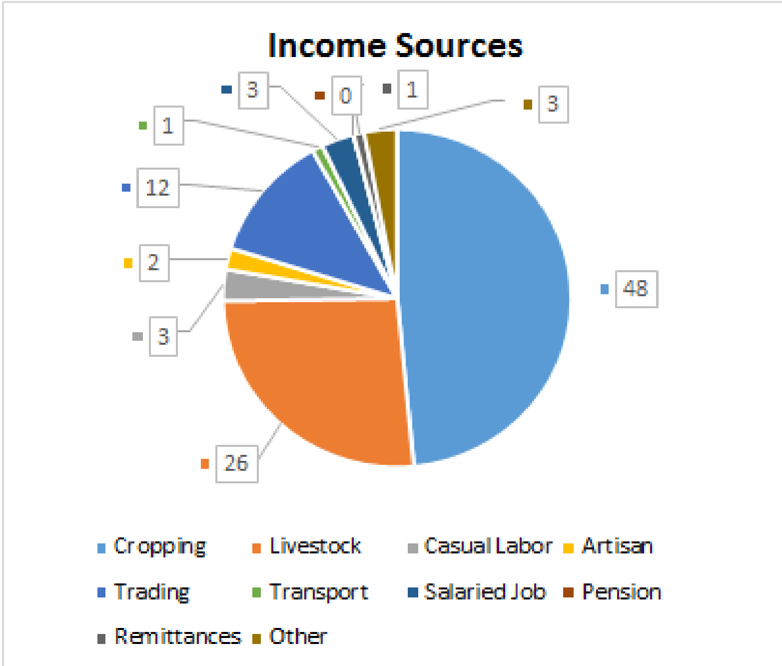



**Figure 3.3.13.** Averaged income sources (in %) for all three regions.

### *3.3.8 Overview of constraints and critical points*

Africa RISING held preliminary discussions with over 4000 smallholders in 47 communities in northern Ghana, who identified the following key constraints to crop production (Pye-Smith, 2013a, 2013b; Ellis-Jones *et al.*, 2012):

- Decline in soil fertility (also mentioned by Adjei-Nsiah, 2012; Quansah *et al.*, 2012, Ellis-Jones *et al.*, 2012)
- Inadequate land preparation (lack of knowledge/tools and machinery)
- Lack of improved seeds
- High cost of inputs such as fertilizers and pesticides
- High prevalence of pests and diseases
- Infestation by weeds.

According to Ellis-Jones *et al.* (2012) these problems are aggravated by erratic rainfall and drought, floods, bush burning, deforestation and the destruction of farmland through small-scale mining in some areas.

The communities also raised concerns about crop storage facilities and post-harvest losses due to pests and diseases. Farmers also mentioned that they lacked knowledge for processing their harvests as well as processing equipment, that the market prices were low, roads to markets inadequate and that transport facilities were also poor.

Concerning livestock, the communities raised the following problems:

- High incidence of pests and diseases, with poor access to veterinary services
- Lack of improved breeds
- Inadequate grazing and watering points in the area

Asking smallholder women about their main challenge they referred to food and education: They must harvest enough to feed their families and earn enough from sales to send their children to school (Pye-Smith, 2013b).

As mentioned under the subchapter on crops, intercropping of groundnut and cowpea was one of the most common crop combinations in the Upper East: As a nitrogen fixer with a relatively short growing period and high nutritional value, cowpea is commonly mentioned in literature as a suitable intercrop for millet, maize, cassava as well as other crops that have high nutrient requirements (Dapaah *et al*., 2003; Karianga, 2004; Eskandari and Ghanbari, 2009; Jamshidi *et al.* 2013). Henriet *et al.* (1997) described that in fact 71.4% of the interviewed farmers in the Sudan Savannah of Nigeria grew cowpea, often intercropped as described above but with yields (0 - 132 kg/ha) strikingly below their sole yield potential (1,500 - 3,000 kg/ha). Olufaro and Singh (2007) found that cowpea productivity in these intercrop combinations can be enhanced by using improved varieties, choosing the appropriate date of planting with respect to the cereal, through higher crop populations, improved soil fertility as well as suitable spatial arrangements. The only study found related to groundnut-cowpea intercropping was a paper by the University of Agriculture in Nigeria on intercropping bambara groundnut with cowpea (Alhassan, Kalu and Egbe, 2012). The combination was found to be productive, with cowpea being the dominant component crop.

Pye-Smith (2013b) reported that awareness on the effect of crop rotation and intercropping with legumes was an important entry point for research and smallholder farms in the intervention communities, that could stop soil depletion and increase farm productivity. There seems to be room for further investigation.

What is also interesting is the production orientation of particular crops: While maize is produced primarily for household consumption and only surpluses are sold, groundnut is mainly produced for the market.

Concerning desired crop characteristics, in 2013, 25 sites in northern Ghana were selected for Mother trials on improved crop varieties within the Africa RISING project. Etwire *et al.* (2013) described the results of an IITA/CSIR-assessment on farmers' preferences concerning maize varieties: Early maturing and drought tolerance were the most important features, but preferences were influenced by their area under maize cultivation, fertilizer usage and family size.

Pye-Smith (2013b) further described, that women in northern Ghana actually play an important role in processing and marketing of crops: A study in the Africa RISING project sites among small and medium-size processors of maize, sorghum, soybean, groundnuts and cowpeas collected information from 97 individuals and three associations. The study determined that 70% of the processors were married women, two-third of them without any formal education and only 3% of them who had completed secondary school. They indicated that the main factors limiting their productivity and income were:

- Low crop yields
- Lack of access to credit
- Poor access to clean water and toilet facilities
- Post-harvest pests and diseases
- Lack of knowledge about processing
- Lack of processing equipment

### *3.3.9 Entry points and suggestions*

Based on the participatory assessment on constraints and opportunities of cereal-based farming systems in northern Ghana by Ellis-Jones *et al.* (2012), Africa RISING identified and published key interventions serving as entry points to explore and test opportunities for sustainable intensification. These are grouped into crop and soil management, livestock production and processing and include the following:

**Crop production and soil management interventions**

- Measures against land degradation to sustain system productivity.
- Measures to improve soil health.
- Introduce improved crop varieties that are early or extra early maturing, Striga and/or drought tolerant and disease/pest resistant from research institutes for on farm testing after validating on-station in mother trials. Promoting community-based seed production to improve seed availability at affordable cost and link

farmers to private seed companies to enhance availability of improved seeds across all regions of Ghana.

- Introduce improved crop management practices, pesticide use, and Striga control. Such training will include leadership, communication, and encourage farmer-to-farmer learning.
- Analyze coping strategies and choices of farmers concerning constraints and opportunities identified. This will involve Community-Based Organizations (CBOs) and their selected representatives in on-farm research.
- Promote cereal–legume integration through rotation and intercropping to improve system productivity.
- Promote crop–livestock interaction for system integration and bio-resource flow.

**Livestock production interventions**

- Sourcing improved breeds of poultry, sheep, and goats from research institutes for multiplication and upgrading of local breeds.
- Promoting poultry, sheep, and goat multiplication and share schemes especially among women and youths to improve their economic base.
- Supporting community livestock health workers (CLHWs) to supplement veterinary services at the community level. As with crop and soil management interventions this can involve CBO selection of suitable CLHWs.
- Conducting training on improved livestock management practices for participating CBOs and farmers at community level. Such training in common with crop intervention training will include leadership, communication, and encourage farmer-to-farmer learning.

**Processing and market interventions**

- Raise awareness on soybean utilization and processing especially for women groups.
- Improve sales and marketing through linking CBOs and farmers to input-output markets, especially for soybean and maize as well as through conducting training for farmer groups on processing and marketing skills. Further, collecting and sharing market information, especially on prices, among farmer groups should be promoted.

To achieve these improvements political commitment and organization will be necessary, especially to:

- Reduce the activities of small miners, charcoal gatherers and bush burners to reverse land degradation,
- Improve market infrastructure and market days,
- Link stakeholders and put the envisioned innovation platforms into practice, which is important to sustain project activities into the future.

### *3.3.10 Model-based evaluation of entry points*

In order to commence with tentative exploration and testing of opportunities for sustainable intensification, specific scenarios have been distilled from the entry points categorized under the broader grouping of 'crop and soil management' related constraints. The starting point for entry point exploration was the current configuration of an AfricaRISING intervention farm in Ghana's Northern Region, coded as 'N Ghana 12'. The scenarios were modelled and their effects highlighted against selected indicators and compared to the original situation of the case study farm 'N Ghana 12'.

'N Ghana 12' is classified as a Type 4, High Resource Endowed farm. This type of farm is in the minority in Ghana's Northern region, making up 20% of total farm types. Characteristic for such farms are large household sizes as well as arable land areas. In the case of 'N Ghana 12', the extended household comprises 30 people while land available for arable farming is 4 ha. Furthermore, livestock numbers are substantially higher on High Resource Endowed farms and indeed, with 9.7 Tropical Livestock Units, 'N Ghana 12' is representative of farms of this category. Animals (goats, sheep and cattle) are fed crop residues and grazed off-farm while crops (maize, cassava, rice and yam) are cultivated on both bush and compound plots closer to the homestead. Of the five plots under crop production, chemical fertilizer is applied to three; namely the maize and rice fields. Despite its material- and natural resources, simulation of farm performance revealed poor productivity, soil organic matter depletion and relatively low returns.

#### 3.3.10.1 Legume intercropping to improve system productivity

Proper integration of leguminous components through rotation or intercropping can contribute to profit maximization, risk minimization, soil conservation, pest- and weed control (*striga*) and nutritional advantages, thus potentially addressing a number of constraints and critical points facing farmers.

Maize is the most commonly cultivated cereal in Ghana's administrative Northern Region and is often sown as a continuous, sole crop on both compound and bush fields. Intercropping maize is thus a way to grow a staple crop while obtaining several benefits from the additional legumes such as protein-rich fodder for animals, grain for sale or consumption and a healthier soil.

Common combinations of intercrops are maize-groundnut, maize-soybean and maize-cowpea. It has been shown through various trials that when maize is grown with an associated legume crop, the legume yield is generally reduced more than that of the dominant maize crop. Mineral fertilizer application exacerbates the effect – maintaining or increasing maize yields while further decreasing the yield of the legume. This is thought to be partly due to the greater competition for light from improved maize growth (Ofori and Stern, 1987).

We conducted a model-based evaluation of the effects of including a maize-cowpea intercrop on whole farming system performance. Cowpea was added to an existing 0.8 ha plot of maize in the farm 'N Ghana 12', which has a total surface area of 4 ha. Two scenarios were explored using data from Ofori and Stern (1986; 1987, Figure 1, Page 46):

1a Addition of cowpea at 34% yield reduction and maize at 16% yield reduction in combination with mineral fertilizer, and:

1b Addition of cowpea at 40% yield reduction and maize at 27% yield reduction without mineral fertilizer.

**Table 3.3.9.** Estimated fresh and dry matter biomass production, nitrogen uptake and fixation of maize and cowpea in maize mono-crop and in intercropping.

| Crop | Part | DM yield (kg/ha) | Nitrogen Uptake (kg/ha) | Total DM (kg/ha) | Total N uptake (kg/ha) | N fixation (kg/ha) |
|---|---|---|---|---|---|---|
| Scenario Ghana 12 | | | | | | |
| Maize | Grain | 1075 | 20.4 | 2386 | 28.9 | 0 |
| | Stalks | 1254 | 7.5 | | | |
| | Bran | 57 | 0.9 | | | |
| Scenario Ghana 12 – EP 1a | | | | | | |
| Maize | Grain | 901 | 17.1 | 5065 | 97.9 | 25; 50 |
| | Stalks | 1051 | 6.3 | | | |
| | Bran | 48 | 0.8 | | | |
| Cowpea | Peas | 646 | 27.8 | | | |
| | Residue | 2420 | 46.0 | | | |
| Scenario Ghana 12 – EP 1b | | | | | | |
| Maize | Grain | 784 | 14.9 | 4565 | 89.0 | 25; 50 |
| | Stalks | 915 | 5.5 | | | |
| | Bran | 42 | 0.7 | | | |
| Cowpea | Peas | 595 | 25.6 | | | |
| | Residue | 2229 | 42.4 | | | |

The resulting yields and nitrogen uptake data used as inputs for the model are presented in Table 3.3.9. The biomass production was assumed to be higher in the mixtures than for the maize mono-crop, due to the additional yield of cowpea. Since the estimation of symbiotic N fixation by the cowpea is difficult we created two sub-scenarios with low and high N fixation rates of 25 and 50 kg N/ha while total N uptake in harvested cowpea biomass (peas and residue) was 74 and 68 kg N/ha in scenarios 1a and 1b, respectively. Thus, N fixation was estimated as 35-70% of total N uptake in the crop.

Table 3.3.10 shows a summary of the changes in selected indicators at farm level resulting from implementing the different field-level scenarios as compared to the current situation on this farm.

**Table 3.3.10.** Values of selected indicators at farm level in a model-based comparison using cowpea-maize intercrop as opposed to maize mono-crop on the farm 'N Ghana 12', Northern Region, Ghana. Addition of cowpea-maize intercrop was either with default mineral fertilizer (Scenario 1a), or without mineral fertilizer (Scenario 1b). The effect of two rates of N fixation on N losses has been tested: fixation of 25 or 50 kg N/ha from cowpea at field level, indicated between brackets.

| **Indicator** | **Current situation** | **Scenario 1a (25)** | **Scenario 1a (50)** | **Scenario 1b (25)** | **Scenario 1b (50)** |
|---|---|---|---|---|---|
| Net OM added (kg/ha/yr) | 522 | 592 | | 588 | |
| Crop N uptake (kg/ha/yr) | 30 | 39 | 34 | 37 | 32 |
| Total N losses (kg/ha/yr) | 58 | 59 | 64 | 52 | 57 |
| N fixation (kg/ha/yr) | 0 | 5 | 10 | 5 | 10 |
| Operating profit (GHC/yr) | 2880 | 3313 | | 3421 | |
| Labor balance (hours/yr) | 0 | 76 | | 37 | |
| Crop residues (kg/ha/yr) | 450 | 469 | | 469 | |
| Green manures (kg/ha/yr) | 0 | 50 | | 46 | |

Both scenarios improved the amount of organic matter added to the soil and the operating profit of the farmer. This increase is due to increased biomass yield, N fixation and residue incorporation from cowpea and improved crop margins as a result of the higher market value of cowpea relative to maize. In scenario 1a the yield of cowpea grain was higher than that of the second scenario where no mineral fertilizer is applied, thus we see an even higher addition of organic matter and operating profit in scenario 1a than in scenario 1b. Furthermore, total N losses have increased in scenario 1a where mineral fertilizer was applied. However, these N losses were slightly lower in scenario 1b where no mineral fertilizer was applied to the field even when N fixation was 50 kg N/ha. Crop N uptake has increased in scenario 1a relative to both the scenario 1b as well as the current situation, due to larger biomass accumulation. However, in both new scenarios we observed an increase in labor hours, as is expected when the farmer has a double crop to sow and maintain as opposed to a single one.

### 3.3.10.2 Improved fallow to avoid land degradation and to sustain productivity

Increasing pressure on land in Northern Ghana has resulted in shorter fallow periods. As a result, the soil has less time to replenish itself before a new cropping cycle begins. As farmers are reluctant to extend fallow periods, it is necessary to consider ways to improve these shorter fallow periods through the planting of fast-growing, nitrogen fixing species for more rapid soil fertility replenishment, weed suppression and resulting positive yield effects on subsequent crops such as maize. Pigeon pea is proposed as an example of such a short-duration fallow crop (Agyare *et al*., 2002; Adjei-Nsiah, 2012). It is a multi-purpose, perennial legume that develops a thick canopy that provides leaf litter for mulching, wood for fuel and grain for food. Furthermore, pigeon pea prunings make excellent fodder for livestock. However, according to Agyare *et al*. (2002), annual pruning of pigeon pea for biomass results in significantly lower seed yields and leaf litter production.

**Table 3.3.11.** Changes in selected indicators in a model-based comparison when pigeon pea was added as a short fallow crop to the farm 'N Ghana 12', Northern Region, Ghana.

| **Indicator** | **Current Situation** | **Scenario 2a Improved pigeon pea fallow: no pruning (residue to soil)** | **% Change** | **Scenario 2b Improved pigeonpea fallow: pruning (residue to animals and soil)** | **% Change** |
|---|---|---|---|---|---|
| Net OM Added (kg/ha/yr) | 522 | 617 | 18% | 608 | 16% |
| Crop N uptake (kg/ha/yr) | 30 | 34 | 13% | 34 | 13% |
| Total N losses (kg/ha/yr) | 58 | 64 | 10% | 64 | 10% |
| N fixation (kg/ha/yr) | 0 | 14 | Increased | 14 | Increased |
| Operating profit (GHC/yr) | 2880 | 3134 | 9% | 3078 | 7% |
| Labor balance (hours/yr) | 0 | 240 | Increased | 320 | Increased |
| Crop residues (kg/ha/yr) | 450 | 505 | 12% | 505 | 12% |
| Green manures (kg/ha/yr) | 0 | 41 | Increased | 33 | Increased |
| N to animals (kg/ha/yr) | 34 | 34 | 0% | 35 | 3% |

The effect of improved fallow using pigeon pea was investigated. We have created two model-based scenarios. In scenario 2a, pigeon pea was added to existing natural fallow land of 0.8 ha on the farm 'N Ghana 12' and left unpruned, with residues being incorporated into the soil after one year. In scenario 2b, we simulated pruning and the resulting lower seed and litter yield after one year, by allocating part of the pruned biomass residues to livestock and grain for household consumption. Table 3.3.11 shows a summary of the changes resulting from implementing these two scenarios as compared to the current situation on the farm.

From the table above we see that organic matter added would increase in both scenarios, although it was larger when pigeon pea was left unpruned and all residues were returned to the soil (scenario 2.1). Crop N uptake has increased in both scenarios, however, total N losses have increased slightly too, due to larger N inputs through fixation. It is apparent that labor hours have increased in both scenarios, but pigeon pea is not considered to be such a labor-intensive, high-maintenance crop so the workload will not have increased by very much. The increase in operating profit in both scenarios could be attributed to the fact that the farmer gained a profitable crop in place of bare fallow land; this extra income from crop returns is regarded as a bonus and is higher when pigeon pea is left unpruned and saleable grain yields are maximized. Finally, we see that the nitrogen in animal fodder is increased due to the high protein content of pigeon-pea biomass fed to livestock in the second scenario.

#### 3.3.10.3 Crop-livestock integration and better bio-resource flow

In Ghana's Northern Region there are huge gaps between the average crop yields attained on smallholder farms and achievable yields as demonstrated in trials. The situation might be improved through better crop-livestock integration where more attention could be paid to the proper collection, storage and use of available on-farm organic inputs such as manure and crop residues.

Rice is the second most important cereal after maize in Ghana and is a cash crop for many farmers (Ragasa *et al*., 2013). Despite this, rice productivity remains low and although mineral fertilizer use in rice plots is high, application rates in the region are lower than recommended, suggesting that the adoption of complementary soil fertility management practices that decrease reliance on expensive external inputs might be worthwhile. Most farmers own some livestock and thus have access to manure; despite this, very few farmers apply it to their rice fields. Numerous studies have demonstrated the beneficial effects of manure on crop yields and it has been shown that the application of 10 Mg of farmyard manure (FYM) per hectare can increase the grain yield of rice by 25% (Satyanarayana *et al*., 2002). However, there are constraints to manure use such as its low quality in the dry season and the labor and costs involved in its collection.

We investigated the effects of applying 4 Mg of FYM to a rice plot of 0.8 ha on the farm 'N Ghana 12', where part of the rice residues are incorporated into the soil and the rest fed to animals, instead of burning as is the current practice on this particular farm. We assume that rice grain yields will increase by 10%. Table 3.3.12 shows a summary of the changes in selected indicators resulting from implementing the scenarios as compared to the current situation on this farm.

**Table 3.3.12.** Changes in selected indicators in a model-based comparison when 4 Mg of FYM was added to a 0.8ha rice paddy on the farm 'N Ghana 12', Northern Region, Ghana.

| Indicator | Current Situation | Scenario 3 Addition of FYM to rice plot and incorporation of rice residues to soil | % Change |
|---|---|---|---|
| Net OM Added (kg/ha/yr) | 522 | 529 | 1% |
| Crop N uptake (kg/ha/yr) | 30 | 30 | 0% |
| Total N losses (kg/ha/yr) | 58 | 56 | -3% |
| Operating Profit (GHC/yr) | 2880 | 2901 | 1% |
| Labor balance (hours/yr) | 0 | 83 | Increased |
| Green manures (kg/ha/yr) | 0 | 8 | Increased |
| Fertilizer costs (GHC/ year) | 415 | 360 | -13% |

From the table above we observe that soil organic matter has slightly increased due to the positive effect of the organic manures on soil fertility, structure, and moisture content for example. Crop N uptake has remained the same while total N losses have decreased. Labor has increased due to the work involved in collecting the manure, storing it and spreading it on the fields. Fertilizer costs have been reduced while operating profit has marginally increased as a result of higher crop returns.

#### 3.3.10.4 Scenario of combined entry points

Next, we observe the combined effect of selected entry points (based on their contribution to the objectives in terms of percentage increase or decrease) on the three objectives for the farm 'N Ghana 12'. Table 3.3.13 summarizes the entry points and indicates whether or not they have been included for the simulation of a final 'alternative scenario' composed of the original farm plus all selected entry points. In figure 3.3.14 the effect of the selected entry points indicated as percentage change (the direction of change being positive in all cases) relative to the objectives of 1. Maximize farm Operating Profit and 2. Maximize the Organic Matter added are visualized in a bar chart. The third objective- Minimize the farm Labor Balance- is not included in the chart, as the impact of an increase or decrease from a labor balance of zero is not readily quantifiable. Furthermore, Entry Point 2b (improved pigeon pea fallow with pruning) was chosen over Entry Point 2a (improved pigeon pea fallow without pruning) due to the beneficial increase of protein in animal feed in the latter scenario.

**Table 3.3.13.** Summary of entry points and their inclusion or exclusion in the 'improved' scenario for the farm 'N Ghana 12', Northern region, Ghana.

| Entry Point Code | Entry Point Description | Final Scenario |
|---|---|---|
| EP 1a | Maize-Cowpea intercrop + mineral fertilizer | No |
| EP 1b | Maize-Cowpea intercrop | Yes |
| EP 2a | Improved pigeon pea fallow (no pruning) | No |
| EP 2b | Improved pigeon pea fallow (pruning) | Yes |
| EP 3 | FYM and residues to rice | Yes |

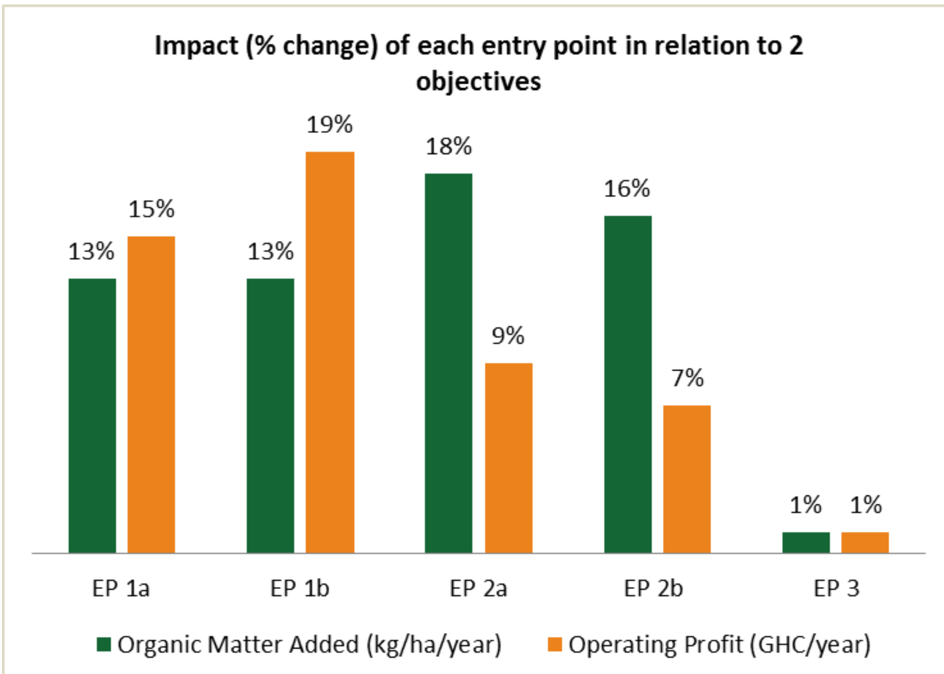



**Figure 3.3.14.** The effect of each entry point in terms of percentage change (in a positive direction in all cases) relative to the objectives of 1. Maximize farm Operating Profit and 2. Maximize the Organic Matter Added for the farm 'N Ghana 12', Northern region, Ghana.

For the final analysis of entry points and suggestions for sustainable intensification of 'N Ghana 12' we included the selected entry points as summarized in Table 3.3.13 and re-configured the farm so that the entry points and their associated components were reflected in the representation of the 'improved N Ghana 12' scenario. Following this, we re-adjusted the feed balance and ran the model. Table 3.3.14 shows a summary of the changes in selected indicators resulting from implementing the improved scenario as compared to the current situation on this farm.

We note, firstly, that despite incorporating the entry points and simulating their effects on 'N Ghana 12', the farm area size remains unaltered (4 ha). In terms of the animal component of the farm, changes in the composition of feed are reflected in the increased levels of nitrogen they ingest. This effect can be attributed to protein-rich legume residues. In terms of the arable component of the farm we observe an appreciable increase in N-fixation, also attributable to the leguminous crops added to the fields as well as a 31% increase in soil organic matter due to a higher rate of incorporation of the enhanced reservoir of high quality crop residues. In the financial sphere it is apparent that decreased reliance on external soil amendments has reduced expenditure on mineral fertilizers, and that high value grain yields from the two new crops (cowpea and pigeon pea) contributed to higher crop returns which boosted the operating profit by 26%. However, we see that these positive effects are offset by the labor balance, which has increased by over 400 hours/year, indicating more work for the farm household. In figure 3.3.15 the combined effect of the selected entry points in terms of percentage change relative to the objectives/ indicators for 'N Ghana 12' is visually depicted in a bar chart.

**Table 3.3.14.** Percentage increases and decreases for selected indicators using a combination of selected on the farm 'N Ghana 12', Northern Region, Ghana.

| Indicator | Current Situation | Combined Scenario with selected entry points | % Change |
|---|---|---|---|
| Farm Area (ha) | 4 | 4 | 0% |
| Crops grown | Maize, Yam, Cassava, Rice | Maize, Yam, Cassava, Rice, Cowpea, Pigeon pea | 2 new crops |
| Animals Owned | 11 Cattle, 10 Sheep, 7 Goats, 30 Chickens | 11 Cattle, 10 Sheep, 7 Goats, 30 Chickens | 0 new animals |
| N to animals (kg/ha/yr) | 34 | 36 | 6% |
| N Fixation (kg/ha/yr) | 0 | 19 | Increased |
| Total N Losses (kg/ha/yr) | 58 | 56 | -3% |
| Green Manures (kg/ha/yr) | 0 | 86 | Increased |
| Crop Residues (kg/ha/yr) | 450 | 524 | 16% |
| Fertilizer costs (GHC/yr) | 415 | 180 | -57% |
| Operating Profit (GHC/yr) | 2880 | 3641 | 26% |
| Net OM Added (kg/ha/yr) | 522 | 683 | 31% |
| Labor (hours/yr) | 0 | 439 | Increased |

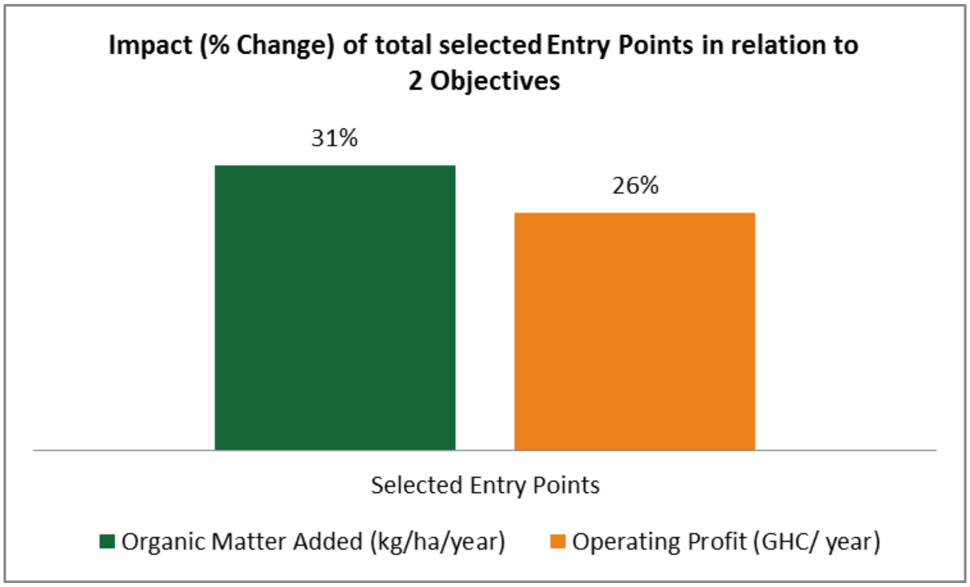



**Figure 3.3.15.** The combined effect of the selected entry points in terms of percentage change (in a positive direction in both cases) relative to the objectives of 1. Maximize farm Operating Profit and 2. Maximize the Organic Matter Added for the farm ‘N Ghana 12’, Northern region, Ghana.

## 3.4 Mali

### *3.4.1 Introduction to country and case study regions*

Mali is a landlocked country in West Africa surrounded by 7 neighboring countries. Agro-pastoralism is the dominant agricultural activity, with arable land covering 5.7 % of the territory (FAO, 2013). 3.4% of the arable land is irrigated, mostly for rice production. With a strong rainfall gradient running north-south, four major agro-ecological zone are distinguished: Saharan, Sahelian, Sudano, Sudano-Guinean zones (Figure 3.4.1). Cotton is the major agricultural export product, whereas the most important cereal crops are rice, millet, maize and sorghum (FAO, 2013).

Farming systems in the Sikasso region of southern Mali (Figure 3.4.2) integrate multiple crops and livestock to provide food and income. Farmers rely on cotton as a cash crop and for access to inputs, particularly fertilizer, through the state-owned Compagnie Malienne des Textiles (CMDT). Maize, sorghum and millet are important food crops, and most households raise cattle and small ruminants (Dufumier, 2005). While crop and livestock production provide the main sources of income, most households also have some source of non-farm income (Abdulai and Crolerees, 2001; ILRI, 2012). As population and pressure on land increase and animal traction allows for increases in cultivated area, farming systems are moving from shifting cultivation with long fallows to more intensified short-fallow systems and permanent cultivation. This process has led to near complete land occupation in the Koutiala area, the heart of Mali's cotton growing region. Because of the attendant decrease in rangeland areas fodder shortages for livestock have become a problem. A vicious cycle of land degradation and declining soil fertility (Traoré*et al.*, 2004) is evidenced by (i.a.) disappointing cereal yields, and decreasing cotton yields (Djouara*et al.*, 2006). In Bougouni however, population density and the fraction of land under cultivation remain low (Dufumier 2005). Here, fallowing is still very common and livestock management practices continue to rely on common grazing areas even as cultivated areas increase.

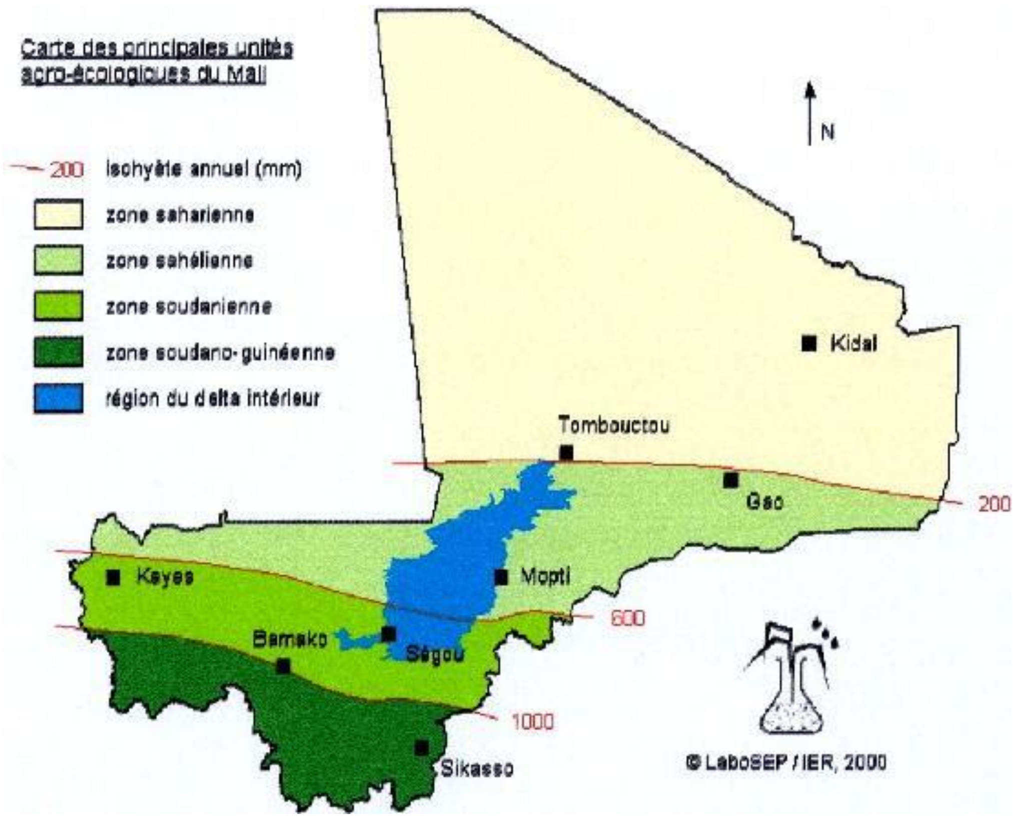



**Figure 3.4.1.** Agro-ecological zones in Mali (FAO, 2013).

Cotton production has been the motor of development in southern Mali since it started in the early 1960s. From 1975 to 2004, the downward trend of world cotton prices were not reflected in the cotton prices paid to farmers in local currency in Mali, where cotton production kept on increasing. This was mainly due to the increasing number of cotton producers under the supervision of the CMDT. The CMDT offered a guaranteed and subsidized price for cotton, credit for fertilizers and equipment (ploughs, carts and oxen), and improved varieties. During 2004-2010, cotton production fell because of CMDT bankruptcy. Indeed, CMDT constantly subsidized the price given to Malian farmers to offset world price decrease and sustain production. This, combined with internal institutional conflicts and corruption, led to the stop of the price subsidy, delays in payment and fertilizer delivery in 2005, resulting in farmers' distrust of the state-owned company and a decline of the cotton production in the subsequent years. Since 2011 however, the world market cotton price increased sharply due to a setback in global production levels. The production in Southern Mali increased again and the CMDT has been offering very interesting prices to regain trust from the producers.

On top of market and institutional uncertainty and variability, the region is characterized by high climate variability and erratic rainfall patterns (Traoré *et al.*, 2013), which are likely to be aggravated by climate change. This emphasizes the need for flexible and diverse farming systems in order to secure household resilience.

Farmers dynamically adapt to changes and variability: during the cotton crisis for example, the uncertainty prompted farmers to abandon cotton (Fok, 2010) and adopt diverse coping strategies according to their environment and resource endowment. For farms located in wet lowlands or those that can afford power-driven pumps, diversification and intensification strategies include growing of bananas and vegetables as cash crops. Sorghum, maize, pearl millet and dairy products are also becoming important income generators thanks to increasing outlets in nearby expanding cities. Off-farm income and remittances from labor migration to urban centers in Mali or abroad may increasingly be re-invested in agricultural production.

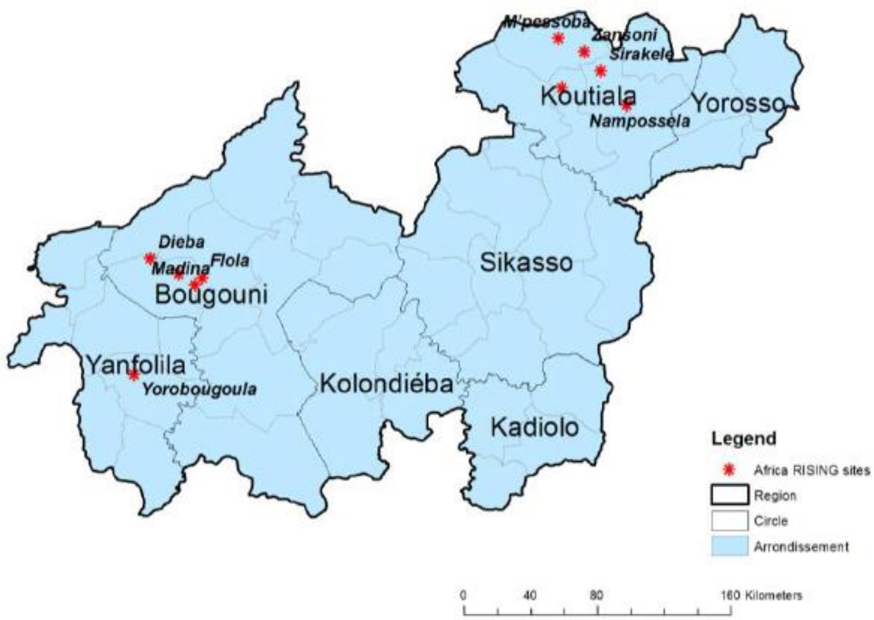



**Figure 3.4.2.** Africa RISING sites in southern Mali.

### *3.4.2 Farm typology*

The average household size is 19.0 (s.d. 14.42) people in Koutiala and 16.7 (s.d. 13.42) people in Bougouni. Households comprise different smaller family nuclei, each cultivating their own land, under the supervision of the household head. Major crops are cotton and maize in both areas, with sorghum and millet contributing importantly to household food production in Koutiala, and a more important role for groundnut in Bougouni (Table 3.4.1). The cultivated area per household member is slightly higher in Koutiala than in Bougouni (Table 3.4.1). The livestock herd sizes are slightly higher in Koutiala than in Bougouni, with in particular, a larger contribution of small ruminants (Table 3.4.2).

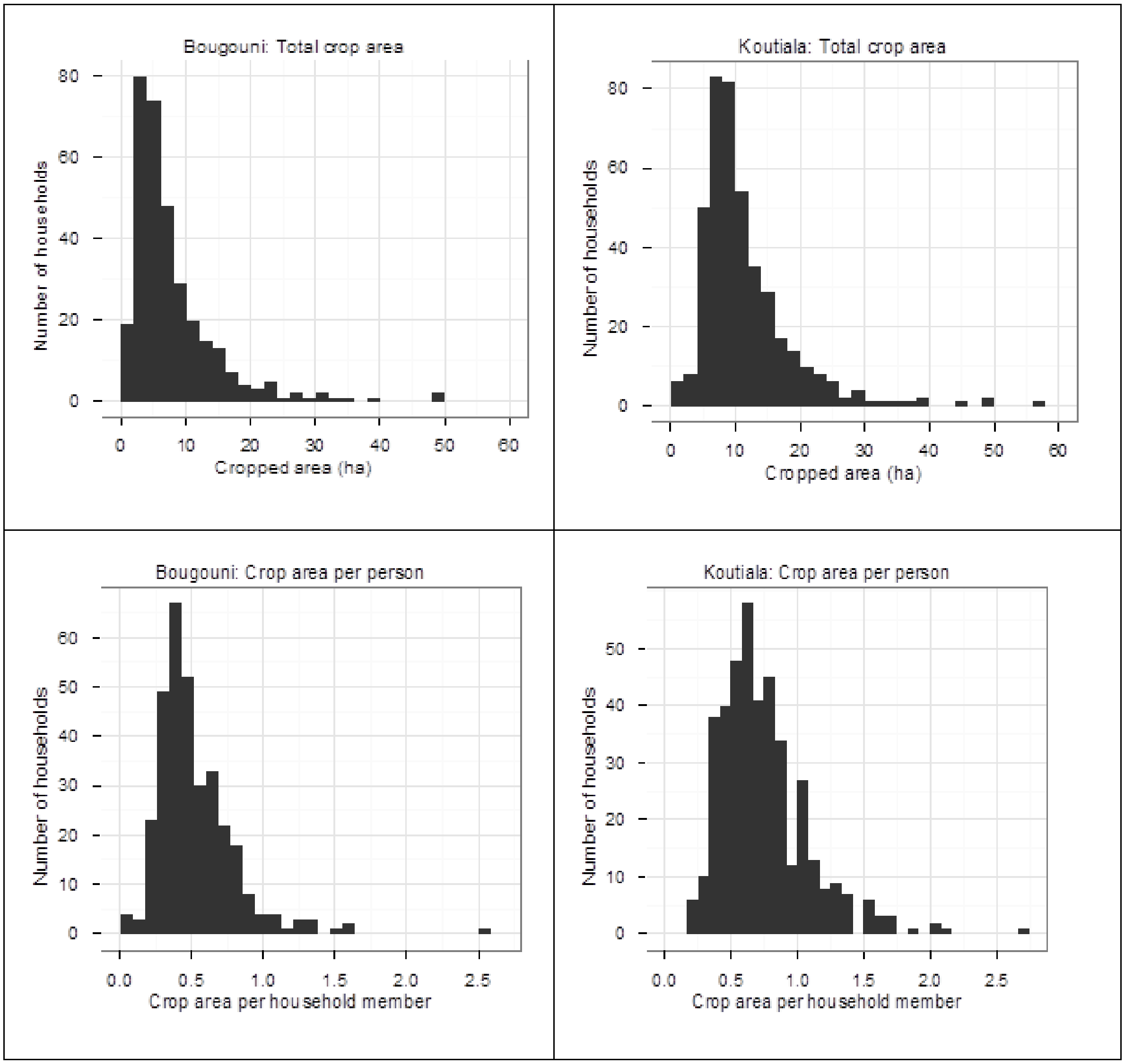
**Table 3.4.1.**Crop land allocation in Bougouni and Koutiala.

| Crop | Bougouni: Mean Area (ha) (standard deviation) | Koutiala: Mean Area (ha) (standard deviation) |
|---|---|---|
| Cotton | 1.73 (2.23) | 2.63 (2.79) |
| Maize | 2.21 (2.12) | 1.50 (1.09) |
| Sorghum | 0.73 (1.02) | 3.02 (2.07) |
| Millet | 0.22 (0.61) | 3.26 (2.04) |
| Groundnut | 1.98 (1.94) | 0.87 (0.68) |
| Cowpea | 0.27 (0.46) | 0.29 (0.58) |
| Rice | 0.79 (0.98) | 0.13 (0.28) |
| Fallow | 3.73 (5.35) | 0.96 (1.43) |
| Total cropped area (excluding fallow) | 8.05 (6.93) | 11.71 (7.20) |
| Cropped area per household member (ha/person) | 0.52 (0.27) | 0.74 (0.33) |

**Table 3.4.2.** Livestock numbers in Bougouni and Koutiala.

| Type | Bougouni: Mean number per household (standard deviation) | Koutiala: Mean number per household (standard deviation) |
|---|---|---|
| TLU | 10.31 (15.79) | 11.75 (12.40) |
| Draft animals | 2.22 (1.88) | 2.93 (2.19) |
| Cattle | 8.37 (16.50) | 7.79 (11.01) |
| Small ruminants | 6.19 (10.62) | 11.17 (13.28) |
| Donkeys | 0.83 (1.00) | 1.79 (2.39) |

The data in Tables 3.4.1 and 3.4.2 indicate a wide distribution. Some illustrative histograms, showing differences for Bougouni and Koutiala also highlight the skewness in the data, with larger frequencies for small areas and herd sizes (Figure 3.4.3).



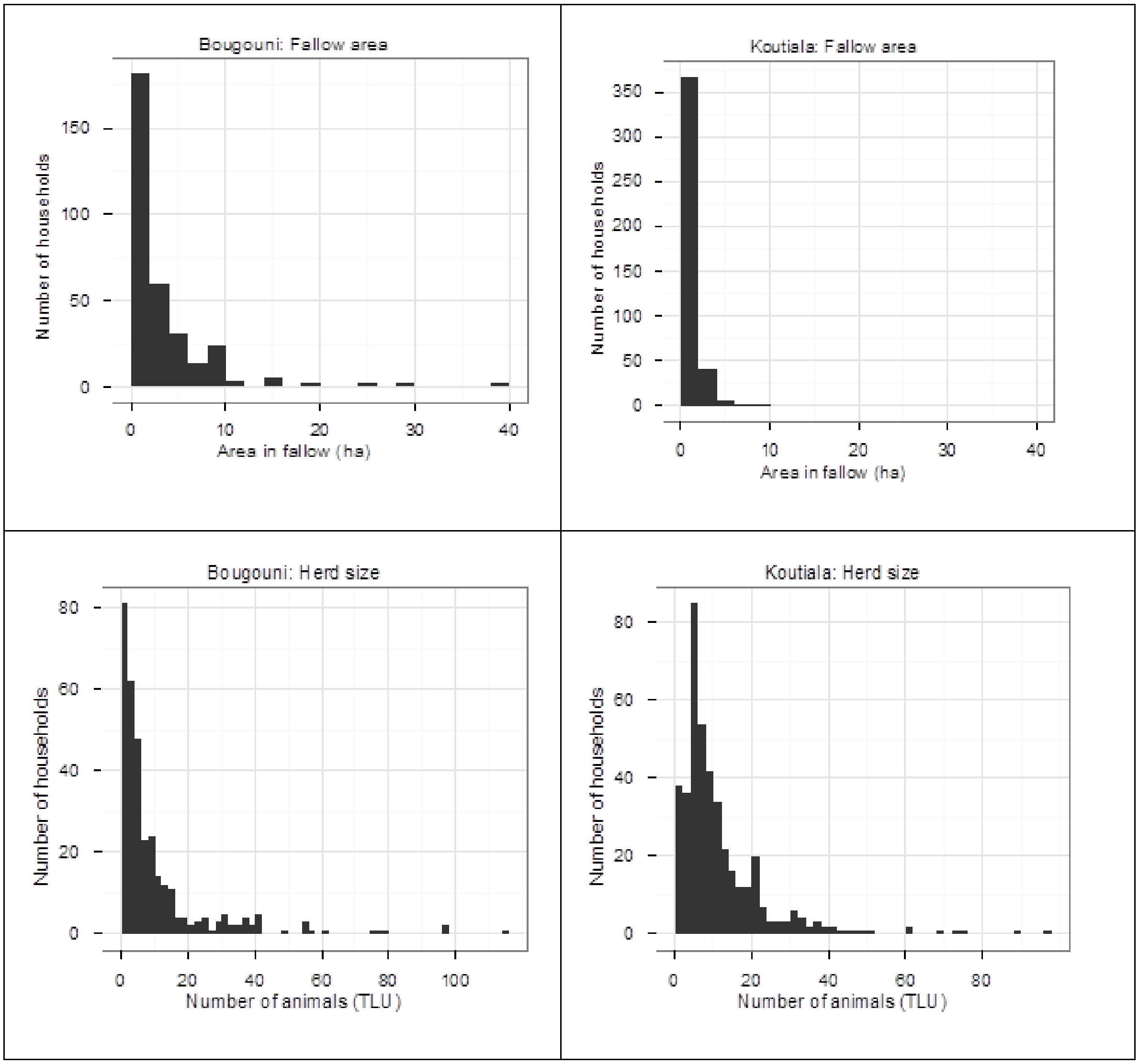



**Figure 3.4.3.**Histograms for some structural farm characteristics in both regions.

Based on a long-term farm monitoring dataset, a farm typology for farms in the Koutiala district has been proposed, together with a decision tree to help classify farms into four types (Figure 3.4.4).

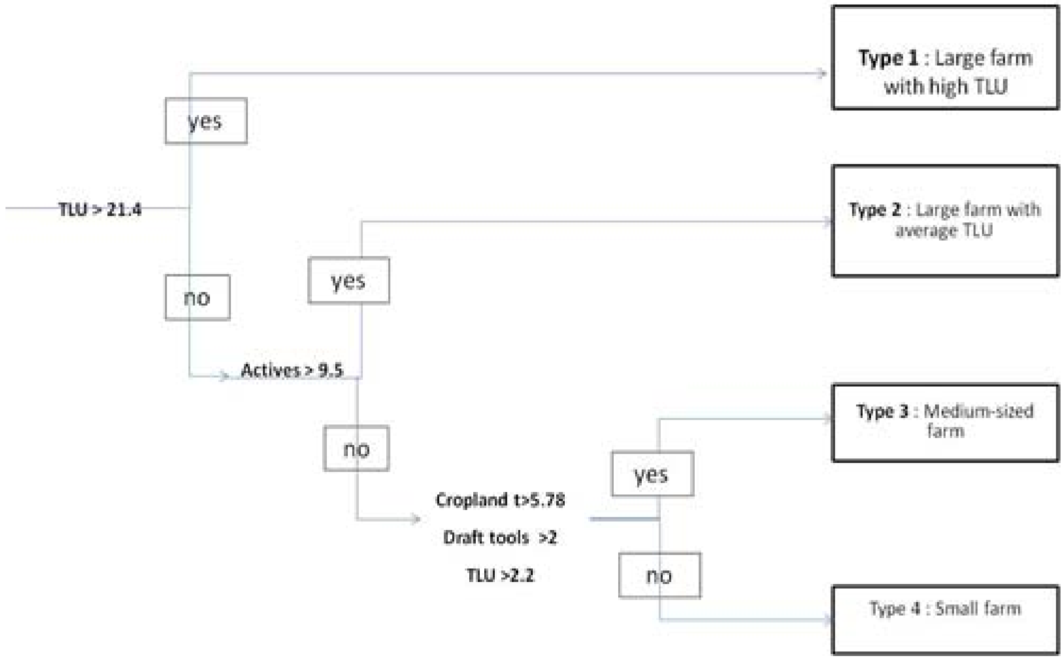



**Figure 3.4.4.**Farm classification decision tree for the Koutiala area (Falconnier, 2013).

Farm type characteristics (Table 3.4.3) show resource endowments decreasing from farm type one to farm type four. Type one farms are large farms with large herds, cropping 20 hectares, with seven oxen and seven draft tools. Type two farms are also large farms but with medium-sized herds. On average, 15 active members crop about 17 ha, with three oxen and four draft tools. Type three farms are medium-sized farms. On average six workers crop almost ten hectares, with two oxen and three draft tools. Type four farms are small farms. On average nearly four workers crop five hectares with one ox and one draft tool. The herds of all farm types are comprised of cattle, small ruminants and donkeys with varying shares of the total herd size.

**Table 3.4.3.** Basic characteristics of the four farm types in Sirakele and Nampossela (Koutiala).

| Type | Family size | Active members | Total cultivated area (ha) | Herd size (TLU) | Draft animals | Draft tools | Number of households in type |
|---|---|---|---|---|---|---|---|
| 1 | 37 | 17 | 20 | 36.5 | 7 | 7 | 54 |
| 2 | 33 | 15 | 17 | 12.4 | 3 | 4 | 75 |
| 3 | 13 | 6 | 10 | 8.0 | 2 | 3 | 243 |
| 4 | 7 | 4 | 5 | 1.7 | 0.6 | 1 | 46 |

Household clustering for the Bougouni area resulted in farm types largely based on resource endowment (Table 3.4.4). Clustering variables used are similar to those used in Koutiala, however given the very high correlation between total population and active members (>0.9) we retained only total population. We also included fallow area, as this is more important and more variable in Bougouni than in Koutiala.

For detailed characterization, a stratified sampling approach was followed with three households selected per farm type (Table 3.4.5). Data is still being collected and entered for detailed farm characterization in Koutiala, but data is available for the two villages sampled in Bougouni.

**Table 3.4.4.** Basic characteristics of the four farm types in Dieba and Sibirila (Bougouni)

| Type | Household population | Total cultivated area (ha) | Herd size (TLU) | Draft animals | Draft tools | Fallow area (ha) |
|---|---|---|---|---|---|---|
| 1 | 60.6 | 29.6 | 53.5 | 6.3 | 8.4 | 5.4 |
| 2 | 34.7 | 16.7 | 18.4 | 3.4 | 4.9 | 6.8 |
| 3 | 15.4 | 8.8 | 7.9 | 2.1 | 3.1 | 3.0 |
| 4 | 8.4 | 4.5 | 0.9 | 0.4 | 0.5 | 1.4 |

**Table 3.4.5.** Number of households of each type, by village in Bougouni

| **Type** | **Village** | **Number of households in type (base data)** | **Number of households in type (detailed characterization)** |
|---|---|---|---|
| **1** | Dieba | 3 | 1 |
| **1** | Sibirila | 4 | 1 |
| **2** | Dieba | 8 | 3 |
| **2** | Sibirila | 4 | 1 |
| **3** | Dieba | 27 | 3 |
| **3** | Sibirila | 26 | 3 |
| **4** | Dieba | 29 | 3 |
| **4** | Sibirila | 11 | 4 |

### *3.4.3 Land*

Households in Koutiala are often land-constrained, while households in Bougouni generally have sufficient access to land and may clear additional land when needed. Soil types are highly heterogeneous both within a village and among villages, with sandy soils representing 50% of cultivated lands in Koutiala and 40% in Bougouni. Clay type soils make up 19% of cultivated area in both zones, with the remainder comprised of loam type soils (ILRI, 2012).

Soil analysis of samples taken from 191 on-farm trials carried out in 2013 in 9 villages of the Koutiala district showed that farmers classify soils based on gravel content and texture (Figure 3.4.5). “Bele” soils are gravelly, while “cien cien” soils are sandy soils with low clay+silt content, and “dugukolofin” are heavier soils with higher clay+silt content. Fertility indicators (C, P, K, pH) don’t differ significantly between farmers’ soil types.

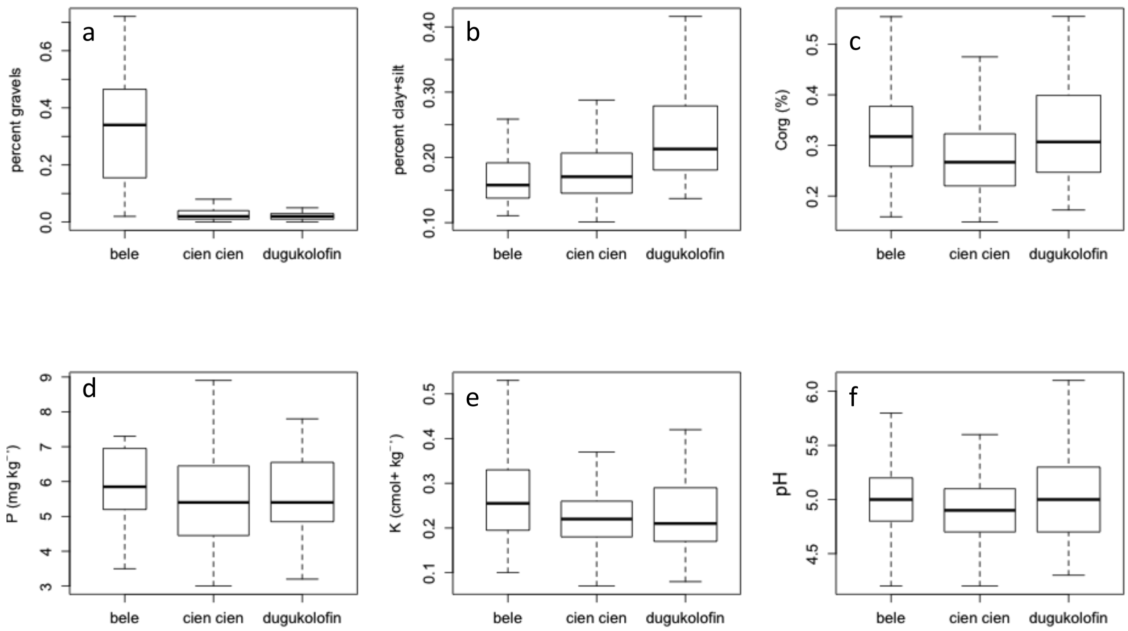



**Figure 3.4.5.** Boxplot showing the soil properties of 191 soil sample in 9 villages of the Koutiala district, classified by farmers’ vernacular names: percent gravels (a), percent clay+silt (b), organic carbon (c), phosphorus (d), potassium (e), pH (f).

79 fields in the Bougouni area were sampled prior to installation of field trials. Soils are predominantly sandy loam, often with high gravel content (Figure 3.4.6). They are generally low in phosphorous and in organic carbon (Figure 3.4.7).

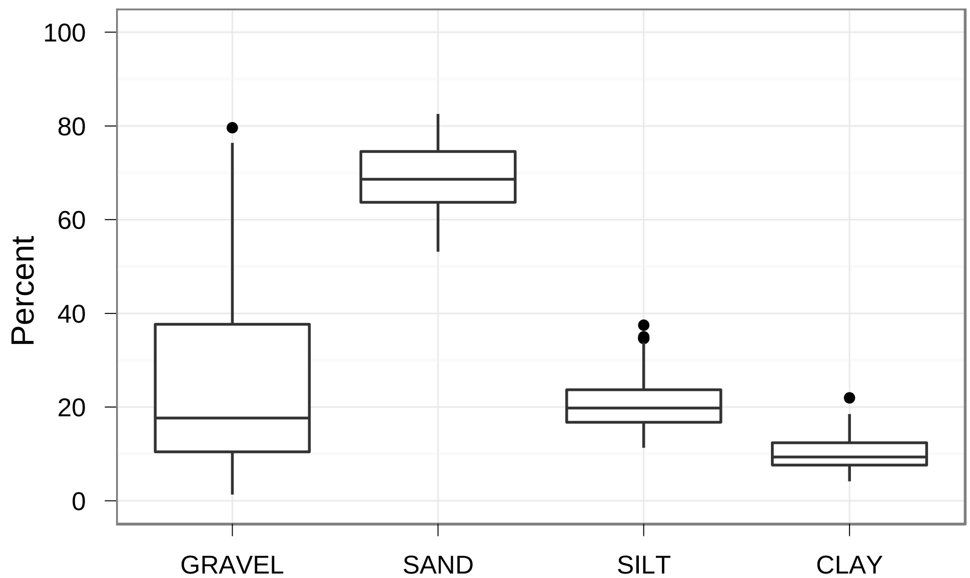



**Figure 3.4.6.** Soil Texture for 79 fields sampled in the Bougouni area.

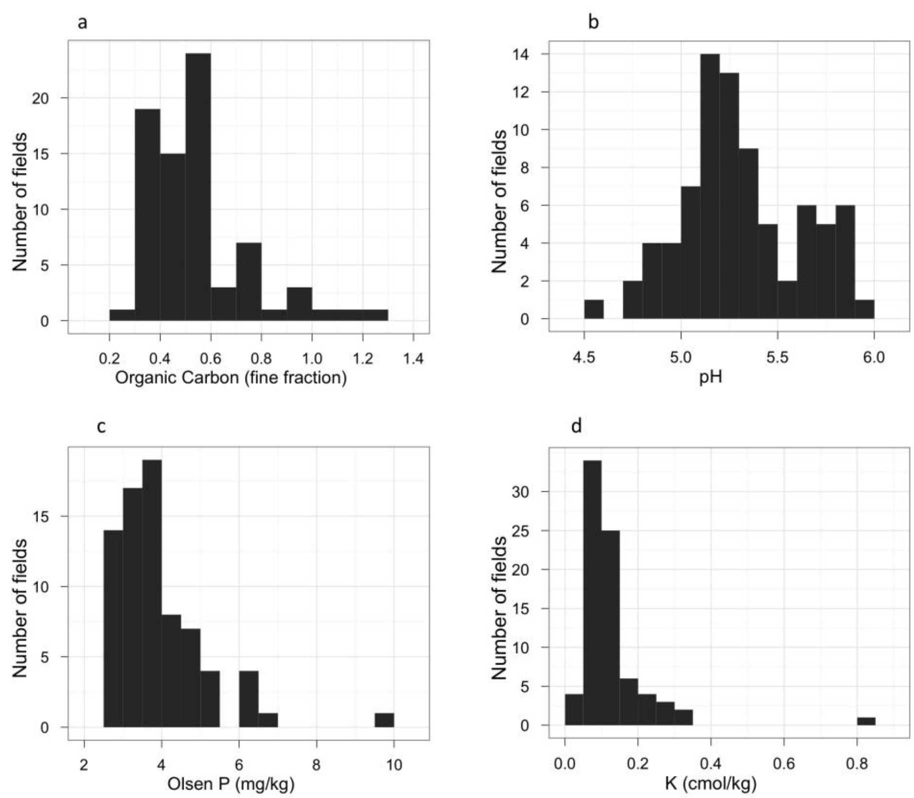
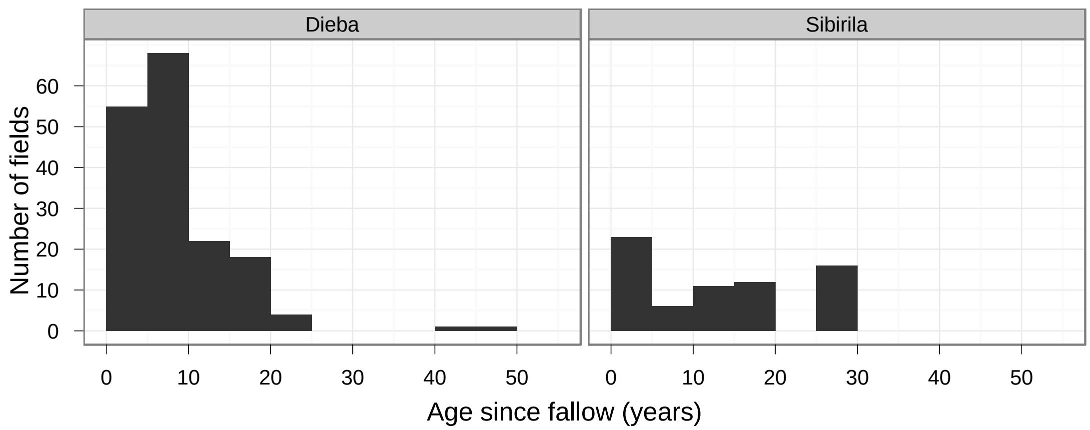


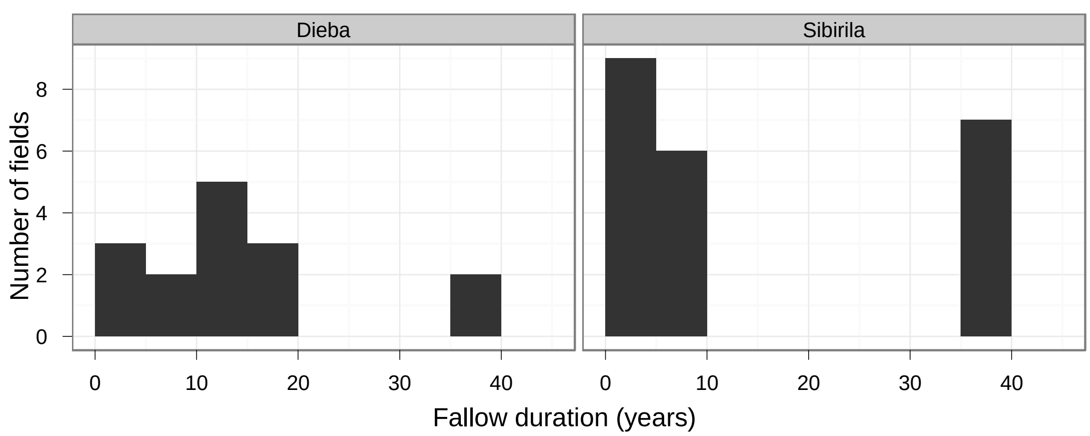

**Figure 3.4.7.** Soil properties for 79 fields sampled in the Bougouni area

Fields are often at a considerable distance from the village, particularly in the area of Bougouni, where the average distance is 3.8 km as compared to 2.3 km in Koutiala (ILRI, 2012). Families may have a large number of fields, including communal family fields and personal fields for women and younger men in the family.

Fallowing is still very common in the Bougouni area and field ages vary from one to fifty years, with a median field age of 10 years from previous fallow. Reported ages since fallowing may be overestimated, as in some cases 1-year fallows were reported within the 3-year field history collected for each field. There are substantial differences between the two villages with respect to fallow duration and field age, as seen in Figure 3.4.8.




(a)




(b)

**Figure 3.4.8.** Field ages from most recent fallow (a) and duration of most recent fallow (b) in Dieba and Sibirila (Bougouni).

### *3.4.4 Crops*

Major crops in Koutiala are cotton, sorghum, millet, and maize; in Bougouni maize is more prevalent and groundnut is an important crop whereas millet is rare. Cotton is the main cash crop in both regions, while cereals are generally used primarily for own consumption, with sales of surplus production. Sales average 15-20% of production for cereal crops. Groundnut may be considered as both a food and cash crop particularly in Bougouni where about 50% of production is sold (ILRI, 2012).

The relative importance of different crops, as well as the cultivation methods, are different for men's and women's fields. Women give higher priority to crops such as groundnut, rice, and fonio and are more likely to cultivate fields by hand, as draft animals are generally only available after family fields and men's fields have been cultivated (Beaudouin, 2005).

The principal agricultural inputs include fertilizers, used by over 90% of households, and pesticides, used by about 90% of households. The purchase of fertilizers and some pesticides is facilitated by the CMDT. Most farmers also use some type of organic fertilizer (97% of households in Koutiala, 87% of households in Bougouni) (ILRI, 2012). Mineral fertilizers and pesticides are applied primarily on cotton and maize, whereas the cotton pesticides are also used on cowpea. In a sample of 19 maize fields and 16 cotton fields all received mineral fertilizers. Herbicides were used on 11 of 19 groundnut fields, 3 of 11 sorghum fields, 16 out of 19 maize fields, and 12 out of 16 cotton fields. Insecticides were used on all cotton fields and fungicides applied to maize seed before planting in 2 fields.

Yields in the Bougouni area are generally low. Figure 3.4.9 shows yields from a sample of 197 fields. These values are the result of preliminary analysis based on farmer-reported yields and should thus be considered approximate. Average crop yields per farm type for the Koutiala area are reported in section 3.4.10 (Table 3.4.23).

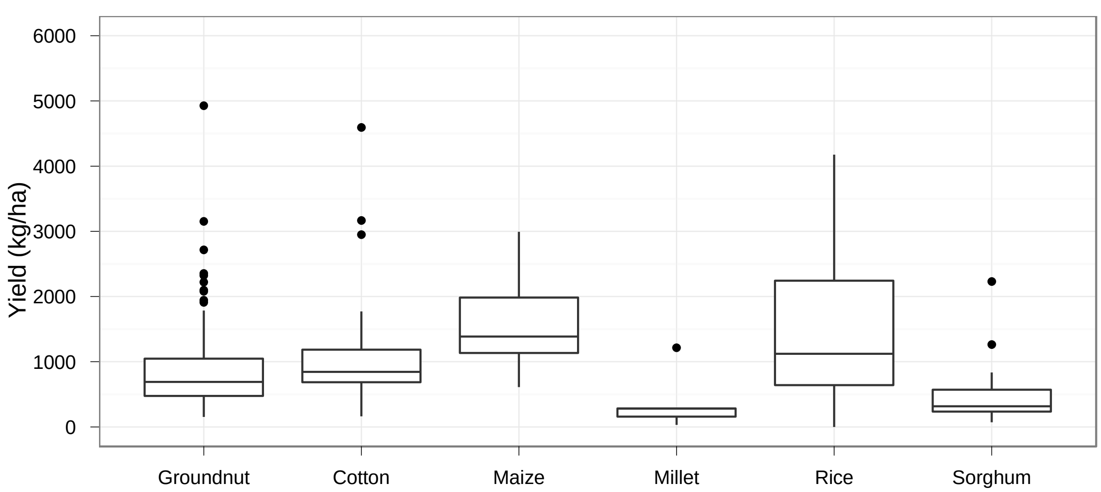



**Figure 3.4.9.** Yields of major crops in the Bougouni area.

Areas allocated to various food and cash crops are changing. In Bougouni, farmers reported on the crops which are increasing or decreasing in area on their farms and their reasons for the changes (Table 3.4.6). Profitability was a major factor in determining crop area changes, both for increases and decreases. Labor constraints were also reported as important for crops which declined in area. Increasing maize, cotton, and groundnut areas and decreasing areas of minor crops seem to indicate a decline in farm diversity, which may have implications for the resilience of these farms in the face of external shocks.

**Table 3.4.6.** Crops increasing and decreasing in area and reasons given for the trends (total households interviewed: 19)

| Trend | Crop | Mentioned by (Number of households) | Reasons given |
|---|---|---|---|
| Increase | Maize | 14 | Profitability, good yields, good for feeding the family |
| | Cotton | 13 | Profitability |
| | Groundnut | 6 | Profitability, good yields |
| | Sorghum | 1 | Profitability |
| Decrease | Sorghum | 13 | Low yields, not profitable, sensitive to strong rains, bird damage |
| | Millet | 14 | Low yields, not profitable, bird damage, sensitive to strong rains |
| | Fonio | 4 | Low yields, lack of labor |
| | Cotton | 2 | Less profitable than previously, lack of labor |
| | Groundnut | 2 | Lack of labor, low yields |
| | Maize | 1 | Less profitable than previously |

Surveyed farmers reported that their crops are mostly sold at or near harvest on local markets or in nearby towns (Bougouni). Exceptions are cotton, which is sold to the CMDT, and organic sesame and cotton, which are sold through Mobiom, the Mouvement Biologique du Mali. Prices are similar in both village and town markets (Table 3.4.7).

**Table 3.4.7.** Crop prices (in CFA, 473 CFA = 1 USD)

| **Crop** | **Average price at harvest** | **Minimum price at harvest** | **Maximum price at harvest** | **Average price after storage** | **Minimum price after storage** | **Maximum price after storage** |
|---|---|---|---|---|---|---|
| **Maize** | 50 | 64 | 150 | 109 | 50 | 200 |
| **Cotton** | 250 | 250 | 250 | 250 | 250 | 250 |
| **Groundnut** | 179 | 100 | 350 | 368 | 100 | 600 |
| **Sorghum** | 76 | 60 | 125 | 136 | 60 | 200 |
| **Cowpea** | 250 | 125 | 400 | 300 | 125 | 500 |
| **Fonio** | 300 | 250 | 350 | 400 | 300 | 500 |
| **Sesame (organic)** | 288 | 200 | 375 | 288 | 200 | 375 |

### 3.4.5 Livestock

As noted above, many families keep livestock, including cattle and small ruminants. Most of these are sedentary, although a significant fraction of households in the Koutiala area (about 30%) have at least a portion of their herd practicing transhumance. This percentage is lower in Bougouni (15.8%). Small ruminants are generally sedentary, with a few households using semi-intensive practices (supplementation, stall feeding, etc.). Use of veterinary products is also common, with some kind of veterinary inputs used by 86% of households in Koutiala and 94% of households in Bougouni (ILRI, 2012).

Cattle are used for animal traction, while donkeys are most commonly used for transport of materials, crop products, etc. Feed sources for livestock are based on natural pasture and crop residues (the former being more important in Bougouni than Koutiala), with supplements or feed from designated fodder crop production providing a smaller contribution (Table 3.4.8). Animal production is, in some cases, constrained by a lack of feed during key times of the year, particularly late in the dry season when pasture grasses and crop residues have been largely exhausted. Commonly purchased animal feeds include cereal bran and cottonseed cake (ILRI, 2012) and salt licks are also often provided. Supplements are mostly given to animals destined for sale, as well as to draft animals to improve their performance.

In the farms surveyed for the detailed characterization, no herds travel more than 5 km from the village. Transhumant livestock pass through the fields of 13 of the 19 farms interviewed, for periods between 1 day (passing without camping) and 5 months. There are no formal contracts in place regarding these transhumant livestock. However, customarily permission is required from well owners before giving water to livestock, and livestock are often required to pass the night near these wells in order to provide manure for the field. In Dieba, some producers have dug wells in their fields specifically to attract transhumant livestock for their manure. In Sibirila, following conflict with transhumant Fulani herders in 2009, camping in the village area is not allowed.

Animals and animal products provide relatively small contributions to household income. Milk production on these farms is very low: Only 3 families report any milk production, and then only in the rainy season. Production ranges from 0.5-3L per lactating animal per day during this period. Six of the 19 farms had sold animals in the previous year: three sold cattle (average 1.3 animals per household) and four sold small ruminants (average 2.3 animals per household).

**Table 3.4.8.** Feed supplements provided by farmers in the Bougouni area(total households interviewed: 19)

| Period | Number of farmers providing supplements | Supplement types (Number of farms reporting) | Reasons given (Number of farms reporting) |
|---|---|---|---|
| | | Cattle | |
| Jun—Oct. | 4 | Salt (4)<br>Crop residues (1)<br>Shrubs (1) | Traction (5)<br>Animal fattening (2) |
| Nov—Feb | 9 | Crop residues (4)<br>Tree fodder (3)<br>Salt (3)<br>Maize bran (1)<br>Cottonseed cake (2) | Traction (8)<br>Fattening (3)<br>Survival (1) |
| Mar—May | 11 | Salt (4)<br>Crop residues (4)<br>Cottonseed cake (3) | Survival (1)<br>Traction (10)<br>Fattening (4)<br>Increased milk production (1) |
| | | Goats | |
| Jun—Oct. | 2 | Tree fodder (2)<br>Cereal bran (1) | Survival (2) |
| Nov—Feb | 1 | Maize bran and salt (1) | Fattening (1) |
| Mar—May | 4 | Crop residues (3),<br>Maize bran (1),<br>Tree fodders (1) | Survival (2)<br>Fattening (2) |
| | | Sheep | |
| Jun—Oct. | 2 | Salt (2) | Fattening (2) |
| Nov—Feb | 5 | Salt (4)<br>Bran (1) | Fattening (3)<br>Survival (2) |
| Mar—May | 6 | Salt (6)<br>Crop residues (2)<br>Maize bran (2) | Fattening (5)<br>Survival (1)<br>Increased milk for lambs(1) |

### *3.4.6 People and livelihoods*

As is clear from the typologies, household size and resource endowments vary widely. While small households may consist of a single nuclear family, large households may include up to 70 members of an extended family.

In both Bougouni and Koutiala agricultural revenues are the principal sources of income. Crop sales make up 65% of income in Koutiala, and 60% in Bougouni. Sales of animals and animal products is the second largest income source, at 18% of income in Koutiala, and 11% in Bougouni. Other important revenue sources vary by zone, with vegetable sales making up 5% of income in Koutiala while sales of wood and other forest products make up 9% of income in

Bougouni (ILRI, 2012). Income from sales of wood will vary widely by village, as some villages prohibit sales of firewood and charcoal.In the detailed characterization in the Bougouni area, 12 of 19 households reported non-agricultural income, including small business, brickmaking, gold mining, grain threshing, and grain storage and sales.

Migration plays a role in both zones, though in different ways. In Koutiala, emigration has become more common over the past 20 years, but remains relatively low. In Bougouni, immigration is more common, with 26% of households originating from other areas, including Koutiala (ILRI, 2012). Both areas have seen a recent decline in seasonal migration as opportunities for local income generation improve.

### *3.4.7 Overview of constraints and critical points*

During preliminary community meetings, the Africa RISING project identified major constraints to agricultural development in the study sites. With respect to crop production the major constraint is the lack of inputs (Table 3.4.9). This is related to the lack of agricultural tools, the high costs of inputs and the long distances to markets. Also soil fertility decline and unfavourable climate conditions are often mentioned as constraints limiting crop production. With respect to livestock production, feed shortage is the major bottleneck followed by water shortage and livestock diseases (Table 3.4.10).

**Table 3.4.9.** Main constraints (top-10) to crop production in the Africa RISING sites in Mali (% of responses)

| Constraint | Koutiala South | Koutiala North | Bougouni |
|---|---|---|---|
| Lack of inputs | 25 | 21 | 26 |
| Soil fertility decline | 15 | 21 | 8 |
| Unfavourable climate | 18 | 22 | 19 |
| Lack of agricultural tools | 13 | 12 | 12 |
| Labor shortage | 4 | 5 | 3 |
| Poor extension & information services | 4 | 5 | 3 |
| High cost of pesticides | 5 | 2 | 7 |
| Lack of land | 3 | 2 | 2 |
| No access to credit | 3 | 1 | 4 |
| Distance to markets | 2 | 2 | 6 |

**Table 3.4.10.** Main constraints (top-4) to livestock production in the Africa RISING sites in Mali (% of responses).

| Constraint | Koutiala South | Koutiala North | Bougouni |
|---|---|---|---|
| Feed shortage | 66 | 73 | 62 |
| Water shortage | 13 | 7 | 21 |
| Diseases | 13 | 13 | 14 |
| Poor grazing management | 6 | 7 | 4 |

### *3.4.8 General entry points and suggestions*

Entry points follow from an inventory of constraints and opportunities, which has been carried out by the Africa RISING project partners in Mali during initial project meetings and participatory sessions with the communities. Here, we first provide a summary of entry points and suggestions for sustainably improving agricultural productivity in the region. After the general summary, a more detailed "what-if" analysis for Bougouni and Koutiala separately provides information on the likely effect of interventions related to the entry points.

With respect to crop production, the use of improved varieties of millet, sorghum and vegetables is promising. Attention to seed production enterprises and cooperatives is necessary to underpin this entry point.

As declining soil fertility is a major constraint to improving agricultural production, soil fertility management is a key entry point. This can be achieved through the (combined) use of chemical fertilizers, organic manure, composting technologies, and the incorporation of leguminous crops. The latter can be done in rotations with cereals or in intercropping arrangements.

Pest and weed control are critical and Striga control is an illustrative example that is important in particular on poor fields where sorghum is cultivated (often by women).

As feed shortages are an important impediment for livestock production, the incorporation of forage or dual-purpose crops (e.g. cowpea) is often advocated as a means to raise animal productivity. This should go alongside efforts to improve feed (including crop residues) storage during the dry season, stall and/or kraal feeding, and sustainable grazing management of the common rangelands. The latter will need underpinning institutional arrangements at the community level. Also, forage technologies and stall feeding interventions can only work if farmers can obtain added value from livestock production through for example a reliable milk outlet in the nearby town. Support for milk cooperatives can be a driving force here.

Component entry points or interventions as above are important, but as we are dealing with mixed systems in which cereal, livestock, tree and vegetable production are all important and interlinked, paying attention to the system as a whole and the integration of the different components, is also believed to pay off. System diversification through keeping different livestock species, diversifying crops and incorporating trees in the system requires management agility, but can benefit system resilience and possibly also productivity. Following the same rationale, integration between components can play its role, e.g. through judicious use of crop residues and tree foliage for livestock feeding, animal manure for soil fertility improvement, and animal draught power for timely farm operations.

The marketing and availability of agricultural inputs, through storage facilities and linkages between producers and input providers, seems to be a key entry point for improving agricultural productivity and sustainability. Similarly, better organized marketing of agricultural products by farmer groups can help to obtain better prices and secure higher and more reliable income.

The above mentioned entry points are valid for the farming systems in Bougouni and Koutiala in general, because they address certain key constraints. However, these general entry points need to be refined for different farm types and contexts based on more detailed analysis and explorations. For example, focusing on manure application could be a very relevant option for farmers with large cattle herds, whereas it is not for a farmer who just keeps a few sheep. It might well be that for the latter type of farmer, fattening sheep in the dry season or just before the holidays could generate a lot of revenues. Small ruminants are often kept by female farmers, so this could be a gender-specific option. This illustrates that farm-specific targeting of options is important and can be done after a detailed analysis of the socio-ecological context of different farm types. In what follows we illustrate with a few examples how this could be done for Bougouni and Koutiala.

### *3.4.9 Entry points for the Bougouni area*

***Crop storage and marketing***

The main crops grown and sold in the Bougouni area are cotton, maize, sorghum, and groundnut. About half of the groundnut produced is sold, for all farm types, and nearly all cotton (small quantities are sometimes saved for seed). Smaller amounts of grains like maize and sorghum are sold, and this varies by farm type (Table 3.4.11).

**Table 3.4.11.** Average amounts harvested/sold by crop and farm type (kg).

| Type | Groundnut | Maize | Sorghum | Cotton |
|---|---|---|---|---|
| **1** | 1650/856 | 10200/966 | 0/0 | 7750/7649 |
| **2** | 2655/1038 | 9105/0 | 215/0 | 4313/4256 |
| **3** | 958/541 | 2417/482 | 700/29 | 3067/2454 |
| **4** | 694/407 | 2026/295 | 212/67 | 1900/1884 |

When calories from all food crops produced are considered, 5 out of 19 households are not food self-sufficient. If we consider only calories from the portion of the crops reported as consumed (not sold), 7 in 19 households are not food self-sufficient (Table 3.4.12).

**Table 3.4.12.** Food self-sufficiency of different farm types (%).

| Type | Average percentage of calorie requirement provided by all farm production (number of non-self-sufficient households) | Average percentage of calorie requirement provided by consumed portion of farm production (number of non-self-sufficient households) |
|---|---|---|
| 1 | 141 (1) | 123 (1) |
| 2 | 226 (1) | 197 (1) |
| 3 | 164 (1) | 119 (2) |
| 4 | 253 (2) | 173 (3) |

Many farms produce a surplus of calories; even considering what is already sold. For these farms increasing the production of cash crops may be attractive, as shifting some of the food crop area to cash crop cultivation poses a low risk to their food security. Without increasing the area devoted to cash crops, there seem to be opportunities to earnings by selling at peak price moments (Table 3.4.13 and 3.4.14).

**Table 3.4.13.** Earnings at average harvest prices in USD (1USD = 472 CFA). For average prices see Table 3.4.7

| Farm Type | Groundnut | Cotton | Maize | Sorghum |
|---|---|---|---|---|
| **1** | 324 | 4043 | 102 | 0 |
| **2** | 393 | 2249 | 0 | 0 |
| **3** | 205 | 1256 | 51 | 5 |
| **4** | 154 | 996 | 31 | 11 |

**Table 3.4.14.** Earnings at average prices after storage (difference from original) in USD (1USD = 472 CFA). For average prices see Table 3.4.7

| Farm Type | Groundnut | Cotton | Maize | Sorghum |
|---|---|---|---|---|
| **1** | 666 (+342) | 4043 | 223 (+120) | 0 |
| **2** | 808 (+415) | 2249 | 0 | 0 |
| **3** | 421 (+216) | 1297 | 111 (+60) | 8 (+4) |
| **4** | 317 (+163) | 996 | 68 (+37) | 19 (+8) |

Selling groundnut at periods of peak prices has the potential to double incomes from groundnut for all farm types. Benefits from peak period sales of maize are similar on a percentage basis but since most maize produced is consumed by the household, absolute benefits are smaller. Benefits to peak-period sales of sorghum are limited, as less sorghum is produced and sold.

Storing groundnut until peak price points (generally in April/May) thus has the potential to increase income among all farm types.

***Improved animal production practices***

Given the extremely limited current milk production in the Bougouni area, stall feeding of cattle for milk production is unlikely to be a viable strategy, at least in the short-medium term. The development of milk collection infrastructure, milk marketing cooperatives, and a cold chain to serve villages which are distant from markets is an institutional challenge that would require considerable investment. However, given the availability of pasture in the area and the existence of animal markets in nearby towns like Bougouni, Faragouraran, and Yanfolila, meat production is a potential opportunity. Crop residues provide a potential source of supplemental feed, but are not used efficiently at the moment (Table 3.4.15). More than 50% of the crop residues are simply left in the fields for grazing. A lot of this material is lost as feed due to decomposition and termite action. Only groundnut and rice crop residues are collected to a limited extent (12%). Groundnut crop residues are harvested during the rainy season, making proper storage of such residues difficult.

**Table 3.4.15.** Destinations of crop residues in Bougouni (Percentage of all crop residues used for each purpose)

| Crop | Incorporated | Burned | Collected for animals | Compost | In-situ grazing | Number of fields |
|---|---|---|---|---|---|---|
| Groundnut | 4 | 0 | 12 | 0 | 73 | 86 |
| Rice | 13 | 0 | 12 | 0 | 64 | 41 |
| Millet | 13 | 0 | 3 | 0 | 56 | 7 |
| Maize | 17 | 1 | 0 | 0 | 70 | 33 |
| Sorghum | 5 | 10 | 0 | 0 | 62 | 25 |
| Cotton | 2 | 27 | 0 | 0 | 65 | 33 |

Note: Percentages do not add up to 100 due to averaging and mis-estimation in original data

Ayantunde et al. (2008) have recommended 600 g groundnut haulms combined with 400 g cereal bran as a cost-effective ration for sheep fattening, based on trials in the Fakara region of Niger. While conditions and common animal breeds in the Bougouni area differ, we take this as a baseline value. Currently, only 12% of groundnut residues are collected for animals as dry season supplemental feed. If that percentage was increased, the number of animals supported could be increased as well.

We estimate the potential fodder availability (Table 3.4.17) from reported grain yields and harvest indices from literature (Table 3.4.16). While harvest indices vary considerably, we have taken intermediate values from Fageria et al. (1997).

**Table 3.4.16.** Harvest indices for various crops used in calculating potential fodder availability

| Crop | Harvest Index |
|---|---|
| Groundnut | 0.40 |
| Maize | 0.42 |
| Millet | 0.26 |
| Rice | 0.44 |
| Sorghum | 0.27 |

**Table 3.4.17.** Average potential fodder available (kg) for different types of farms.

| Type | Groundnut | Maize | Millet | Rice | Sorghum |
|---|---|---|---|---|---|
| 1 | 2475 | 14086 | 2248 | 1025 | 2447 |
| 2 | 3982 | 12574 | 285 | 1553 | 977 |
| 3 | 1436 | 3337 | 0 | 594 | 946 |
| 4 | 1041 | 2797 | 0 | 280 | 660 |

Actual amounts of fodder available will be lower due to harvest occurring at grain maturity, as well as losses in collection and transport. If we assume that 50% of this potentially available fodder is actually used, and that animals are supplemented at a rate of 600g groundnut haulms/day for 90 days, the number of animals that can be supported from this on-farm production ranges from 3 to 90 animals. Averages by farm type are listed in Table 3.4.18.

**Table 3.4.18.** Number of sheep that could be fed for 90 days from on-farm groundnut fodder production.

| **Farm Type** | **Sheep supported** |
|---|---|
| **1** | 23 |
| **2** | 37 |
| **3** | 13 |
| **4** | 10 |

The profitability of this activity will vary depending on the time when animals are sold. Prices in Mali tend to spike just before the Muslim holiday of Tabaski, which occurred on October 15, 2013 and will occur on October 5, 2014 and September 24, 2015. Calculating profitability is additionally complicated by the fact that animals are not generally sold by weight but rather based on visual inspection of the animal. We can estimate these prices from trial data by regressing price to weight data obtained when animals are purchased and sold (Figure 3.4.10), but these values should be considered highly variable.

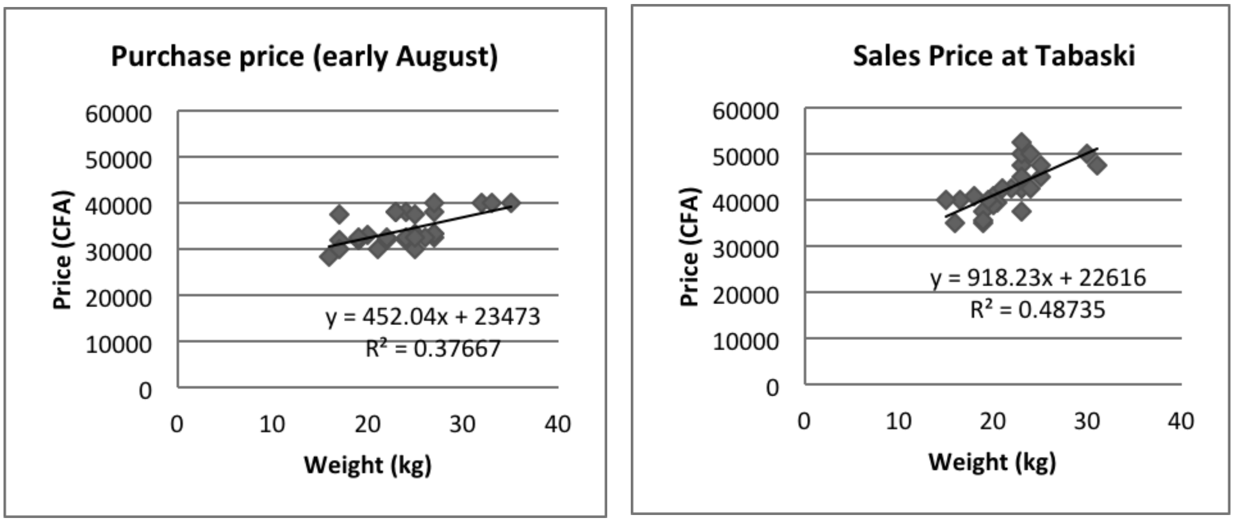



Figure 3.4.10. Weights and prices of Djallonke sheep at purchase at off-peak time (August) and price at sale near Tabaski. Prices expressed in CFA (1 USD = 473 CFA)

Ayantunde et al. (2008) estimate average daily gain with 600 g groundnut and 400 g cereal bran at 91.7 g/day. 600 g groundnut haulms without cereal bran resulted in a gain of 30.8 g/day. Taking these values, we can expect a sheep with initial weight of 20 kg to gain approximately 2.7 kg (without cereal bran) up to 8.3 kg (with cereal bran) over the course of the 90-day supplementation period. Costs to consider include veterinary services and possibly costs for cereal bran (Table 3.4.19). This may, however be available from home food production. As there is no local market for selling groundnut haulms this cost is taken as zero. Costs are estimated from previous trials.

**Table 3.4.19.** Costs for supplemental feeding of sheep (USD per sheep).

| Feeding strategy | Veterinary services | Cereal bran | Total |
|---|---|---|---|
| Ration 1: Groundnut haulms 600g/day | 3.2 | 0 | 3.2 |
| Ration 2: Groundnut haulms 600g/day plus cereal bran 400g/day | 3.2 | 0 | 3.2 |
| Ration 2 with purchased cereal bran | 3.2 | 11.4 | 14.6 |

In non-Tabaski periods, the only marginally profitable scenario is feeding 600 g groundnut and 400 g cereal bran, if both come at no cost (Table 3.4.20). Near Tabaski, all feeding strategies are potentially profitable, but excluding cereal bran from the feeding ration is more profitable than paying for it. However if, as currently, Tabaski falls during the rainy season, storing crop residues to use near peak price periods is not likely to be practical.

**Table 3.4.20.** Returns on supplemental feeding of sheep (USD per sheep).

| Feeding strategy | Weight gain | Gross profit at off-peak price | Gross profit if sold at Tabaski price | Net profit at off-peak price | Net profit if sold at Tabaski price |
|---|---|---|---|---|---|
| Ration 1: Groundnut haulms 600g/day | 2.7 kg | 2.6 | 23.1 | -0.6 | 20.0 |
| Ration 2: Groundnut haulms 600g/day plus cereal bran 400g/day | 8.3 kg | 7.9 | 31.4 | 4.8 | 28.3 |
| Ration 2 with purchased cereal bran | 8.3 kg | 7.9 | 31.4 | -6.7 | 16.9 |

Potential profits are significant when it is possible to fatten animals near Tabaski, particularly for larger farm types which can support large numbers of animals (Table 3.4.21).

**Table 3.4.21.** Potential earnings from sheep fattening with groundnut haulms for different farm types (USD).

| Farm Type | Sheep supported | Ration 2: non-peak prices | Ration 2: Tabaski prices | Ration 1: Tabaski prices |
|---|---|---|---|---|
| 1 | 23 | 109.51 | 650.03 | 459.32 |
| 2 | 37 | 176.16 | 1045.70 | 738.90 |
| 3 | 13 | 61.89 | 367.41 | 259.62 |
| 4 | 10 | 47.61 | 282.62 | 199.70 |

***Improved crop-livestock integration***

The activity above already provided one example of improved crop-livestock integration by increasing the use of crop residues as animal feed. Other activities could include raising young animals for sale or supplemental feeding of oxen in the late dry season to improve draft power during planting periods. Any of these activities would also result in increased manure availability for use on crop fields. Manure is in general applied only to maize and cotton fields, at relatively high average doses of 5.3 t/ha for maize and 5.7 t/ha for cotton where it is applied. However, only five out of 19 sampled maize fields received manure, while four out of 16 cotton fields did.

None of the sampled groundnut or sorghum fields received manure. Increasing manure availability would require some stable or otherwise centralized feeding of animals. These practices result in increased demand for labor, for collecting crop residues, manure management, and manure spreading before planting. Current farmer practice tends more towards supplementation with tree fodder, which is collected as needed during the dry season. This system is limited in the number of animals it can support, and results in feed deficits during the late dry season. Thus improving feed storage (without necessarily increasing area allocation to fodder crops) could lead to improved livestock and crop productivity.

***Discussion***

Farms in Bougouni are not faced with land constraints as there is ample land available. Inputs are only applied to maize and cotton, and manure/compost production and application is very uncommon. If the soil fertility of a field drops too low, it is simply left fallow and a new piece of fallow land is opened up. Important limitations for farmers to increase farm level production include draught power (to cultivate more land), labor (to produce and apply manure, to weed), and cash (to buy inputs). Given these limitations, taking advantage of higher prices during certain periods of the year by better grain storage is an obvious intervention that would be effective for all farm types and can be implemented relatively easily from a technical point of view. Warrantage systems, which combine grain storage and sales with micro-credit, would be interesting institutional innovations to explore. Storage of livestock feed, including crop residues (both high quality residues from legume crops and lower quality cereal residues) and hay produced with cut and carry grasses from the rangelands, would require more labor but could clearly result in higher farm profitability. More detailed analysis of labor calendars and the trade-offs associated with labor allocation decisions still have to shed light on the feasibility of these options in the farm context.

As the first year of on-farm trials did not result in conclusive findings, detailed analysis of options to adjust cropping systems have not been included for Bougouni so far.

### *3.4.10 Entry points for the Koutiala area*

For the Koutiala area, an important constraint to increase farm level productivity is fodder shortage. Growing fodder crops and better crop-livestock integration are promising entry points for addressing this constraint. With this in mind, intercropping cereals with cowpea and growing cowpea as a sole crop were tested on farm and later on positively evaluated by farmers. As land availability is limited in Koutiala, the adoption of a particular option on a farm goes at the expense of another land use (in this case, at the expense of another crop). As a result, trade-offs are associated with these decisions. Here we report on an e*x ante* trade-off analysis of the adoption of these options for different farm types in the Koutiala region. The current situation was compared with possible future scenarios in terms of food self-sufficiency and income per worker. For a number of other options tested with farmers, we report on a simple profitability analysis, comparing the gross margins on a per hectare basis.

Analysis of farm trajectories over the two past decades showed that (i) the CMDT collapse in 2004 impacted cotton area and maize area for the four farm types, and (ii) the household size and number of workers have continuously increased (Falconnier et al., 2013). To reflect these dynamics in the characterization of the current situation, we considered the 2010 data on household endowments from the Suivit-Evaluation Permanent (SEP) dataset. For the crop area and herd size we calculated the averages over the 2004-2010 period (Table 3.4.22). Productivity of the different crops was averaged for each farm type over the 17 years of the SEP monitoring (Table 3.4.23).

**Table 3.4.22.** Characteristics of the four farm types. Household demography is 2010 data. Crop area was average over the 2004-2010 period. The number of adult cows was estimated using herd structure data from Ba (2011). (Source: SEP dataset.)

| Farm type | Number of workers | Number of HH members | Sorghum (ha) | Millet (ha) | Cotton (ha) | Ground-nut (ha) | Maize (ha) | Total cropped land (ha) | Number of cattle | Number of cows |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 28 | 45 | 3.6 | 4.7 | 6.7 | 0.8 | 2.5 | 18.3 | 45 | 16.2 |
| 2 | 18 | 27 | 3.4 | 4.0 | 3.8 | 0.6 | 1.6 | 13.5 | 7 | 2.24 |
| 3 | 7 | 13 | 2.2 | 2.2 | 2.7 | 0.6 | 1.0 | 8.7 | 5 | 1.1 |
| 4 | 5 | 8 | 0.8 | 0.6 | 0.2 | 0.3 | 0.2 | 2.1 | 0.32 | 0 |

In 2013, 110 farmers from 9 villages in the Koutiala district tested a wide range of options on a total of 192 trials, including fertilizer and improved varieties of sorghum and maize, soybean with inoculum and fertilizer and several options for increasing fodder production. For the future scenarios, the adoption of some of the options tested by the farmers in 2013 was considered.

For the maize-cowpea intercropping scenario, the profitability of the different options was calculated by adjusting the yields with the partial land equivalent ratio (pLER), obtained from the trials:

pLER (maize) = maize yield in the intercropping / maize yield in the sole crop.

For the scenarios where the amount of haulms produced on-farm exceeded the need of the actual number of reproducing cows, we assumed that the excess was sold.

**Table 3.4.23.** Average yield and gross margin for each farm type and each crop in the current situation.

| Farm type | Crop | Crop yield (kg DM $ha^{-1}$) | Gross margin (US$ $ha^{-1}$) |
|---|---|---|---|
| 1 | cotton | 1051 | 305 |
| | maize | 2427 | 685 |
| | sorghum | 1107 | 329 |
| | millet | 884 | 327 |
| | groundnut | 974 | 994 |
| 2 | cotton | 944 | 256 |
| | maize | 2081 | 572 |
| | sorghum | 871 | 258 |
| | millet | 668 | 246 |
| | groundnut | 734 | 737 |
| 3 | cotton | 912 | 242 |
| | maize | 1888 | 500 |
| | sorghum | 907 | 269 |
| | millet | 697 | 257 |
| | groundnut | 644 | 641 |
| 4 | cotton | 754 | 253 |
| | maize | 1298 | 382 |
| | sorghum | 650 | 191 |
| | millet | 524 | 192 |
| | groundnut | 419 | 400 |

For livestock products, effects of future scenarios were not obtained from on-farm trials, but from literature. De Ridder et al. (2013) explored different option of cattle feeding during the hot dry season (March-June). The farmer practice (free grazing and low supplementation) was compared to a supplementation treatment, i.e. extra supplements of cotton seed cake (2 kg $day^{-1}$ $cow^{-1}$) and cowpea hay (1 kg $day^{-1}$ $cow^{-1}$). A stable feeding treatment was also tested: animals were kept in the stable during the hot dry season and fed with cowpea hay (2.5 kg $day^{-1}$), cotton seed cake (2 kg $day^{-1}$ $cow^{-1}$), and crop residues (2.6 kg $day^{-1}$ $cow^{-1}$). We considered the productivity and calving interval of reproducing cows as reported by de Ridder et al. (2013), and mortality rate as reported by Ba (2011). Gross margin was calculated considering milk, heifers and bull calves as outputs.

Gross margins (GM) were calculated for each crop and livestock scenario and for each farm type, assuming all products are sold, as:

*GM = (production * price) - variable costs*

Labor and on-farm produced manure were not valued as costs as they are provided by the own family/farm. The 2013 average farm gate price was used (calculated as the mean of the maximum and the minimum price through the year). These prices had been gathered through Participatory Rural Appraisals in three villages of the Koutiala district.

Results on productivity and gross margin for the different options are summarized in Tables 3.4.24 to 3.4.27.

**Table 3.4.24.** Average productivity and profitability of the different cropping options tested by farmers in 2013.

| Crop | Treatment | Average productivity (kg DM ha$^{-1}$) | Gross margin (US$ ha$^{-1}$ year$^{-1}$) |
|---|---|---|---|
| maize | local variety | 715 | 218 |
| | local variety+fertilizer +manure | 1856 | 458 |
| | hybrid | 790 | 153 |
| | hybrid + fertilizer +manure | 1861 | 371 |
| sorghum | local variety | 844 | 250 |
| | local variety+fertilizer +manure | 1309 | 352 |
| | hybrid | 879 | 248 |
| | hybrid + fertilizer +manure | 1431 | 376 |
| soybean | control | 397 | 145 |
| | control+inoculum | 575 | 178 |
| | control+P+manure | 431 | 151 |
| | control+P+manure+inoculum | 588 | 174 |
| cowpea(*) | grain variety, control | 328 (1108) | 448 |
| | grain variety + P | 392 (1179) | 482 |
| | fodder variety, control | 1 (2321) | 539 |
| | fodder variety + P | 1 (2463) | 549 |

(*) For cowpea, values between brackets refer to fodder quantities. For the gross margins, it is assumed that all fodder is sold (not fed to the livestock)

**Table 3.4.25.** Average productivity and profitability of the different intercropping options tested by farmers in 2013.

| Crop | Cowpea variety, pattern (*) | Average productivity (kg DM ha$^{-1}$) | | | Gross margin (US$ ha$^{-1}$ year$^{-1}$) |
|---|---|---|---|---|---|
| | | cereal grain | cowpea grain | cowpea fodder | |
| maize/cowpea (**) | grain variety, AP | 1114 | 62 | 175 | 282 |
| | fodder variety, AP | 1083 | 74 | 248 | 305 |
| | grain variety, SP | 968 | 0 | 915 | 380 |
| | fodder variety, SP | 818 | 0 | 1242 | 420 |
| sorghum/cowpea(**) | grain variety, AP | 779 | 124 | 86 | 310 |
| | fodder variety, AP | 840 | 166 | 93 | 363 |
| | grain variety, SP | 791 | 0 | 1465 | 578 |
| | fodder variety, SP | 665 | 0 | 925 | 411 |

(*) AP: additive pattern; (SP): substitutive pattern
(**) For cowpea, it is assumed that all fodder is sold (not fed to the livestock)

**Table 3.4.26.** Partial Land Equivalent Ratio of maize and cowpea fodder in the maize/cowpea intercropping trials in 2012 and 2013

| Pattern | Year | Number of trials | LER | pLER (maize grain) | pLER (cowpea fodder) |
|---|---|---|---|---|---|
| Additive | 2013 | 32 | 1.27 | 0.79 | 0.46 |
| | 2012 | 6 | 1.57 | 1.10 | 0.48 |
| | average | | 1.42 | 0.94 | 0.47 |
| Substitutive | 2013 | 32 | 1.40 | 0.67 | 0.71 |
| | 2012 | 6 | 1.74 | 0.55 | 1.08 |
| | average | | 1.57 | 0.61 | 0.90 |

**Table 3.4.27.** Productivity and gross margin of reproducing cows for different treatments

| Treatment | Productivity (kg $cow^{-1}$) | | | Gross margin (US$ $cow^{-1}$ $year^{-1}$) |
|---|---|---|---|---|
| | milk | manure (*) | calves (number $cow^{-1}$) | |
| Control | 65 | 200 | 0.27 | 115 |
| Supplemented (cowpea hay+cotton seed cake) during the hot dry period | 163 | 250 | 0.28 | 94 |
| Kept in stable during the hot dry period (cowpea hay + cotton seed cake + cereal stover) | 226 | 400 | 0.28 | 122 |

(*) Manure is not valued in the gross margin calculation

For the analysis of the effects of maize-cowpea intercropping, we assume that this option might replace sole maize production. The ex-ante assessment of adoption of maize-cowpea intercropping indicated that for high resource endowed farms with large herds (type 1) and for medium resource endowed farms (type 3) it is more profitable to sell the fodder produced than to use it for stall-feeding of cows. However, even when selling the fodder, the increase in the income per worker increase is low (Figure 3.4.11 and 3.4.12).
For type 1 farms, intercropping cowpea with maize following the substitutive pattern (SP) is not advisable as it increases the risk of not achieving food-self-sufficiency (Figure 3.4.11, a and b). With the additive pattern (AD) on the other hand, the level of average food self-sufficiency can be maintained. For farm type 1, when intercropping cowpea with maize and feeding the fodder to the cows (Figure 3.4.11 b), there is no direct effect on the average income per worker. However, extra manure is collected in the stable, and this manure could be used to increase crop production. If spread evenly over the total cropped land, an extra 177 kg of manure could be applied per hectare, which is a 10% increase compared to current practice. The effect of this management needs to be further assessed using dynamic simulation models.

For medium resource endowed farms intercropping cowpea on only 25% of the maize area allows feeding the cows of that farm type in the stable during the hot and dry period (March-June) (Figure 3.4.12 b), and food self-sufficiency is not threatened. However, this strategy does not lead to an increase in income per worker. Increasing the percentage of maize area intercropped with cowpea to more than 50% would allow for selling some fodder surplus, which in turn increases income per worker.

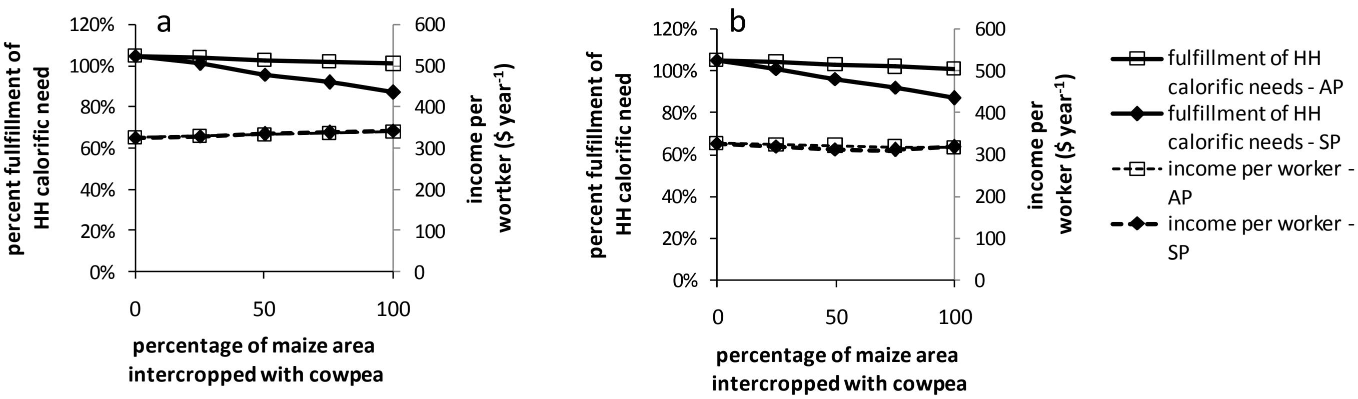



**Figure 3.4.11.** *Ex-ante* assesment of the effect of maize-cowpea intercropping adoption on income per worker and household (HH) food self-sufficiency for high resource endowed farms with a large herd when all fodder produced is sold (a) or used for stall feeding of cows (b). AP = Additive Pattern, SP= Supstitutive Pattern.

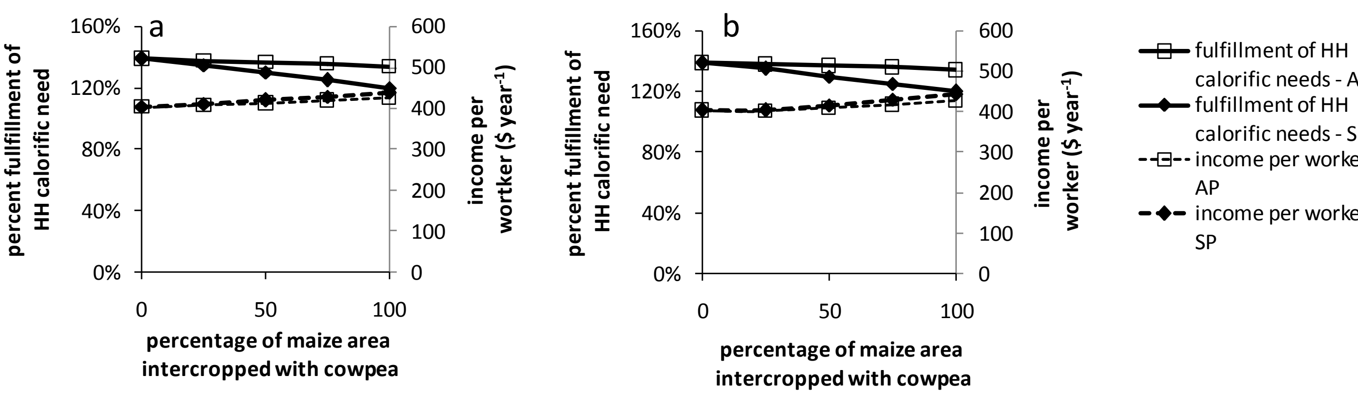



**Figure 3.4.12.** *Ex-ante* assesment of the effect of maize-cowpea intercropping adoption on income per worker and household (HH) food self-sufficiency for medium resource endowed farms when all fodder produced is sold (a) or used for stall feeding of reproducing cows (b). AP = Additive Pattern, SP= Supstitutive Pattern.

For the analysis of the effects of pure cowpea production, we assume that this option might be adopted on (a maximum of 20% of) the current sorghum fields. For type 1 farmers, replacing 20% of the sorghum area by pure cowpea allows stall-feeding 50% of all cows of this farm type during the hot dry season, and would lead to slight increase in the income per worker. However, in this case the risk of not achieving food self-sufficiency is increased (Figure 3.4.13).

Replacing 5% of the sorghum area of a type 3 farm by pure cowpea would allow stall feeding the cow of that farm type during the hot dry season (Figure 3.4.14). Increasing the percentage of sorghum replaced would allow for selling some fodder surplus, which in turn increases income per worker.

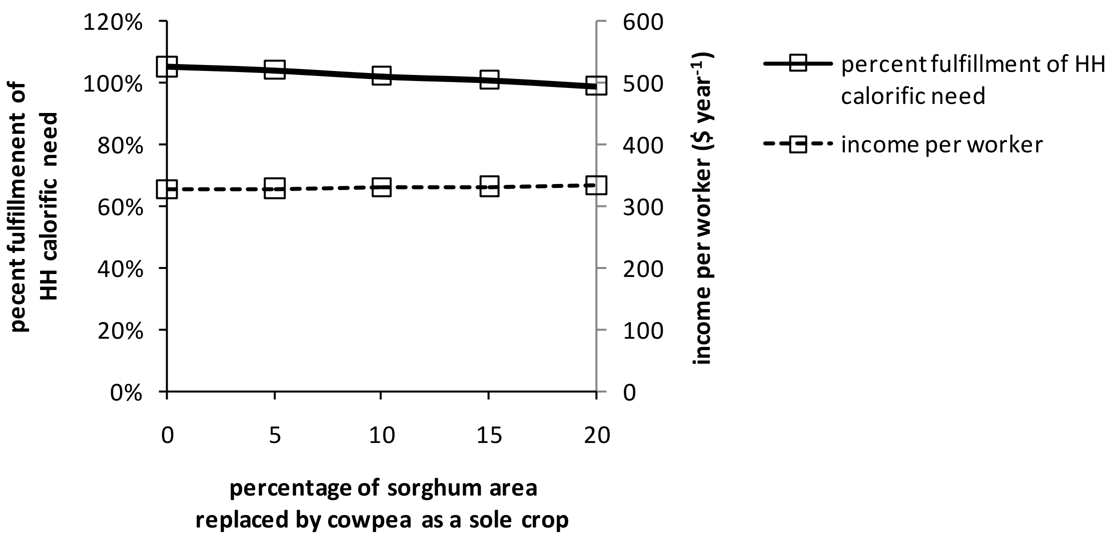



Figure 3.4.13. *Ex-ante* assesment of the effect of replacement of sorghum area by pure cowpea on income per worker and household (HH) food self-sufficiency for high resource endowed farms with a large herd.

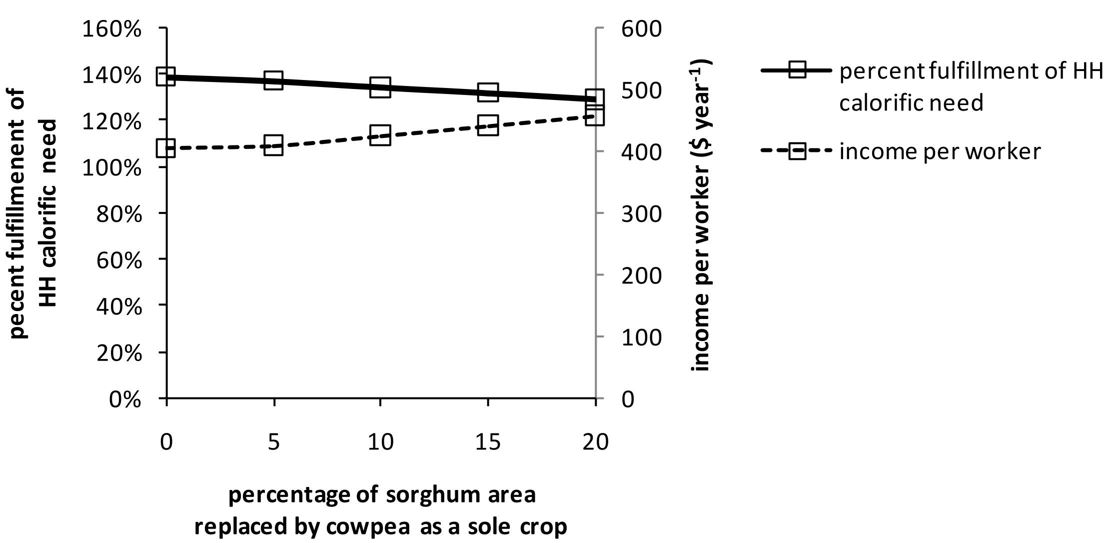



Figure 3.4.14. *Ex-ante* assesment of the effect of replacement of sorghum area by pure cowpea on income per worker and household (HH) food self-sufficiency for medium resource endowed farms.

***Discussion***

Unlike the situation in Bougouni, land availability is a constraint for crop and livestock production in Koutiala. Because of that, the options tested in Koutiala are directed at increasing land productivity (intercropping, use of fertilizer, improved varieties) and animal productivity (through improved feeding practices).

The profitability analysis showed interesting differences between land use options (crops) and farm types in the current situation. When these are compared with the profitability of the tested options, it can be seen that some options appear indeed to be promising for certain farm types. Based on one year of trial results, some options however seem to be less profitable than current practices. Nevertheless, some of these might still be valued by farmers for example because they are nutritious (e.g. soybean), because they provide both fodder and feed (e.g. the intercropping of cereals with cowpea) or because they increase farm diversity.

The ex-ante assessment of the effect of integrating certain options on the farm revealed a trade-off between food self-sufficiency and income per worker. This trade-off is weaker for the additive pattern of intercropping, and less problematic for the medium resource endowed farms, where the average food self-sufficiency remained around or above 120% in all cases. Where food self-sufficiency for the type 1 farms approaches 100% on average, the risk of not achieving the threshold becomes dangerously high (100% on average means that in some years, the food self-sufficiency level is below 100%). With current high prices for livestock feed on the market (cowpea haulms, cotton seed cake), stall feeding cows appears to be only marginally more profitable than leaving cows wondering around to free graze whatever they find (Table 3.4.27). This finding comes with the reservation that the extra manure produced with stall feeding was not valued, but also the extra labor needed for stall feeding (and managing the manure etc) was not counted as a cost. For farms with relatively low livestock:land ratio (0.6 for type 3 versus 2.5 for type 1 farms), the strategy to sacrifice some food crop land to produce fodder is promising: a modest area would suffice to feed the cows and excess fodder could be sold at attractive prices. For farms characterized by a high livestock:land ratio (type 1 farms), much larger cropland areas would have to be dedicated to fodder production and this seems not to be profitable.

Further analysis will comprise ex-ante assessments of the likely impact of grain storage and selling during high price period and also the other two farm types will be considered.

# 4. Comparison between AR-intervention sites

The comparison between intervention areas emphasizes commonalities and differences between the case study regions in order to derive common entry points and approaches for sustainable intensification, to enable conclusions on the scalability of measures and to facilitate an exchange of experiences with certain measures between the countries. Ideally, through detailed and repeated surveys within the Africa RISING intervention communities, insights on factors for success and failures of certain measures or development pathways towards sustainable intensification can be revealed. In this chapter we compare findings from Tanzania, Malawi and Ghana.

The comparison first presents features of the whole sample per country and per region, then builds on typical characteristics among the latter and provides an answer to the questions: What do farmers typically do with similar resources in the different AR case study regions e.g. two hectares of land is a typical size for farms in the Upper Eastern region of Ghana as well as in Babati, Tanzania: What are their inputs, how much work do farmers typically invest, what is the result in terms of yields, revenues and addition of organic matter to their soils? Which of the two farms is closer to the goal of sustainable intensification and is there anything the one farm could learn from the other?

## 4.1 Land

Figure 4.1 compares the percentages of farmers in the case study regions in Ghana (Gh), Malawi (Mw) and Tanzania (Tz) disposing of a certain arable land size (in hectares): The chart shows that most of the farmers in the Malawian sites farm on less than 3 hectares of land (59 % between 0-1 hectare and 30 % between 1 and 2 hectares), while most farmers in the Ghanaian intervention communities farm on 2-5 hectares (77%). In the Tanzanian sites the situation seems more diverse, with peaks at 3 (20.5 %) and at 9 hectares (14.5%) of land cultivated per farm.

The AR surveys further revealed that most farmers own the land they cultivate (92% in the Ghanaian sites, 94 % in the Malawian sites and 98 % in the Tanzanian sites) while some rent in land (7.5 % in Malawi, 10 % in Ghana and 18 % in Tanzania) and very few rent out (0 % in Ghana, 1.3 % in Malawi and 2.3 % Tanzania). The result seems to indicate that smallholder farmers in the case study region are rather safe in terms of land rights, that there are opportunities to rent in further land while the need for land is commonly too high or benefits of its cultivation too large to rent out. It has been reported (GFP, 2011) that most of the agricultural land in the Upper West and Upper East of Ghana are in control of lineage and family headmen and that individual rights in appropriated land are quite pronounced, inheritable and secure. It is an interesting feature of local land rights in Northern Ghana that it is typically not allowed to plant trees on land rented in (typically, additional negotiations are necessary) since it is considered that doing so may result in claims of ownership for the land (GFP, 2011). Since only few smallholders rent out land it can be concluded that land 'rented in' must be obtained from a different source e.g. medium or large-scale farmers.

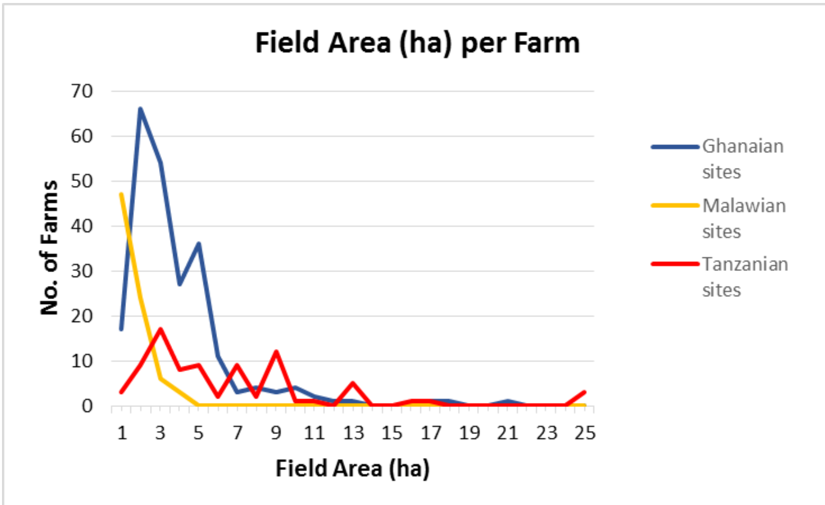



**Figure 4.1.** Field Area (ha) per farm per country.

Comparing the regions in terms of farm sizes (see Figure 4.2), Dedza and Ntcheu in Malawi show similar distributions. In Ghana, the Upper East and Upper West are rather similar, while the Northern Region draws a divergent pattern. In Tanzania, Kongwa & Kiteto evince a strong up-and-down trend in their sample, while the graph of the Babati-sample shows a steadier drop, strikingly similar to the distribution of farms in Upper East and Upper West of Ghana.

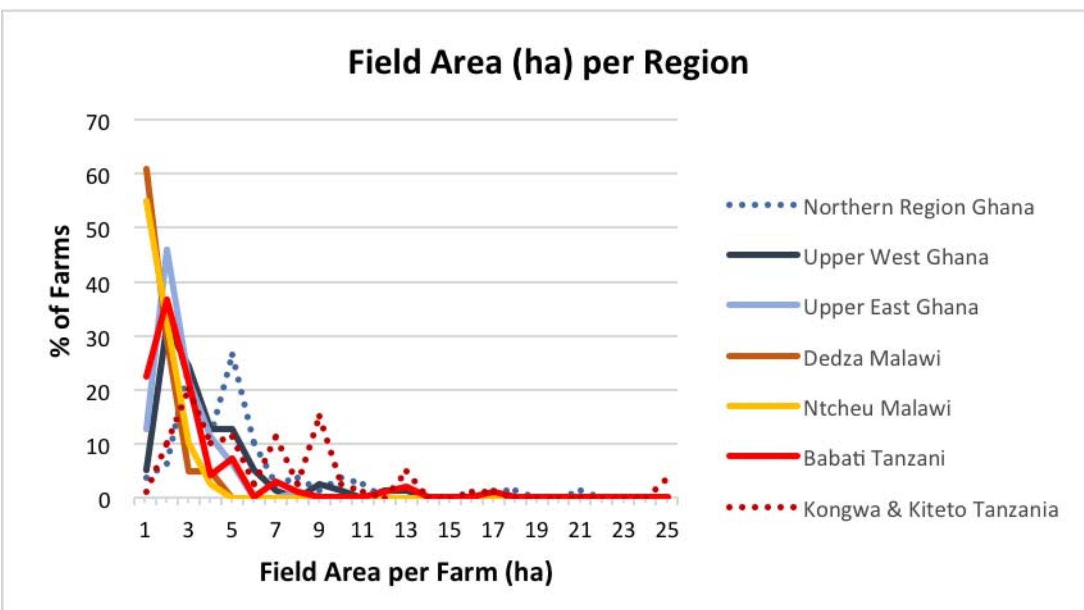



**Figure 4.2.** Field Area per farm per region.

Also in terms of land ownership there is a marked similarity between Upper West and Upper East in Ghana and Babati in Tanzania (see Figure 4.3). A land size of about two hectares seems to evince the greatest common shares among all regions except the Northern Region (Gh) and Kongwa & Kiteto (Tz).

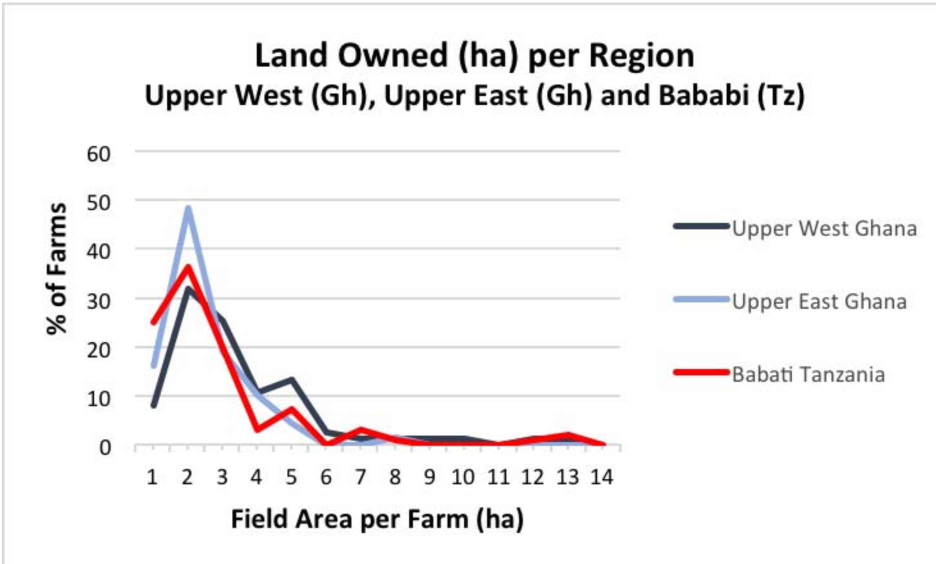



**Figure 4.3.** Land Owned (in ha) in selected regions: Upper West (Gh), Upper East (Gh) and Babati (Tz).

An interesting aspect in the context of land is the relation of labor inputs to field area. As illustrated in Figure 4.4 our samples seem to suggest that the greater the field area the lower the labor inputs per hectare.

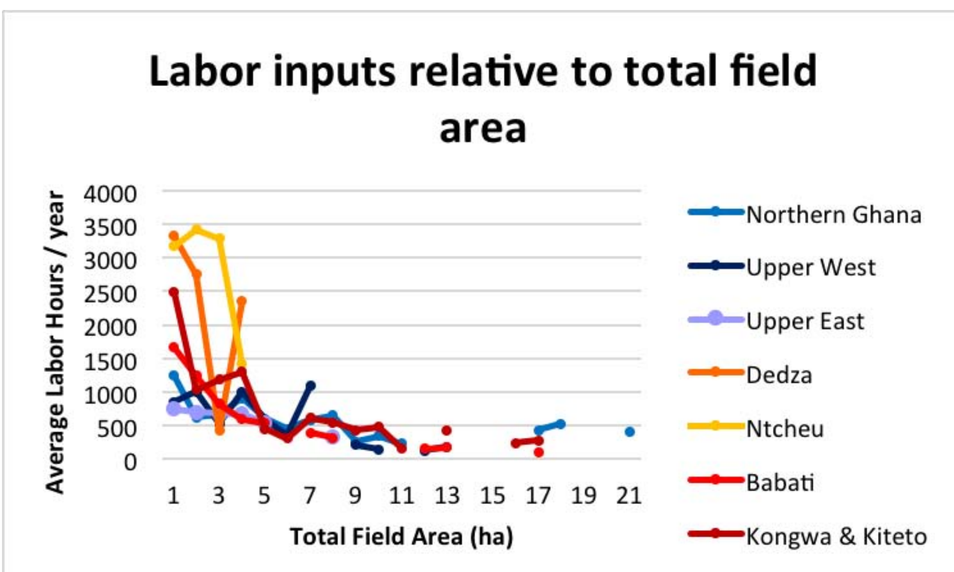


**Figure 4.4.** Average labor inputs in hours per hectare associated to certain farm sizes.

Table 4.1 presents average farm sizes and mean values for labor input for the different regions as well as inputs for farms with areas ranging between 1.5 and 2.5 hectare. The range was chosen since two hectares was determined to be a typical farm size for the Upper West (Gh), Upper East (Gh) and Babati (Tz) and quite common as well for both regions in Malawi. At the same time only few farms are of the exact size, hence the range increased the sample size and balanced inter-regional fluctuations in the distribution of cases around two hectares.

**Table 4.1.** Labor inputs: hours per hectare per year.

| Region | Average farm size in hectares | Average labor inputs per hectare | Average labor inputs per hectare of farms with a field area between 1.5 and 2.5 hectares |
|---|---|---|---|
| Northern Region (Gh) | 5.2 | 637 | 769 (ø 2.2 ha) |
| Upper West (Gh) | 3.1 | 730 | 599 (ø 2.0 ha) |
| Upper East (Gh) | 2.1 | 771 | 695 (ø 2.0 ha) |
| Babati (Tz) | 2.4 | 1097 | 995 (ø 1.9 ha) |
| Kongwa & Kiteto (Tz) | 9.9 | 718 | 988 (ø 2.0 ha) |
| Dedza (Mw) | 1.0 | 2966 | 2054 (ø 1.8 ha) |
| Ntcheu (Mw) | 1.1 | 3175 | 3400 (ø 1.9 ha) |

Concerning labor inputs per hectare (for field sizes between 1.5 and 2.5 hectares) each country seems to evince a different typical level of labor inputs. Beyond the national borders in terms of both labor inputs per hectare and total field area, the Northern Region (Gh) seems to be most similar to Kongwa & Kiteto (Tz).

Figure 4.4 and Table 4.1 simply compared the average labor inputs of farms with a certain field area, although labor requirements do not only differ according to land size, but also according to the cropping pattern and soil fertility. The single subplots (making up the total field area) might furthermore be located in certain distances to the household, requiring longer or shorter walks, eventually allowing the use of certain tools in only one location. Data was not sufficient to further investigate the latter, but for the Ghanaian sites, labor inputs per subplot and crop were available.

It seems intuitive that the greater a coherent land area, the lower the unit efforts and costs for actions that would be needed even if there was just one hectare to cultivate. Data from the Northern Region confirms this hypothesis (see Figure 4.5). The samples from the Upper West (Gh) and Upper East (Gh) show similar distributions while the useful sample size was significantly smaller, hence Northern Ghana was chosen to exemplify the relation.

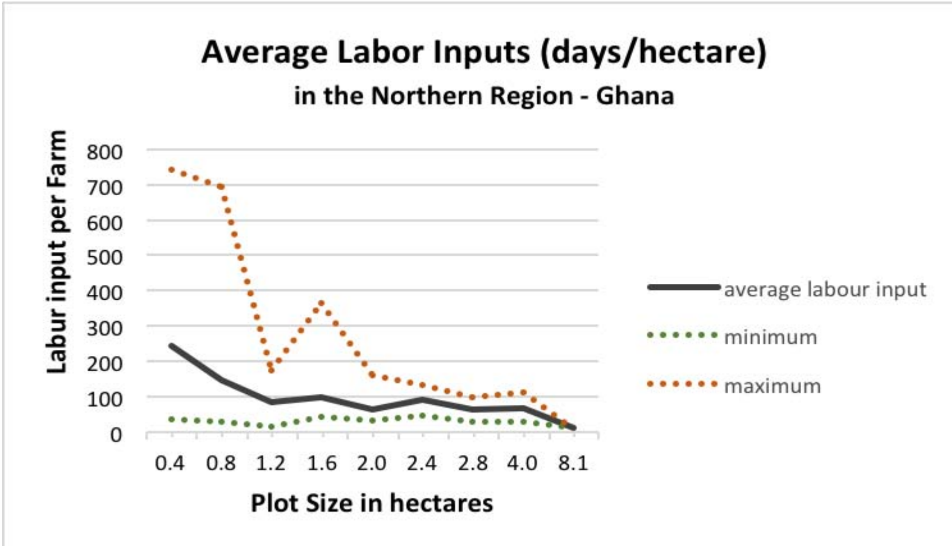



**Figure 4.5.** Average labor inputs per hectare in the Northern Region (Gh).

As mentioned, different crops typically do require different labor inputs. Figure 4.6 illustrates labor inputs per hectare for maize and groundnuts in the Northern Region (Gh). It accounts for the fact that the labor inputs per plot size differ and indeed the resulting distribution suggests that on plot sizes below one hectare, groundnut is more labor intensive than maize, but that this relation is inverted and attenuated for plot sizes above one hectare. Figure 4.6 also contains an indication of the sample size associated to the different plot sizes, revealing that for plots below 1.6 hectare the sample size is 5 to 14 while there are only 2 to 4 samples for the bigger plot sizes. The fact that greater plot sizes are less common may be representative, but the labor inputs for these might not be. The distribution of the sample nevertheless provides important hints on trends and correlations.

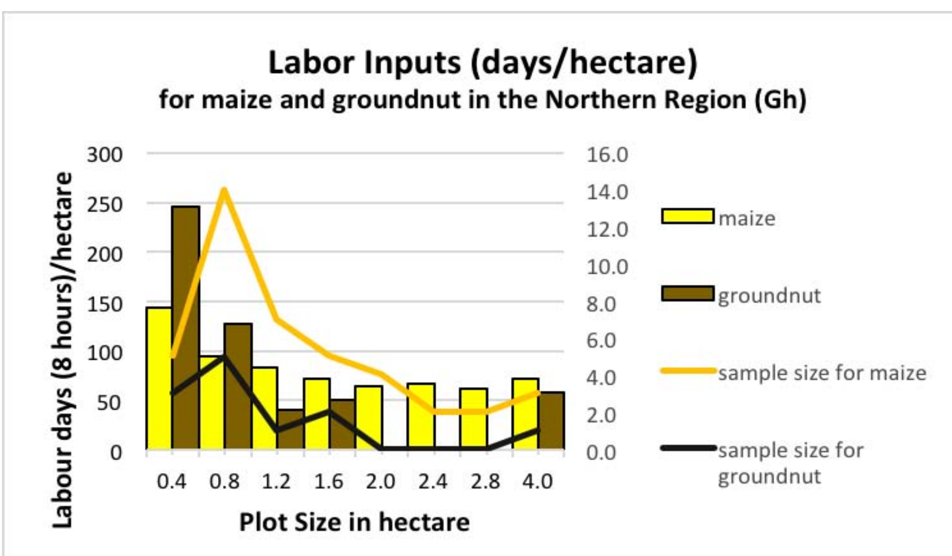


**Figure 4.6.** Average labor inputs per hectare for maize vs. groundnuts in Northern Ghana.
Another parameter associated to the factor land is the soil fertility. Table 4.2 demonstrates typical soil characteristics for all case study regions. While information for the sites in Malawi and Tanzania is available from the detailed characterization, the soil characteristics for the sites in Ghana were taken as specific as possible from literature.

**Table 4.2.** Regional soil characteristics.

| **Region** | **Soil pH** | **Organic matter (%)** | **Total N (%)** | **Available P (mg/kg soil)** |
|---|---|---|---|---|
| Northern Region (Gh) | 4.5-6.7 | 0.6-2.0 | 0.02-0-05 | 2.5-10.0 |
| Upper West (Gh) | 6.0-6.8 | 0.5-1.3 | 0.01-0.07 | 2.0-7.4 |
| Upper East (Gh) | 5.1-6.8 | 1.1-2.5 | 0.06-0.14 | 1.8-14.8 |
| Dedza (Mw) | 5.32 | 3.18 | 0.11 | 6.65 |
| Ntcheu (Mw) | 5.8 | 1.94 | 0.08 | 5.9 |
| Babati (Tz) | 6.35 | 4.03 | 0.26 | 6.64 |
| Kongwa & Kiteto (Tz) | 5.88 | 1.45 | 0.06 | 1.24 |

The organic matter content, total N and available P are relatively high in Babati (Tz) and Dedza (Mw) while it is rather low in the Upper West (Gh), Upper East (Gh) as well as in Kongwa & Kiteto (Tz). Provided that the same crops are grown, it would hence be expected that despite similar average farm sizes, yields would be lower in the Upper West (Gh) and Upper East (Gh) than in Babati (Tz), particularly since the labor inputs are higher for the latter as well. The different crops are however differently responsive to the different soil characteristics, e.g. best yields of groundnuts are achieved in soil with a pH between 6 and 6.4 and a moderate organic matter content, which could explain higher groundnut yields in the Ghanaian sites (see section 4.2).

## 4.2 Crops

Concerning diversification in crop cultivation, the crop count indicates the number of crops grown per farm and has been determined for the all seven case study areas. The distribution of the samples is illustrated in Figure 4.7.

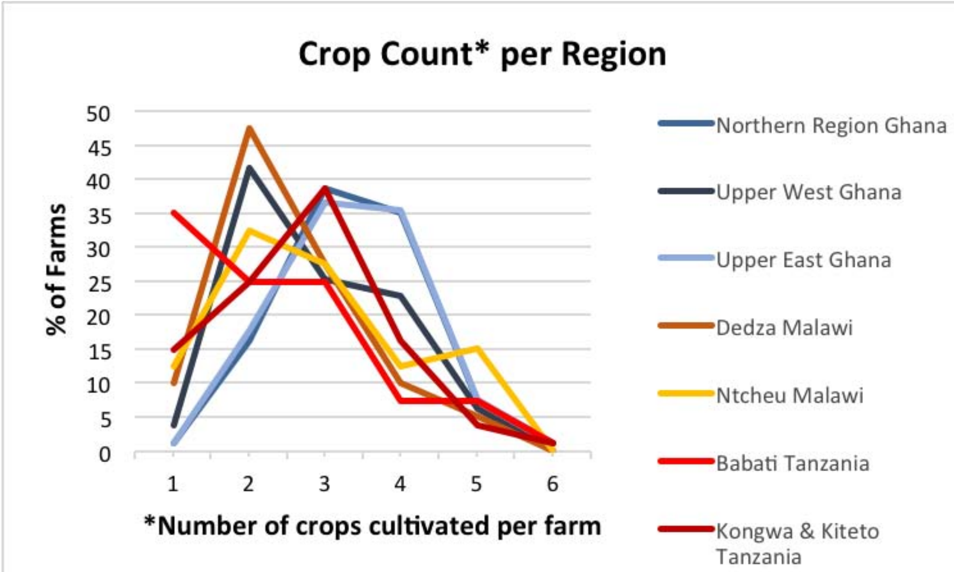



**Figure 4.7.** Crop counts per region.

A basic observation is that apart from Babati (Tz) a maximum of 15 % of the farmers in all regions are only growing one crop. The common maximum is 5 different crops per farm.

The regional averages are rather similar as illustrated by Table 4.3 below, with the Northern Region (Gh) and the Upper East (Gh) as well as the Upper West (Gh) and Ntcheu (Mw) being most similar respectively.

**Table 4.3.** Regional averages for crop counts.

| Region | Northern Region (Gh) | Upper West (Gh) | Upper East (Gh) | Dedza (Mw) | Ntcheu (Mw) | Babati (Tz) | Kongwa & Kiteto (Tz) |
|---|---|---|---|---|---|---|---|
| Average crop count | 3.4 | 2.9 | 3.3 | 2.5 | 2.9 | 2.3 | 2.7 |

The comparison of the region-specific distributions reveals two patterns: One with a peak at 2 crops (embracing the Upper West (Gh) and Ntcheu (Mw)) and another one with a peak at 3 crops (embracing the Northern Region (Gh), the Upper East (Gh) and Kongwa & Kiteto (Tz)). Despite its peak at '1', Babati (Tz) seems to fit into the first pattern.

Among those farms in Babati that only grow one crop, maize was found to be their choice in 94 % of the cases. Maize was found to be the most important crop in almost all regions, followed by a legume: groundnut in the Ghanaian and Malawian sites, while beans are even more common than groundnuts in Dedza (Mw). Pigeon pea, sunflower and sorghum were also found to be important in the AR-sites in Tanzania. The top 5 most common crops per region are listed in Table 4.4 below. A check of typical crop types of farms between 1.5 and 2.5 hectares led to the same results and will hence constitute the basis for the simplified input-output analysis in Farm DESIGN (see section 4.5).

**Table 4.4**. Most common crops per region.

| Rank | Northern Region (Gh) | Upper West (Gh) | Upper East (Gh) | Dedza (Mw) | Ntcheu (Mw) | Babati (Tz) | Kongwa & Kiteto (Tz) |
|---|---|---|---|---|---|---|---|
| 1 | Maize | Maize | G/nut | Maize | Maize | Maize | Maize |
| 2 | G/nut | G/nut | Maize | Bean | G/nut | Pigeon pea | Sunflower |
| 3 | Rice | Cowpea | Millet | G/nut | Bean | Bean | Pigeon Pea |
| 4 | Yam | Millet | Rice | Cowpea | Cowpea | Rice | Millet Sorghum |
| 5 | Soybean | Rice | Cowpea | Soybean Sweet Potato, Tobacco Cotton | Pumpkin | Sunflower Sorghum | G/nut |

Table 4.5 illustrates the average yields for Northern Ghana, Central Malawi and North-Eastern Tanzania. The values are based on averages of the detailed and rapid characterization as well as results of experimental trials encountered in literature.

**Table 4.5.** Average yields for the main crops in the AR-sites in Ghana, Malawi and Tanzania.

| Crop | Ghana | Malawi | Tanzania |
|---|---|---|---|
| Maize | 1074 | 1451 | 1593 |
| Groundnut | 687 | 284 | 563 |
| Bean | | 193 | |
| Cowpea | 628 | 125 | |
| Sunflower | | | 280 |

## 4.3 Livestock

The typical livestock types in all countries are cattle, sheep, goats, chickens, pigs and donkeys. Chickens, due to their affordability and the popularity of their products (eggs and meat) make up the largest number of animals in all three countries, followed by goats in the Ghanaian and

Malawian sites and cattle in the sites in Tanzania. Figure 4.8 illustrates the shares of livestock types in the three countries.

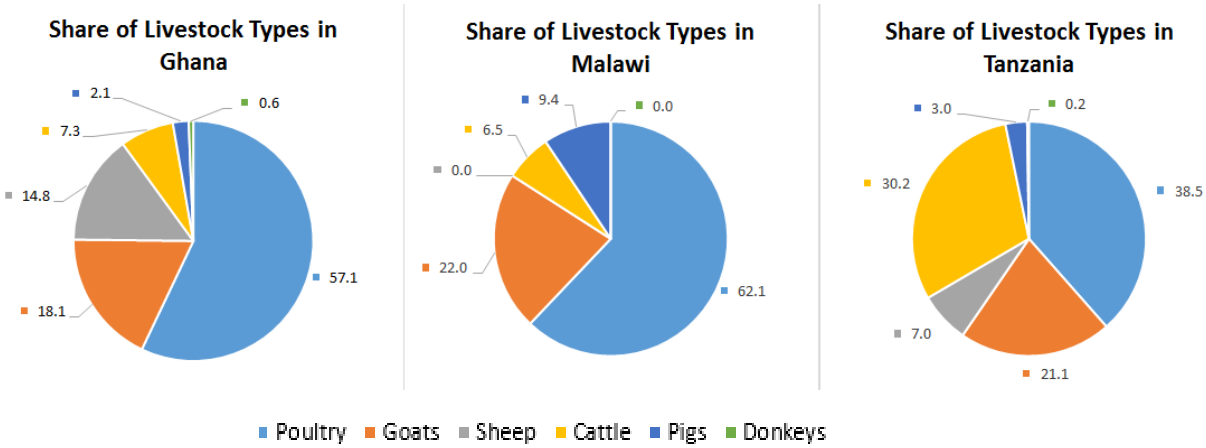



**Figure 4.8.** Share of livestock types in the AR-sites in Ghana, Malawi and Tanzania respectively.

Concerning poultry, more than 90 % of farmers in the AR-sites in Ghana and more than 75 % of farmers in the Tanzanian sites as well as in Ntcheu (Mw) own chickens. Dedza (Mw) is the only region where only 55 % of the farmers own chickens.

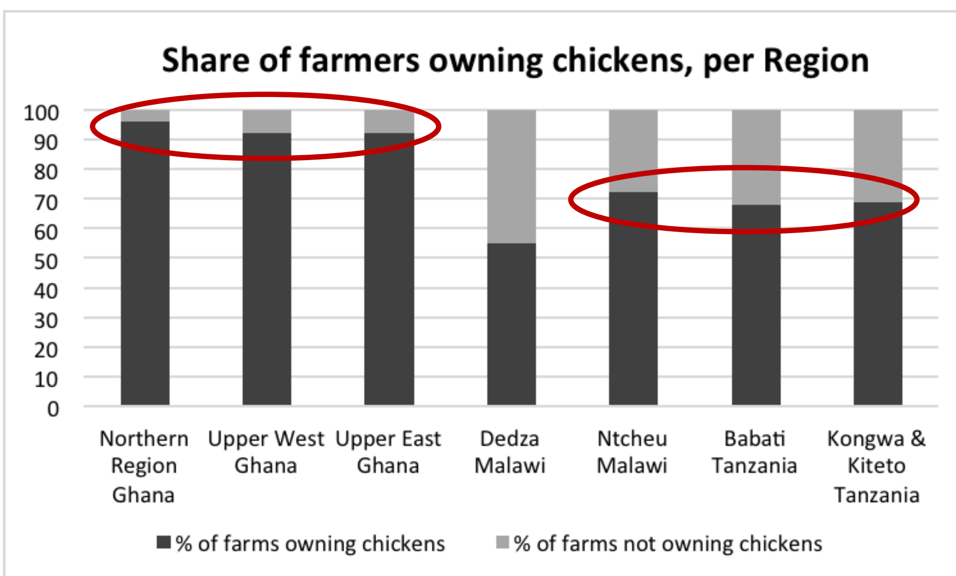



**Figure 4.9.** Percentage (%) of farmers owning chickens, per region.

Concerning goats, as illustrated in Figure 4.10, the proportion of farmers owning goats is significantly lower in the sites in Malawi and Tanzania (43 - 54 %) than in the Ghanaian sites (69 – 86%).

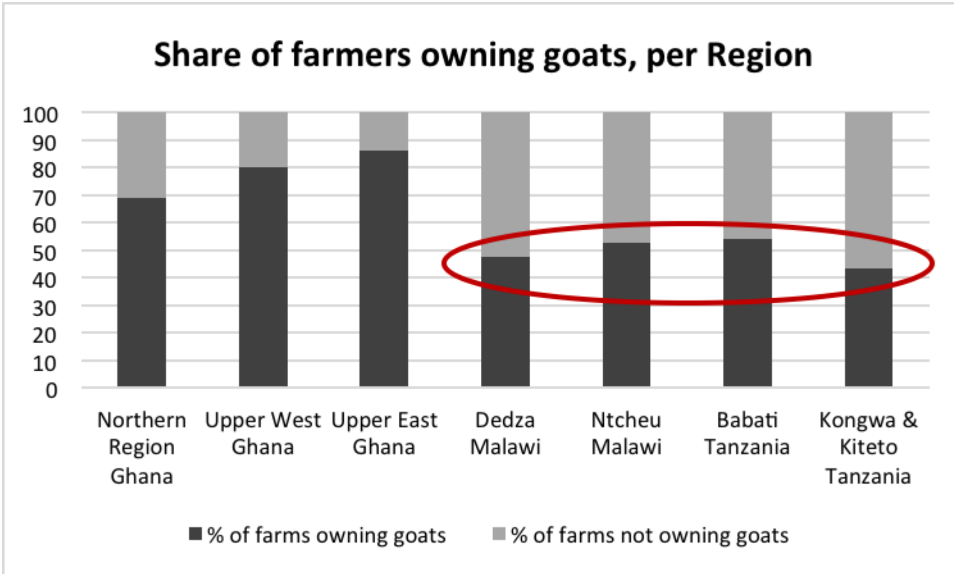



**Figure 4.10.** Percentage of farmers owning goats, per region.

Concerning cattle ownership in the case study regions (Figure 4.11): 60% or more of farmers in the Northern Region (Gh), the Upper West (Gh), Dedza (Mw), Ntcheu (Mw) and Kongwa & Kiteto (Tz) do not own any cattle. The shares of cattle ownership are higher in the Upper East (Gh) as well as in Babati (Tz).

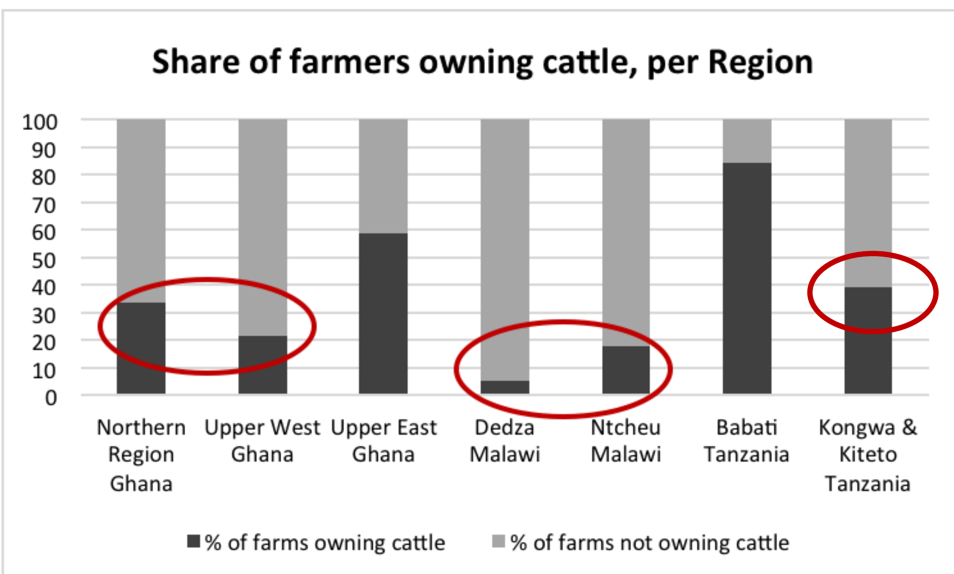



**Figure 4.11.** Percentage of households owning cattle, per region.

Among those farms that own cattle the average number of cattle per region ranges between 0 and 6, as indicated in Table 4.6. In terms of cattle numbers in Dedza (Mw) usually do not own cattle, while in Ntcheu (Mw) farmers own one cow, the Upper West (Gh) owns two cattle, the Upper East (Gh) and the Northern Region (Gh) own 3 cattle, in Babati (Tz) farmers own 5 cattle on average while in Kongwa & Kiteto (Tz) farmers own 6 cattle. There are marked differences between the countries. Table 4.6 provides a brief overview of the average number of animals per farm per region. The colors illustrate the maximum (green) and minimum (red) values.

**Table 4.6**. Average number of animals per household in the different regions.

| Region | Northern Region (Gh) | Upper West (Gh) | Upper East (Gh) | Dedza (Mw) | Ntcheu (Mw) | Babati (Tz) | Kongwa & Kiteto (Tz) |
|---|---|---|---|---|---|---|---|
| Chicken | 30 | 17 | 12 | 6 | 6 | 8 | 9 |
| Goats | 7 | 7 | 5 | 2 | 2 | 5 | 5 |
| Cattle | 3 | 2 | 3 | 0 | 1 | 5 | 6 |
| Sheep | 7 | 4 | 4 | 0 | 0 | 2 | 2 |
| Pigs | 0 | 1 | 1 | 1 | 1 | 0 | 1 |
| Donkeys | 0 | 0 | 1 | 0 | 0 | 0 | 0 |

## 4.4 People and livelihoods

The most important features under the aspect 'people and livelihoods' are the household size and age distribution, revealing the percentage of household members contributing most of the labor to the farm. In addition it is interesting to compare the regional gender shares among household heads as well as the labor ratio, defined as the amount of hired labor as a proportion of total labor input (hired + family labor).

Figure 4.12 illustrates the sample distributions concerning household sizes. The two regions in Malawi are rather similar, but also the Upper West (Gh), Upper East (Gh), Babati (Tz) and Kongwa & Kiteto (Tz). The latter is depicted in Figure 4.13.

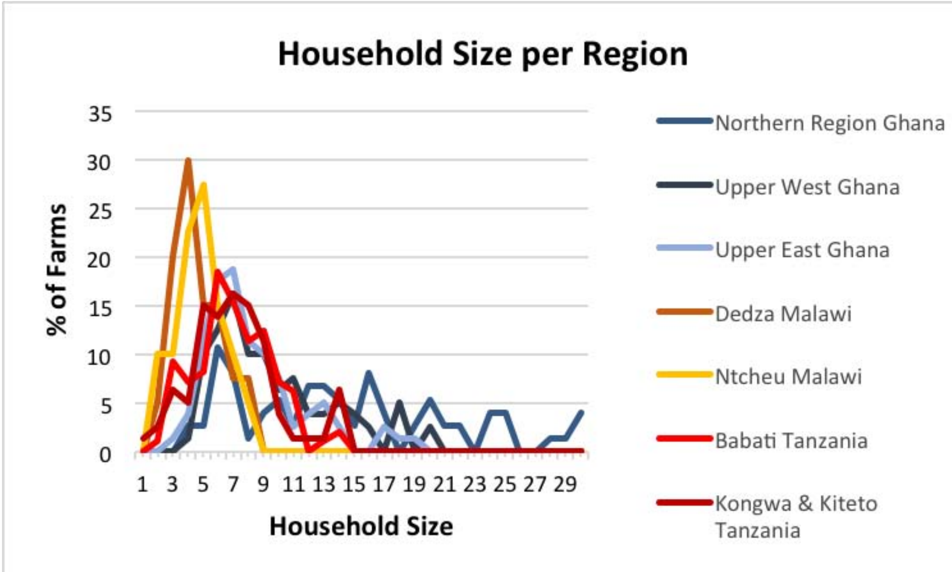



**Figure 4.12.** Household size, per region.

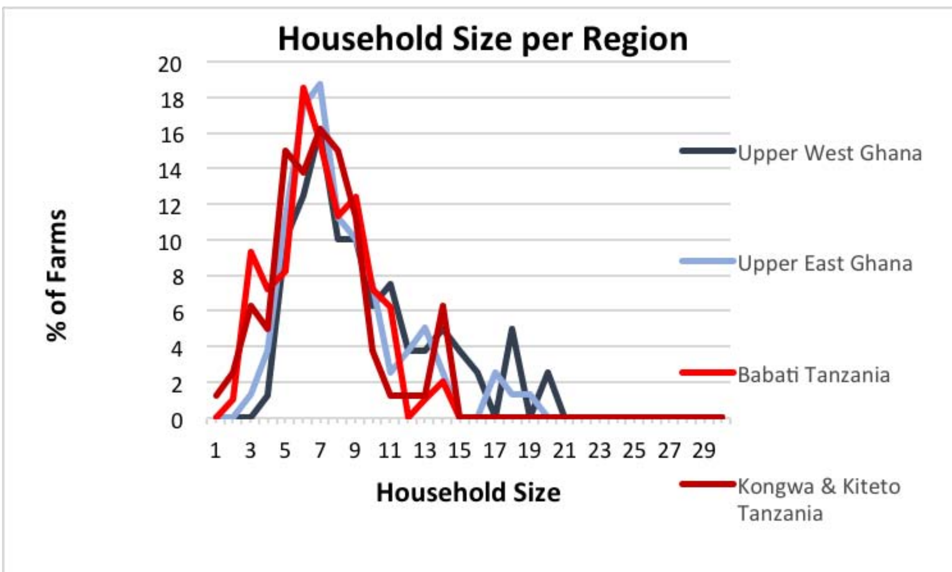



**Figure 4.13.** Household size, in selected regions.

Table 4.7 shows the average household sizes per region. While the averages in the Malawian and the Tanzanian sites are almost identical the regional averages for the AR-sites in Ghana show quite strong differences. The Northern Region (Gh) evinces an average that is almost double as high as the value for the Upper East (Gh). The Upper East (Gh) and the Upper West (Gh) are relatively close to each other, and more similar to Babati (Tz) and Kongwa & Kiteto (Tz) than to the Northern Region (Gh). The proportion of female-headed households was low in Babati (Tz), in the Upper East (Gh) as well as in the Northern Region (Gh), whereas it was highest in the two Malawian intervention sites (Table 7). Both regions of Malawi had an intermediate position with 20-30% of female-headed households. The proportion of hired labor in the total labor input was generally lower than 20%, only in Babati (Tz) this percentage was higher, with 26% of the labor input originated from hired farm workers (Table 4.7).

**Table 4.7.** Average household size, percentage of female and male-headed households, and the proportion of hired labor in the total farm labor input.

| Region | Average household size | Percentage HH heads | | Proportion of hired labor |
|---|---|---|---|---|
| | | Female | Male | |
| Northern Region (Gh) | 15.9 | 5.3 | 94.7 | 0.10 |
| Upper West (Gh) | 9.6 | 14.3 | 85.7 | 0.18 |
| Upper East (Gh) | 8.3 | 3.9 | 96.1 | 0.14 |
| Dedza (Mw) | 4.7 | 20 | 80 | 0.16 |
| Ntcheu (Mw) | 4.8 | 30 | 70 | 0.11 |
| Babati (Tz) | 7.0 | 2 | 98 | 0.26 |
| Kongwa & Kiteto (Tz) | 7.1 | 10 | 90 | 0.16 |

Concerning the age distribution within households, the labor contributions per household member per age group (0-17, 18-35, 36-60 and 60+ years) have been compared for regions in Malawi and Tanzania, drawing a similar pattern (see Figure 4.14): The age group of 36-60 years seems to contribute most of the labor in agriculture possibly because younger family members are working off-farm. In Dedza as well as in Kongwa & Kiteto average labor inputs in age groups 18-60+ years are almost steady.

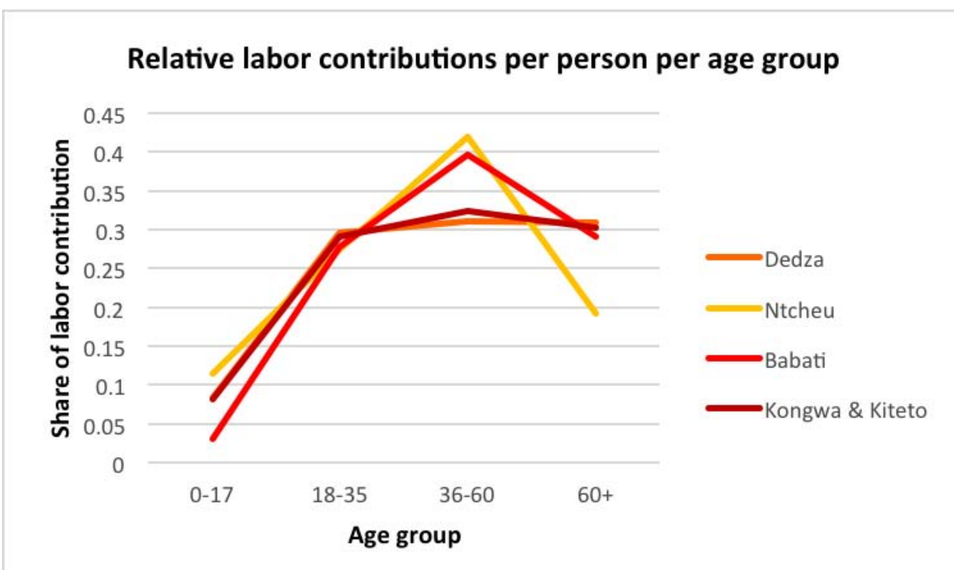



**Figure 4.14**. Relative labor contributions per person per age group.

Based on these findings it seems interesting to focus the comparison of intervention sites on the age group 36-60 years. Figure 4.15 illustrates the age distribution of the regional samples, showing that Kongwa & Kiteto (Tz) as well as Babati (Tz) have about 10 % more family members in the age group 36-60 years than Ntcheu (Mw). Ntcheu (Tz) has a higher share of family members in the age group 0-17 years, with a relative low share of 11% of labor contribution.

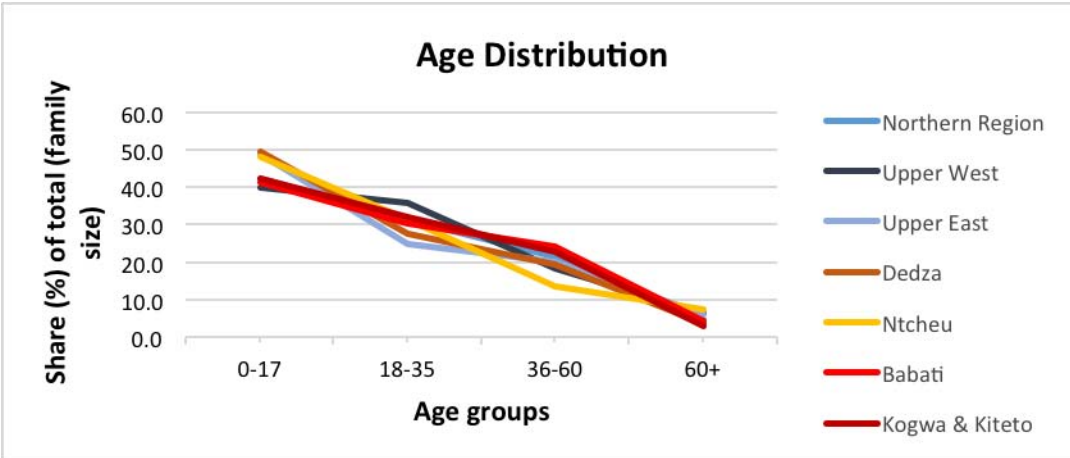



**Figure 4.15.** Age distribution, per region.

In absolute terms, The Ghanaian farms have a larger number of family members, but also a steeper drop in these from one age group to another, so that for the Upper West (Gh) and the Upper East (Gh) values in the age groups 36-60 years are about the same as in the Tanzanian sites (see Figure 4.16).

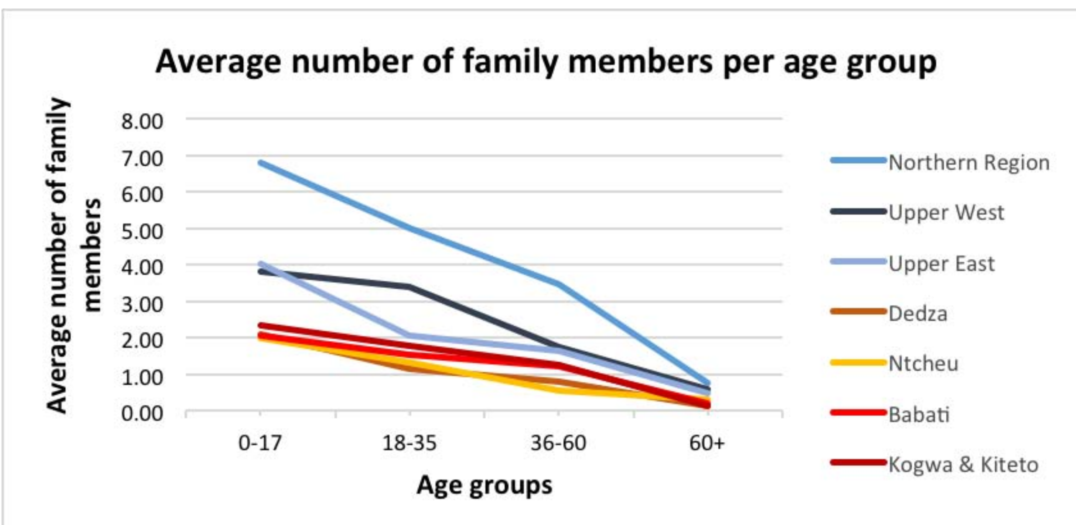



**Figure 4.16.** Average number of family members per age group, per region.

In terms of absolute family labor force the Ghanaian farms in principle have higher labor availability than farms in Malawi and Tanzania. It must be considered though that greater amounts of the farm products will be required to satisfy home consumption as well.

## 4.5 Comparing the balances of typical farms

Based on the information presented in the preceding sections, the following can be stated on commonalities and differences concerning resource allocation between the different regions:

A farm size of two hectares was very common for farms in the Upper East (Gh), Upper West (Gh), Babati (Tz), Dedza (Mw) and Ntcheu (Mw). Comparing farms with an area of that size, we can state that in all regions farmers planted on average 3 crop types, with maize being most commonly cultivated. The second most important crop was groundnut, except in Dedza (Mw) where beans were more common, Babati (Tz) where pigeon pea was more common and in Kongwa & Kiteto (Tz) where growing sunflowers was encountered more frequently. Soil samples revealed regionally different levels of organic matter contents, but also the pH, the nutrient composition, the common fertilizer application and labor inputs influence the yields. Labor inputs per hectare ranged between 600-770 hours per year in the AR-sites in Ghana, 1000 hours in the sites in Tanzania and 2000-3400 hours in the AR-sites in Malawi, all indications for farms with a total size around two hectares. The share of hired labor ranged from 10% (Northern Region, Ntcheu) to 26% (Babati). Labor inputs per animal type are not known. Households were commonly led by men (Table 4.7), with a share of more than 90% in Kongwa & Kiteto (Tz), the Northern Region (Gh) and Babati (Tz). The share of female-headed household heads was highest in the Ntcheu with 30%, followed by Dedza (Mw) with 20 % and the Upper West (Gh) with 14.3 %.

The comparison between the intervention sites revealed strong commonalities, e.g. in land sizes, land ownership, crop counts and types, but also great differences e.g. in terms of family sizes, labor inputs, soil characteristics and animal numbers per region.

In order to further explore the meaning of different farm compositions and management decisions per region, three hypothetical farms have been created based on the average characteristics in those regions that were found most similar in comparison of the AR-intervention sites. The main criteria for selecting the regions (one per country) were a similar land size, similar crop types, crop counts and soil characteristics, thereby fixing central structural features while allowing a diversity of functional (management) characteristics. On this basis the Upper East (Gh), Ntcheu (Mw) and Babati (Tz) have been chosen for the simplified input-output analysis. The final goal of this input-output analysis was to provide a typical balance for regional farms, revealing the economic, social and environmental performance and hence its relative proximity to the goal of sustainable intensification.

While the annual revenues indicate the economic viability of a farming business, the addition of organic matter is used as an indicator for the contribution to soil fertility and hence environmental quality of the farming system. The social dimension is less tangible and mainly important when suggesting structural or functional changes to the farming system that imply modifications in labor requirements and distribution. This chapter does not suggest any changes to the hypothetical farming systems and while a maximum of organic matter and profits seem to be suitable indicators of success, no general judgment can be made on labor ratios and distribution. The use and division of labor is the result of individual family choices and arrangements, cultural norms as well as characteristics of the regional labor market determining price, availability and alternative labor options to farming to the family members. While a farmer's prime goal is to minimize overall labor requirements, the demand for hired labor in a region may be essential to the general socio-economic wellbeing and the functionality of local markets. This chapter therefore does not employ the social dimension for the evaluation of sustainable intensification, but it illustrates current social characteristics such as gender contributions and the labor ratio as typical and important features of the respective systems.

Figure 4.17 to 4.19 illustrate the simplified input-output analysis for an average farm in the Upper East in Ghana, for Ntcheu in Malawi and for Babati in Tanzania.

In order to compare the economic revenues per farm in the three different countries the profits are compared in terms of their purchase power parity. Instead of using global concepts like the international Dollar or the Big Mac Index, the purchase power in Ghana, Malawi and Tanzania can be compared by the amount of maize the profits would buy. Maize is the main staple crop in all three countries and is directly related to expenses and diets of most households. Table 4.8 illustrates the conversion factors as well as the results per country.

**Table 4.8.** Maize Purchase Power of the average farms in the Upper East (Gh), Ntcheu (Mw) and Babati (Tz).

| | **Profit in Local currency** | **USD rate** | **USD** | **Maize price** | | **Maize purchase power (conversion of profit to maize kg)** | |
|---|---|---|---|---|---|---|---|
| Mw | 262,377 | 0.0024 | 630 | 150 | MWK/kg | **1749** | http://www.fao.org/giews/countrybrief/country.jsp?code=MWI |
| | | | | 0.4 | USD/kg | **1574** | http://www.foodsecurityportal.org/api/countries/maize |
| Gh | 729 | 0.39 | 284 | 0.45 | GHc/kg | **1620** | http://mofa.gov.gh/site/?page_id=11395 |
| Tz | 3,805,265 | 0.0006129 | 2332 | 500 | USD/ton | **4664** | http://www.ratin.net/index.php/tanzania |
| | | | | 0.4 | USD/kg | **5831** | http://www.foodsecurityportal.org/api/countries/maize |

Sources of information listed in the last column.

Table 4.8 would imply that the Tanzanian farm generates highest profits in absolute terms and also terms of maize purchase power. The Tanzanian farm is particularly profitable due to the high milk yields (as indicated during surveys in Babati) and the high number of cattle. Despite the higher profits in USD, the Ghanaian farm has a higher maize purchase power than the

Malawian farm (if maize sells at 50 MKW/kg, as determined during surveys in Ntcheu). Assuming a higher maize price (150 MKW/kg) the profit rises and maize purchase power of the farm in Ntcheu (Mw) rises above the one of the farm in the Upper East (Gh). It must be considered that from the profits different average family sizes have to be supported: In the Upper East (Gh) farming households have on average 8.3 family members, in Ntcheu (Mw) there are on average 4.8 family members and in Babati (Tz) farms evince average family sizes of 7. Per person, the maize profits hence amount to 195 kg per person per year in the Upper East (Gh), 292 kg per person in Ntcheu (Mw) and 714.3 kg per person in Babati (Tz). The ranking would hence result in Tanzania having the best performing farm, followed by Malawi and Ghana. The Farm DESIGN figures (entries) can be adjusted and updated and could potentially be used to monitor the average performance and reactions to changes of market prices and climate in time (impacting the yields) of farms in all case study regions.

Comparing the additions of organic matter, the farm in Malawi has the highest inputs (609 kg/ha/year), followed by the Tanzanian farm (561 kg/ha/year) and the Ghanaian one (501 kg/ha/year). Comparing the inputs to the general amounts of soil organic matter in the different regions (see also Table 4.2) Babati has a considerably higher organic matter content (4.03%) in soils than farms in Ntcheu (1.94 %) or farms in the Upper East (1.1 – 2.5%). It must be noted that the overall soil organic matter balance also depends on the decomposition rate of organic matter in the soil, but the balance entails complex calculations with higher uncertainties than the determination of organic matter added, hence only the latter is used for the comparison of AR-intervention sites.

Based on the maize purchase power and the additions of organic matter, the farm in Tanzania shows a better performance than the farm in Malawi, while the farm in Malawi in turn performs better than the farm in Ghana.

**Figure 4.17.** Simplified input-output analysis for an average farm in the Upper East on Ghana.

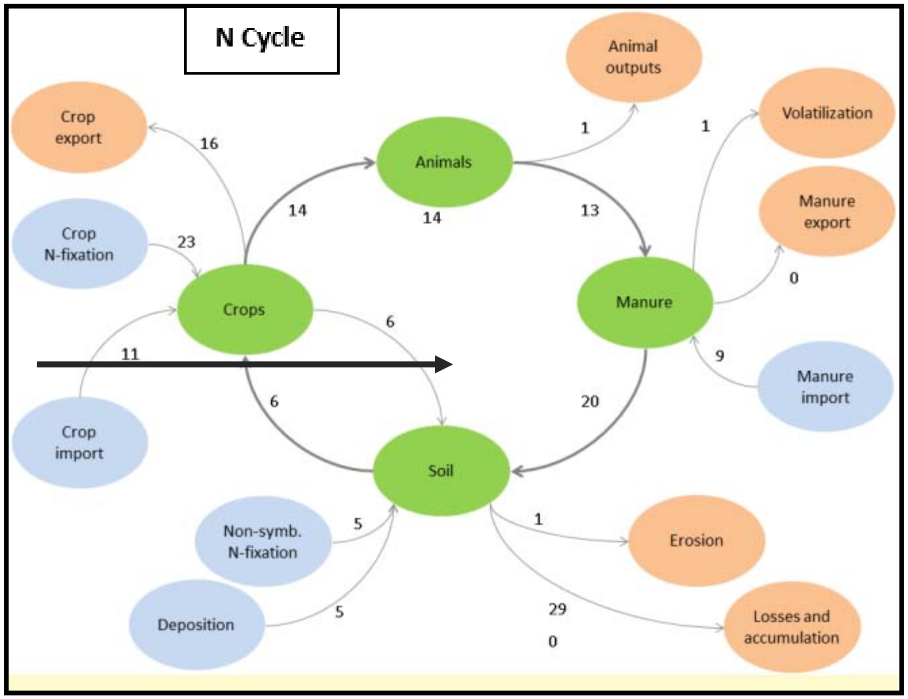
**Inputs**

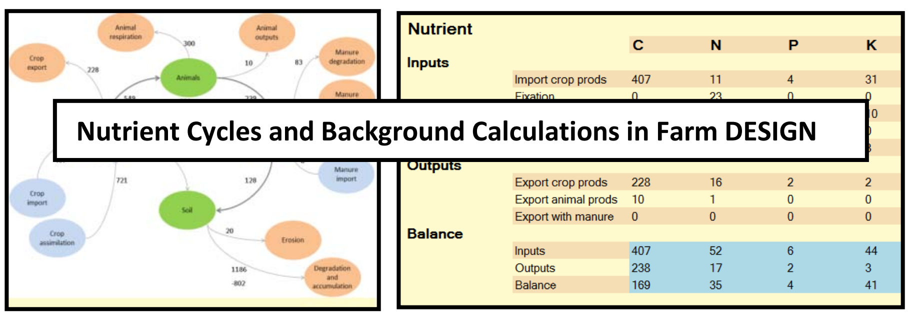
**Organic Matter added: 501 kg/ha/yr**

**Total labor: 1533 hours/yr**

**Family labor**: **1320 hours/yr**

**Share of hired labor**: **14 %**




| Nutrient | | C | N | P | K |
|---|---|---|---|---|---|
| Inputs | Import crop prods | 407 | 11 | 4 | 31 |
| | Fixation | 0 | 23 | 0 | 0 |
| Outputs | Export crop prods | 228 | 16 | 2 | 2 |
| | Export animal prods | 10 | 1 | 0 | 0 |
| | Export with manure | 0 | 0 | 0 | 0 |
| Balance | Inputs | 407 | 52 | 6 | 44 |
| | Outputs | 238 | 17 | 2 | 3 |
| | Balance | 169 | 35 | 4 | 41 |

**Outputs**

**Profit: 918 GHS/yr**
**Maize Purchase Power: 1620 kg**

**Maize Yield: 640 kg/ha**

**G/nut Yield: 454 kg/ha**

**Cowpea Yield: 448 kg/ha**

**List of structural characteristics:**
Field area: **2.1 hectare**
Crops: **Maize, G/nut, Cowpea**
Cattle: **3** (beef, 100 % home)
Goats: **5** (meat, 70 % market)
Sheep: **4** (meat, 65 % market)
Chicken: **12** (meat, 43 % market; eggs, 30 % market)
Fertilizer: **NPK 15-15-15** 1 bag/ha
**Sulphate of Ammonia**

**Figure 4.18.** Simplified input-output analysis for an average farm in Ntcheu in Malawi.

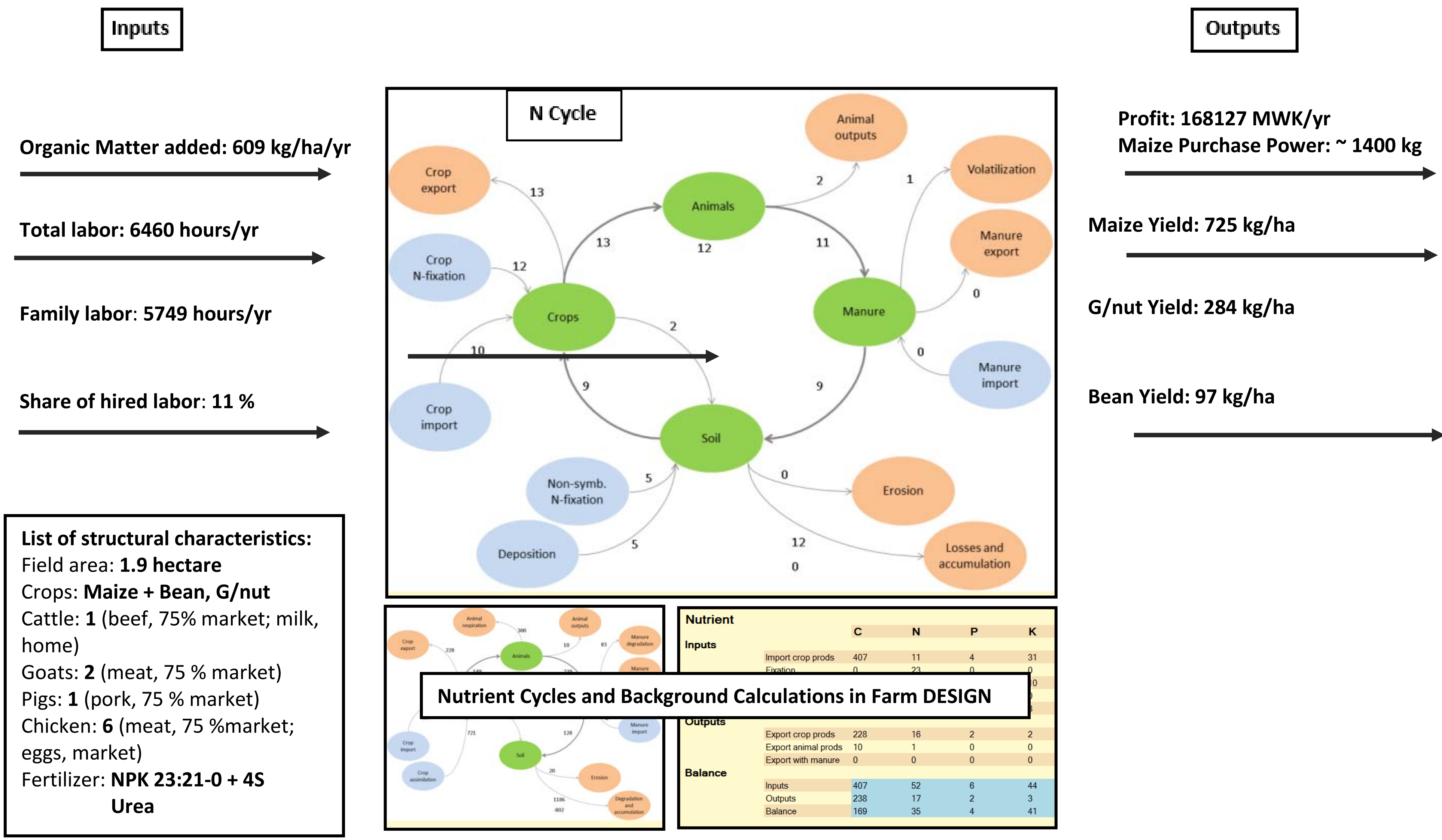


**Figure 4.19.** Simplified input-output analysis for an average farm in Babati in Tanzania.

**Inputs**

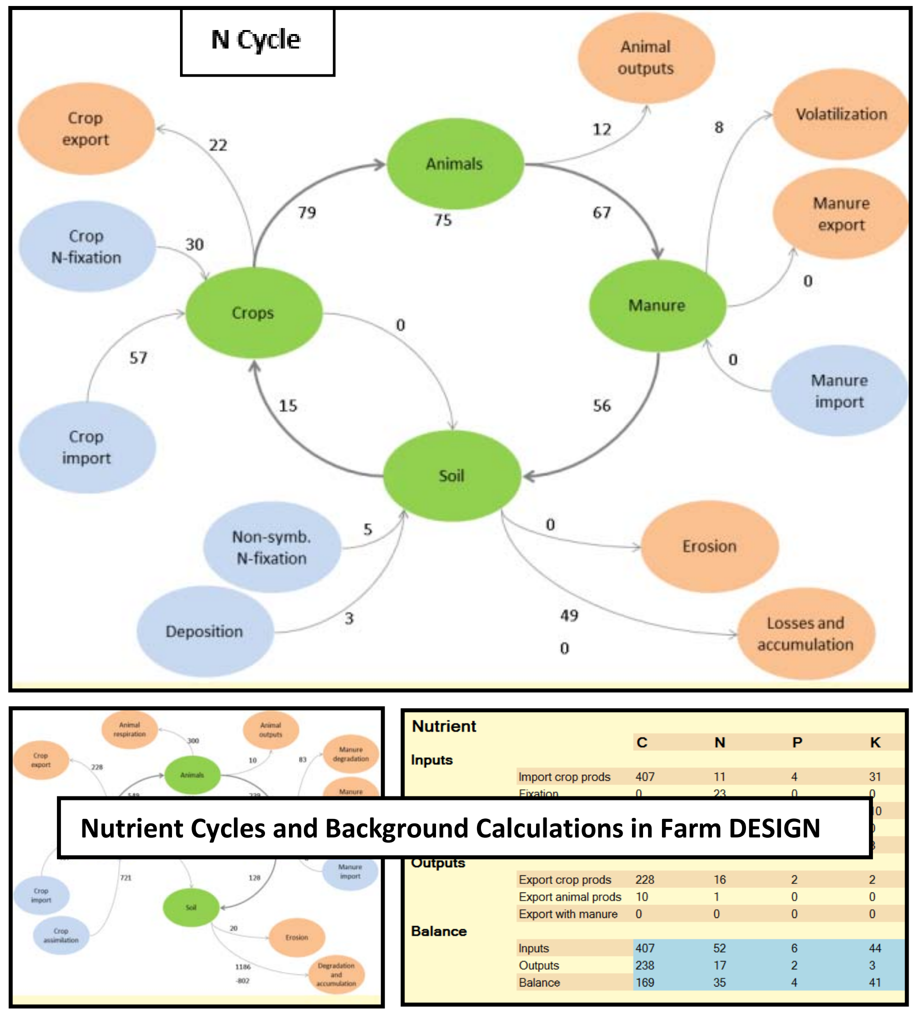
**Organic Matter added: 561 kg/ha/yr**

**Total labor: 1873 hours/yr**

**Family labor: 1386 hours/yr**

**Share of hired labor: 26 %**

**List of structural characteristics:**
Field area: **1.9 hectare**
Crops: **Maize + Pigeon Pea**
Cattle: **5** (beef, 50 % market; milk, 80% home)
Goats: **5** (meat, 60 % market)
Sheep: **2** (meat, home)
Chicken: **8** (meat, home; eggs, 33% market)




**Outputs**

**Profit: 3,805,265 TZS/yr**
**Maize Purchase Power: ~5000 kg**

**Maize Yield: 800 kg/ha**

**Pigeon Pea Yield: 250 kg/ha**

# 5. Explorations

The model-based explorations have been performed for three farms selected from the detailed characterization interviews in Malawi and Tanzania and for three farms selected from the data received from Ghana. The results from these explorations are presented in this chapter. These results give a realistic indication of the potential of the model to explore trade-offs and to identify entry points.

## 5.1 Introduction

The explorations all used three objectives, namely to maximize farm operating profit, to maximize the organic matter added to the soil and to minimize the farm labor balance. The results are visually represented in Figures 5.1, 5.2 and 5.3 below.

The explorations have been performed for three farms from each country's detailed characterization survey. For each country the three farms were chosen based on their resource endowment to include a low, medium and highly resource endowed farmer. In Tanzania two farms were chosen from Babati and one from Kongwa and Kiteto, in Malawi, one from Dedza and two from Ntcheu and in Ghana the three farms were from the administrative Northern Region. These farms were selected from the typology based on the detailed characterization but configured in the model using raw data from the rapid characterization. The farms from Ghana that were chosen represent the three different farm types: Low Resource Endowed (LRE – Type 2), Medium Resource Endowed (MRE – Type 3) and High Resource Endowed (HRE – Type 4).

A number of different decision variables were used; crop areas, animal numbers, animal production and crop residue destination were allocated upper and lower limits specific to each farm. Taking into consideration the dreams and desires of the farmers, new crop and animal types, and their respective products, were included in the model. Constraints were set on the feeding of the animals such that the model did not under or over feed the current and/or future animals, and on the areas of the fields, such that it was not possible for the model to allocate more land than that which was available.

The exploration and discussion of the results from the exploration will be presented in 3 separate sub chapters for each county.

## 5.2 Tanzania

The current situation as well as the exploration options for each farm are described briefly in Tables 5.1.

**Table 5.1.** The current situation and the exploration options for the three selected farms in Tanzania.

| | **Chitego 13 HRE** | **Seloto 16 MRE** | **Sabilo 14 LRE** |
|---|---|---|---|
| **Current Situation** | | | |
| District | Kongwa | Babati | Babati |
| Farm area (ha) | 8.0 | 2.6 | 1.8 |
| Crops currently grown | Maize, Sunflower & Pigeon peas | Maize, Bean, Pigeon peas & Sorghum | Maize, Bean, Pigeon peas, Sunflower & Sorghum |
| Animals currently owned | 20 Cows<br>10 Goats<br>8 Chickens | 2 Cows<br>6 Bulls<br>2 Goats<br>2 Sheep<br>15 Chickens | 1 Improved Cow<br>5 Local Cows<br>5 Local Bulls<br>15 Goats<br>3 Sheep<br>3 Donkeys<br>10 Chickens |
| Operating Profit (Tsh/year) | -652 363 | 485 365 | 596 906 |
| Organic Matter added (kg/ha/year) | 497 | 567 | 907 |
| Labor balance (hours/year) | 0 | 0 | 0 |
| **Exploration** | | | |
| No. of decision variables | 19 | 18 | 22 |
| Crop Exploration | Future crop: Hybrid maize, residue allocation | No new crops, residue allocation | No new crops, residue allocation |
| Animal Exploration | Animal numbers from zero to double current level, animal production | Animal numbers from zero to double current level | Animal numbers from zero to double current level |

‘Chitego 13’ (HRE), the only farm from Kongwa and Kiteto, is an extensive farm, with the largest area (8 ha) of the three farms. They have the most cattle with the smallest number of crops. They also own an infertile field of about 2 ha which they use as a pasture. They have to allocate many crop residues to animals and thus also have the lowest amount of organic matter added, 497 kg/ha/year. They also have the lowest operating profit and in fact are making a loss.

‘Sabilo 14’ (LRE), from Babati district, is the smallest farm yet has the greatest diversity in animals and crops, they make the most profit (almost 600 000 Tsh) and add the most organic matter (907 kg/ha/year) to their farms as a result of the animal products that they sell and the manure from the animals that they keep.

‘Seloto 16’ (MRE), also from Babati district, is a medium farm with an intermediate area and diversity of crops and animals. The operating profit and organic matter added are also intermediate between the other two farms.

The three sets of coloured points in each sub graph in Figures 5.1 represent the Pareto optimum solution points that have been generated by Farm DESIGN’s exploration. The three sets of points have been generated separately in three different runs of the model, but are plotted here on one set of axes to examine their positions relative to each other, and relative to their initial starting positions, their current situations indicated by red points.

The current situation of the farms as shown by the red points enables us to initially compare the position of the original farm configuration relative to the generated alternatives. In Figure 5.1 ‘Chitego 13’ (green) and ‘Seloto 16’ (dark red) have a much higher operating profit than ‘Sabilo 14’ (rich yellow) and ‘Chitego 13’ has the greatest amount of organic matter added. They all have exactly the same labor balance.

In Figure 5.1, the green points representing ’Chitego 13’, the HRE farm, exhibits the greatest jump in operating profits as can be seen in sub graphs 1 and 3. However not all solutions are equally favorable in terms of labor as can be seen in sub graphs 2 and 3. This great jump in operating profits can be seen when we examine a point in the top right hand point of this cloud of alternative Pareto optimal solutions. Here the operating profit is 2 549 013 Tsh/year that is 3 201 376 Tsh per year more than the current situation. This point also has the greatest organic matter added at 675 kg/ha/year, a 178 kg/ha/year improvement from the current situation. At this point the farm has twice as many goats, seven extra chickens and one extra cow, plants almost all the land about 7 ha to hybrid maize which yields well and provides returns, the remaining land is allocated to sunflowers and a small portion is pigeon peas. The tradeoff of this jump in profits is the fact that the farmer would have to hire in extra labor or else work longer hours. If we consider sub graph 3 and examine a second point at equal labor requirement to the current situation in the cloud of green points, we see that such a point at equal labor requirement provides 2 246 568 Tsh/year (2 898 931 Tsh/year more) while only having a drop in organic matter added of 20 kg/ha/year to 65 kg/ha/year. At this point similarly to the first point, almost all land is planted to hybrid maize with about 1 ha planted  to sunflowers and a small part to pigeon peas. There are no extra cows, only three extra goats and half as many chickens as in the current situation. In order for the farm to move in a trajectory towards the first point mentioned, the second point could be seen as a stepping stone towards this goal.

When we examine the dark red cloud of the MRE farm, 'Seloto 16' it is apparent that the jump in operating profit is not as large as 'Chitego 13' (green), but the options to increase organic matter are greater. An improvement of 323 kg/ha/year as compared the increase from 'Chitego 13' of 178 kg/ha/year. At a point of maximum operating profit in the upper right hand corner of the cloud of dark red points in sub graph 1, more residues are allocated to the soil, yet cattle numbers remain constant, whereas goat sheep and chicken numbers are slightly increased. As 'Seloto 16' only has a small area of land as compared to 'Chitego 13', the potential for increasing profit through planting hybrid maize is limited. All potential solutions have reduced labor balances thus in this regard there is no relevant trade off with labor, as there was in 'Chitego 13'. The vertical spread of dark red points is less than the green points in sub graph 2.

Examining the rich yellow points of 'Sabilo 14' (LRE), it is apparent that there is also a large jump in amounts of organic matter added, slightly larger than for 'Seloto 16'. What is different in this cloud is that not all solutions increase operating profit, and that there is a frontier of points that demonstrate a trade-off between operating profit and organic matter. If we compare a point in the cloud from 'Sabilo 14' where operating profit is highest at 1 554 859 Tsh/year, there is an increase of 263 kg/ha/year of organic matter added. When compared to a point in the most right side of the cloud where profit is at 1 067 666 Tsh/year , there is a much larger increase in organic matter added, 1240 kg/ha/year, an increase of 333 kg/ha/year from the current situation. At this second point animal numbers have not been increased as much as in the first point and areas planted to crops are similar, but residues allocated to the soil are greater. Both points have reduced labor requirements.

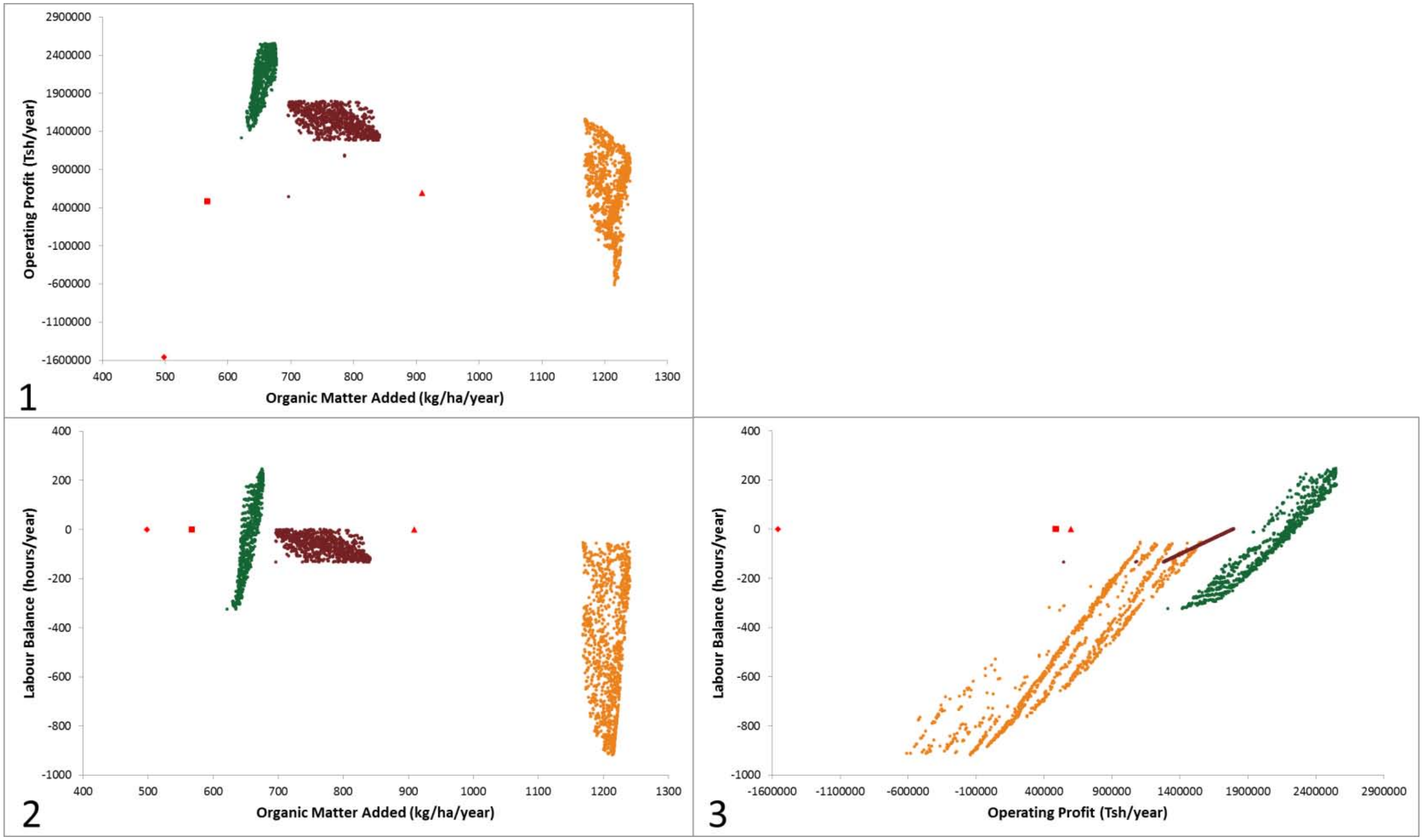



Figure 5.1: Pareto optimum solutions for the exploration of the farms 'Chitego 13', 'Seloto 16'and 'Sabilo 14' in Tanzania using three objectives. The red symbols indicate the performance of the original farm configuration; ♦'Chitego 13', ■ 'Seloto 16' and ▲ 'Sabilo 14'. The other symbols represent the performance of Pareto-optimal alternatives of each farm; • 'Chitego 13', • 'Seloto 16' and • 'Sabilo 14'.

## 5.3 Malawi

The current situation as well as the exploration options for each farm is described briefly in Tables 5.2.

**Table 5.2.** The current situation and the exploration options for the three selected farms in Central Malawi.

| | **Amosi 9 LRE** | **Mbidzi 7 MRE** | **Dauka 6 HRE** |
|---|---|---|---|
| **Current Situation** | | | |
| District - EPA | Ntcheu - Nsipe | Dedza –Linthipe | Ntcheu - Kandeu |
| Farm area (ha) | 0.4 | 0.8 | 1.8 |
| Crops currently grown | Maize, Pumpkin | Maize, Bean, Groundnut | Maize, Pumpkin, Groundnut, Tobacco |
| Animals currently owned | 3 Goats<br>2 Pigs<br>5 Chickens | 20 Chickens | 8 Cattle<br>3 Goats<br>4 Pigs<br>28 Doves<br>3 Chickens |
| Operating Profit (Mk/year) | -4 273 | 204 806 | 356 580 |
| Organic Matter added (kg/ha/year) | 726 | 737 | 1074 |
| Labor balance (hours/year) | 0 | 25 | 2 986 |
| **Exploration** | | | |
| No. of decision variables | 16 | 13 | 14 |
| Crop Exploration | Future crop: Groundnut, residue allocation | Future crops: Tobacco, residue allocation | no new crops, residue allocation |

| | Amosi 9 LRE | Mbidzi 7 MRE | Dauka 6 HRE |
|---|---|---|---|
| Animal Exploration | Future production, Animal numbers from zero to double current level | Future local cows and pigs, Animal numbers from zero to double current level | Improved production, Animal numbers from zero to double current level |

'Amosi 9', from Ntcheu district is a single mother who is constrained by her energy and time in her farming activities. The farm is the smallest of the three, and she grows the least variety of crops. In fact she sometimes is not able to harvest all the pumpkins and last season left them in the field to rot. She does focus on the livestock activities, but is still in the process of intensifying this aspect. She is not very resource endowed, but is very determined to succeed. Because she does not sell any animal products she is currently making a loss, but does subsidize her income with purchasing and reselling vegetables like tomatoes.

'Dauka 6', also from Ntcheu district, are a wealthy farm by their own admission. They have the widest range of crop and animal types, have the additional income and cash flow to purchase hybrid maize seed and fertilizers. They are the only farm of the three to grow a nonfood crop for cash. They do not qualify for subsidized fertilizer, but even with these added costs make the greatest profits. They have cattle for manure production and as they graze their cattle on communal grasslands they can allocate crop residues to the soil. This gives them the greatest amount of organic matter added to the soil. They are constrained by the fact that their fields are far from their house, and transport of manure from the homestead to the fields is expensive. They are adopters of new technologies, and desire to be modern farmers.

'Mbidzi 7', the only farm from the Dedza district, is a medium farm focused mainly on crop production. Legumes are intercropped and sold to provide cash, as are chicken eggs and meat. The operating profit and amount of organic matter added is intermediate between the other two farms. She desires to grow tobacco as she would like the extra cash, but is constrained by her small farm area. She would also like to own larger livestock like pigs or cattle, but does not have the cash flow to set up such an enterprise. She works on other farms with her daughter to be paid in legume seeds thus has very low cultivation costs.

The three sets of colored points in each sub graph in Figures 5.2 represent the Pareto optimum solution points that have been generated by Farm DESIGN's exploration. The three sets of points have been generated separately in three different runs of the model, but are plotted here on one set of axes to examine their positions relative to each other, and relative to their initial starting positions, their current situations indicated by red points.

The current situation of the farms as shown by the red points enables us to initially compare the relative position of the original farm configuration relative to the generated alternatives. In

Figure 5.2, when compared to the other two farms, farm 'Dauka 6' (green) has the greatest profit, the highest labor balance and the greatest amount of organic matter added. 'Amosi 9' (dark red) has the least operating profit and least organic matter added.

In Figure 5.2 for the farm 'Dauka 6' (green) there seems considerable scope to improve the operating profit. There is the greatest increase in profit from the current situation. If we examine a point on the upper right hand side of the green cloud in sub graph 1, then we can see that there is an improvement of 1 328 524 Mk/year to 1 685 101 Mk/year. The organic matter added at this point is 1506 kg/ha/year which is almost 1 000 kg/ha/year more than the original situation. The animal numbers have all doubled which would account for the greater profit and increased manure production, however in order to keep these animals the labor requirement have also doubled from 2 986 hours/year to 5 854 hours/year at this point. The crop allocation favours groundnut (0.9ha) over tobacco (0.01 ha) and maize and pumpkin (0.7 ha). If we examine the green points in sub graph 2, and examine a point that uses an equal amount or slightly less labor on the right hand side of the green cloud, we see that the operating profit drops by about 44 000 Mk/year. At this point all variables are similar to the first point but the number of goats is reduced 1 goat. This seems to indicate that keeping additional goats results in large increases in labor required. The groups of green points that can clearly be seen in sub graphs 1 and 3 are solutions with similar variables however with increasing numbers of cows.

The rich yellow points of 'Mbidzi 7' have not moved as far from their current situation in terms of profit and organic matter added as the points for 'Dauka 6'. Looking at a point where profit is at a maximum at the the top of the yellow cloud in sub graph 1, we can see that profit at this point is 680 770 representing an increase of 475 964 Mk/year, much less than the increase in 'Dauka 6' of 1 328 524 Mk/year. This farm does not have as many options as 'Dauka 6' in terms of animal numbers. They are restricted by the amount of forage they can provide their animals from a much smaller area of land. Nonetheless, at the point of maximum profit, they have a cow and 5 pigs which are responsible for the jump in profit. Maize and Bean intercrop is given preference over groundnuts, and almost all the area is planted to the maize intercrop. With regards the labor requirement of 'Mbidzi '7 farm, it is apparent in sub graphs 2 and 3 that very few of the points present options with less labor. In fact the first point explained above has the greatest increase of labor required. In sub graph 3 there are a few yellow points that increase profit, decrease labor and also increase organic matter added. Examining these points more closely we see that the only animal type present on the farm are an increased amount of chickens, and that much more land is allocated to groundnut (0.6 ha) than maize and bean (0.2ha). This point could possibly represent an intermediate point to which the farm could move towards.

The dark red points of the farm 'Amosi 9' show the greatest increases to organic matter out of all the three farms presented in Figure 5.2. In sub graph 1 looking at the point on the most right hand side of the red cloud, the organic matter added has increased by 664 kg/ha/year to 1 390 kg/ha/year. At this point the numbers of chickens and pigs have increased, whereas the number of goats has remained constant. At this point the farm makes a profit of 774 425 which is a great improvement from their current situation where they are making a loss. As labor is already a restrictive factor for this farm we could examine a point in sub graph 3 that has equal or less labor to the current situation. At such a point operating profit is 745 009 Mk/year and organic matter added is improved by 402 kg/ha/year to 1139 kg/ha/year. The animal numbers again are all increased except for goats which have decreased. The wide range of organic matter added could be a result of the small farm area such that small changes to allocation of residues to animal feed or to the soil result in larger changes in organic matter added when worked out on a per hectare basis.

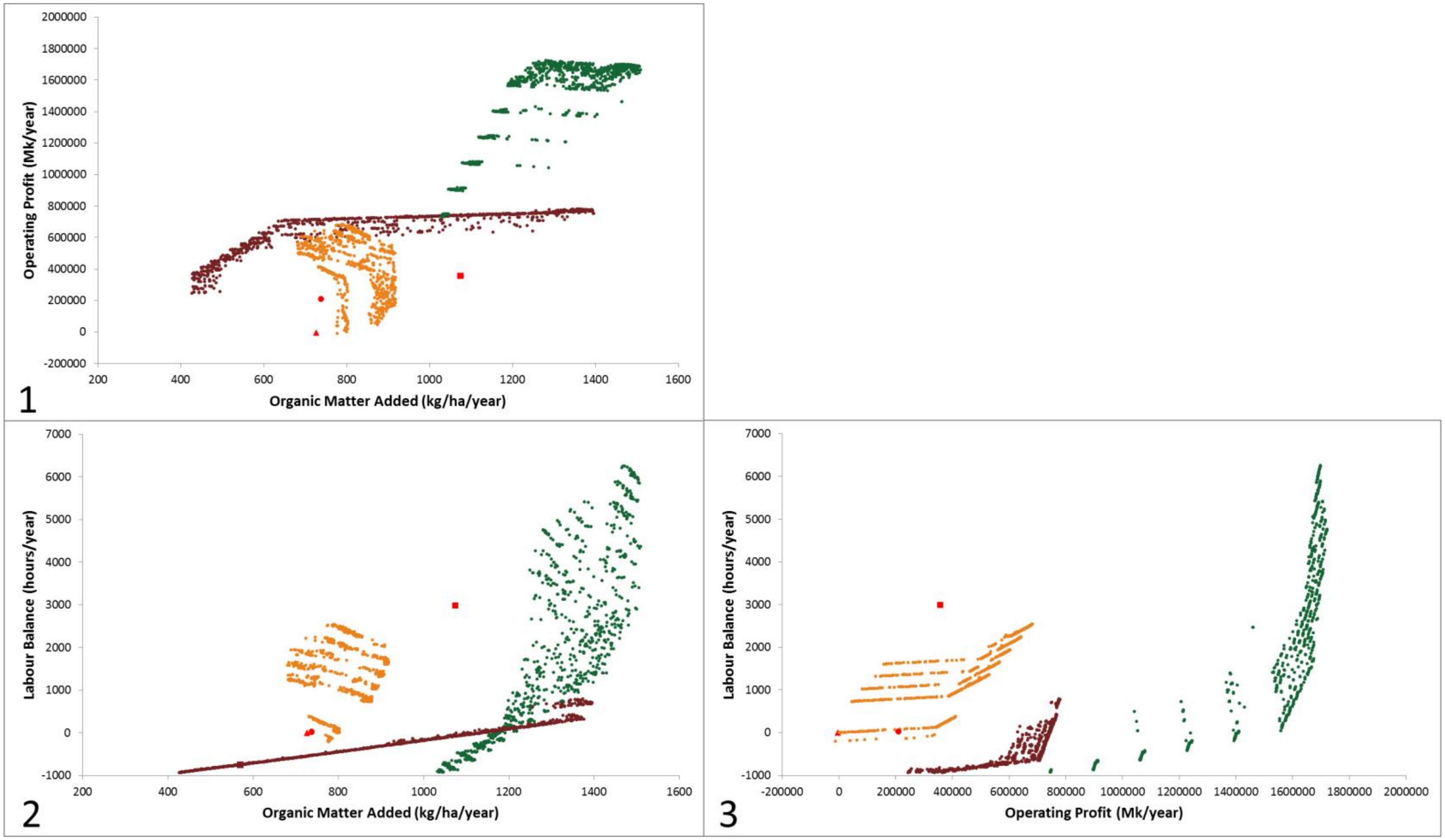



Figure 5.2: Pareto optimum solutions for the exploration of the farms 'Amosi 9', 'Dauka 6'and 'Mbidzi 7' in central Malawi using three objectives. The red symbols indicate the performance of the original farm configuration; ▲'Amosi 9', ■ 'Dauka 6' and ● 'Mbidzi 7'. The other symbols represent the performance of Pareto-optimal alternatives of each farm; • 'Amosi 9', • 'Dauka 6' and • 'Mbidzi 7'.

## 5.3 Ghana

The current situation as well as the exploration options for each farm are described briefly in Tables 5.3.

**Table 5.3.** The current situation and the exploration options for three selected farms in Ghana's Northern region.

| | **N Ghana 40 LRE** | **N Ghana 36 MRE** | **N Ghana 12 HRE** |
|---|---|---|---|
| **Current Situation** | | | |
| Farm area (ha) | 2.0 | 3.6 | 4.0 |
| Crops currently grown | Maize, Rice, Groundnuts | Maize, Cowpea, Yam, Soybeans | Maize, Cassava, Yam, Rice |
| Animals currently owned | 6 Goats<br>36 Chickens | 6 Goats<br>5 Sheep<br>12 Chickens<br>15 Guinea fowls | 11 Cattle<br>10 Sheep<br>7 Goats<br>30 Chickens |
| Operating Profit (GHC/year) | 1212 | 3689 | 2880 |
| Organic Matter added (kg/ha/year) | 631 | 490 | 522 |
| Labor balance (hours/year) | 0 | 0 | 0 |
| **Exploration** | | | |
| No. of decision variables | 10 | 14 | 19 |
| Crop Exploration | No new crops, residue allocation | No new crops, residue allocation | No new crops, residue allocation |
| Animal Exploration | Animal numbers increased | Animal numbers from zero to double current level | Animal numbers increased |

‘N Ghana 40’ is classified as a low resource endowed farm. This type of farm is well represented in the Northern region of Ghana (21.25 % of all farms are similarly classified). ‘N Ghana 40’ is distinguished by the smallest household size of 6 people and smallest arable land size of 2 ha relative to the other selected farms. Furthermore, ‘N Ghana 40’ is also considered to be asset-poor in terms of material property and livestock. Indeed, only two types of livestock are reared on this farm, namely goats and chickens. The variety of crops cultivated is limited to maize, rice and groundnuts; a portion of which is sold while the remainder is earmarked for household consumption. Most members of this farm type sell their labor to supplement meagre farm income and in this case too, off farm work contributes more to income than on farm work does. ‘N Ghana 36’ is a medium resource endowed farm. Statistically, it represents the largest farm type in Ghana’s Northern region (47.5 %). The mean TLU for this farm type is 4.1, and thus the chosen farm ‘N Ghana 36’ seems fairly typical in this regard, exhibiting a variety of smaller animals including goats, sheep, chicken and guinea fowls. With a household size of 10 individuals and a land area of 3.6 ha, this farm occupies an intermediate position between the two other selected farms. In terms of crop choices, this farm is the only one to include two legumes in the current cropping season, namely cowpea and soybean. Partly due to the high market value of the legumes, a portion of which are sold along with animal products, this farm exhibits the highest operating profit of the three.

‘N Ghana 12’ is considered to be a high resource endowed farm. This type of farm is in the minority in Ghana’s Northern region, making up 20% of total farm types. Characteristic for such farms are large household sizes as well as arable land areas. In the case of ‘N Ghana 12’, the household comprises 30 people while land available for arable farming is 4 ha, making it the largest farm of the sample. Furthermore, livestock numbers are substantially higher on these farms and indeed, with a TLU of 9.7, ‘N Ghana 12’ owns more livestock than the other two farms, and perhaps more importantly, are the only farm out of the three with a cattle herd. Crops are cultivated on both bush and compound plots and include maize, cassava, yam and rice. However, this farm exhibited poor yields and limited sale of animal products which may account for the low operating profit relative to available resources.

The three sets of colored points in each sub graph in Figures 5.3 represent the Pareto optimum solution points that have been generated by Farm DESIGN’s exploration. The three sets of points have been generated separately in three different runs of the model, but are plotted here on one set of axes to examine their positions relative to each other, and relative to their initial starting positions, their current situations indicated by red points.

The current situation of the farms as shown by the red points enables us to initially compare the relative position of the original farm configuration relative to the generated alternatives. In Figure 5.3 ‘N Ghana 36’ (rich yellow) has the highest operating profit yet it has the least organic matter added whereas ‘N Ghana 40’ (dark red) has the lowest operating profit but the highest amount of organic matter added. All three farms have the same labor balance.

In Figure 5.3 we note that for the farm 'N Ghana 12' (green points), most solutions further reduce the labor hours of the farmer, increase soil organic matter and positively affect the operating profit of the farm. The vast cloud of alternative options is a result of the high number of decision variables set prior to model exploration, and thus the solution space offers ample room for choice. We observe that the point of maximum organic matter added represents a 63 % increase relative to the current level. In fact, most generated options increase soil organic matter. In terms of labor, it is noticeable that only a small portion of options marginally increase the labor balance, with the rest of the points reducing labor hours to considerable levels. The current operating profit is 2880 GHC/year. This relatively low figure is due to the fact that the farmer has not included high value legume crops in this season's cropping cycle and the income generated from sales of animal products is limited. Despite this, the point of maximum operating profit in the solution space is almost double that of the initial value (83%) and again, most solutions increase the farmer's profits. If we examine the point of maximum operating profit more closely, we see that there is a marginal tradeoff in terms of organic matter added which decreases by 27 kg/ha/year and labor which increases by 5 hours/year. These changes are driven by adjustments made to the farm configuration that include increasing the total cropping area by 0.4 ha and re-allocating it to two crops (maize and cassava) as opposed to the original four crops and fallow land in place before. This has decreased the diversity of the farm but on the other hand, crop returns are boosted by 48%.

Examining the solution space of the farm 'N Ghana 36' (rich yellow points) we observe, firstly, that all points vastly improve the labor balance, thus freeing up time for the farmer and his family and saving on costs for hired labor. Furthermore, with the current operating profit standing at 3689 GHC/year, we note from the graph that the solutions generated present an array of options that both increase and decrease the operating profit even further. The range of values span from 3172 GHC/year to 4686 GHC/year. At its highest point, operating profit is raised by 27 %. Finally, great scope for improvement and opportunity lies in the soil, with the solutions for increasing the amount of organic matter added peaking at 855 kg/ha/year which represents a 74 % increase from the current state. Closer inspection of a point at the outer edge of the yellow cloud in subgraph 1 reveals that the rise in profits is driven by a re-allocation of arable land to crops that generate the most returns, i.e. those with the highest market value, which in this case are soybean and cowpea. Farm income is further boosted by reduced dependence on external fertilizers and sales from live birds, in particular guinea fowls and chickens, whose numbers have increased. We also see that the re-allocation of resources favors returning a portion of all crop residues to the soil as green manure, thus explaining the higher levels of organic matter added. Finally, the drastic decrease in ruminant herd size accounts for the steep drop in labor hours, which decrease as animals numbers are reduced.

Looking at 'N Ghana 40' (dark red points) we see relatively fewer options for improvement to the current farm configuration, as the solution space is constrained by the lower number of decision variables set prior to model exploration. In its original state, 'N Ghana 40' exhibits the highest level of soil organic matter added out of the three farms, due to large percentage of crop residues being returned to the soil as green manure. From the graphs, we observe that the generated solutions do not offer much in the way of boosting this figure, with alternatives either decreasing or increasing the current level. At its highest point, the amount of organic matter added to the soil is increased by 14%. This is offset, however, by a corresponding drop in operating profit to a minimum level of 184 GHC/year while burdening the farmer with maximum labor hours, making such a solution socio-economically unsustainable. In terms of the labor balance, the graphs show that the direction of change is similarly flexible, with options potentially decreasing the balance or increasing it by around 130 hours/year respectively. At its maximum level, operating profit has increased by 50%. The drivers behind higher profits can be revealed by examining a point on the right hand side of the dark red solution space in subgraph 3. Here we see a farm configuration where animal numbers and returns from animal product sales remain the same, but the total crop area of the farm has decreased by 0.1 ha, accompanied by a slight decrease in labor hours. Despite this smaller farm size, we observe an increase in profits by 41 %, which seems to be due to higher crop margins caused by a re-allocation of cultivated crops that favors profitable groundnuts over maize and rice.

## 5.4 Conclusions

The model-based exploration generated new insights into the possible trajectories that farmers would take towards sustainably intensification. However the alternative situations do not yet include the entry points that we have presented. Intensification using hybrid seeds for instance, can be argued to not really be sustainable if the farmers are always reliant on purchasing seed from a multinational seed company every year and are thus less autonomous. The exploration data that is generated by FarmDESIGN should thus be complemented by the analysis of the entry points as covered in chapter three. Potential points in the alternatives between the end objective and the current situation could map out a set of land use changes and animal number dynamics that could be seen as stepping stones towards sustainable intensification. In order for these farmers to move through this trajectory towards these improved alternatives, using the entry points presented, they would need to have the resources, management skills and extension support to execute these land use changes. Their dreams and desires need to be considered and their willingness to adopt these changes needs to be discussed with the farmers. The participation of the farmers is crucial to this process of sustainable intensification.

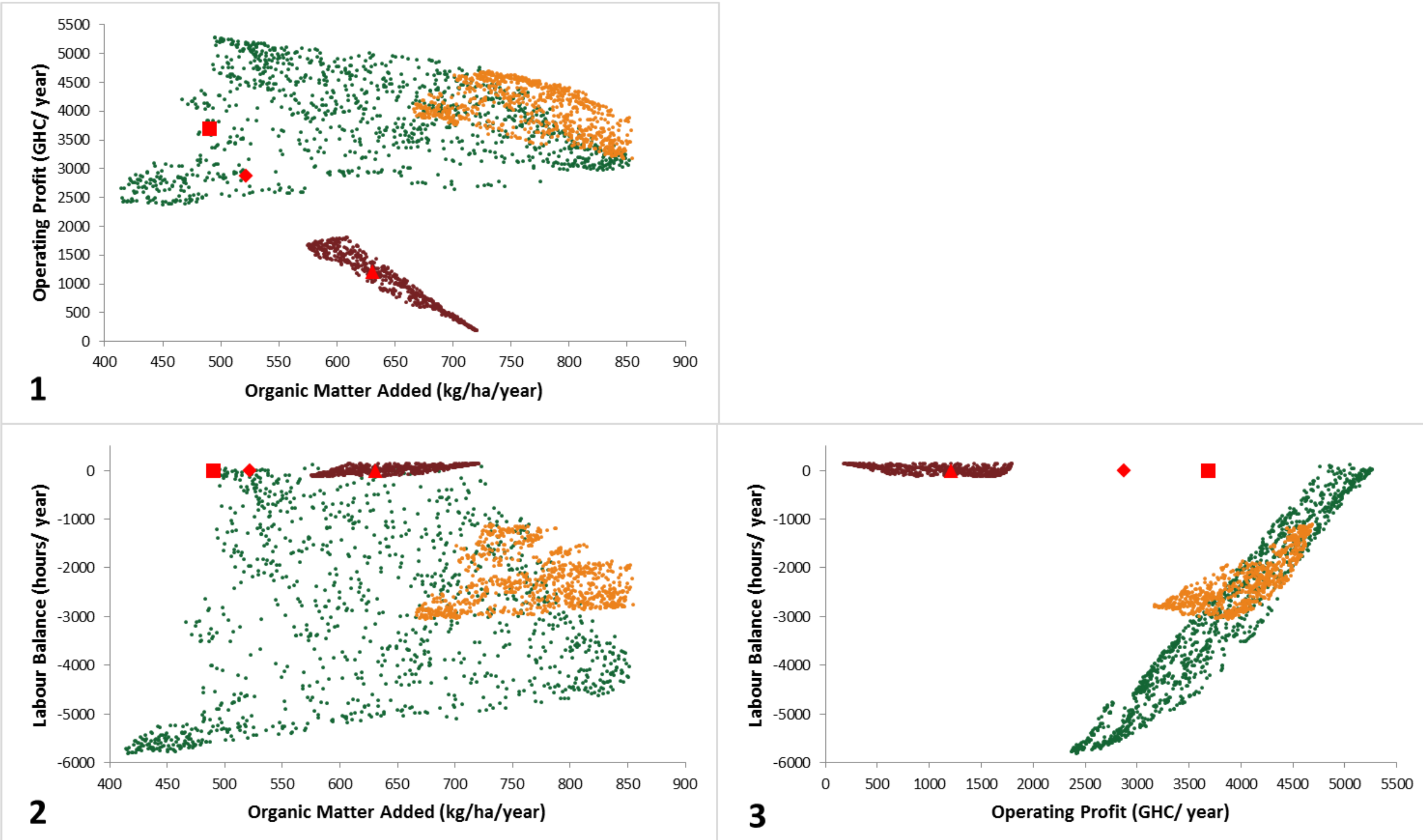



Figure 5.3: Pareto optimum solutions for the exploration of three selected farms in Northern Ghana using three objectives. The red symbols indicate the performance of the original farm configuration; ▲ 'N Ghana 40', ■ 'N Ghana 36' and ♦ 'N Ghana 12'. The other symbols represent the performance of generated Pareto-optimal alternatives for each farm ● 'N Ghana 40', ● 'N Ghana 36' and ● 'N Ghana 12'.

# References


Abdulai, A., Crolerees, A., 2001. Determinants of income diversification amongst rural households in Southern Mali. Food Policy, 26: 437–452.

Adjei-Nsiah, S., 2012. Role of Pigeonpea Cultivation on Soil Fertility and Farming System Sustainability in Ghana. International Journal of Agronomy Volume 2012, Article ID 702506.

Africa RISING Technical Report, 2013. Sustainable intensification of key farming systems in East and Southern Africa. Available online: http://www.cgspace.cgiar.org/handle/10568/32857 (Date of last access 08.12.2013).

Agyare, W.A., Kombok, J.M., Karbo, N. and Larbi, A., 2002. Management of pigeon pea in short fallows for crop-livestock production systems in the Guinea savanna zone of northern Ghana. Agroforestry Systems, 54: 197-202.

Ahwoi, K., 2010. Government's Role in Attracting Viable Agricultural Investments Experiences from Ghana. Paper presented at The World Bank Annual Bank Conference on Land Policy and Administration, Washington, DC April 26 and 27, 2010.

Alhassan, G.A., Kalu, B.A. and Egbe, O.M., 2012. Influence of planting densities on the performance of intercropped bambara groundnut with cowpea in Makurdi, Benue state, Nigeria. Special Issue: Development and Sustainability in Africa – Part 1. International Journal of Development and Sustainability, 1(3): 860-879.

Andersen, E., Elbersen, B., Godeschalk, F. and Verhoog, D., 2007. Farm management indicators and farm typologies as a basis for assessments in a changing policy environment. Journal of environmental management, 82: 353-362.

Ayantunde, A.A., S. Fernandez-Rivera, and A. Dan-Gomma. 2008. Sheep Fattening with Groundnut Haulms and Millet Bran in the West African Sahel. Rev. Elev. Med. Vet. Pays Trop. 61(3-4): 215–220.

Ba, A. 2011. Exploitation du cheptel bovin dans la zone cotonnière au Mali-Sud. PhD SupAgro Montp.: 170p.

Bonye, S.Z. and Kpieta, R.A., 2012. Women, Ownership and Access to Land in the Upper East Region of Ghana. International Journal of Humanities and Social Science 2(9) Available online at: http://www.ijhssnet.com/journals/Vol_2_No_9_May_2012/7.pdf (Date of last access: 05.12.2013).

Brand, G., 2011. Towards increased adoption of grain legumes among Malawian farmers – Exploring opportunities and constraints through detailed farm characterization. Unpublished MSc thesis Plant Production Systems & Sustainable Development. Universiteit Utrecht, Wageningen UR.

Bridges, E.M., 1997. World soils, 3rd Edition. Cambridge University Press, Cambridge, UK.

Beaudouin, M., 2005. Diagnostic agraire en zone cotonnière malienne : Bougouni , terres d ’accueil à préserver. 184 pp.

Damaliphetsa, A.M., Kaunda, E.K.W., Makwenda, B.S.J. & Chilongo, T., 2007. Policy Analysis on Agriculture in Relation to Rural Livelihood Improvement. Available online at: http://41.87.6.35:8080/xmlui/handle/123456789/272 (Date of last access: 18.12.13).

Dapaah, H.K., Asafu-Ahyei, J.N., Emin S.A. and Yamoah, C., 2003. Yield stability of cassava, maize, soya bean and cowpea intercrops. Journal of Agricultural Science, 140: 73–82.

De Ridder, N., O.M. Sanogo, and H. van Keulen. 2013. Milk, the new white gold for smallholder farmers in West Africa?

Djouara, H., Belières, J.F. Kébé, D., 2005. Les exploitations agricoles familiales de la zone cotonnière du mali face à la baisse des prix du coton graine. Cahiers Agricultures, 15(1): 64–71.

Dufumier, M., 2005. Etude des systèmes agraires et typologie des systèmes de production agricole dans la région cotonnière du Mali. 1–83.

Ellis-Jones J., A. Larbi, I. Hoeschle-Zeledon, I. Y. Dugje, I. A. Teli, S. S. J. Buah, R. A. L. Kanton, J. M. Kombiok, A. Y. Kamara, and I. Gyamfi. 2012. Sustainable intensification of cereal-based farming systems in Ghana’s Guinea savanna: constraints and opportunities identified with local communities. IITA report. IITA, Ibadan, Nigeria. 22 pp.

Eskandari, H. and Ghanbari, A., 2009. Intercropping of Maize (Zea mays) and Cowpea (Vigna sinensis) as Whole-Crop Forage: Effect of Different Planting Pattern on Total Dry Matter Production and Maize Forage Quality. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 37(2): 152-155.

Etwire, P.M., Abdoulaye, T., Obeng-Antwi, K., Buah, S.S.J., Kanton, R.A.L., Asumadu, H., Abdulai, M.S., Haruna, A. and Etwire, J.C., 2013. On-farm evaluation of maize varieties in the transitional and savannah zones of Ghana: Determinants of farmer preferences. Journal of Development and Agricultural Economics, 5(6): 255-262. Available online at: http://www.academicjournals.org/article/article1379501311_Etwire%20et%20al.pdf (Date of last access: 17.12.2013).

Fageria, N. K., Baligar, V. C., & Jones, C. A. (1997). Growth and Mineral Nutrition of Field Crops. CRC Press.

Falconnier, G., 2013. Understanding farm trajectories for better targeting of agricultural technologies. Fourth International Symposium on Farming Systems Design, Lanzhou, China, 19-22 August 2013. Available online at: http://www.fsd2013.com/uploadfile/2013/0906/20130906122245145.pdf

FAO, 2005. Fertilizer Use by Crop in Ghana. Soil Fertility in Ghanaian Agro-Ecological Zones. Available online at: http://www.fao.org/docrep/008/a0013e/a0013e05.htm#bm05.1 (Date of last access: 17.12.2013).

FAO, 2012. Gender Inequalities in Rural Employment in Ghana. An Overview. Available online at: http://www.fao.org/docrep/016/ap090e/ap090e00.pdf (Date of last access: 05.12.2013).

FAO, 2013. The Gender and Equity Implications of Land - Related Investments on Land Access, Labor and Income - Generating Opportunities in Northern Ghana. The Case Study of Integrated Tamale Fruit Company. Available online at: http://www.fao.org/docrep/018/aq535e/aq535e.pdf (Date of last access: 05.12.2013).

FAO, 2013. Country profile: Malawi. Available online at http://www.fao.org/countryprofiles/index/en/?iso3=MWI (Date of last access: 18.12.13).

FAOSTAT, 2011. Food and Agricultural commodities Malawi 2011. Available online at http://faostat.fao.org/DesktopDefault.aspx?PageID=339&lang=en&country=130 (Date of last access: 19.12.13).

Fok, M., 2010. Facteurs d'efficacité des arrangements institutionnels en politique cotonnière africaine. Cahiers Agricultures, 19(1): 68–74.

Fraley, C. and Raftery, A.E., 2000. Model-based clustering, discriminant analysis and density estimation. Department of Statistics, University of Washington, Seattle WA, USA. Technical Report no. 380.

Germer, J. and Sauerborn, J., 2008. Map of Agro-Ecological Zones in Ghana. Available online at: https://www.uni-hohenheim.de/respta/climate.php (Date of last access: 17.12.2013).

GFP, 2011. Land Tenure in Ghana: Making a case for incorporation of customary law in land administration and areas of intervention by the growing forest partnership. Document available online at: http://www.growingforestpartnerships.org/sites/gfp.iiedlist.org/files/docs/ghana/ghana_land_tenure-gfp_project.pdf (Date of last access: 05.03.2014).

Ghana Statistical Service, 2008. Ghana Living Standards Survey. Report of the fifth round (GLSS 5). Available online at: http://www.statsghana.gov.gh/docfiles/glss5_report.pdf (Date of last access: 10.12.2013).

Groot, J.C.J., Rossing, W.A.H., Tichit, M., Turpin, N., Jellema, A., Baudry, J., Verburg, P.H., Doyen, L., and Van de Ven, G.W.J., 2009. On the contribution of modelling to multifunctional agriculture: learning from comparisons. Journal of Environmental Management, 90: 147-160.

Henriet, J., van Ek, G.A., Blade, S.F. and Singh, B.B., 1997. Quantitative assessment of traditional cropping systems in the Sudan savanna of northern Nigeria. I. Rapid survey of prevalent cropping systems. Samaru Journal of Agricultural Research, 14: 37–45.

IFPRI, 2013. Aflatoxin control strategies in the groundnut value chain in Ghana. Available online at: http://www.ifpri.org/sites/default/files/publications/gsspwp33.pdf (Date of last access: 10.02.2014)

International Livestock Research Institute, 2012. Etude de base du projet: Sustainable intensification of cereal-based farming system in Sudano-Sahelian zone of West Africa. Le cas du Mali dans les cercles de Koutiala et Bougouni. Rapport proviso ire.

Jahnke, H.E., Tacher, G., Keil, P. and Rojat, D., 1987. Livestock production in tropical Africa with special reference to the tsetse-afferent zone: In proceedings of a meeting held in Nairobi, Kenya from the 23rd to 27th November 1987 organized by the International Livestock Centre for Africa and the International Laboratory for Research on Animal Diseases. ILCA/ILRAD 1988.

Jambo, E., 2013. Personal communication 6 – 13 September 2013.

Jamshidi, K., Yousefi, A.R. and Ovesi, M., 2013. Effect of cowpea (Vigna unguiculata) intercropping on weed biomass and maize (Zea mays) yield. New Zealand Journal of Crop and Horticultural Science Volume 41, Issue 4, 2013.

Karianga, B.M., 2004. Intercropping Maize with Cowpeas and Beans for Doi land Water Management in Western Kenya. ISCO 2004 - 13th International Soil Conservation Organisation Conference – Brisbane, July 2004 Conserving Soil and Water for Society: Sharing Solutions. Available online at: http://www.tucson.ars.ag.gov/isco/isco13/PAPERS%20F-L/KARIAGA.pdf (Date of last access: 18.12.2013)

Mahama, C., 2012. Farm animals are vital to Ghana's food-secure future. Online article available at: http://opinion.myjoyonline.com/pages/feature/201207/89867.php (Date of last access: 19.12.2013).

Naminse, E.Y., 2011. The Impact of Ruminant Production on Household Income and Food Security in Ghana. Symposium Paper. Available online at: http://www.ifama.org/events/conferences/2011/cmsdocs/2011SymposiumDocs/330_Symposium%20Paper.pdf (Date of last access: 19.12.2013).

Njira, K.O.W., Nalivata, P.C., Kanyama-Phiri, G.Y. and Lowole, M.W. 2012a. Biological nitrogen fixation in sole and doubled-up legume cropping systems on the sandy soils of Kasungu, Central Malawi. Journal of Soil Science and Environmental Management, 3(9): 224-230.

Njira, K.O.W., Nalivata, P.C., Kanyama-Phiri, G.Y. and Lowole, M.W. 2012b. Effects of sole cropped, doubled-up legume residues and inorganic nitrogen fertilizer on maize yields in Kasungu, Central Malawi. Agricultural Science Research Journals, 3(3): 97-106.

Ofori, F. and Stern, W.R., 1986. Maize/ cowpea intercrop system: Effect of nitrogen fertilizer on productivity and efficiency. Field Crops Research, 14: 247-261.

Ofori, F. and Stern, W.R., 1987. The combined effects of nitrogen fertilizer and density of the legume component on production efficiency in a maize/cowpea intercrop system. Field Crops Research, 16(1): 43-52.

Ojiem, J.O., Ridder, N. de, Vanlauwe, B, Giller, K.E., 2006. Socio-ecological niche: A conceptual framework for integration of legumes in smallholder farming systems. International Journal of Agricultural Sustainability, 4: 79-93.

Olufaro, O.O. and Singh, B.B., 2007. Ed Fatokun *et al*. Challenges and Opportunities for enhancing sustainable cowpea production. Chapter 4.3. Advances in cowpea cropping systems research. IITA Publication. Available online at: http://www.iita.org/c/document_library/get_file?uuid=9d04c2dc-2606-46e3-993f-3a9bd420a05a&groupId=25357 (Date of last access: 18.12.2013).

Pye-Smith, C., 2013a. Africa RISING - promoting sustainable intensification in Northern Ghana. Website entry on the Africa RISING wikispace. Available online at: http://africa-rising.net/2013/12/02/cps-ghana1/?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+agintensificationafrica_news+%28Africa+RISING+news%29 (Date of last access: 17.12.2913).

Pye-Smith, C. 2013b., Africa RISING - focusing on women and children in Ghana. Available online at: http://africa-rising.net/2013/12/18/cps-ghana3/ (Date of last access: 19.12.2013).

Pretty, J., Toulmin, C. and William, S., 2011. Sustainable intensification in African agriculture. International Journal of Agricultural Sustainability, 9: 5-24. Royal Society, 2009. Reaping the benefits: Science and the sustainable intensification of global agriculture. London: Royal Society.

Quansah, C. Fening, J.O., Ampontuah, E.O., Afreh, D. and Amin, A., 2012. Potential of Chromolaena odorata, Panicum maximum and Pueraria phaseoloides as Nutrient Sources and Organic Matter Amendments for Soil Fertility Maintenance in Ghana. Biological Agriculture and Horticulture, 19: 101-113. Available online at: http://www.tandfonline.com/doi/pdf/10.1080/01448765.1001.9754915 (date of last access: 10-01-14).

Ragasa, C., Dankyi, A., Acheampong, P., Nimo Wiredu, A., Chapoto, A., Asamoah, M. and Tripp, R., 2013. Patterns of Adoption of Improved Rice Technologies in Ghana. IFPRI Working Paper 35 of the Ghana Strategy Support Program.

Rufino, M.C., Herrero, M., van Wijk, M.T., Hemerik, L., de Ridder, N. and Giller, K.E., 2009 Lifetime productivity of dairy cows in smallholder farming systems of the Central highlands of Kenya. Animal, 3: 1044.

Rufino, M.C., Tittonell, P., van Wijk, M.T., Castellanos-Navarrete, A., Delve, R.J., de Ridder, N. and Giller, K.E., 2007 Manure as a key resource within smallholder farming systems: Analysing farm-scale nutrient cycling efficiencies with the NUANCES framework. Livestock Science, 112: 273–287.

Satyanarayana, V. Vara Prasad, P.V., Murthy, V.P.K. and Boote, K.J., 2002. Influence of Integrated use of farmyard manure and inorganic fertilizers on yield and yield components of irrigated lowland rice. Journal of Plant Nutrition, 25(10), 2081-2090.

The Montpellier Panel., 2013. Sustainable intensification: A new paradigm for African agriculture. London. Available online at: http://www.ag4impact.org (Date of last access 06.12.2013).

Tittonell, P., Zingore, S., Van Wijk, M.T., Corbeels, M. and Giller, K.E., 2007. Nutrient use efficiencies and crop responses to N, P and manure applications in Zimbabwean soils: exploring management strategies across soil fertility gradients. Field Crops Research, 100: 348–368.

Tittonell, P., Corbeels, M., van Wijk, M.T., Vanlauwe, B. and Giller, K.E., 2008. Combining organic and mineral fertilizers for integrated soil fertility management in smallholder farming systems of Kenya – explorations using the crop-soil model FIELD. Agron. J.,100: 1511–1526.

Tittonell, P., Muriuki, A., Shepherd, K.D., Mugendi, D., Kaizzi, K.C., Okeyo, J., Verchot, L., Coe, R. and Vanlauwe, B., 2009. The diversity of rural livelihoods and their influence on soil fertility in agricultural systems of East Africa – a typology of smallholder farms. Agricultural systems, 103: 83-97.

Traoré, B., Corbeels, M., van Wijk, M.T., Rufino, M.C. and Giller, K.E., 2013. European Journal of Agronomy. European Journal of Agronomy, 49: 115–125.

Traoré, K.B., McCarthy, G., Gigou, J.S., Doumbia, M.D., Bagayoko, A., Yost, R.S., Konaré, H., Dioni, L., Coulibaly, H., Sidibe, A., Kablan, R.A., 2004. Aménagement en courbes de niveau et conservation du carbone. IRD.

USAID, 2012. The Market for maize, rice, soy and warehousing in Northern Ghana. Available online at: http://www.fintrac.com/cpanelx_pu/EAT/14_39_5614_EAT_Assessment_Ghana_fin_09Feb12.pdf (Date of last access: 10.01.2014).

Van Wijk, M.T., Tittonell, P., Rufino, M.C., Herrero, M., Pacini, C., de Ridder, N. and Giller, K.E., 2009. Identifying key entry-points for strategic management of smallholder farming systems in sub-Saharan Africa using the dynamic farm-scale simulation model NUANCES-FARMSIM. Agricultural Systems, 102: 89–101.

Wood. T.N., 2013. Agricultural Development in the Northern Savannah of Ghana. Available online at: http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1000&context=planthealthdoc (Date of last access: 17.12.2013).

World Bank, 2010. Discussion Paper 15. The Social Dimensions of Adaptation to Climate Change in Ghana. Development and Climate Change. Available online at: http://climatechange.worldbank.org/sites/default/files/documents/Ghana-EACC-Social.pdf (Date of last access: 17.12.2013).

World Bank, 2014. PPP conversion factor - GDP (LCU per international dollar) in Tanzania, Ghana and Malawi. Available online at: http://www.tradingeconomics.com/tanzania/ppp-conversion-factor-gdp-lcu-per-international-dollar-wb-data.html (Date of last access: 12.03.2014).